Modularity and Outsourcing:

The Nature of Co-Evolution of Product Architecture and Organisation Architecture in the Global Automotive Industry[1]

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Comments welcome.

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At a juncture when the outsourcing of modules has become a panacea for all sorts of problems in the auto industry, it is worthwhile taking a sober look at what can, and cannot, be expected from it. Recently, both OEMs (original equipment manufacturers) and suppliers are interested in capturing value from vertical dis-integration of a modular sort, but neither side appears to know fully what costs and gains are involved in pursuing a specific path to outsourcing modules. Baldwin and Clark (1997 and 2000) clearly laid out the 'power of modularity' using the US computer industry and its one time near monopolist, IBM, as evidence. But in many other sectors whose industry structure is more fragmented from the start, such as the automotive industry, there exists a choice in paths to be taken to 'go modular'. Depending on the path chosen, as this chapter will show, technological know-how and capabilities end up being distributed quite differently between OEMs and suppliers. While the scope for choice of different paths is limited to an extent by the existing industry structure and initial conditions in organisational capabilities, much of it is in the hands of the companies involved in the supply chain. As Starr noted over three decades ago, 'turning to the modular approach produces a great deal of unplanned obsolescence' and 'the design and engineering costs of entering into such production configurations can be exceptionally high' (Starr 1965, p.139). The question is whether there is enough will power within leading automotive companies to incur this necessarily high set-up cost of going modular. This strategic choice, in turn, will determine the future of the industry structure, and in particular the power dynamics between the OEMs and suppliers. This chapter analyses how strategic considerations moderate the way product architecture affects organisation architecture and vice versa.

The chapter is structured as follows. The first section provides a definition of modularity in product architecture and organisation architecture. Three distinct paths to achieving the outsourcing of modules are identified by separating out outsourcing and modularisation. The second section examines the mixed motives of OEMs and suppliers wishing to 'go modular'. It is argued that different combinations of these motives predispose companies to choose a different path to outsource modules. Lastly, the chapter considers the implications of these different paths for industry dynamics and supplier relationships. Although the empirical details of this paper is largely about the auto industry, much of the findings have relevant implications for any industry that designs, produces and distributes a complex product involving multiple technologies.

1. Modularity in Product Architecture and Outsourcing in Organisation Architecture

Modularity, be it in product or organisation architecture, is a bundle of characteristics that define (a) *interfaces* between elements of the whole, (b) a function-to-component (or task-to-organisation unit) mapping that define what those elements are, and (c) hierarchies of decomposition of the whole into functions, components, tasks, etc. Much of the existing literature addresses some, but not all, of the characteristics that are relevant to defining modularity. This section outlines these characteristics firstly in product architecture, before moving onto a discussion of their links to organisation architecture. This section concludes with three basic implications. First, it is argued that ranking the bundle of characteristics into a uni-dimensional integral-modular spectrum is difficult. Second, a move towards a modular product architecture gives scope for reconsidering the corresponding organisation architecture, but there is no simple deterministic link between the type of product architecture and organisation architecture. Third, the added value of employing the term 'architecture', rather than 'design' (namely 'product architecture' rather than 'product design', and 'organisation architecture' rather than ‘organisation design’) lies in the explicit recognition of the existence of an architect. What distinguishes an architect from a designer is the former’s knowledge of the entire system, which is a precondition for executing systems integration effectively. In theory, modularity captures the notion of a clear division of labour between the architect with architectural design knowledge and designers with knowledge of each module. In a dynamic world of technological change, however, such a division of labour appears to be neither feasible nor desirable. Hence the importance of architects as ‘systems integrators’, where systems in question are both products and organisations.

1.1. Modularity in Product Architecture

A starting point for defining modules, for many scholars and practitioners, is the notion that they exhibit strong interdependence within and independence between them (Baldwin and Clark 2000, Ulrich 1995). A sole focus on interfaces leads to a definition of product architecture as ‘a complete set of component interface specifications’ (Abernathy and Clark 1985). In management literature, more than in the engineering literature, there is a tendency to home in on interface specification as an important feature of modularity. Most recently, Baldwin and Clark (2000) devoted much of their seminal book to elaborating various ways in which partitioned chunks of a product can be mixed, matched and reused, using different operators, such as splitting and substituting, augmenting and excluding, and inverting and porting. Similarly, Pine (1993), following Ulrich and Tung (1991), identified different ways in which modules can be connected, for example by component swapping and sharing. Less sophisticated discussion of modular interfaces has focused on a binary contrast between standardised vs customised interfaces, or between open and closed (i.e. proprietary) interfaces. In this interface-focused perspective, modularity is often identified with standardised and open interfaces, not least because they enhance the possibility of mixing and matching. Nevertheless, there are other interface characteristics, such as reversibility (i.e. ease with which chunks can be disconnected, by plugging or bolt-nut connection rather than welded connection), that mitigate the absence of interface standardisation. Thus, modularity in interface specification is itself a bundle of characteristics that enhances the independence between modules as physical chunks (Fixson 2002). As noted later in this section, the relevant features of such independence differ when we consider modules in the arena of design, production, or use and reuse.

The fact that specifying the nature of interfaces is a necessary but not a sufficient condition for defining modularity becomes obvious when one poses the question: what is the boundary of the modules for which the interfaces apply? One answer is provided by Ulrich (1995) who defines the product architecture as 'the scheme by which the function of a product is allocated to its physical components.' He goes on to define modularity in terms of both elements and interfaces: 'a modular architecture includes a one-to-one mapping from function elements in the functional structure to the physical components of the product, and specifies de-coupled interfaces between components. An integral architecture includes a complex (non one-to-one) mapping from functional elements to physical components, and/or coupled interfaces between components.' (Ulrich 1995, p.422). This modular-integral dichotomy is conceptually powerful, particularly as it points to function containment within a chunk as an operational guideline for defining the boundary of a module. But once any deviation takes place from a 'purely modular' case (i.e. functional containment in each component, with de-coupled interfaces), it is difficult to rank different combinations of characteristics along a modular-integral spectrum. For instance, is a product architecture with a one-to-one mapping from functions to components but without de-coupled interfaces more or less modular than a product architecture with a many-to-one mapping from functions to components with de-coupled interfaces?

Any complex product may be decomposed into hundreds or thousands of elementary components, and a bundle of components may be a module, but it is not at all evident how large a bundle should constitute a module. One partial solution to this question is to introduce the notion of nested hierarchies, in which components and functions are simultaneously part of a higher level system and consist themselves of multiple subsystems. As Simon noted 40 years ago, complex systems tend to organise themselves in hierarchies (Simon 1962). Hierarchies solve the problem of complexity by enabling a repeated decomposition into smaller elements. Following Clark (1985), Fujimoto (1997) and Takeishi and Fujimoto (2001) identified multiple hierarchies linked to product and process technology, and those linked to customers and markets. Specifically, we might compare corresponding levels in two hierarchies, for instance a hierarchy of product functions (as identified by customer needs) and a hierarchy of product components. Then, the function-to-component mapping at each level in the hierarchy may exhibit varying degrees of modularity or integrarity (a la Ulrich). For a product like computers, the mapping might be quite modular (i.e. more like one-to-one than one-to-many or many-to-one) at relatively high level in the hierarchy (e.g. data input function in keyboards). For automobiles, it seems that whilst some large chunks (such as engines and seats) exist, they tend to contain multiple functions (e.g. comfort, safety, etc for seats), and modularity in the sense of a simpler function-to-component mapping may exist at lower levels in the hierarchy.

Any product has to be designed, produced and used by explicitly recognising the hierarchy of components and functions. But different phases of the product life cycle demand different objectives, and the need to coordinate between them imposes another layer of complication in attempting a single optimal decomposition of products. For modularity-in-design (MID), product designers are interested in reducing leadtime and cost for design and development. One way of achieving this objective is to engage in parallel development of modules by independent design teams. By making sure that design tasks are independent between modules, one module can be redesigned without affecting other modules. In modularity-in-production (MIP), production managers are interested in increasing operational efficiency. Modules are normally interpreted here as sub-assemblies that are easy to test (an idea of function containment is evident here) and install (i.e. with a small number of fixing points). But at a lower level in the product hierarchy, modular sub-assemblies themselves are used as a way of postponing customization, by mixing and matching standardised components. Operational efficiency, therefore, results from both component interchangeability, late customisation and the resulting inventory reduction, in order to meet the demand for product variety. Lastly, in modularity-in-use (MIU), consumers are interested in ease-of-use (including compatibility and upgradability) and ease of maintenance (including minimising the cost of repair and recycling). For this, easy disconnection between modules and even within modules is essential. Taking account of these three phases in the product life cycle means that competing demands are likely to be put on what is a module. For instance, a high degree of design integration within a cockpit module – for example by making the casing of the HVAC (heating, ventilation, and air conditioning) unit be a carrier for wiring harnesses – conflicts with the MIU objective of minimising the cost of repair and reuse. Relevant interface characteristics are also different: function containment for designers, ease of installation for producers, ease of disconnection and reuse for consumers. Hence it would be rare for modular boundaries to be optimised with respect to every phase.

To summarise, modularity as a concept can only be defined as a bundle of characteristics concerning module interfaces, the function-to-component mapping, and hierarchies in different phases of the product lifecycle. In a 'pure modular' case, interfaces are standardised and reversible, there is a one-to-one mapping of all functions and components, and mapping at each level between any pair of hierarchies is also one-to-one. In the absence of such product architecture, it is no wonder that system integration (in the sense of ensuring that the whole product, when put together, works well) is necessary in nearly all cases. A systems integrator may be a centralised coordinator with architectural knowledge, that polices and adjusts the design rules that define interconnections amongst interfaces. In the course of iterative adjustments, however, local knowledge from module teams is necessary to make the adjustments. A good example in the car is the achievement of a particular noise/vibration/harshness (NVH) level at different maximum speeds, as engineers develop their understanding of the subtle linkages between the body, chassis, engine and drive-train. A whole workable automobile continues to rely on such system integration know-how.

Given the continued importance of system integration in designing and producing cars, it is not surprising that the two modules studied by the author, namely cockpits and door inners, exhibit different boundaries from model to model in Europe. Exhibit 1gives a schematic sketch of the sort of components that may be included in the cockpit module, containing at a minimum the instrument panel (or dashboard) and the cross car beam. In reality, a variety of other parts – such as an instrument cluster, the HVAC (heating, ventilation, and air conditioning) unit, the steering column and wheel, and airbags – may be assembled by suppliers before the sub-assemblies leave the suppliers' site (as shown in Exhibit 2). Similarly, a door module typically contains, at a minimum, the carrier plate with a window regulator, window motors, and a locking mechanism. But other components, such as loudspeakers, fasteners, wiring harnesses, and glass guidance mechanisms may be added in some cases (see Exhibit 3). These tables give systematic evidence for Europe, that the product architecture of a car differs substantially from model to model, and that the notion of mixing and matching, or sharing and re-using modules across models, never mind across OEMs, is not generally possible due to large variations in modular boundaries.

Exhibits 1 , 2 & 3 About Here

1.2 Outsourcing in Organisation Architecture

Modularity is a concept that has been applied to a wide range of fields that deal with complex systems (Schilling 2000). Organisations are such complex systems that may be modularised, by developing well-defined interfaces between organisation units, and a clear task-to-organisation unit mapping at various levels in organisational hierarchies. By analogy to product architecture, organisation architecture may be defined as a scheme by which tasks are allocated to organisational units and by which those units interact and co-ordinate with each other. Task allocation as the main starting point for designing an organisation reveals the rationalist bias in organisation analysis (in the sense employed by Scott 1998). If we start with the notion of 'strong interdependence within and independence between', then an organisation is modular if it consists of units with people whose tasks are interdependent within, and independent between, the units, be they teams, departments, or divisions.

As with modular product architecture, *interfaces* between modular organisation units must be well defined. Standardisation is one of the several ways in which interfaces can be well defined. For example, a production team that works according to standard operating procedures may be considered to have standardised organisational interfaces than a team of craftsmen each with their own way of doing things. The notion of standardized or codified rules concerning how tasks are coordinated between organisation units has led some management scientists to focus mainly on interfaces, rather than a task-to-organisation unit mapping, to define organisational modularity. For instance, Fine (1998) employs the term 'value chain architecture', and calls it modular when the architecture is characterised by ownership separation, geographical distance, and cultural distance. The implicit assumption made here is that with these characteristics, tasks which pass between modular organisation units have to be necessarily well defined (i.e. explicit and codified). Also, this definition indicates that interface characteristics for organisation architecture, just as for product architecture, are multiple, and different aspects matter more for different tasks or phases in the product life cycle (see later discussion in this section).

Apart from a focus on interfaces, organisation architecture may also be characterised mainly with *hierarchy* in mind. All organisations consist of some sort of hierarchy, with various possible ways in which tasks are decomposed and allocated to smaller organisation units. Hierarchy in organisation architecture, in our current context, may be manifested in both an internal authority structure of a company and the tiering of suppliers in the supply chain. In all vertical relationships, task delegation without meddling is a mark of autonomy. Thus, for both horizontal and vertical links within, and between, organisation units, modularity may be characterised by a relative absence of the need for interaction. Task containment within an organisation unit, rather than task sharing between units, is one way to achieve independence or autonomy. As an example, a project team that undertakes all phases of a project, or an autonomous work group that can assemble an entire car, may be considered more independent from the rest of the organisation, than a functional team that has to coordinate with other functions in the organisation. But within the development function, a development team that has a clearly defined set of tasks that do not depend on the completion of tasks by other teams is autonomous and therefore modular.

In economics, Langlois (1999) goes as far as to argue that the price system in well functioning markets is the standard interface that allows modular organisation units to coordinate with one another without communicating except on one dimension, the price. Here modularity in organisation negates the need for hierarchy completely. But at the same time, when this happens, it becomes rather nonsensical to talk about a modular 'organisation' coordinated by the invisible hand. If interfaces are defined solely by the price system, there is no role for an organisation architect. It is precisely because both the internal organisation and the supply chain are coordinated by price and other mechanisms that it makes sense to separate the role of an organisation architect and organisation designers.

Interfaces for organisation architecture are more difficult to specify, as compared to those for physical product architecture, for another reason. This is due to the view of organisations as a process or as a natural system (Scott 1998), rather than as a rational Weberian structure with a clearly defined set of goals. Many classics in organisation theory have struggled with competing conceptualisations of organisations as technical vs institutional, or as closed vs open systems. More specifically, in dealing with the contradictory pull of autonomy and interconnectedness, Burns and Stalker (1961) assigned connectedness to the mechanistic organisation and autonomy of components to the organic organisation. Similarly, Lawrence and Lorsch (1967) argued that differentiation within an organisation could be compensated for by integrative mechanisms such as cross-functional committees. Thus, whilst mechanistic organisations and differentiation may be associated with modularity in organisation architecture, these organisational characteristics are also associated with the integrative mechanisms that bind an organisation together. Thus, in a rational perspective of an organisation, modularity may be characterised by de-coupling, i.e. by two organisation units that are independent and do not respond or interact to each other at all. But in alternative perspectives of an organisation, de-coupling negates the essence of an organisation, and therefore there is no such thing as a de-coupled organisation architecture. This leads us to take note of the concept of loose coupling (Orton and Weick 1990), to preserve the notion of an organisation as a simultaneously rational and indeterminate system. In decomposing and integrating a product, we relied on the notion of an architect with an architectural design knowledge. In differentiating and integrating an organisation also, we need the notion of an organisation architect who can design an organisation and adapt both spontaneously and deliberately to demands for changes in organisation design. The visible hand, therefore, has to be well and alive.

Outsourcing is basically the reallocation of tasks from within an organisation unit to another unit, normally separated by ownership. In the context of the outsourcing of modules, OEMs may consider outsourcing design and development only, production and assembly only, or both. In the design and development phase, a module supplier may be given full responsibility in developing the module, or it may co-develop the module with the OEM in a co-located design team. Thus, module design may not happen within an organisation with unified ownership, but both cultural and geographical proximity is important for the success of co-development. In production and assembly, the development of supplier parks and modular consortia indicate that the outsourcing of modules goes hand in hand with the development of a more 'integral' organisation, with geographic proximity facilitating much interaction and communication. In this case, although ownership is separate, proximity is a necessity and a manifestation of the importance of organisational integration.

OEMs' decision on the sequencing of various tasks for outsourcing has implications for organisation architecture. In Exhibit 4, there is a presumption of a well-defined evolutionary path, with an OEM outsourcing the logistics and assembly of modules first, before it gives greater responsibility in the form of quality assurance, purchasing and sourcing of components that go into the module (i.e. control over tier 2 suppliers), and eventually engineering and development. Incentives for OEMs and suppliers are compatible if this evolution is followed through; for OEMs, gradual outsourcing with an increase in the confidence level in the relationship is supposed to minimise the chances of being captured or held up by suppliers; suppliers can earn greater value added eventually with design integration work, making them willing to buy into low-margin assembly-only business in the first instance. In reality, however, in some emerging market locations like Brazil, it is never intended that locally based suppliers go much beyond doing the assembly of modules designed elsewhere. At the same time, some global modular suppliers, such as Intier (the automotive wing of Magna), are investing heavily in systems knowledge about the whole car, so that they can win from the start a business to design and develop a module.

Exhibit 5 gives evidence of which party, the OEM or the module supplier, has control over selecting second-tier suppliers of components that go into cockpit modules produced in Europe. It indicates how extensive the practice of OEMs nominating component suppliers is, and how far this reality is from the rhetoric as gauged through the author's interviews, that OEMs control only strategically important parts such as airbags. Supplier interviewees also spoke derisorily about the OEMs' reluctance to let go, as captured by the term 'shadow engineering'. But this seemingly wasteful overlapping in design and supplier selection tasks is an attempt by OEMs to retain their systems integration capability. Thus, Exhibit 5 may be interpreted in a number of ways. One possibility is that this is a transition towards a situation in which OEMs will focus purely on styling and marketing, withdrawing from manufacturing and assembly all together. In this scenario, some OEMs would wish to delegate systems integration tasks to powerful suppliers that can design a whole car. Another possibility is that the Exhibit portrays a more static picture of the state of play, with OEMs wishing to retain systems integration knowledge in-house.

1.3 Three Paths to Outsourcing Modules

Once we recognise that the outsourcing of modules requires a sequencing of different tasks for outsourcing, the picture becomes quite complex. However, let us simplify for analysis by assuming that there is only one set of tasks – either design only, or production only, or a package of design and production – to be outsourced. Take an OEM which has a non-modular product design and whose organisation is highly vertically integrated in-house. The OEM has a choice of three trajectories for moving from the initial position to the ultimate position of the outsourcing of modules: (1) by designing modules and producing them in-house first before outsourcing them; (2) by outsourcing non-modular components before moving towards modular design; and (3) by simultaneously implementing modular design and outsourcing.

In the first path, modular design is likely to be adopted only if it brings about significant performance improvements and solutions to problems arising from design integration, ergonomics or complexity. By the time modules are outsourced, OEMs would be in a position to teach suppliers, and much of the module design as well as architectural knowledge would remain with OEMs. In the second path, outsourcing rather than modularisation is the initial driver, and benefits of modularity may take some time to emerge when outsourcing runs ahead of modularisation. This is not least because it is unclear whether the OEM or the supplier will end up taking a lead in proposing modular design and the integration of components. In the third case, a simultaneous implementation of modularisation and outsourcing is possible if there are capable module suppliers already in the marketplace. OEMs can achieve a faster pace of innovation but face the danger of losing in-house capability and control. At the same time, suppliers face an opportunity to influence the direction of technological innovation, and to capture a greater share of returns to R&D. Thus, the path followed to outsource modules has a clear implication for the ultimate distribution of capabilities and know-how between OEMs and suppliers.

Moreover, the overall level of complexity in the supply chain may, or may not, decline depending on this distribution of capabilities. Specifically, an OEM that produces modules in-house or has suppliers with solution is likely to benefit from an overall improvement as a result of modularization. By contrast, an OEM which outsources modules without an in-house set of solutions may end up not improving the amount of complexity in the total supply chain and therefore pay more dearly for the modules than if they were produced in-house.

1.4 Implications for the Link between Product Architecture and Organisation Architecture

A predominant view of the link between product architecture and organisational architecture in engineering science is to start with product architecture and to work out a corresponding organisation design. A specific example of this rational organisation design that follows from product architecture is the derivation of the Task Structure Matrix (TSM) from the Design Structure Matrix (DSM) (Baldwin and Clark 2000 following Eppinger). With a slightly different concern, Sanchez and Mahoney (1996), in discussing strategic use of modularity in product design, contend that products design organisations. Thus nonmodular products are best produced in nonmodular organisations. But modular products call for modular organisations, and this correspondence is beneficial for enhancing organisational flexibility, eliminating the need for hierarchical coordination.

This chapter takes a different stance. First, modularity in product architecture gives greater scope for choice in organisational design, thus giving an opportunity to trace 'path dependence' at the juncture at which such choice exists. Second, organisation inertia may well make the reverse causal direction (from organisation architecture to product architecture) important. Thus, product architectural choice influences organisational design, but pre-existing organisation structures and capabilities also influence product design (Gulati and Eppinger 1996).

To be fair to Sanchez and Mahoney, they too recognise this two-way causation: ‘although organisations ostensibly design products, it can also be argued that *products design organisations*.’ (Sanchez and Mahoney 1996, italics in the original). It is then an empirical question to gauge which causal direction has been stronger over a particular period of time.

Given the above perspective, the notion that product architecture causes organisation architecture is not so deterministic. In the car industry, product modularisation may be considered to go together with outsourcing, if not straightaway but ultimately, because open and well-defined interfaces lower barriers to entry. But the fact that IBM adopted a distinctly non-modular organisational structure to manage its System 360 mainframe computer, doing its best to keep interfaces proprietary to prevent others from supplying compatible modules indicates clearly that a decision over product modularity is separate from a decision over outsourcing.

Moreover, there is evidence in other industries that the reverse causation of organisational architecture affecting product architecture may be quite strong and significant. Certainly, experience in the disk drive industry suggests that, at least for a period, an industrial organisation of small, highly specialised firms was closely linked to within-module innovation (Chesbrough and Kusunoki 1999). These specialist firms had limited incentives for changing the product architecture because they had particular skills within narrowly defined domains. Thus at least in the short-run, product architecture was constrained by organisational architecture. Similarly, Henderson and Clark (1985) have shown that in the photolithography industry, few firms successfully weathered the shifts in architectural innovation rather than within-module innovation. These examples suggest that far from optimising organisational architecture to capitalise on the specialisation of the element of a given product architecture, the organisation in fact seems to constrain shifts in product architecture. When these shifts do take place, they are likely to be slow and met with internal organisational resistance because of the effect that they have on labour, capabilities, and power.

If there is a two-way relationship between organisational architecture and product architecture, then we would expect that a range of product architectures emerge depending on organisation history. For instance those firms with a highly integrated supply chain architecture might be expected to retain a more integral modular product architecture. If so, integral product architecture is likely to persist in Japan even in the presence of modular design by some non-Japanese manufacturers, unless a radical solution is proposed for a module whose technical and economic benefits outweigh the well-established advantage of integration exploited by close co-ordination in the supply chain. Likewise, firms that have made a significant investment in both deep and diverse technical knowledge are unlikely to promote modular product architecture that provides competitors with advantages within modules and renders their integrative skills less valuable.

By contrast, the popularity of the notion of modularization in the US and Europe may in part be due to the hope that it might enable the retention of, or reversion to, arm's-length trading with suppliers without being locked in to any committed relationships. Then we would expect a greater move towards modularization where supplier relations are market-based than where they are long-term and obligational. There is some evidence in the auto industry that US and European OEMs are ahead of Japanese OEMs in thinking about modular product architecture, and one may conjecture that one reason for this is the pre-existing organisation architecture of OEMs and their supply chain. However, apart from the pre-existing organisation architecture, there is also a difference in the mix of strategic drivers that predisposes certain OEMs to be more interested in outsourced modules than others. The next section discusses these drivers which are relevant to the global car industry.

2. Modular Strategies: Why are OEMs and suppliers interested in 'going modular'?

The automobile industry has been the source of innovative management practices in production in the twentieth century. After the 1910s, Ford's moving assembly line, making use of standardised and interchangeable parts, revolutionalised the way cars were made, leading to mass production supplanting craft production in most locations. A second paradigm shift occurred with the advent of Toyota Production System and its diffusion in the form of lean production that emphasised the elimination of waste and good functional quality. Now the focus of many OEMs and suppliers is on so-called modular strategies in product design and production. What opportunities and threats are driving OEMs' and suppliers' wish to 'go modular'? This section identifies four strategic drivers, and discusses their implications for OEM-supplier relations. Wherever appropriate, a comparison with the computer industry is made. It is evident that modularity in the auto industry is not just an engineering principle but part of corporate strategy. OEMs' motives for adopting modules are multiple, and different motives lead to a varying degree of push for outsourcing modules.

2.1 Four Strategic Drivers: Marketing, Production, Finance and Technology

Marketing Strategy

Perhaps the most topical driver for going modular is manifested by some OEMs' interest in benchmarking Dell Computers Inc. Dell represents 'best practice' in combining the power of the Internet with 'Build to Order' (BTO) and mass customisation (Pine 1993). Mass customisation enables the assembly of a great variety of products by standardising components that can be mixed and matched. Postponing customisation until end users specify the exact mix and match enhances operational and logistical efficiency.

No OEM is yet to host a Dell-like web site that enables the final purchaser to track the car being built in the factory. In reality, 'Build to Order' is still a long way from being implemented in its true form, because paint defects give unpredictable variability in production, and make it difficult to assign a specific customer to BIW (body-in-white) (Holweg and Pil 2001). Cars are also a much more complex product than computers, typically containing 4000 components compared to 50 or so components for computers, potentially enabling much greater product variety. Despite these complications, major OEMs are exploring ways of improving their ability to 'build to order' with a view to serving consumers' demand for a highly sophisticated car that is individualised through factory-installed options. And if consumers demand delivery with a short leadtime (say within a week from the order date), having modules with standardised interfaces becomes an essential complement to 'Build to Order'. In this sense, the demand for BTO may drive the implementation of modular design and production.

Nevertheless, Build to Order is much easier when parts are compact, lightweight and easy to ship. This condition is violated in the case of large chunks of a car, such as seats and front ends. That is why product variety in cars is likely to be pursued, not by decomposing the car into large chunks and mixing and matching them, but more by specifying colour, trim and options such as wheel hubs, mirrors, audio units, and navigation systems. Personalisation and the retention of a distinct look-and-feel of a car may therefore be pursued by mass customisation of specific components at a low level in the product hierarchy, combined with a fairly integral product architecture that addresses 'drivability' and other desirable functions that users look for in the total car.

The electronification of the car, particularly after the advent of telematics, may make cars more similar to computers in their need for upgrading and compatibility. Just as computers require software upgrades, cars require more frequent upgrades in navigation systems than in body-in-white shells. This demand for upgradeability may promote standardisation in software for cars, but not necessarily in physical modular chunks.

Mass customisation is not a new idea, but B2C e-trading may make it more popular and possible, as OEMs accumulate systematic information about consumer tastes, typically retained by dealers to date. The potential for using this information to enhance customer loyalty is vast.

But there is no evidence so far that if offered the choice, consumers would wish to mix and match large chunks of the car – e.g. retain a Mazda engine and seats and slot them into a Jaguar.

Production Strategy

Attaining operational efficiency on the factory floor has been a longstanding objective of the car industry. In fact, as a principle of production, modularity has a century old tradition dating back to the so-called American Production System, in which the core idea of interchangeable parts preceded the advent of mass production (Best 1990). Eventually, mass production, typified by Ford's moving assembly line, led to standardising work methods through time and motion study. Standardisation means that the sequence in which each detailed production task is to be carried out is specified, as is the exact time taken for each task. In fact, 'product architecture' is defined by major OEMs today as the 'build sequence', indicating how important the assembly process is in car manufacturing.

Standardising task time allows assemblers to meet mass production's basic requirement, which is to balance the line. When standardisation is difficult to achieve, complex and ergonomically difficult tasks are taken off the main line, and it is those sub-assemblies which are made off the main assembly line, that came to be called modules. In the 1980s, Renault conducted an ergonomic review, and ended up taking difficult tasks off the main assembly line, organising in-house sub-assembly lines for powertrain, dashboards, front ends and doors. Around the same time, it was extensive automation at Cassino plant that led Fiat to rethink its organisation of assembly. Automation necessarily introduced a degree of inflexibility, and Fiat responded by replacing a very long final assembly line with a shorter one fed with multiple sub-assembly lines. In such context, a module came to be defined as 'a set of components assembled, which can be checked and tested before final assembly.' At this stage, modules were assembled in-house by OEMs, and there was no notion of outsourcing.

The more recent initiative in the 1990s to introduce production modules is associated with the OEM's wish to cope with in-line complexity due to ever-increasing product variety. Product variety requires manufacturing flexibility, which is often equated with the flexibility of the process equipment in the plant (e.g. CNCs and robots) and low set-up times. But as Ulrich argues, 'much of a manufacturing system's ability to create variety resides not with the flexibility of the equipment in the factory, but with the architecture of the product' (Ulrich 1995, p.428). For flexibility, the product architecture must allow for the use of a relatively small number of building blocks in different permutations. This permutation process is none other than assembly, and this enables firms to postpone some of the final assembly for customisation. The reliance on assembly rather than parts fabrication to engender product variety is essential in a product such as the automobile, which has many metal parts requiring unavoidable tooling and set-up costs (Whitney 1993).

But in order to understand why this later phase of introducing production modules in the 1990s is associated with outsourcing, we must turn to the next driver in finance.

Financial Strategy

Since the 1990s, some major OEMs began to speak of modularisation to mean the outsourcing of modules. 'Being assembled and tested outside our facilities' was added to the definition of a module at Fiat, whilst Ford reported rather sensationally its intention to outsource key parts of its final assembly operations, which 'could signal the company's gradual withdrawal from final assembly as a core activity – transforming Ford from a carmaker into a global consumer products and services group.' (*Financial Times*, 4 August 1999).

Outsourcing has always been associated with the exploitation of lower wages either in emerging markets or in non-unionised workplaces. This is borne out by the fact that the simultaneous implementation of modularisation and outsourcing has occurred most frequently in the context of greenfield site investment projects. But there is wide recognition that lower wage rates in themselves are a limited and short-lived source of competitive advantage (Rommel et al 1996). Either, the wage gap may be eroded over time, or lower productivity may offset the wage advantage. Module suppliers are typically expected to locate very close to the final assembly plant, either on a supplier park or as part of a modular consortium. This geographical proximity, combined with tight synchronisation of operations between the assembler and suppliers, put pressure on wage differentials to close.

A much more powerful force sustaining the interest in modularisation even where it faces scepticism in operational and labour terms is the goal of moving assets off the books of OEMs to suppliers. Outsourcing of modules in greenfield sites enable OEMs to shift initial investment costs and risks to suppliers. This is said to enhance return on assets (ROA) for OEMs, which would in turn assist them in raising their shareholder value. This belief in the need to go on an 'asset diet' was heightened by the decline in the valuation of automotive firms in the midst of the dotcom boom, reaching a mere 2.5% of the total market capitalisation in Europe and 1.2% in the US in mid-2002. Nevertheless, the direction of causation and the exact mechanism for asset diet to lead to shareholder value enhancement are open to question.

There is some evidence from our study that OEMs with a lower return on assets are keener on modularisation (although this is different from claiming that modularisation leads to better ROA). They also tend to face severe financial pressure from low profitability of small car segments (particularly in B and C classes). The predominance of small passenger cars in European, relative to US, markets may also explain why European-based OEMs have started showing interest in outsourcing modules earlier than their North American counterparts. Nevertheless, at least two reasons caution against the viability of this financial strategy for OEMs.

First, in existing assembly sites, outsourcing has been quite slow, not least due to union opposition to it. General Motors' Yellowstone Project had to be abandoned after UAW opposed it fiercely, creating a notion that modularity is a dirty word and a euphemism for outsourcing and undercutting of union labour rates. It has not been possible, therefore, to simply go for 'downsize and distribute' (Lazonick and O'Sullivan 2000), even if management wanted to proceed faster.

Second, one implication of shifting the burden of capital investment to suppliers is a higher overall cost of capital, assuming that suppliers with their smaller size face a higher cost in raising capital than OEMs. Those higher capital costs must be absorbed somehow, possibly by returning to OEMs in the form of higher prices for the modules they buy. Alternatively, suppliers may attempt to lower their cost of capital by continuing to grow and consolidate in a wave of mergers and acquisitions. Either way, OEMs are beginning to turn the logic of transaction cost economics upside down, by making suppliers bear the cost of investing in customer-specific assets (for example in the form of supplier-owned tooling). This necessarily enhances suppliers' incentive to make the tooling as general and reusable as possible.

Technological Strategy

The last strategic driver for going modular is technological. The automobile has always been a complex multi-technology product. But the range of new technologies captured by the car has increased over time, with greater electronics content, new materials (aluminium, magnesium, and plastics being candidates for an alternative to steel), and new energy sources (notably LPG, electricity and fuel cells). Some OEMs, even devoid of the aforementioned financial pressure, are reacting to this phenomenon by redefining their core competence and by shifting more and more responsibility for R&D to suppliers. By making suppliers bear the upfront cost and risk of R&D, OEMs hope to ease access to supplier-developed technologies by making them engage in design or concept competition. But as the outsourcing of R&D proceeds, suppliers would naturally wish to implement a tighter appropriability regime by patenting previously unpatented ideas.

Whether or not new technology enhances modularity or integrality in product architecture depends on whether the value of innovation is seen to lie within the module, across systems or at the component level. If there is a degree of stability in product architecture, innovation may be spurred by parallel processing of modular design teams each free to adopt new technology within the module without affecting the other modules (Tomke and Reinertsen 1998). Even here, there is an issue around which supplier is best appointed tier one to play the role of a within-module design integrator. For example, for a historical reason, the dashboard supplier (with plastics technology) is normally the first tier supplier of a cockpit module, which requires other technologies in instrumentation and electronics. To enhance the design integration of the cockpit, it may be better to appoint a supplier with an electronic and electrical capability to be tier one module supplier.

In a more dynamic setting, modularity is often only a short run solution to product architecture. Under uncertainty, it is better to err on the side of integrality than on modularity in product architecture to promote innovation (according to a simulation by Ethiraj and Levinthal 2002). Moreover, if technological change may shift between modularity and integrality, it may be better to err on the side of integrality in organisation architecture to avoid what Chesbrough and Kusunoki (1999) call a 'modularity trap'. In such a trap, benefits from a shift in an industry from a modular to a more integral phase of technological development cannot be exploited fully by firms due to inertia in organisation structure more suited to serving modular product architecture. One solution to avoiding the modularity trap is to follow Brusoni et al (2001)'s prescription: multitechnology firms need to have knowledge in excess of what they need for what they make, to cope with uneven rates of change in technologies on which they rely. The unevenness of technical change renders systems integration capability all the more important, as it requires addressing unpredictable inter-module or inter-system interdependencies.

For this reason, OEMs may well choose to outsource production or assembly, but not outsource technological knowledge. But this latter is a matter of strategic choice. OEMs face a choice between remaining a product architect (thus retaining technical leadership in all sorts of technologies as well as total product architectural knowledge), and becoming a modulariser that follows the architectural decisions of other OEMs. Sustainable profits come in the former case from architectural and technological innovation, whilst the source of competitive advantage in the latter is likely to lie in other areas such as brand management.

The above analysis is somewhat at odds with the traditional transaction cost explanations of the boundary choices of firms since these choices are generally not thought of as strategic, but rather arising in response to operational costs associated with asset specificity and opportunism. In a study of the auto industry, Monteverde and Teece (1982) suggest that 'assemblers will vertically integrate when the production process, broadly defined, produces specialized, nonpatentable know-how.' However, the creation of even patentable know-how could be undertaken either within, or outside, the firm, depending upon strategic considerations of whether or not OEMs remain product architects.

2.2 Linking Strategic Drivers to Outsourcing of Modules

To summarise, OEMs' incentives to modularise are multiple, driven by changing phenomena in marketing, production, financial markets and technology. It was shown that in the car industry, thinking about modules has had the longest history in the production area, whilst the other three drivers are of more recent import. Also, financial incentives seem to be of utmost importance in many OEMs' 'modular strategies' in the 1990s and beyond.

Nevertheless, a different mix of the four drivers gives rise to a different choice in the path to outsourcing modules. As we saw, production strategy may lead to more use of modules in the sense of sub-assemblies, but in itself is neutral to whether or not these modules are outsourced or not. A financial driver in itself will predispose OEMs to outsource first and foremost. But without an accompanying logic in production, marketing or technology, they may not get to switching from outsourcing components to outsourcing modules.

Outsourcing is a decision about organisation architecture, and about the drawing of the boundary of the firm. This section has shown that such a decision is a matter of strategic choice.

But this choice is commonly mediated by labour and capital market conditions, as Baldwin and Clark (2000) show in the case of computers. They argue that with IBM's System 360, some design teams internal to IBM decided to spin out as independent firms, while other design teams emerged outside of IBM to compete head-on. Baldwin and Clark attribute this de-verticalisation of the US computer industry to a combination of the modular design principle and the availability of venture capital to finance modular design teams.

Given this analytical framework, we can account for differences between the evolution of modules in the computer industry and the auto industry, and between firms in different countries within each industry (see Exhibit 7 for a summary of computers vs autos comparisons). The trigger for the use of modules in the computer industry was users' demand for compatibility. This starting point with modularity-in-use (MIU) meant that for modularity-in-design (MID), global design rules were consciously created for modular plug-able computers. A modular product architecture led to a modular organisation with independent design teams but within a single corporation. The eventual disintegration of the industry into modular suppliers in the US, but not in Japan, may be accounted for by the inter-firm mobility of technical labour and the availability of venture capital for start-ups in the US and their relative absence in Japan.

Exhibit 7 About Here

In the car industry, the starting point for adopting modularity was in production, specifically in assembly involving complex and ergonomically difficult tasks. Modularity-in-production (MIP), initially undertaken by OEMs themselves, enabled the outsourcing of modular assembly to tier-one suppliers. But unlike in the computer industry which saw much spin-outs and start-ups in the process of adopting modules, the car industry faces excess capacity, slow growth, and globalisation. It is not surprising, then, that in the labour market, savings on operator wage costs rather than the mobility of technical labour is at issue. In the capital market, rather than venture capital assisting the process of vertical dis-integration, investment banking advice has led to much consolidation of suppliers wishing to remain, or become, module suppliers. New opportunities for saving on labour costs and M&A are both less common in Japan than in Europe or the US. These differences contribute to the reasons why modularization is pursued more keenly in Europe and the US than in Japan.

3. Conclusions

This chapter has had two major aims: a clarification of the concept of product architecture and organisation architecture, and understanding how strategic considerations mediate the way product architecture affects organisation architecture and vice versa. Empirical evidence focused mainly on the automotive industry with some comparisons with the computer industry. Modularity as a key concept in product architecture, and outsourcing as a counterpart in organisation architecture, were discussed in relation to the notion of systems integration, where systems are both products and organisations.

In relation to the first aim, product or organisation architecture was identified as a bundle of characteristics that define (a) interfaces between elements of the whole, (b) a function-to-component (or task-to-organisation unit) mapping that define what those elements are, and (c) hierarchies of decomposition of the whole into functions, components, or tasks at different stages in the product cycle. Multiple dimensions exist, even in defining interfaces, and this makes it not possible to rank different types of architecture along a uni-dimensional integral-modular spectrum. In both the product and organisation realms, an explicit recognition of hierarchies of decomposition helps clarify the analysis. In product architecture, different stages in the product cycle put different demands on modularity. In particular, MID (modularity-in-design), MIU (modularity-in-use) and MIP (modularity-in-production) are three arena, each with a different set of objectives, demanding different degree of integration and modularity at varying levels of the product hierarchy. Choosing optimal module boundaries is not straightforward also when facing technological change because a modular product architecture requires considerable stability over time rather than a different set of module boundaries for each time period. For all these reasons, the role of the product architect, with a product-wide systems knowledge, continues to be important in the car industry.

The chapter also discussed how the relationship between product architecture and organisational architecture is tenuous for a number of reasons. The pre-existing organisational architecture may act as a hindrance to changing product architecture, thus making the causation in changes between product architecture and organisational architecture two-way. Three distinct paths to outsourcing modules were identified, with each path resulting in a different distribution of know-how and capabilities between OEMs and suppliers. The choice of a path depends, in part, on the initial organisation architecture. The Japanese penchant for sticking to an integral product architecture, as compared to the US/European OEMs' keen endorsement of outsourced modules, is explained in terms of the greater organisational integration that already exists in Japanese OEMs and suppliers.

Moreover, a mix of strategic drivers were identified as mediating the link between product architecture and organisational architecture. First, in marketing, OEMs' policy to pursue Build to Order may encourage product modularity, but leaves the question of outsourcing (i.e. organisational modularity) unaffected in theory. Second, a policy to improve production efficiency may lead to the creation of sub-assembly lines, but whether or not they are retained in-house or outsourced is indeterminate solely with this strategy in mind. Third, in technological strategy, a choice to remain a product architect, rather than a 'modulariser' (that follows the architectural decisions of other OEMs), is likely to lead to changes in product architecture (from integral to modular and back to integral) without much change in organisation architecture that continues to 'know more than it makes' (Brusoni et al 2001). Lastly, financial strategy to enhance shareholder value via asset reduction is associated with outsourcing (i.e. changes in organisational architecture) without necessarily any shift in product architecture. A comparison between the car and computer industries also points to the importance of labour and capital market conditions as factors mediating the outsourcing decision. It is no wonder that a difference in the mix of these strategic drivers, combined with pre-existing architectural differences, has led to a diversity of product and organisational architecture amongst car manufacturers.

To conclude, this chapter went beyond the pre-existing general discussion of the influence of product modularity on organisation design, specifically by using evidence in the auto industry to discuss what changes modularity might bring to the organisation of design, development and production. Modularity in product architecture gives greater scope for choosing among alternative organisation architectures. But the exact choice of organisational form and boundaries depends on corporate strategy, factor conditions, and the existing distribution of capabilities.

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Exhibit 1: Cockpit Module Boundaries

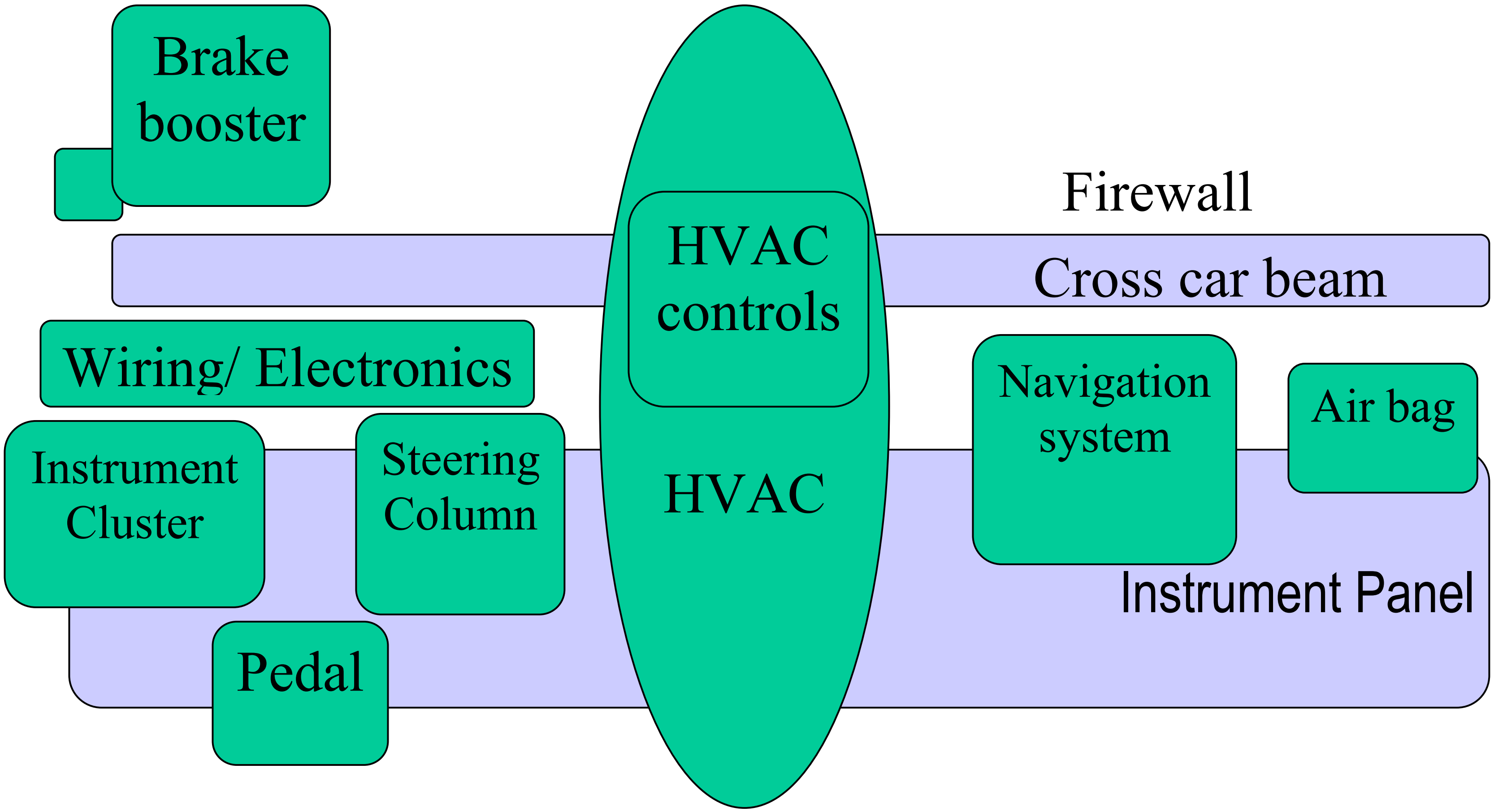

Exhibit 2: Cockpit Module Boundaries For European Car Models

	A	B	C	D	E	F	G
IP/dashboard	x	x	x	x	x	x	x
Cross car beam	x	x	x	x	x		x
Instrument cluster				x	x	x	x
Centre displays/dials							x
Switches				x	x	x	x
Centre console				x			x
Radio/ I.C.E.					x	x	x
Globebox	x	x	x	x	x	x	x
Air ducts		x		x	x	x	x
Bezels/vent control		x	x	x	x	x	x
HVAC system				x	x		x
Steering column				x	x		x
Steering wheel				x			
Driver airbag				x			
Passenger airbag		x		x	x	x	x
Pedal box							x
Wiring harness				x	x	x	x
Firewall							x

Source: IMVP European Module Supplier Survey 2000

Exhibit 3: Door Module Boundaries for European Car Models

	A	B	C	D	E	F	G
Carrier plate		x	x	x	x	x	x
Window regulator	x	x	x	x	x	x	x
Window motors	x	x	x	x	x	x	x
Electronic control box	x	x	x				
Internal locking		x	x	x	x	x	x
External locking					x		x
Latch		x	x	x	x	x	x
Water seal	x	x	x	x	x	x	x
Side impact padding							x
Wiring harness		x	x	x		x	x
Loudspeaker		x	x	x			x
Door trim							
Fasteners				x	x	x	x
Structure frame	x						
Glass	x						
Division car	x						
Power support		x					
Glass guidance				x	x	x	
Inside handle				x	x	x	

Source: IMVP European Module Supplier Survey 2000

Exhibit 4: Sequencing of Tasks for Outsourcing to Module Suppliers

	LOGISTICS and MODULE Assembly		Purchasing and Quality Management		Development and Sourcing	
	OEM	Supp lier	OEM	Supp lier	OEM	Supp lier
Logistics		○		○		○
Assembly		○		○		○
Quality	△	△	△	○		○
Purchasing	○			○		○
Sourcing	○		○			○
Engineering	○		○			○
Development	○		○		○	○

Exhibit 5: Control over Components For Cockpits

	A	F	G	H	I	J	K	L	M
IP/dashboard	△	X	X	X △	X △	X △	X	△	X
Cross car beam	△	X	X	O	X △	O	O		△
Instrument cluster	△			△	△	△	△	△	X
Central displays/dials				△					X
Switches	△			O	△	△	△	△	△
Centre console	△			X	△				X
Radio/I.C.E					△		△	△	X
Sat navigation etc.					△	△			
Glovebox	△	X	X	X △	△	X	X	△	O
Airducts	△	△		XO	△	X	X	△	O
Bezels/vent control	△	△	△	O	△	O	X	△	O
HVAC system	△			△	△	△	△		X
Steering column	△			△	△	△	△		X
Steering wheel	△			△					
Driver airbag	△			△					
Passenger airbag	△	△		△	△	△	△	△	X
Pedal box					△	△			△
Wiring harness	△			X	△	△	X	X	X
Other wiring				X					
Firewall					△				△
Keyless entry				△					
Steering column shroud				X △	△				
Sound insulation					△				

X = Produced in-house by module supplier
O = bought from suppliers selected by module supplier
△ = bought from suppliers nominated by OEM

Source: IMVP Europea △ n Module Supplier Survey 2000

Exhibit 6: Three Paths to Outsourcing Modules

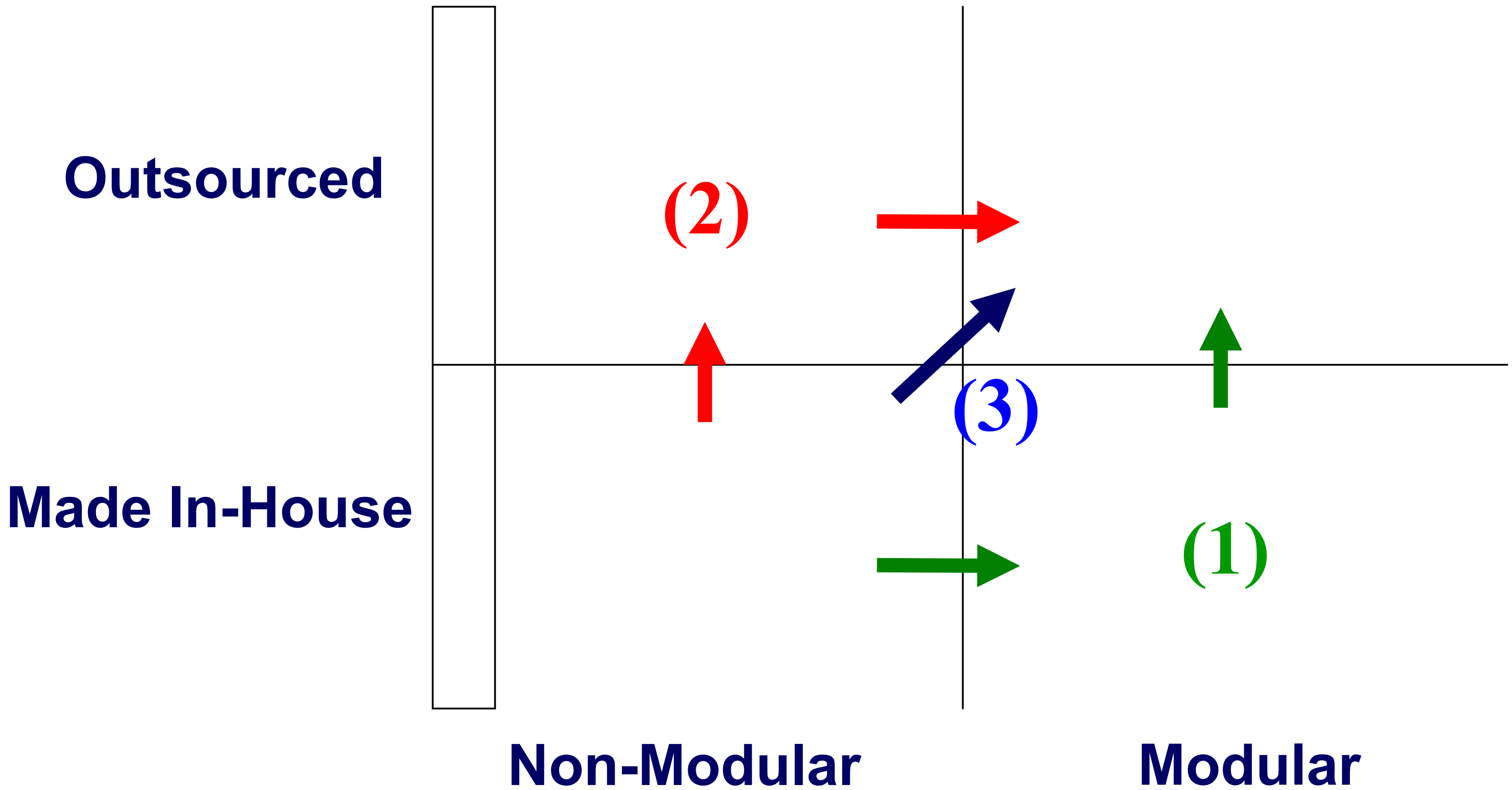

Exhibit 7: Computers and Autos Compared

	Computers	**Automobiles**
Catalyst for Modularity	MIU→MID	MIP→MID
Organisational Adaptation	Modular design teams & start-ups first, outsourcing later	Outsourcing, tiering & consolidation of suppliers
Labour Markets	Mobility in technical LM	Wage differentials between OEM and suppliers
Capital Markets	Venture capital for start-ups	Investment banking advice for M&A