THE IMPACT OF IMPLEMENTATION OF A MODULAR PLATFORM STRATEGY IN AUTOMOBILE MANUFACTURING NETWORKS

Jesús Lampón*
Pablo Cabanelas**
Javier González Benito***

* GEN and Universidade de Vigo
** Universidade de Vigo
*** Universidad de Salamanca
The impact of implementation of a modular platform strategy in automobile manufacturing networks

This paper explores the impact of the implementation of modular platforms, to replace the standard platforms used to date, on the strategic outputs of automobile manufacturing networks. Analysis of the production network of manufacturers in Europe shows that the use of modular architecture improves the coordination of manufacturing networks by increasing manufacturing mobility and thriftiness ability. The changes resulting from this new modular strategy also allow for reorganisation of manufacturing capacity and the partial elimination of current overcapacity. From the point of view of production systems, the adaptation of processes and facilities in manufacturing plants to this new architecture should aim to increase flexibility by integrating production around a single platform, allowing for different dimensions and a large number of models in a single plant.

**Keywords:** Modular platforms, manufacturing networks, operational flexibility, economies of scale, economies of scope, automobile sector.

1. Introduction

The development of product families based on platforms has been widely applied in different sectors globally, a fact that has not gone unnoticed by the product development and operations management literature (Wheelwright and Clark, 1992; Meyer and Lehnerd, 1997; Robertson and Ulrich, 1998; Becker and Zirpoli, 2003). The automotive sector, especially, has seen great development of its products, mainly in the late 1990s and the first years of the 21st century, resulting from the use of a ‘standard platform’ for different models in the same segment. This milestone has led to greater efficiency in design and development processes, as well as greater economies of scale in production and procurement due to greater standardisation (Wilhelm, 1997; Cusumano and Nobeoka, 1998; Muffatto, 1999; Becker and Zirpoli, 2003).

Today, the platform strategy in this sector is being reviewed with the development and adoption of what are known as modular platforms, which offer a new scalable design allowing models in different segments to be produced on a single modular platform (Buïga, 2012). This incipient modular strategy entails extensive internal changes in the sector’s production organisation, especially in the international production network of automobile manufacturers (Lampón and Cabanelas, 2014). Thus, analysis of the effects of this strategy on the strategic outputs of firms’ international production networks is relevant (Shi and Gregory, 1998; Colotla et al., 2003; Miltenburg, 2009). Automobile manufacturers organize their production in international networks and, from an intra-firm operations management perspective, the configuration and coordination of such manufacturing networks enable them to achieve better results (Shi and Gregory, 1998; Vereecke and Van Dierdonck, 1999; Gulati et al., 2000; Colotla et al., 2003; Rudberg and Olhagerb, 2003; Miltenburg, 2009).

The purpose of this research, therefore, is to analyse the changes in the strategic outputs of automobile manufacturers’ networks resulting from the implementation of modular platforms, with a special emphasis on changes relating to network coordination: scale and scope economies (thriftiness ability) and operational flexibility (manufacturing mobility). The paper is organised in three sections. The first summarises the key theoretical issues behind the modular platform strategy and the strategic outputs of production networks. The second
covers the empirical study in the European production network of automobile manufacturers. The third draws the main conclusions and describes the practical relevance and implications of the modular platform strategy.

2. Review of the literature

2.1. From standard platforms to modular platforms

Although the concept of the platform is widely accepted and used in the automobile sector, there is no a single definition among automobile manufacturers (Muffatto, 1999; Ghosh and Morita, 2002; Simpson et al., 2006; Mahmoud-Jouini and Lenfle, 2010). Its components depend on the manufacturer, so the literature has different definitions of the platform as a physical product. The platform generally refers to the core framework of the automobile and its basic element is the underbody. This is made up of the front floor, underfloor, engine compartment and frame (Muffatto, 1999), although it may also include other components, such as the drive train and axles (Ghosh and Morita, 2002) or the suspensions and power train (Muffatto and Roveda, 2000). The platform concept used in this research combines the physical product and process approaches adopted in the literature: a set of assets shared by a variety of products (Robertson and Ulrich, 1998) that are physically compatible in the assembly processes (Muffatto and Roveda, 2000).

The use of platforms is not a new phenomenon. The production of product families based on platforms is a strategy that has been successfully applied in the automobile sector since the 1960s (Cusumano and Nobeoka, 1998). But the greatest changes regarding process flexibility and efficiency took place around the turn of the century, when platforms were reduced and standardised to develop a single common platform for different models within the same segment (Holweg, 2008). The main objective of such standardisation was to rationalise the number of platforms and to share common components and systems among those models assembled on a single platform (Patchong et al., 2003; García et al., 2005). This standardisation strategy focused on aspects of product development —simplification of engineering and design processes, reduction of costs and development time, and the ability to update products (Muffatto, 1999; Suk et al., 2007). It also aimed to take advantage of the economies of scale resulting from a greater number of common units per platform, such as savings on the purchase of components (Korth, 2003). From a manufacturing perspective, the platform standardization strategy offered advantages for globalizing production processes because it allowed flexibility among plants, the possibility of transferring production from one plant to another (Robertson and Ulrich, 1998; Smith and Reinertsen, 1998), and cost reduction by using resources on a worldwide scale (Wilhelm, 1997).

In recent years the platform strategy has been reviewed, and new modular platforms have been, and will continue to be, adopted in the sector (Sehgal and Gorai, 2012; Global Automotive Modular Platform Sharing Market Analysis 2013-2023). From the technical point of view, such modular platforms are configured differently based on a single scalable design, allowing for changes in structural dimensions (such as the front and rear overhangs, the wheelbase and the track width). This modularisation of the structural element of an automobile, the platform, means that it is possible not only to assemble several models within a single segment (same size), as with the classic standard platforms, but also several models in different segments (different sizes) (Buiga, 2012). Although the modular platform strategy has not yet been fully implemented, the forecasts of several automobile manufacturers (e.g. Volkswagen, PSA Peugeot-Citroën, Nissan-Renault) mention savings in product development
costs and in the procurement of components from the auxiliary industry (Lampón and Cabanelas, 2014).

2.2. Manufacturing network strategic outputs: Thriftiness ability and manufacturing mobility

From the operations management approach, manufacturing networks theory focuses on network-level outputs instead of traditional factory-level outputs (e.g. cost, quality, delivery). In the literature on the value of manufacturing networks, two main areas can be identified: configuration issues, and coordination issues. The former stem from multi-plant research, and location-based criteria dominate (DuBois et al., 1993; Ferdows, 1997). The latter are mainly concerned with the transfer and dissemination of resources, especially technology and network learning (Gailbraith, 1990; Flaherty, 1996; Zander, 1999; Ferdows, 2006). Today, research on manufacturing networks from an intra-firm operations management perspective has integrated these perspectives of configuration and coordination to gain an overall view of the manufacturing network (Shi and Gregory, 1998; Vereecke and Van Dierdonck, 1999; Gulati et al., 2000; Colotla et al., 2003; Rudberg and Ohlagerb, 2003; Miltenburg, 2009).

The integrated perspective of manufacturing networks theory highlights four strategic outputs or capabilities (Shi and Gregory, 1998; Colotla et al., 2003; Miltenburg, 2009): accessibility, thriftiness ability, manufacturing mobility and learning ability. Accessibility, mainly derived from the configuration of the network, includes ease of access to production factors, proximity to markets, and other location advantages. Thriftiness ability, mainly derived from coordination of the network, reflects the ability to increase efficiency through networking, especially to achieve scale and scope economies and avoid duplication of activities. Manufacturing mobility, derived from the configuration and coordination of the network, refers to flexibility in transferring products and processes among plants and in changing production volumes. Learning ability, mainly derived from network coordination, refers to the possibility of wider internal and external exchange and benchmarking, the ability to learn about customers’ needs, process technology and management systems, and the facility with which this knowledge is shared.

Accessibility to supply sources and low-cost production factors, and the thriftiness ability gained by scale and scope economies determine the network’s effectiveness. Of these two strategic outputs, in networks that already have a defined spatial configuration, it is thriftiness ability that allows network efficiency to be improved through coordination among plants. Moreover, learning ability and manufacturing mobility represent the longer-term capabilities of network restructuring. Manufacturing mobility, especially, is used to adapt the production to the volatility of the current international environment (Shi and Gregory, 1998; Miltenburg, 2009).

2.3. Effect of modular platform implementation on key manufacturing network strategic outputs

Improved operational flexibility is one of the results of the platform standardisation strategy (Wilhelm, 1997). Yet production networks using standard platforms are still fairly rigid from the point of view of production mobility (Fleischmann et al., 2006). Mobility in production networks using standard platforms is only possible among plants working for the same segment is thus limited to a specific number of plants in the network as a whole. The modular platform strategy allows plants in different segments to share the same modular platform, so the production network can include a larger number of plants. Manufacturing mobility,
expressed in terms of operational network manufacturing flexibility, is the ability to utilise the total global capacity of the network optimally by shifting production volumes around plants in order to cope with volatility in the international business environment (Kogut and Kulatilaka, 1994; Buckley and Casson, 1998; Rangan, 1998; Shi and Gregory, 1998). This operational flexibility (manufacturing mobility) allows swift transfers within the system and quick strategic responses, directly determined by the network’s manufacturing configurations and associated with the presence in a large number of countries and number of plants (Allen and Pantzalis, 1996; Tong and Reuer, 2007). The first hypothesis suggests:

**H1:** Operational flexibility (manufacturing mobility) is greater in a manufacturing network with a modular platform than with a standard platform

Automobile manufacturers’ networks are organised on the basis of platforms. The facilities and production processes of the plants that form part of such networks are designed and arranged according to the products they make, so each plant only assembles products that share the same platform. The modular platform strategy allows for different dimensions in this structural element and for the assembly of models from different segments on a single platform. In addition to the determinants of the actual product —both geometrical and for safety— there are other aspects, which depend on the characteristics and decisions of each automobile manufacturer, that determine the number of models the manufacturing network can produce using the same modular platform. They include the design of the platform, that is, the degree of modularisation or scalability, aspects relating to the configuration of the manufacturing network, and process and facility design. As a result, depending on the modularity of the platform and the redesign of processes and facilities undertaken by manufacturers to adapt to these new platforms, it may be feasible for plants using standard platforms designed for production in a single segment to expand their range of models within the same segment or, even, to include different segments. Economies of scope (thriftiness ability) refer to advantages gained by aggregating different products in the global product portfolio so that the cost of producing more products is less than the sum of producing these products individually (Kogut, 1989; Shi and Gregory, 1998). Therefore, the second hypothesis proposes:

**H2a:** Economies of scope (thriftiness ability) in a manufacturing network are greater with a modular platform than with a standard platform.

As a result of increasing the number of models and of plants in a manufacturing network using a modular platform, on the one hand manufacturing capability is increased and, on the other, a larger number of resources are shared among a larger volume of products. Economies of scale (thriftiness ability) refer to advantages gained by aggregating production volumes across plants (Shi and Gregory, 1998). Much of this relies on global rationalisation and the move towards standard global products (Levitt, 1983). So the third hypothesis suggests:

**H2b:** Economies of scale (thriftiness ability) in the manufacturing network are greater with a modular platform than with a standard platform.

3. **Research methodology**

3.1. **Data**
Every company takes a slightly different approach to the modular platform because of their differences in terms of structure, strategy, product-portfolio and R&D. The definition of a modular platform differs from one company to another. For analysis of these modular platforms, we use the Global Automotive Modular Platform Sharing Market Analysis 2013-2023 as the study universe. This report stresses that the difference between a traditional standard platform and a modular one can be a grey area, and defines a modular platform as one that offers sufficient versatility to adapt to a wide variety of models in different price and size segments. This broad definition includes modular platforms that have been, or are being implemented: the Volkswagen MQB platform, the PSA Peugeot-Citroën EMP2 platform, the Renault-Nissan CMF platform, the Daimler MRA platform, the BMW UKL platform, General Motors’ D2XX platform and Volvo’s SPA platform.

These seven manufacturers have produced in Europe a total of 14.2 million cars and light commercial vehicles, that is, 73.5% of total production on the continent (OICA, 2012). This leadership in European production can also be seen in production using standard platforms. The Volkswagen PQ35/46, the PSA Peugeot-Citroën PF2 and the Renault X85/B were the top 3 platforms in millions of units produced in Europe (Sehgal and Gorai, 2012). This characteristic indicates the high concentration within Europe of these manufacturers’ production networks —BMW produces 75% of all its vehicles worldwide in Europe, and PSA Peugeot-Citroën 71% (OICA, 2012)— so the development of manufacturing networks using modular platforms is mostly taking place in Europe.

To gather information on these platforms, a questionnaire on the adoption of modular platforms was sent to the team managers of all seven manufacturers. The field work was done from October 2013 to March 2014. The questionnaire requested information on the year the modular strategy was adopted, technical specifications of the platform (modularity and modules involved), models and segments included, the standard platforms they replace, the plants to be included in the manufacturing network, installed/used production capacity and the objectives to be achieved by the modular strategy. It also asked about the main changes in processes and facilities made in each of the production units within the manufacturing plants (body-in-white shop, paint shop and final assembly shop). Five filled-in questionnaires were received by mail, and two were obtained by telephone but interviewees omitted some questions.

3.2. Variables

The operational flexibility, economies of scope and economies of scale variables used to test the research hypotheses on networks’ strategic outputs were defined as follows:

- **Operational flexibility**: The larger the manufacturing network (number of plants), the greater the operational flexibility for coordinating and transferring resources internationally (Lampón et al., 2013). The variable is defined as the number of plants sharing the same platform (Lee, 2006).
- **Economies of scope**: Advantages gained by aggregating different products in the global product portfolio (Kogut, 1989). From the point of view of development and manufacturing processes in the automotive sector, a product is the equivalent of a model. Therefore, the more models that can be produced in the manufacturing network, the greater the economies of scope. The variable is therefore defined as the average value of the number of models produced per plant in the manufacturing network using the same platform.
- **Economies of scale**: Advantages gained by aggregating production volumes across plants (Shi and Gregory, 1998). These production volumes can be expressed in real production or capacity used (for which the value depends on aspects outside the
manufacturing network such as demand during the period of analysis), or as installed capacity directly linked to production processes and facilities, which is more appropriate for our research. The variable is defined as the installed production capacity in all the network’s plants using the same platform in millions of units/year.

3.3. Descriptive analysis of manufacturing networks using a modular platform

The Volkswagen MQB (Modularer Querbaukasten) platform

Manufacturing with the MQB platform began in 2012. This platform allows variations in all dimensions except for that from pedals to front axle and is made up of three structural modules with different options (3 front and under-body chassis, 5 front floor and 4 rear floor). The MQB will be applied for four of the Volkswagen brands (VW, Audi, Seat and Skoda) and replaces the standard PQ25, PQ35 and PQ46 platforms, on which the models in segments B, C and D are assembled. The European manufacturing network will comprise 14 plants for the assembly, initially, of 24 different models of these four brands with an annual production capacity of 3.91 million units. The main objectives are to reduce development costs for new models and to use a larger number of common components for different models.

The PSA Peugeot-Citroën EMP2 (Efficient Modular Platform)

Manufacturing using the EMP2 modular platform began in 2013. This platform allows for several structural dimensions (4 track widths and 5 wheelbases) and includes several modules (2 cockpits, 2 suspension architectures and 6 low rear unit modules), supporting the assembly of 13 different models in segments C and D of the group’s two brands, which were previously assembled on the PF2 and PF3 platforms. The new EMP2 modular platform will be the base for assembling 50% of this manufacturer’s vehicles. Once it has been fully adopted, a total of 6 of the group’s plants in Europe will assemble on this modular platform, which has a production capacity of 1.87 million units/year.

The Renault-Nissan CMF (Common Module Family)

This was first adopted towards the end of 2013, and final adaptation of the manufacturing network is planned for 2020. From a technical point of view, the CMF has four compatible modules (2 engine bays, 3 cockpits, 3 low front units and 3 low rear units) that can be arranged in different ways. 10 models will be assembled initially on this new platform in Europe in 2013-2016 – two Nissan and eight Renault, rising to 14 models worldwide when adaptation reaches 100%. The implementation of this platform, with multi-make manufacturing on the production lines of the company’s European plants, will involve 7 plants with an assembly capacity of 1.48 million vehicles per year.

The BMW UKL (Unter Klasse) platform

There are two versions of this platform: UKL1 for the front-wheel drive models and UKL2 for the rear-wheel drive models. The UKL1 allows for 3 different wheelbases and is made up of three structural modules (front bulkhead and engine bay, the main floor, and the rear/wheelhouse section). 12 Mini and BMW models can be assembled on it. The first model to use this platform was the Mini Hatchback in 2014, and other models will gradually be included until the process is complete in the two German plants that are currently producing
the BMW series 1 models. The aim is to produce a total of 900,000 vehicles a year on this platform.

The Daimler MRA (Mercedes Rear wheel drive Architecture) platform

The new MRA platform allows for different wheelbases and different vehicle widths. Daimler completes this Vehicle Architecture with what it calls its Modular Strategy, with 90 common modules for the most important components (e.g. front and rear suspension, powertrain, engine and transmission sets, electric architectures) that are shared by all its models. This strategy brings added benefits to the production process, especially shorter production time and lower production costs. This MRA modular platform will allow 8 models in segments D, E and F to be assembled, and the European manufacturing network using this platform will have an annual capacity of 900,000 vehicles.

The General Motors D2XX (Delta 2 XX) platform

This modular platform has been designed with common chassis and powertrain components and a set of basic adaptable modules (e.g. brakes, suspensions) so that different sizes and layouts can be defined. The D2XX will replace the standard Delta II and Theta II platforms, so on a worldwide level it will be possible to assemble 12 models of different brands (Opel, Chevrolet, Buick, GMC and Cadillac), allowing for production of 2.5 million vehicles a year by 2018. Manufacturing on this platform will begin in Europe in 2015 only for 6 models, because some of this company’s brands are sold on other geographical markets so are not produced in Europe. Estimated annual capacity is about 1 million vehicles.

The Volvo SPA (Scalable Platform Architecture)

Manufacturing in Europe using the SPA platform will begin in 2015 at the plant in Torslanda (Sweden) with the new Volvo XC70. This platform has a high degree of modularity, with five sections, and allows all dimensions to be varied, except from pedals to front axle (front and rear overhangs, track width and wheelbase). The aim is for this platform to serve as the base for 7 models in the D and E segments and to achieve a production capacity for the network in Europe of 500,000 vehicles a year.

Although we focus here on manufacturing networks in Europe, plants in other parts of the world will also form part of these modular platform networks. By way of example, production of the new Golf on the VW MBQ platform began in 2014 in Puebla (Mexico). PSA Peugeot-Citroën started production at its plant in Whuan (China) using the EP2 modular platform and will complete worldwide adoption of the platform in Buenos Aires (Argentina). In the case of Daimler, global implementation of the MRA platform in its manufacturing network includes, apart from the two German plants mentioned above, the plants in Tuscaloosa (USA), East London (South Africa) and Beijing (China).

-----------------------------------------------TABLE 1-----------------------------------------------
When implementing their modular platform strategies, manufacturers have focused on two key features of processes and facilities in the assembly plants\(^1\) of their production networks: (1) body-in-white shops working with a single common platform, and (2) the capacity of the final assembly line, shared by all products.

First, the single flow configuration of body-in-white shops meant that every product went through the same sequence of stations, limiting the ability to produce different body styles on the same system. The manufacturers needed a new architecture for the body-in-white production line that could handle model diversity and new automobile launches easily and quickly without overinvestment. In the case of the VW plants that have been adapted to the new modular platform, the body-in-white production line is now more radial than linear. The different three modules required to configure the platform are produced at different weld/bonding stations. Once the different modules are made, are selected and combined to obtain the vehicle floor platform that will be assembled. The PSA Peugeot-Citroën factories with modular platforms are characterized by a modular design of the body-in-white assembly process. Different versions are produced in the same flow, without a specific production line. Each assembly island is versatile so can produce different configurations of the base that are similar at all sites.

Second, in final assembly lines, each production plant had to cover all the production market segments. This meant they needed to implement mixed model final assembly lines so that different automobile models could be sequentially personalized on the same final assembly line. In Volvo (at the Torslanda plant), the final flexible assembly line for seven different models makes complexity compatible with the strategy to simplify the production process because of very accurate parts sequencing along the line. The focus is on supporting the operator to ensure that the exact part for each specific vehicle is in place ready to fit. They also use kitting, that is, when the car reaches the operator, a complete kit of the correct parts for that vehicle will be with it. In Renault-Nissan, actions on assembly lines have focused on improving internal logistics flows. Efficiency has been improved by flexible supply of the sub-assembly and parts to the line. The assembly line boasts a highly efficient logistics layout with a 100% kit supply system to the line-side, which saves operators having to pick parts from more than one place. In the case of BMW, on the mixed model final assembly lines at its Oxford plant, investments have focused on facilities allowing for greater speed and flexibility for changing the sequence of models. These facilities include new height-adjustable skillets on two production lines to ease the assembly process, while 44 automated guided vehicles carry pre-assembled cockpits to the track. The sunroof installation facility is fully automated. In addition, new robots equipped with cameras have been implemented in different processes to watch over and identify different options in the product, and guarantee accuracy.

### 3.4. Statistical analysis and discussion of results

The analysis for testing the hypotheses involved the comparison of the network strategic outputs of each modular platform (MP) with those of the same manufacturer’s standard platform (SP), using a non-parametric statistical test. We compared each of the seven modular platform networks with two standard platform networks for each manufacturer, except for VW where the comparison was with three. Therefore, the number of cases compared was 15. The non-

---
\(^1\) A typical automobile assembly plant contains three shops. The body shop has the most complex manufacturing flow and is located at the beginning of the assembly process. Welders in the body shop assemble the raw materials, which are stamped parts, creating the body in white. After leaving the body shop, the body in white goes to the paint shop. The last step is the final assembly shop, where the painted body is merged with the remaining parts to make a marketable product. These parts range in importance from vital (e.g. the engine system) to decorative (e.g. the hubcaps) (Patchong et al., 2003).
parametric statistical test chosen was the Wilcoxon signed-rank test for related samples and paired data, which allows the comparison of medians of related samples to identify if there are significant differences between them. Tables 2 and 3 summarise, respectively, the descriptive statistics of the network strategy outputs for each network analysed and the results of the Wilcoxon test.

The results for the three variables in the Wilcoxon signed-rank test comparing the sample of modular platform manufacturing networks with the sample of standard platform manufacturing networks (Table 3) point to significant differences. For the operational flexibility variable, the degree of significance is 1% (p = 0.002), and 12 of the compared ranks of pairs are positive, which means that for those 12 cases the number of plants forming part of the modular platform network is greater than that for standard platform networks. In particular, Table 2 shows that the number of manufacturing plants that form part of a modular platform network is greater by 4 plants than that of standard platform networks. So, operational network manufacturing flexibility (manufacturing mobility), expressed in terms of the ability to manufacture products in more than one factory and to utilise the total global capacity of the network optimally by shifting production volumes to other plants, is greater in modular platform manufacturing networks. H1 is therefore confirmed.

For the economies of scope variable, significance is also 1% (p = 0.001). In addition, of the 15 pairs compared for both samples, the rank difference is observed to be positive in all cases. This indicates that the number of models assembled in a modular platform network is always greater than in the standard platform network it replaces. Table 2 shows that, on average, in each plant forming part of a modular platform network, 12.27 models are assembled as opposed to 5.60 in a standard platform network. Therefore, the economies of scope (thriftiness ability) variable indicates that the advantages gained by aggregating different products in the global product portfolio — and especially, the capabilities obtained by the sharing of manufacturing among broad product lines — are greater in modular platform networks, thus confirming H2a.

For the economies of scale variable, the degree of significance is 1% (p = 0.002) and 12 of the compared ranks of pairs are positive, indicating that the capacity of modular platform manufacturing networks is greater than that of standard platform networks. Table 2 shows that the average production capacity, expressed in millions of units per year, in the sample of the 15 European modular platform networks is 1.672, as opposed to 0.753 for standard platforms. The economies of scale variable (thriftiness ability) indicates that the advantages gained by aggregating production volumes across plants is greater in modular platform networks than in standard ones, thus confirming H2b.

Finally, in the comparative analysis of the adoption of modular platforms by different manufacturers, VW is seen to have made more extensive changes in its production standards, allowing for models from three different segments to be assembled on the same modular platform. The VW modular strategy, together with its broad product portfolio and large production volumes (3.91 million units/year using the same modular platform), will bring it
greater benefits in terms of flexibility and economies of scope and of scale in comparison with other smaller manufacturers such as BMW, Daimler or Volvo (which produce less than one million units/year).

4. Conclusions and implications

According to the manufacturing networks theory, from an operations management approach, the modular platform strategy adopted by automobile manufacturers will lead to improved strategic outputs from their production networks; specifically, those derived from the coordination of manufacturing plants in the network —thriftiness ability and manufacturing mobility. This thriftiness ability gained by economies of scale and scope will enhance network performance, while manufacturing mobility will help the network to restructure in order to cope with the volatility of the current international production environment.

The immediate implications for automotive manufacturing managers seem to be clear. This modular strategy can be considered a new milestone in automotive manufacturing which brings with it a far-reaching change in production processes, offering a new standard that allows for the optimisation of global production networks. In fact, manufacturers that do not adopt this modular strategy in the short term will be at a disadvantage in terms of operational flexibility (manufacturing mobility) and economies of scope and of scale (thriftiness ability), so will be less competitive.

The number of models that each of the plants belonging to a modular platform network can assemble will increase considerably. However, a larger number of plants in the network will be able to choose to produce a model so there will be greater internal rivalry among plants for the allocation of production quotas. In addition, the surplus capacity of the modular platform network, which previously was distributed among several standard platform networks, will now be concentrated in a single modular platform network. This circumstance is especially important in the automotive industry which has surplus capacity, considered by some to be structural even before the crisis, of about 25% in Europe (Wiese, 2012). This, together with the greater operational flexibility of these networks for transferring resources internationally, will facilitate processes of restructuring and rationalisation on a global level. Therefore, automotive manufacturers will be in a position to improve the efficiency of their manufacturing networks and to eliminate some of their installed surplus capacity. If such elimination takes place, the manufacturing plants that belong to modular platform production networks will be under great pressure because of the real possibility that they might be closed down or transferred.

From a production system perspective, automobile manufacturers have encountered problems in implementing a modular platform strategy in two areas: body-in-white shops, which serve a single common platform, and capacity of the final assembly line, which all products share. Problems in the former are being resolved by introducing new modular layouts in the weld/bonding stations making it possible to assemble the different configurations of the platform and the different body styles of multiple models. The latter challenge requires the production system of mixed model assembly lines to be reviewed and updated (Kinutani, 1997; Lee and Vairaktarakis, 1997; Kochan, 2003; Ponticel, 2006). Thus, all the components of the models, and their different versions, can be arranged at the line-side, minimising operator errors in the assembly of the different variants and ensuring fast and flexible changes in the sequence of models without losing production capacity. Actions such as the automation of the most complex assembly processes, the use of kitting and redesign, and the implementation of a system organising the whole logistics flow with external and
internal supplies to the final vehicle assembly point, have made it possible to achieve the necessary flexibility.

Finally, in view of the incipient appearance of this modular platform strategy, the authors propose that future research assess its benefits once it has been fully adopted. It will then be possible to analyse the balance between the cost and the real benefit of this new strategy and its effect for each manufacturer in line with the variables included in such new research.
References


<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Modular platform</th>
<th>Year of adoption in Europe</th>
<th>Technical specifications</th>
<th>Segments</th>
<th>Standard platforms (a)</th>
<th>Main objectives of implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volkswagen</td>
<td>MQB</td>
<td>2012</td>
<td>Variation in all dimensions except pedals to front axle (front and rear overhangs, track width and wheelbase). The platform is made up of three structural modules with different options (3 front and under-body chassis, 5 front floor and 4 rear floor)</td>
<td>B, C, D</td>
<td>PQ25, PQ35, PQ46</td>
<td>To multiply by 5 the volume of orders from a single supplier</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>To reduce the cost of developing new products by 20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>To reduce engineered hours per automobile by 30%</td>
</tr>
<tr>
<td>PSA Peugeot-Citroën</td>
<td>EMP2</td>
<td>2013</td>
<td>Variation in dimensions allowing for 4 track widths and 5 wheelbases. Includes three compatible modules (2 cockpits, 2 suspension architectures and 6 low rear units)</td>
<td>C, D</td>
<td>PF2, PF3</td>
<td>To reduce the cost of purchasing components by 18%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>To produce 50% of their vehicles on this platform</td>
</tr>
<tr>
<td>Renault-Nissan</td>
<td>CMF</td>
<td>2013</td>
<td>Different platform configuration made up of 4 compatible modules (2 engine bays, 3 cockpits, 3 low front units and 3 low rear units)</td>
<td>C, D</td>
<td>X84/C, D</td>
<td>To reduce the cost of purchasing components by 20-30%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>To reduce the unit cost of developing new products by 30-40%</td>
</tr>
<tr>
<td>BMW</td>
<td>UKL</td>
<td>2014</td>
<td>Two versions: UKL1 for front-wheel drive models and UKL2 for rear-wheel drive models. Allows for 3 different wheelbases and is made up of three structural modules (front bulkhead and engine bay, the main floor and the rear/wheelhouse section)</td>
<td>B, C</td>
<td>R50, E80</td>
<td>n/a</td>
</tr>
<tr>
<td>Daimler</td>
<td>MRA</td>
<td>2014</td>
<td>Allows for different wheelbases and different track widths. This new approach called MB Vehicle Architecture is complemented by the MB Modular Strategy: 90 common modules for the main components (e.g. front and rear suspension, powertrain, engine and transmission sets)</td>
<td>D, E, F</td>
<td>n/a</td>
<td>To reduce unit manufacturing time by 25%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>To reduce total manufacturing cost by 20%</td>
</tr>
<tr>
<td>General Motors</td>
<td>D2XX</td>
<td>2015</td>
<td>The new modular platform design is based on common chassis and powertrain components and the use of adaptable basic modules (e.g. brakes, suspensions) for different sizes and configurations</td>
<td>C, D</td>
<td>Delta II, Theta II</td>
<td>To reduce development costs by $1 billion a year (2014-2020)</td>
</tr>
<tr>
<td>Volvo</td>
<td>SPA</td>
<td>2015</td>
<td>The SPA structure is engineered in 5 sections, of which 4 (the front overhang, cabin, rear luggage space and rear overhang) can vary in size. The only fixed section is the engine bay and bulkhead. This allows for variation in all longitudinal dimensions (front and rear overhangs and wheelbase) except for pedals to front axle.</td>
<td>D, E</td>
<td>D3, EUCD</td>
<td>n/a</td>
</tr>
</tbody>
</table>

(a) Platforms replaced by the modular platform. In the case of BMW, the nomenclature corresponds to the internal code assigned to the set of models assembled on this platform.

(b) In segment D, only crossovers will be assembled on this modular platform.

(c) Ford platform nomenclature (Volvo was acquired by Ford and subsequently sold to China’s Geely Holding Group in 2010, retaining the Ford nomenclature).

Source: Drawn up by the author.
<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>S D</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Economies of scope</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard platform (SP)</td>
<td>15</td>
<td>5.60</td>
<td>2.720</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>modular platform (MP)</td>
<td>15</td>
<td>12.27</td>
<td>6.519</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td><strong>Operational flexibility</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard platform (SP)</td>
<td>15</td>
<td>2.80</td>
<td>2.396</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>modular platform (MP)</td>
<td>15</td>
<td>6.13</td>
<td>4.454</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td><strong>Economies of scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>standard platform (SP)</td>
<td>15</td>
<td>0.753</td>
<td>0.6051</td>
<td>0.20</td>
<td>2.44</td>
</tr>
<tr>
<td>modular platform (MP)</td>
<td>15</td>
<td>1.672</td>
<td>1.2286</td>
<td>0.50</td>
<td>3.91</td>
</tr>
</tbody>
</table>
Table 3: Results of the Wilcoxon test

<table>
<thead>
<tr>
<th></th>
<th>Operational flexibility (MP) – Operational flexibility (SP)</th>
<th>Economies of scope (MP) – Economies of scope (SP)</th>
<th>Economies of scale (MP) – Economies of scale (SP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive ranks</td>
<td>12</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Negative ranks</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Draws</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Z</td>
<td>3.084</td>
<td>3.415</td>
<td>3.062</td>
</tr>
<tr>
<td>Asymp. sig.</td>
<td>0.002</td>
<td>0.001</td>
<td>0.002</td>
</tr>
</tbody>
</table>