Automotive cockpit modularity: migration issues for local tier 1 suppliers

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Abstract

One area that is seen to be crucial in future car production is that of the vehicle cockpit module as this represents an important element that can be outsourced and lead to potential gains in quality and delivery performance for both automotive manufacturers and their suppliers. This paper examines some of the key issues facing cockpit module suppliers. Through an exploratory approach the motivations for cockpit component suppliers becoming cockpit module suppliers are explored and the issues and implications associated with this local transition are outlined and analysed. Findings from the study suggest that the development of local supplier expertise, combined with an expanded supply chain management role, increased financial risk and proximity related operational issues are key factors that need to be carefully considered before organisations make the transition to cockpit modular supplier.

Keywords: Modularity, cockpit modules, suppliers, automotive

Introduction

An intriguing and emerging trend in Supply Chain Management in the automotive industry is the relationship between the Original Equipment Manufacturer (OEM) and its tier suppliers with respect to the design, development and delivery of complex engineered products in a modular form (Fixson et al. 2004). Whilst module production and modularity are not new concepts (Starr, 1965), it appears that more and more automotive manufacturers are now realising that modular strategies for production can offer potential long-term benefits to OEMs, suppliers and customers (Kochan 2003, Innovations report 2005, Siemens 2005).

There has been a plethora of definitions of modularity given in the literature for either Modularity in Design (Salerno and Dias, 2001, Lau et al. 2005), Modularity in Production (Sako 2002, Salerno and Dias 2001), and Modularity in Organisations (Salerno and Dias 2001, Takeshei and Fujimoto 2003, and Sako 2002). However, it is difficult to find a unified definition for modularity. Baldwin et. al. (1997) describes modularity as the process of “building a complex product or process from smaller subsystems that can be designed independently yet function together as a whole”. Sako and Murray (1999) give a definition from the product dimension, where they claim that a modular product is a “complex product whose individual elements have each been designed independently and yet function together as a seamless whole”.

Modularity as a concept has its roots in product design (Galsworth, 1994, Baldwin et. al., 1997) and in recent years a number of modularity themes have emerged. The theme of Modularity in Product Design and Product Architecture has been explored by a number of authors. Fixson and Sako (2001) discuss modularity in product architecture in relation to a comparison of the automotive and computer industries and they propose a conceptual model that encompasses types of innovation, cost and time, users and other factors that determine product architectures. They conclude that the consolidation in the auto industry between OEMs and suppliers may lead to an industry-wide standard for global product architectural rules. Fixson (2002) further discusses product architectures in relation to design strategy and he proposes an analysis framework consisting of three perspectives of system, hierarchy and lifecycle through which modularity is examined.

The aim of this paper is to explore the challenges and issues which local automotive component suppliers face as they make the transition to cockpit module suppliers. To facilitate understanding of the key concepts associated with modularity in the automotive industry the introduction is divided into three thematic areas. Firstly, the generic concept of modularity within the automotive sector will be explored and a description of a typical cockpit module will be introduced. Secondly, the operational benefits forthcoming from modularity for the OEM will be discussed. Thirdly, the changes to component supplier’s roles and relationships forthcoming from the transition to module supplier will be analysed.

Modularity

The concept of modular design and production has been applied within the manufacturing sector for a number of years and is perhaps best associated with the computer industry. Manufacturers within this sector have employed modularity to help cope with the increasing complexity of technology by breaking down the product into modules which allows greater flexibility (Baldwin and Clark, 1997). In recent years the concept of modularity has been extensively applied within the automotive sector. However, it has been suggested that ambiguity exists in relation to what modularity constitutes in the automotive sector and therefore the term has been used to cover a variety of practices (Camuffo, 2000).

The analytical framework suggested by Takeishi and Fujimoto, covering modularity in the automotive industry, is useful in helping to clarify the different, and therefore distinguishable, facets of modularisation. Firstly, '*Modularization in Product*', which focuses upon product architecture and the required interrelationship between product function and structure. Achieving this 'one to one correspondence between the products subsystems and their functions' (Takeishi and Fujimoto, 2001, p. 3), allows modules to be designed with a high degree of autonomy and reduces the interdependence with other modules In essence, this refers to introducing and achieving modularity in product design. Others concur with the issue of interdependence, as they describe modularity in design as something which 'intentionally creates a high degree of independence or 'loose coupling' between component designs' (Sanchez and Mahoney, 1996, p. 65)

Secondly, '*Modularization in Production'* – describes the manufacturing system structure where, as a result of a modular product design, the product (car) is produced from a series of modules each assembled on a sub-line before transfer to the product assembly line. A non-modular manufacturing system would be as a result of the product structure not containing any 'structurally cohesive large modules' (Takeishi and Fujimoto, 2001, p. 3) and therefore the product would be constructed from a series of components or small modules on the product assembly line.

Thirdly, '*Modularization in Inter-firm Systems'*- describes the situation where 'large modules are assembled by suppliers on <u>their</u> own assembly lines and are delivered and assembled into finished products on the main line of the automaker' (Takeishi and Fujimoto, 2001, p. 4). The proximity of suppliers to the OEM and their particular role can vary greatly as will be discussed later in this section. This facet of modularity is essentially the outsourcing of the assembly of the module to the supply base. Graziadio and Zilbovicius (2003) accord with the previously outlined distinctions as they have separated modular strategy in the automotive industry into 'modularity' (changes to product and production systems) and 'outsourcing' (transference of activities, responsibilities and costs) to suppliers.

Even though a clearer articulation as to what the discrete components of modularity are has been outlined, this does not equate to the fact that all OEMs adopt all three facets. Takeishi and Fujimoto (2001) have outlined how automakers are approaching modularisation from different perspectives, i.e. Western automakers are keen on 'outsourcing' and this has stimulated changes to their 'production systems', whilst the Japanese appear to be driving modularity in 'product' to aid quality performance on <u>their</u> in–house assembly lines. Therefore, it would appear that the implementation of modularity in the automotive sector has at the root of its development different motivations and does not always include outsourcing, with a number of modules designed and assembled in-house.

Therefore a clearer distinction of what constitutes modularity in the automotive sector has emerged which can be summarised as changes to product architecture to create modular based designs which in turn enables modular based production systems to function. These changes could be executed within an OEM without the need for a change in the role of suppliers; they would remain as component suppliers. However, it would appear that the most radical and challenging aspect of the adoption of modularity in the automotive sector is that of outsourcing module design and assembly into the supply base. This transfer of responsibility represents considerable change not only in supplier status, but also in operational scope. It is this aspect of change which this paper will focus upon as the ability of suppliers to function effectively in this role would appear to be fundamental to the sustainability of the outsourcing of modular production.

The aim of this research as outlined earlier is to explore the challenges and issues which component suppliers face as they make the transition from component manufacturers to cockpit module suppliers. Therefore it is useful to briefly outline what the cockpit module is and why it is an appropriate module to investigate this transition. The cockpit module concept is based on the principle that a complete unit is built that comprises the vehicle instrument panels, air-conditioning, steering column, audio system and other components that is then delivered to the OEMs final assembly line as one single module. A typical arrangement for a cockpit module configuration is shown in Figure 1.

The perceived benefits forthcoming from cockpit modularity are reductions in cost, weight and the number of parts (Sako and Warburton, 1999), in addition to the generic operational benefits from modular production and outsourcing which will be discussed in the next sub-section. The cockpit module is a very complex module which requires knowledge and capabilities across a number of technologies and disciplines and is therefore suitable to analyse the issues and challenges faced by local component suppliers as they make the transition to module suppliers.

Prior to analysing the changes this transfer represents for the supplier, it is useful to briefly explore the perceived benefits for the OEM from modularity which appear to be driving modularity, particularly outsourcing, in the automotive sector.

Operational Benefits for the OEM

Modular product design allows significant operational benefits for the OEM largely as a result of the reduction in product complexity at the final assembly stage, i.e. a reduction in the number of components to be assembled. The assembly of the module, constructed as a module, off the main assembly line reduces final assembly complexity (Sako and Murray, 1999). This reduction in the amount of activities on the final assembly line normally results in a reduction in the number of stations on the line and therefore ultimately a decrease in the product lead-time as modules can be build in parallel off the main line. Whilst these benefits are considerable, it should be remembered that they are achievable without the outsourcing of modules and can be achieved in-house by the OEM. It is generally the considered opinion that the greatest benefits forthcoming from modularity within the automotive industry are achieved when the design and manufacture of the module is transferred to a module supplier (outsourcing). The resulting benefits for the OEM achieved through this transfer are considered to be:

- A reduction in the cost of assembly resulting from lower supplier wages. Welch (2001) has outlined this position in the US, where the wage gap between OEM and unionised supplier employees was approaching $7/hr. However, Sako (2003) has suggested that this gap will be eroded over time or be offset by a reduction in supplier productivity. In addition, with regards to the cockpit module in particular, the savings achieved through lower labour rates have been questioned due to the low percentage that assembly labour represents of the total module value, indeed in our research the assembly labour was approximately 1.5% of the module cost.

- The *transfer of development costs*, e.g. design and engineering, as some activities are undertaken by the module supplier. In addition to the cost advantage some OEMs need to make these strategic partnerships as they need to gain access to their supplier's R&D and other capabilities (Morris et al, 2004). This approach inevitably reduces the investment risk for the OEM, although it could leave them exposed to other risks such as over dependence on one supplier, which is discussed later.

- The *reduction in supply chain management costs* (Veloso and Kumar, 2002) as the supplier now undertakes the management and coordination of the module supply chain. A clear example of this type of supply chain task reduction is that associated with the SMART car produced by Mercedes-Benz and Swatch. This collaboration manages 25 module suppliers instead of the 200-300 associated with non-modular manufacture (Doran, 2005). Whilst this may be an extreme case, it does indicate the magnitude of the reduction in the OEM's supplier management task which can be achieved through the outsourcing of modular supply.

- The reduction in plant and equipment costs as the products are manufactured by the supplier. However, this logically assumes an increase in the supplier's costs and therefore no overall reduction. McAlinden et al (1999) have suggested that the justification, or perhaps more aptly, the sector's rhetoric, supporting this approach is that supplier investment may be less as a result of better line design and the fact the line may be used to produce modules for more than one customer.

Therefore, it would appear that significant OEM cost savings, combined with an associated reduction in investment risk, are achieved, largely through the outsourcing of module design and supply; however doubts hang over the achievement or sustainability of some of these savings (labour savings and the reduction in plant and equipment costs).

Changing Supplier Role and Relationships

Modular outsourcing can be considered to have had a major impact upon the role of suppliers and their position within the supply chain. The position of the module supplier has been termed 'tier 0.5' (Harrison & Van Hoek, 2002) and logically sits between the OEM and the traditional first tier supplier level. This labelling is largely due to the enhanced product development and manufacturing role they have to undertake in addition to an expanded supply chain management role. The desire to be recognised as a 0.5 tier supplier would appear to be immense, and as the modular strategy, including outsourcing, becomes embedded within more OEM production systems this pressure will increase (Baldwin and Clark, 1997). The transition to 0.5 supplier status brings with it a number of fundamental changes which the supplier has to address.

Firstly, *new capabilities* will have to be developed as they expand the scope and boundary of the role. This largely can be broken down into technical, production and administrative capabilities (Graziadio and Zilbovicius, 2003). The required range of additional capabilities will ultimately depend upon the exact scope of the supplier task, in terms of their role in the design of products, what components are bought in from the supply chain and their specific manufacturing and assembly role.

Secondly, *the 0.5 tier role* presents an enhanced level of supplier management duties and responsibilities for the module supplier due to the increase in the number of component suppliers which now come under their control. The importance of this role can not be underestimated nor is the OEMs reliance on the supplier's ability to manage the module supply chain (Frigant and Lung, 2002).

Thirdly, the *location or proximity* of the supplier to the OEM's final assembly facility. As the role of 0.5 supplier is adopted, the relative location of the supplier to the OEM becomes an important factor. As would be expected in a diverse automotive sector there are a variety of different proximity models which have been adopted, influenced by factors such as: manufacturing system design, the specific supplier role, delivery lead-times and transport constraints associated with large and bulky modules. Perhaps the ultimate in supplier proximity is the VW plant in Resende, Brazil where seven module supplies are located on the VW site, where they manufacture their respective modules and also assemble them into the vehicle for the OEM (Collins et al, 1997). In this example the location of suppliers on-site at the OEM is essential to the operation of the final assembly line. Another example of close supplier proximity is in the SMART car plant in France, where on-site suppliers supply modules directly to the SMART final assembly line and are fully integrated into its operation. The drive behind this particular model appear to be a need for shortened car assembly lead-times of 4.5 hours and the ability to respond to increasing product customisation (Van Hoek and Weken, 1998). The key difference between the SMART plant and the VW plant is that they do not assemble the module into the vehicle – this remains a task of the OEM.

However, not all module suppliers are located on the OEMs site, but exist as separate, autonomous suppliers off-site. The Delphi facility is located ten minutes away from the Mercedes plant into which they supply cockpit modules. These examples indicate that module production and assembly can equally take place on or off the OEM's site, the localised context in particular relating to the scope of the suppliers role would appear to be a heavy influence. One additional factor which may affect the location of the module supplier in relation to the OEM's plant is that of the size and weight of the module and the associated transport difficulties and costs.

Fourthly, *relationship changes* – the introduction of modular production utilising outsourced modules, can bring with it potential changes in the relationship between module supplier and the OEM. To understand this change it is first best to consider the traditional relationship of a component supplier with the OEM. The OEM may adopt a policy of dual sourcing for some of its key components. This policy was not apparently to drive down price through competition, but as a means to ensure product quality and delivery reliability (Womack et al, 1990). Therefore dual sourcing could be seen as a policy to minimise the risks to production, but which also limits supplier power. However, it would appear that due to the investment and development costs associated with modular supply, OEMs have largely adopted one supplier per module. This is supported by the OEM in our research and by the allocation of modules to single suppliers in the SMART project. This single sourced relationship has led to increased interdependency between the supplier and the OEM, resulting from the 'single market - single source' scenario (Frigant and Lung, 2002). This situation has led some to speculate that an increase in supplier involvement, which modular supply represents, has the potential to increase the economic power of the suppliers (Van Hoek and Weken, 1998).

Millington et al (1998) when discussing automotive Local Assembly Units (LAU's) have agreed that the level of dependency does increase between the OEM and the supplier, but has outlined the mediating effects of the considerable costs of termination to both sides. Therefore, the relationship would appear to change as much higher levels of mutual dependency exist between the OEM and the module supplier. However, how power is positioned in the relationship would appear to be difficult to assess as both sides have a lot to lose from the relationship disintegrating.

In conclusion, this section has highlighted that modularity has become established as a concept within the automotive sector and major operational benefits for the OEM are forthcoming, particularly as a result of outsourcing module design and assembly to the supply chain. This transference suggests a changing role for suppliers where additional capabilities and supply chain management tasks are evident, in addition to changes in the proximity to, and the relationship with, the OEM. It is largely the effects of these factors and their resulting implications which this paper is going to analyse within the context of the transition of local component suppliers to 0.5 tier suppliers. It can be inferred that at a ‘global’ level some organisations may possess the required modular design and assembly knowledge, but it will be at the ‘local’ level where key challenges will be faced by component suppliers as they develop their operations to become cockpit module suppliers to specific OEMs. The aim of this research is therefore to examine the issues and subsequent implications that are forthcoming from this local transition and which do not appear to have been examined in sufficient detail elsewhere.

Methodology

The aim of this research was to undertake an exploratory study of the issues and subsequent implications which local component suppliers face as they make the transition to cockpit module suppliers**.** The research is based on the principles of exploratory research as defined by Voss et al (2002), which was developed from the earlier work of Handfield and Melnyk (1998). In this instance, an exploratory study was the preferred approach as it allowed the problem to be better comprehended as few studies have been conducted in this area (Sekaran, 2003).

In order to facilitate this approach, it was decided to interview senior managers from within organisations which had made this transition. It is estimated that there are approximately 7 cockpit module suppliers operational within the UK. These organisations were approached and 2 agreed to engage with the research. These organisations were acceptable to the objectives of the study as they were both automotive component manufacturers, with no previous <u>local</u> experience of producing cockpit modules and who had recently started supplying cockpit modules to an OEM (the OEM was the same in both cases). These organisations were:

- MS1 -A cockpit module supplier to the OEM, which had evolved from a local manufacturing unit supplying Internal Plastic (IP) mouldings to the OEM.

- MS2 -A cockpit module supplier to the OEM, which had evolved from a local manufacturing unit supplying HVAC units to the OEM.

Whilst, the focus of this research is concerned with the transition of local component suppliers to module suppliers, it is appropriate to consider the OEM context into which both respondent organisations supply modules. Therefore, the OEM, to whom both organisations supply modules, was approached and an interview and guided observation was arranged with the Director of Engineering. This data was not analysed in conjunction with the data collected from the suppliers, but was used to provide research context and to produce the OEM cockpit production and supply grid in the next section.

Whilst, this number of organisations may be relatively small, it is similar to Doran's (2005) work which looked at a modular supply chain and analysed 3 organisations within it. A process of 'purposive sampling' (Silverman, 2000), was utilised to select individuals from within each organisation on the basis that they were of interest to the study as a result of the position they held (Executive Directors and Functional Managers who had direct responsibility for cockpit modular strategies in each organisation). In total 7 interviews were conducted with staff across the three organisations.

Data was collected via semi-structured interviews utilising a question schedule which was largely informed by the literature and covered the following key areas: '*motivations for modular development', 'the specific modular role', 'operational changes and challenges',* and *'proximity related issues'*. The use of semi-structured interviews was deemed the most suitable technique for data collection as it allowed data of the required depth and breadth to be gained and exposed facets which may not have become visible using other methods due to the flexibility of the technique. This technique enables the interviewer to guide 'the discussion by asking specific questions' (Rubin & Rubin, 1995, p 5), whilst still maintaining the freedom of question choice and direction. The questions schedules were issued to the respondents prior to the interview occurring. The interviews were recorded to allow later transcription and each lasted approximately 90 minutes. The transcribed data was coded and analysed to identify key concepts (Easterby-Smith et al, 2003) which outlined the issues these organisations were facing as they made the transition to module supplier. In addition to the interview data the researchers undertook guided observations of the production lines in each company to aid data verification and to highlight any additional issues for discussion.

A detailed description of each organisation now follows:

MS1 - is a joint venture between one of the most diversified automotive suppliers in the world and the 3rd largest Japanese vehicle parts maker and was established in 1990. They provide advanced solutions for the design, manufacture and sub assembly of plastic based assembly systems. MS1 benefits from the resources that are available from its parent companies in respect to technological and product development. They are integrated into a global organisation which covers products such as instrument panels, door trim panels and interior trim components. They started volume production in 1992 producing Interior Panels (IP) for the local OEM. In addition, they also produce a range of IP products for other non-local UK based OEMs. MS1 were appointed to design and assemble the cockpit model (off-site) for the OEM's first model to have an outsourced cockpit module in 2001.Their purpose built assembly site (separate from the IP plant) opened in 2002, and synchronously supplies the OEM site with cockpit modules every 20 minutes, with an 8 minute 'door-door' transit time. The plant annually supplies 113,000 cockpit modules to the OEM. The plant is largely autonomous from the MS1 IP facility, but does share some supporting services and the Operations Manager reports to the MS1 Manufacturing Director.

MS2 - is the local manufacturing unit of a global organisation which evolved from the merger of two major Japanese automotive supplier corporations in 2000. This plant design and manufacture heater ventilation and air conditioning systems, engine cooling systems, and exhaust systems including catalytic converters, largely for the local OEM. They employ 500 staff and have an annual turnover of £120m. In 2004, MS2, were awarded the contract to design and assemble the cockpit module (on-site) for the OEM's next new model. They synchronously supply the OEM with cockpit modules from an assembly line next to the OEMs final assembly line. There is on average 4 minutes between the module leaving the MS2 assembly line and it being fitted into the vehicle by OEM staff. The on-site operation is largely autonomous from the main MS2 plant, but does share some supporting services and reporting structures. They annually supply approximately 108,000 cockpit modules to the OEM.

OEM - The OEM is part of a global group, with an annual output of almost 5 million vehicles and a workforce in excess of 265,000. Operating profits of 6.29 billion euros and an operating margin of 11.1 %, makes it one of the most profitable car manufacturers in the world. The site which MS1 and MS2 supply into is the largest car plant in the United Kingdom and the most productive in Europe and currently manufactures 3 models for the European market and employs 4500+ workers. The company has the largest UK presence of any car manufacturer, accounting for 20% of total UK production.

Since the OEM began production more than 20 years ago it has built more than 10 different main models. In the last 4 years the company has undergone a major alliance with another global OEM and this resulted in a strategic revival plan. A significant part of this plan was to design, develop and implement global supply chain strategies and embed innovative modular strategies within their manufacturing system. The move to modular assembly was seen to be the way forward for the next generation of vehicle production and key to the success of this venture was the collaboration and development of strategic partnerships with organisations such as MS1 and MS2. Cockpit modules have become emblematic of this strategy and are incorporated in all new model designs. MS1 were the organisation appointed to design and assemble the cockpit model (off-site) on the first model to have an outsourced cockpit module in 2001. In 2004, MS2, were awarded the contract to design and assemble the cockpit module (on-site) for the next model.

Findings

Production Systems, Supplier Roles and Supplier Location

As previously outlined in the methodology section, both organisations supplied cockpit modules to the OEM. Prior to the discussion of the findings relating to supplier issues and implication associated with the adoption of cockpit module manufacture status it is useful to situate the various cockpit manufacture and supply positions which exist in this particular OEM. The analytical framework suggested by Takeishi and Fujimoto, covering modularity in the automotive industry and outlined in the previous section, is useful in helping to clarify the different, and therefore distinguishable, facets of modularisation. These generic positions have been developed to form the grid (Figure 2), which allows the various cockpit manufacturing and supply positions within this particular OEM to be understood. The arrow indicates the cockpit assembly progression path.

The OEM is currently utilising three separate cockpit assembly scenarios:

A – on older models the cockpit does not exist as a module, the cockpit is assembled progressively within the vehicle on the OEM's final assembly line from components supplied by a large number of component suppliers.

B – on newer models the cockpit exists as a 'module' due to the modular concept being incorporated into the design pahse and this is assembled off-site by MS1 and delivered (on a synchronous basis) to the OEM for fitting into the vehicle.

C – on the latest model the cockpit exists as a 'module' due to the modular concept being incorporated into the design phase and this is assembled on-site by MS2 and transported 5 metres to the OEM's final assembly line for fitting into the vehicle.

The grid not only clarifies the various cockpit assembly and supply scenarios, but the distinction between cells 3 and 4 is worthy of further discussion with respect to the two case-study cockpit module suppliers. MS1 was awarded the cockpit module for a new model in 2002, where they had to build this outside (off-site) of the OEM plant and supply the completed modules on a synchronous basis. This arrangement required that MS1 invest in a new building closer to the OEM plant, purely for cockpit production and a fleet of vehicles to facilitate synchronous deliveries. MS1 were against this approach and wanted to assemble the module next to the line at the OEM, thus reducing logistics issues and the obvious additional costs associated with offsite assembly.

The OEM's response when questioned on this issue, stressed the decision taken to go off-site was largely dictated by lack of internal space restrictions at that time and agreed that the cost of logistics for this type of operation "is huge". The OEM had apparently learned from the experience and the next cockpit module (awarded to MS2 in 2004) is built by MS2 employees on site at the OEM and fed directly into the assembly line, the change largely due to the cost implications of offsite assembly.

This issue raises obvious questions about the optimal location/configuration for the assembly of the cockpit module by suppliers. The literature largely outlines examples of off-site assembly, Camuffo (2001), Welsh (2001). However a key example of on-site assembly has been outlined by Collins et al (1997) who described two versions of the on-site approach; *integrated*, categorised by integrated on-site 'hole in the wall' relationships' where the supplier assembles the modules on sub-lines and the fitting is left to the OEM on the main line (e.g. Skoda Octavia Plant) and *modular consortia* where the supplier assembles the module and fits it directly to the vehicle on the OEM's main line (e.g. VW Resende Plant).

The optimal solution from an operations viewpoint must be to move to least an integrated approach as outlined above. This reduces the costs associated with suppliers assembling modules largely as a result of the negation of infrastructure and transport costs. However, as some commentators have outlined this approach and more controversial solutions such as the module consortia model may fall foul of local unions (Welch, 2001) (Collins et al, 1997) and this may be inhibiting the widespread development of this practice. Later in the paper, we will review the experiences of both module suppliers with respect to their particular mode of operation.

Motivations for Local Component Suppliers Becoming Cockpit Module Suppliers

The key motivations for the case study organisations to be become module suppliers were considered two fold. Firstly, *business development*, resulting from repositioning themselves as cockpit module suppliers within the European automotive industry. Both case study companies had a parent organisation who was a global supplier of cockpits and other modules (front-end modules etc) to the automotive industry and whose intention it was to develop their modular capabilities within Europe. Business repositioning through developing modular supplier status has been recognised as a key motivation for development within the component supplier sector (Baldwin & Clark, 1997). In particular, MS2, as a result of proving their cockpit module supply capabilities in the UK, have been made the OEMs 'preferred' supplier for cockpit modules worldwide. This in turn will allow the company to develop its modular design and production capabilities further as a result of this longer term commitment from the OEM.

Secondly, *business growth*, forthcoming from the increase in revenue as a result of becoming a module supplier, thereby, being able to produce a new product with a much higher value than their existing products. MS1 are a good example of this effect, where prior to becoming a cockpit module supplier their turnover was £60 million/year from the production of Instrument Panels (IP) and other moulded plastic components. This increased to £160 million/year as a consequence of becoming a cockpit module supplier, where the average price per module was £800, compared with £95 for their IP products. However, the profit margins made on these revenue increases has been questioned by Sako & Wharburton (1999) who believe profitability will lag as a result of 'margin dilution' on bought in parts. This did not appear as an issue raised by the module suppliers in our research, but this is to be expected as all the organisations involved were sensitive to discussing cost data.

Issues and Implications for Local Component Suppliers Becoming Cockpit Module Suppliers

The issues resulting from this transition are discussed under the following thematic headings: *Developing Local Expertise, Supplier Management, Investment & Risk* and *Proximity.*

Developing 'Local' Expertise

When an organisation has inspirations to become a cockpit supplier it has to develop and embed a range of new knowledge and skills at a 'local' level to achieve this capability. The scope of the new knowledge which the module supplier is expected to develop is obviously affected by the type of module supplier role the OEM requires them to adopt. The OEM in this research had adopted the position of 'modulariser; (Sako & Murray, 1999) with respect to the cockpit for their new models, where production, design and technical expertise is expected to be provided by the suppliers, although the OEM was still involved in key design and supplier decisions, i.e. the 'imposing' of suppliers for critical or valuable components – as discussed in the next section.

The module suppliers had both relied upon their parent organisations expertise for the design of the cockpit module and negotiations on such issues with the OEM. As a result of this situation the major challenge for both organisations was not to develop design expertise <u>but</u> to develop 'local' knowledge in product engineering, from a systems, technology and assembly viewpoint. However and equally as important, supporting operations knowledge and capabilities (quality, project management, and logistics) had to be developed in parallel as in affect the operational responsibility is transferred from the OEM to the module supplier.

In this case, both suppliers were cockpit component suppliers prior to becoming module suppliers and both outlined the problems in developing the required capabilities at the rate expected by the OEM. The capabilities of some first tier organisations to effectively adopt the role of module developer and supplier has been questioned by some OEMs and this concern is seen in some locations (Japan) to be one of the factors restricting the <u>outsourcing</u> of module development and supply (Camuffo, 2000).

Supplier Management

The 0.5 tier role presents an enhanced level of supplier management duties and responsibilities for the module supplier due to the increase in the number of module components which now come under their control and for which suppliers have to be managed. However, the most significant and problematic aspects of the new supply relationships would appear to be as a consequence of the OEM having an 'imposed' parts policy. Imposed parts is a term to describe the situation where the OEM dictates which supplier (normally first tier) will supply the cockpit module supplier with particular parts. Graziadio & Zilbovicus (2003) have outlined a similar situation in their work, but have not discussed the implications of this practice. In our research, the imposed parts were largely high value or system critical items such as HVAC, radio, and electrical harnesses. The module suppliers believed this policy was largely as a result of the ability of the OEM to get a better price for these items due to their global bargaining power.

To illustrate this situation, MS1 had 23 of its 39 component suppliers imposed by the OEM. This situation was considered in some cases to lead to issues of ‘recognition’, whereby some suppliers would not initially recognise the authority or customer status of the module supplier. An ongoing consequence in both organisations of this arrangement was having to build relationships with ‘imposed’ suppliers who were direct competitors in some other aspects of their business. This situation caused tensions in the relationship and as a result design and other confidential information was difficult to obtain.

A final observation relating to the impact of modular operations upon the supply chain and its management is worthy of discussion. Doran has stated that a symptom of the modular approach is the ‘*transfer of a high percentage of value- added activity to first-tier suppliers from the OEM and the subsequent cascading of value-creation activity between each of the key value adding elements of a modular supply chain*’ (Doran, 2004, p. 103). In this research, this concept has only partially being realised, in that the assembly of the cockpit has been transferred from the OEM to the module supplier. However, the secondary cascading to the lower tiers of the supply chain that Doran predicted has not occurred. It is suggested that this is as a result of:

- The module supplier organisations within this study, whilst having management and operational links to their company’s local manufacturing facilities, i.e. the IP facility in the case of MS1 and the HVAC facility in the case of MS2, were largely autonomous module assembly units. This ensured that the focus and scope of their operations were on cockpit assembly and therefore the focus on the core modular activities existed within the unit from its conception. This situation where ‘autonomous’ business organisations are being created from within local component suppliers to supply module to OEMs ultimately limits the amount of cascading through the modular supply chain.

- The existing key 1st and 2nd tier suppliers' function in the supply chain largely remained unchanged, as a result of the imposed parts policy of the OEM, as they continued to supply the same components, albeit to a different customer.

Investment & Risk

The localised migration from cockpit module component supplier to cockpit module supplier is one that appears to be limited to large global organisations with the financial resources and the relevant expertise. In essence the principal costs are effectively transferred to the module supplier. The costs associated with the migration to becoming a cockpit module supplier were considered large and included elements such as tooling, development costs (infrastructure, systems, technology, and people) and in the situation of MS1 a new factory to house the assembly of the module. MS2 outlined how the development costs were not shared with the OEM and had to be "amortised" into the price of the product and additionally that tooling was only paid for by the OEM once production started.

The issue concerning the amortisation of the development costs into the price of the module perhaps demonstrates the complex financial arrangements associated with modular development and supply. The cost of each module may be higher as a result of the higher capital borrowing costs of the module supplier (Sako, 2003), than it would have been if the OEM had kept it in-house. However, the OEM has benefited in the short term by not having to finance the development costs of the module.

In addition to the level of investment associated with the migration to module supplier status, Executives in both companies were concerned about the risk forthcoming from a potential change in the OEM's modular strategy and the switching of cockpit business to another supplier. However, the fear of supplier switching, at least on existing models, would at present appear to be unfounded due to the investment and development costs associated with implementing modular supply and as a result OEMs have largely adopted one supplier per module. This is supported by the decisions of the OEM in this research and by the allocation of modules to single suppliers in other projects, i.e. the SMART project.

Proximity (On-site/Off-site Operation)

The two cockpit module supplier organisations, whilst both producing cockpit modules, for different models, did so in different locations; MS1, off-site in a purpose built plant and MS2, on-site at the OEM on a sub assembly line adjacent to the final assembly line. The key differences between off-site and on-site modular operations will now be outlined and discussed.

Reaction Time – MS2 as a result of the limited storage capability between themselves and the OEM’s final assembly line have less time to react to quality problems than the equivalent off-site operation. MS2 has only 4 minutes between the module leaving their line on an AGV until it is fitted into the vehicle, which left them with limited time to fix any process defects. MS1 has, as a result of being off-site, approximately a twenty minute window to react to quality issues.

Environment –On-site operation is considered by MS2 management to be a very different environment when compared with working in their own facility. A number of operators transferred from the local HVAC facility to the module unit within the OEM, but did not like the ‘high pressure’ environment and asked to be transferred back. This has led to product quality problems as temporary agency staff, which account for 45% of the direct operators on-site, have had to be brought in at short notice. An additional impact of on-site operation was that management believed the responsibilities of staff was greater than the comparable roles in the local MS2 HVAC facility and as a result managers were working a ‘level above’ there normal position.

Autonomy – Operating on-site was considered to bring with it a reduction in autonomy, due to the obvious increase in accessibility and opportunities for OEM monitoring. MS2 management believed that as they are on-site they are required to look at, and resolve, every issue, where if they were off-site they believed the OEM’s staff would rectify the problem themselves and not inform the off-site operation. In addition, they felt that any problems they were encountering became widely known very quickly to the OEM. MS1 had experienced a higher level of autonomy than their on-site counterparts, in that they were able to control their own destiny, in terms of being able to set up and use their own systems and were largely able to be autonomous in their operations.

The four key issues outlined above relating to the migration to cockpit module supply status have been grouped together within a ‘Migration Matrix’ (Table 1) which thematically compares the key issues forthcoming from this transition. This resource will be useful from both a research and managerial perspective. Researchers will find it a useful resource to aid their investigations into similar organisations that have made the transition from component to module supplier. This would help ascertain if the issues and implications forthcoming from this study are representative of the experiences of other cockpit module suppliers who supply to different OEMs. In addition, managers of organisations wishing to progress up the automotive supply chains will find the issues and implications useful for reflection when undertaking decision making.

Conclusions

This paper has explored the challenges and issues which local component suppliers face as they make the transition from automotive component manufacturers to cockpit module suppliers. A number of findings have emerged and these were discussed under four thematic groupings. A number of these have increased and progressed our knowledge of the issues associated with operating as a cockpit module supplier, which have either not been outlined in previous work or covered in such depth.

The notion of developing *‘local’ expertise* is seen to be crucial as a wide range of skills and expertise are required and this needs to be developed and embedded at the local level to ensure long term success as a competent and capable module supplier. S*upply chain management* is important with respect to communications and trust. Developing and nurturing the relationship is crucial and existing OEM practices and policies may be restrictive for a module supplier. The reconfiguration of the cockpit module supply chain, where first tier supplies are elevated to 0.5 tier status has presented a clear problem for supply chain management and relations. In particular the ‘imposed parts’ policy can lead to competitive tensions developing in the supply chain. This policy has made the management of the modular supply chain more difficult for the module supplier and ultimately begs the question, were the module suppliers in this research actually allowed to operate as 0.5 tier suppliers? This aspect is an interesting one as the imposed parts policy potentially limits the power of the module supplier, perhaps at a time when it could be argued their power was growing as a result of developing their knowledge and capabilities in this area. Whilst, the issue of an OEM selecting module component suppliers has been previously outlined by Graziadio & Zilbovicus (2003), the implications of this practice have not been previously identified and discussed.

A significant issue that emerged from this research is that of the *financial risk* associated with a supplier making the transition from component supplier to module supplier. Costs associated with the migration such as tooling and capability developments were seen to be very large and as a result migration was considered a high risk strategy. The research has exposed the nervousness of both module suppliers with respect to the investment levels expected and the possible transient nature of OEM's modular strategies. It is further suggested that the combined effects of capability development requirements, high investment levels coupled with supplier nervousness regarding OEMs long term modular intentions will act as a market entry barrier for smaller organisations wishing to become cockpit module suppliers. In addition, this research also concurs with earlier work by Sako and Warburton (1999) which outlined that the majority of cockpit module business was awarded to organisations that possess plastic moulding capabilities, i.e. (MS1) or have access to it through company parentage (MS2).

The findings relating to supplier *proximity*, i.e. on-site/off-site operations centred around three aspects; *reaction time* which is significantly shorter for on-site operations, thereby potentially causing problems for defect correction; the physical *environment* that on-site represents which is perceived as being a much more stressful environment. In addition, as a result of the claustrophobic nature of on-site operations, the level of organisational *autonomy* is considered to be much lower than in the counterpart off-site operation.

However, on-site operations do present a clear benefit over off-site assembly from the OEM's perspective. This research has highlighted the policy u-turn of the OEM in this regards where all new model cockpit modules will be assembled on-site at the OEM by the module supplier's employees (MS2 were the first organisation to do this). The OEM's Engineering Director when interviewed on the issue of proximity, although not covered in this paper, suggested that the cost of logistics for off-site operation "is huge". This issue is interesting as it highlights the financial benefits to the OEM of on-site cockpit modular assembly; whilst at the same time has indicated the disadvantages and problems for the on-site supplier relative to their off-site counterpart.

As product and operational responsibility is fully, or partially, transferred to the 0.5 tier organisations, there is also the prospect that OEM knowledge and capabilities, in the form of their existing employers, will migrate to these organisations. This is likely as the demand for their individual capabilities will be reduced within the OEM. Early signs of this occurring were evident in one of the organisations who had recruited two purchasing experts in cockpit modules from the OEM to help manage the expanded logistical function.

A migration matrix and a cockpit production and supply grid have been developed from the research findings, where the former identifies the key issues associated with the suppliers' transition from non-modular to modular supply and the latter which helps to identify and map the shift within an OEM from non-modular to modular production. It is argued the migration matrix captures many of the key issues and challenges faced by automotive suppliers in their quest for modular supply status.

The limitation of this research, which is normally evident in other exploratory studies, is the small number of organisations involved. In addition, the fact both organisations supplied modules to the same OEM does not allow the findings to be validated or compared against another OEM context. However, the single OEM context does provide additional support for some of the findings (e.g. the implications of the OEM imposed supplier policy). The results of this work have shown that further research is needed in this area. Therefore, the next logical step is to undertake research which both deepens and broadens our knowledge of modularity in the automotive sector. Research which deepens our knowledge would focus on a number of key areas which have been identified in this exploratory study, e.g. proximity related supplier operational issues and supply chain tensions. This would help ascertain if the issues and implications forthcoming from this study are representative of the experiences of other cockpit module suppliers who supply to different OEMs. Future research objectives should also be broadened to cover generic modular strategies and identify the attitudes regarding modularity as a manufacturing concept within the automotive sector and identify the perceptions and viewpoints of OEMs who do, and do not, engage in outsourcing cockpit modules.

References

Baldwin, C.Y. and Clark, K.B. (1997) “Managing in the age of modularity”, *Harvard Business Review*, September – October, pp. 84-93.

Camuffo, A. (2000) *“Rolling out a ‘World Car’: globalisation, outsourcing and modularity in the auto Industry”*, International Motor Vehicle Programme (IMVP) Working paper, (http://imvp.mit.edu/papers/0001).

Collins, R., Bechler, K. and Pires, S. (1997) “Outsourcing in the automotive industry: From JIT to Modular Consortia”, *European Management Journal*, Vol 15 No 5 pp. 498-508.

Doran, D. (2004) “Rethinking the supply chain: an automotive perspective”, *Supply Chain Management: An International Journal*, Vol 9 No 1, pp.102-109.

Doran, D. (2005) “Supplying on a modular basis: an examination of strategic issues”, *International Journal of Physical Distribution and Logistics Management*, Vol 35 No 9, pp. 654-663.

Easterby-Smith, M., Thorpe, R. and Lowe, A. (2003) *Management Research An Introduction.* 2nd Edition, SAGE, Thousand Oaks.

Fixson, S.K. and Sako, M. (2001). “Modularity in Product Architecture: Will the Auto Industry Follow the Computer Industry?”, *International Motor Vehicle Programme (IMVP) Fall meeting*, Sept 10-11th, Cambridge, MA.

Fixson, S.K., Ro, Y. and Liker, J.K. (2004). “Modularity and Outsourcing: A study of Generational Sequences in the U.S. Automotive Cockpit Industry”, Proc. of the Academy of Management Conference.

Frigant, V. and Lung, Y. (2002) “Geographical Proximity and Supplying Relationships in Modular Production”, *International Journal of Urban and Regional Research*, Vol 26 No 4, pp. 742-755.

Graziadio, T and Zilbovicius, M. (2003) “*Exploring The Reasons For Different Roles Of Module Suppliers In A Car Assembly Plant”*, Eleventh Gerpisa International Colloquium, Paris, 11-13th June.

Harrison, A and Van Hoek, R. (2002) *Logistics and Strategy Management*, FT Prentice Hall, London.

Handfield, R.S. and Melnyk, S.A. (1998), “The scientific theory-building process: a primer using the case of TQM”, *Journal of Operations Management*, Vol 16, pp. 321-339.

Innovation report Johnson Controls Cockpit modules (2005). http://www.innovations-report.com/html/profiles/profile-1356.html.

Lau, A.K.W and Yam, R.C.M. (2005). “A case study of product modularisation on supply chain design and coordination in Hong Kong and China”, *Journal of Manufacturing Technology Management*, Vol 16 No 4, pp. 32-446.

McAlinden, S., Smith, B. and Swiecki, B. (1999) “*The Future of Modular Automotive Systems: Where are the Economic Efficiencies in the Modular-Assembly Concept?”* Research Memorandum No. 1. University of Michigan Transportation Research Institute. November.

Millington, A.I., Millington,C.E.S., and Cowburn,M. (1998) “Local assembly units in the motor components industry”, *International Journal of Operations & Production Management*, Vol 18 No 2, pp. 180-194.

Morris, D., Donnelly, T. and Donnelly, T. (2004) "Supplier parks in the automotive industry", *Supply Chain Management: An International Journal*, Vol 9 No 2, pp. 129-133.

Rubin, H.J., and Rubin, I.S. (1995) *Qualitative Interviewing, The Art of Hearing Data*, SAGE, Thousand Oaks.

Sako, M. and Murray, F. (1999) Modular strategies in cars and computers, 6/12/99, Financial Times Ltd.

Sako, M. and Warburton, M. (1999)."*Modularisation and Outsourcing Project: Interim of European Research Team"*, MIT IMVP, 6-7th October, (http://imvp.mit.edu/papers/99/).

Sako, M. (2003). "*Modularity and outsourcing: The nature of co-evolution of product architecture and organisation architecture in the global automotive industry"*, Eleventh Gerpisa International Colloquium, Paris, 11-13th June.

Salerno, M.S., Dias, A.V. C. (2001). "Product Design Modularity, Modular Production, Modular Organisation: The Evolution of Modular Concepts", Actes du GerPISA, No. 33.

Siemens VDO Cockpit solutions (2005).
http://www.siemensvdo.com/NR/rdonlyres/81E68CAD-F9F1-4B50-9E89-38CDC62A3C6B/0/svbrochurecockpitsystemeng.pdf.

Sanchez, R. and Mahoney, J. (1996) "Modularity, Flexibility, and Knowledge Management in Product and Organizational Design", *Strategic Management Journal* Vol 17 (Special Issue), pp. 63-76.

Sekaran, U. (2003) *Research Methods for Business*, 4th Edition, Wiley, New York.

Silverman, D. M. (2000). *Doing Qualitative Research: A Practical Handbook*. Sage, London.

Starr, M.K.(1965).”Modular Production – a New Concept”, *Harvard Business Review*, Vol. 43, Nov-Dec, 1965, pp.131-142.

Takeishi, A. and Fujimoto, T. (2001) “*Modularisation in the Auto industry: Interlinked Multiple Hierarchies of Product, Production and Supplier Systems”*, CIRJE-F-107 discussion paper, Tokyo University.

Takeishi, A. and Fujimoto, T. (2003). “Modularisation in the Car Industry”, *The Business of Systems Integration*”, Vol 1 No 9, pp. 254-279.

Van Hoek, R. and Weken, H. (1998) “How Modular Production can Contribute to Integration in Inbound and Outbound Logistics”, *International Journal of Logistics: Research and Applications*, Vol 1 No1 , pp. 39-56.

Veloso, F. and Kumar, R. (2002) “*The Automotive Supply Chain: Global Trends and Asian Perspectives”*, Asian Development Bank Report, January.

Voss, C., Tsikriktsis, N., Frohlich, M., (2002) “Case research in operations management”, *International Journal of Operations & Production Management*, Vol 22 No 2, pp. 195-219.

Welch, D. (2001) Why Detroit is Going To Pieces*, Business Week*.

Womack, J.P, Jones, D.T., and Roos, D. (1990) *The Machine That Changed The World*. Rawson Associates, New York.

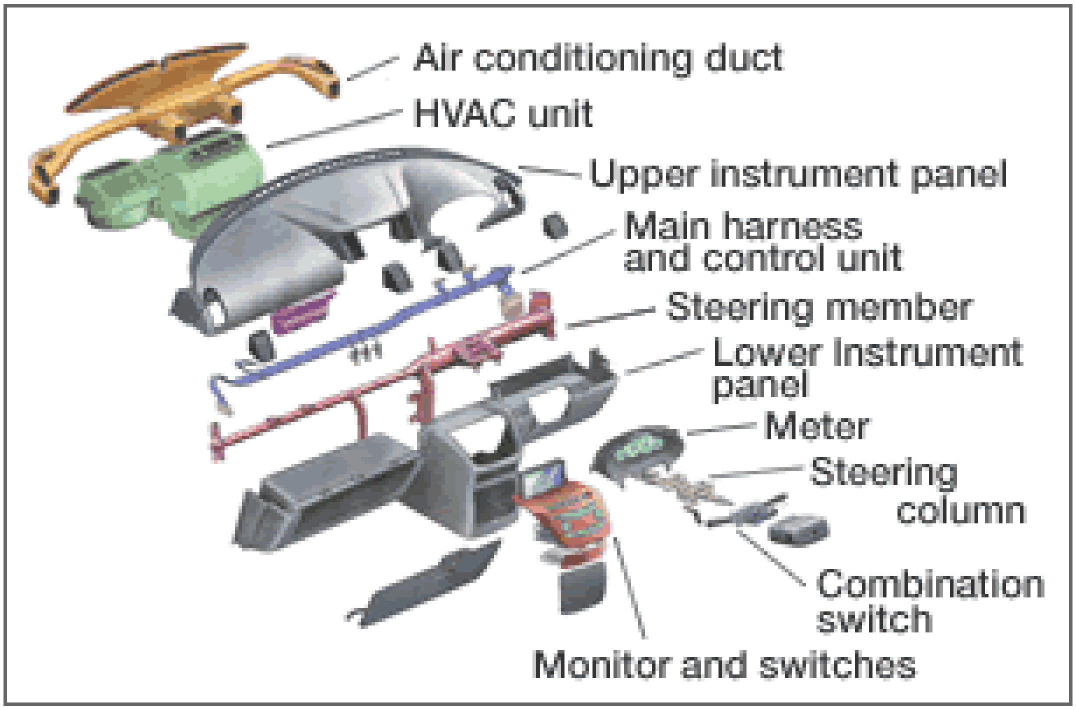

Figure 1. Example of Cockpit Module

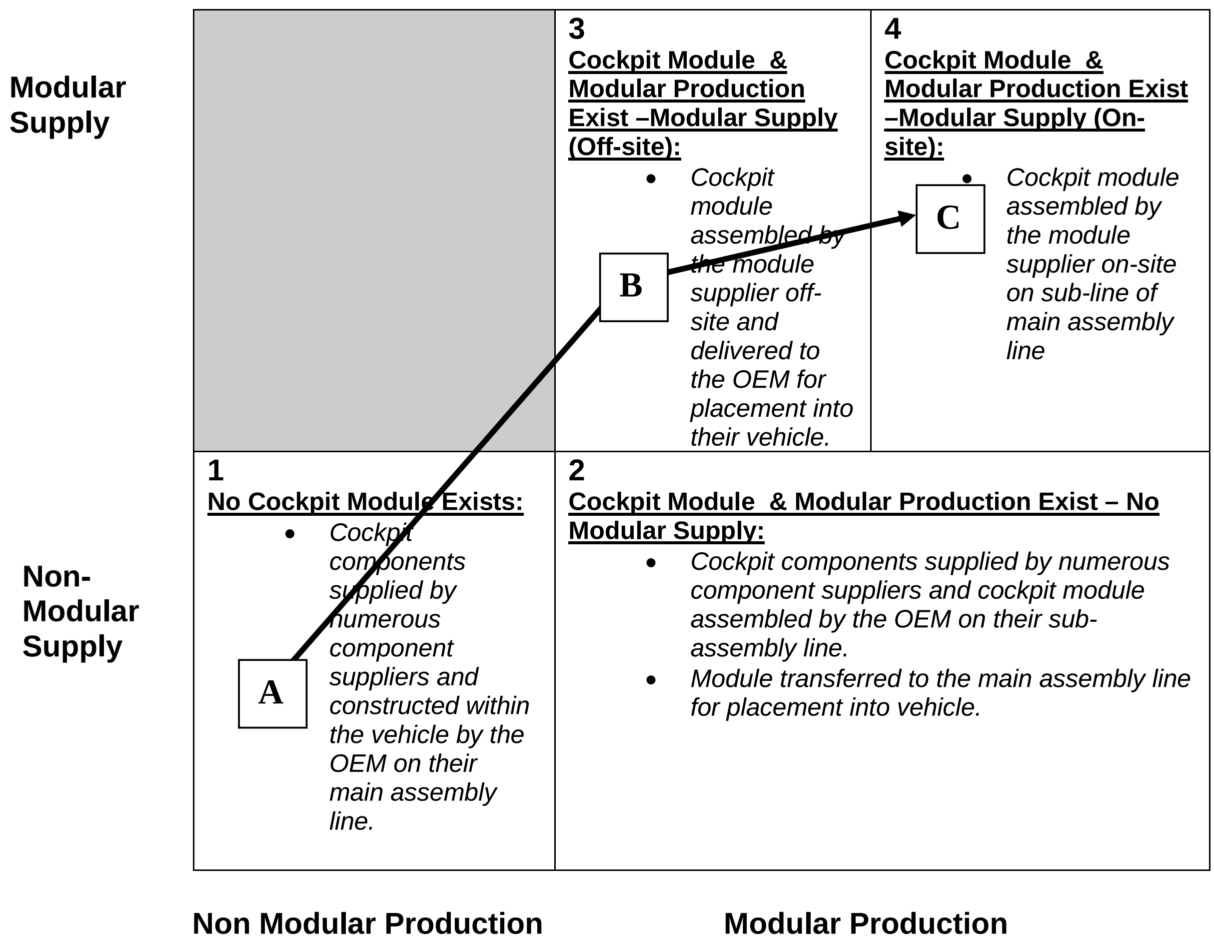

Figure 2: Cockpit Production and Supply Grid

	Location Constraints	Financial Risk	Capabilities	Supply Chain Management
Cockpit Component Supplier (CCS)	**Medium** *Location can be local, national or international.* *Constrained by product lead-times and supply status.*	**Low** *As a result of two key factors:* • *Existing supplier of a relatively small number of components.* • *Expertise, technology and infrastructure already exist within organisation.* *However, business growth may be constrained to finding new markets & customers for existing products. May be affected by OEM's choice of module supplier.*	**Existing and Limited** *The organisation will currently possess the limited capabilities to produce the cockpit components they currently supply.*	**Moderate** *Resulting from relatively small number of existing component suppliers to coordinate and manage.*
Cockpit Module Supplier (CMS)	**High** *Location normally in close proximity to OEM plant.* *Constrained by size/weight of module and supply status of cockpit, normally synchronous.* *Onsite operation presents new challenges:* • *Reduced Reaction time.* • *Changing Environment* • *Reduction in Autonomy*	**High** *Resulting from:* • *The high levels of investment required in people, technology and infrastructure to enable module development and production* • *The uncertainty of OEM commitment to the modular concept* • *The risk of losing module business due to inability to meet new demands.* • *Risk to component business as a result of focus diversion* *However, large potential for business growth.*	**New and Extensive** *Resulting from extension of role from product supplier to module developer and supplier.* *Additional capabilities include:* • *Cockpit systems knowledge and technology* • *Cockpit assembly* • *Logistics/supply* • *Quality assurance* • *Project management*	**Complex** *As a result of:* • *The increase in the supplier management task.* • *The possible tensions in the supply chain caused by issues of competition.* • *Possibility of OEM imposed parts*

Table 1 Migration Matrix