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EXPANDING PRODUCT AUDIT METHODOLOGY THROUGHOUT THE AUTOMOTIVE SUPPLY CHAIN TO FACILITATE IMPROVEMENT IN CRAFTSMANSHIP DURING NEW PRODUCT INTRODUCTION

Glen A Turley, Mark A Williams, Charles Tennant.

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Introduction

In the automotive segment, quality and reliability can no longer distinguish a premium vehicle from other automotive brands. Therefore premium manufacturers must compete on the perceived quality that a product exhibits, known as craftsmanship. Craftsmanship is affected by both the level of the design and the ability to conform to that design in the production environment. This means a company's New Product Introduction (NPI) process can have a significant effect upon craftsmanship. Also with more complex design and manufacturing processes being outsourced to the supply base, the relationship between suppliers and the Original Equipment Manufacturer (OEM) is critical to craftsmanship definition and execution. This paper focuses upon how conformance to craftsmanship design can be achieved through the introduction of a common product audit methodology throughout the supply base. The adoption of this methodology was found to achieve rapid part maturation in terms of quality and craftsmanship during the delivery stage of New Product Introduction.

Background

Warwick Manufacturing Group (WMG) based at the University of Warwick has recognised the role of the supply base in the premium automotive industry. In April 2003, a £72 million automotive research wing of WMG was founded, known as the International Automotive Research Centre (IARC). The IARC was funded by the regional development agency, Advantage West Midlands (AWM).

The main research scope for the IARC at present is the Premium Automotive Research and Development (PARD) Programme. This programme is collaborating with Jaguar – Land Rover (JLR) to work with the regional premium supply base, to support them in the manufacture of high value premium products. The programme currently employs over 100 staff working on 20 different research projects, covering skills development, advanced materials, web-based shop floor and craftsmanship.

The Craftsmanship project is focussed on improving perceived product quality. The project covers a number of different areas which range over the timeframe of the New Product Introduction (NPI) process. From target setting in the initial stages to measurement systems

reporting that occur in the later stages of the process. This study concentrates on audit methodologies and their role within the supply base to achieve perceived quality execution targets in time for product launch. The application of this is based later on in the product development process where prototype products are being manufactured.

The new product introduction process

The NPI process in the automotive industry allows a company to move from concept ideas and innovation all the way through to product realisation and mass production by following a structured process [1]. A world-class NPI process can provide a number of sources of competitive advantage for a firm, such as allowing firms to reach the market quicker [2]. This involves introducing products that are aligned with the "needs" and "wants" of the customer and allowing resources and activities to be managed effectively and efficiently throughout development [3, 4].

There are a number of basic elements to a NPI process. From an analysis of the available literature there is differing detail on the amount of these basic elements [5, 6, 7]. Three key stages of the NPI lifecycle have been described.

- Definition: - This is where benchmarking and market research activities take place in order to identify targets and desirable attributes at vehicle level. These attributes are linked to "needs" and "wants" of the target customer.

- Design and Development: - Targets and attributes are broken down into subsystem (Chassis, Interior Trim, Body in White, etc) and component level so that detailed design can take place. Once the detailed design has taken place it is validated from component level back up to vehicle level in the virtual world through simulation.

- Delivery: - This is where the design and manufacturing infrastructure is validated and matured in the physical environment through the production of prototypes. Marketing activities for Product Launch also take place at this stage [8].

In the automotive industry, moving from the start of the definition phase to product launch, at the end of the delivery stage can range in time from three to five years for new generation products [2]. This lengthy process contains many complex activities that can lead to requirements that are linked to the "needs" and "wants" of the customer being lost or re-aligned without thought for their significance. Being able to identify sources of negative customer impression will help ensure conformance in product delivery to the needs identified in the definition phase. Having this assessment of negative quality impression built-in to the NPI process would help facilitate a successful product launch.

Quality of execution of all tasks in the NPI process is a vital component of new product success. The amount of tasks and their complexity along with trade offs between speed and quality of execution makes the NPI process extremely difficult to manage [9]. These difficulties have led to some activities in the process being undertaken with better execution than others. Trial or prototype production is an activity that has been seen to be ineffectually performed by the automotive industry and is one of the most important facets of the delivery phase of the NPI process [3]. This has meant that when products have been launched into the market place they do not achieve the required level of quality that the customer expects [10]. It is only when initial customer feedback data is available that the product can mature and

expected quality is then achieved and surpassed. If a process to identify sources of negative customer impression is incorporated into prototype production. This will lead to the required conformance in the delivery phase and allow products to be launched without variable or poor quality. Conquering this initial stage of a new products lifecycle will aid in preventing products from failing in the market place because of sources of negative customer impression related to product quality [10].

Craftsmanship within the premium automotive segment

Distinctions between Premium Automotive and Volume Manufacturers are becomingly increasingly blurred [11]. Therefore premium vehicles must maintain a performance gap by focusing attention into new areas. Craftsmanship is one area where premium vehicles can establish a competitive advantage from other brands. Research within the PARD programme at the University of Warwick has shown that craftsmanship is based on the customers' interaction with the product. This interaction allows the consumer to make a judgement about the product based on all their senses (visual, touch sound, smell, etc), this leads to a perception of quality being formed for that product. The research has led to the following definition being produced.

"Craftsmanship is the perception of quality experienced by a customer, based on sensory interaction and emotional impact." [12]

To achieve craftsmanship, it must be considered at every stage of the NPI process. It is affected by both the level of the design and the ability to conform to that design in the physical production environment [12]. Craftsmanship cannot be considered as just the traditional skill in workmanship [13] or purely a design process [14]. It requires attention to detail at every stage of product development. From understanding the needs of the consumer to material selection and on into excellence of execution in the delivery phase. Craftsmanship is an essential component of overall customer impression, whose conformance to intent needs to be achieved during product delivery.

Role of the supply base in new product introduction

It is recognised in manufacturing that an OEM's supply base provides over 50% of the value-added of the final product [15]. The performance of these suppliers is critical to the overall impact that a new product has when it is delivered to the market place and its reception by the consumer. Therefore they have a major role to take in the NPI process, influencing the speed of delivery, cost and craftsmanship of the final product.

The impact upon overall new product performance is magnified further in the automotive industry with the trend towards "Black-Box Engineering". This is where the engineering of a part or assembly is not rigorously controlled by the OEM, but instead suppliers take a share of the responsibility [16]. This usually involves the OEM identifying the styling, functional characteristics and component/assembly interfaces. The supplier then carries out the detailed design embodying the targets set by the OEM, deciding how it is to be manufactured and installing the process facilities. This has led to the situation where suppliers are producing ever more complex assemblies for the OEM, known as modules. These modules are self-contained assemblies, with all electronic, functional and heating and ventilation components

built-in. These modules are then connected to the vehicle as one unit. Examples include Instrument Panels, Bumpers and Roof Overhead Systems.

The increase in supplier responsibility during the NPI process has meant that the specification has become an evolving document [16]. It acts as a guide to the product development process, changing and increasing in content and detail as the product heads towards realisation and market release. The relationship between the supplier and the OEM has become vital to the effectiveness and efficiency of new product introduction. A number of sources have stressed the need for early supplier involvement in the NPI process [16, 17, 18]. It is key that this supplier involvement is maintained, if not increased throughout development because as the level of detail increases in the specification, more contact is required between the OEM and supplier to establish a common understanding.

The development of specification and being able to evaluate quality and craftsmanship of supplier components can bring huge advantages in terms of launch quality if done correctly. However in British Manufacturing many OEM's are not in position to maintain supplier product quality during the delivery of new products, with a significant amount unable to have access to supplier data [9]. The research conducted on the PARD programme has shown that supplier measurement systems often fail because they are not linked to the OEM's strategic objectives, which are inherently customer focussed. Suppliers' measurement should not only concentrate on its customer (the OEM) but also the end user [19]. Having a customer focussed common metric within both the OEM and supply base during the delivery phase will allow the perceived quality of the product to be improved. As OEM manufacturing operations and its purchased components are two of three biggest sources of negative customer impression [20].

Product audit methodology

This paper has outlined a number of important issues that affects the delivery of a premium vehicle to the market.

- A products introduction to the market place often exhibits variable quality.
- Premium products can gain a competitive advantage through craftsmanship.
- Supplier measurement can fail because they are not aligned to end-user requirements.

These issues, which contribute to products not meeting the "needs" and "wants" of the customer being launched into the market place, has led to the following research question, which this study aims to address.

"How can product quality and craftsmanship requirements be achieved during the New Product Introduction Process of a Premium Automotive Manufacturer?"

This research question can be answered if the following two objectives can be achieved.

- To translate the identification of product quality and craftsmanship concerns down through the supply chain.
- To align product metrics which highlight product quality and craftsmanship concerns between the OEM and its supply chain.

Having a common audit system at both the OEM and its supply base during trial or prototype production should identify these concerns and ensure conformance to customer requirements in the production environment. This will improve the overall quality of execution of the delivery phase of the NPI process and assist in a successful product launch. The audit methodology should evaluate the product against an evolving quality standard that increases in detail as the specification matures. This will enable a mutual understanding between the OEM and supplier and provide a forum for communication which will enhance their relationship and the delivery of the product.

It is said that the best measures are customer focussed and goal orientated [19]. Due to the fact that both traditionally and in today's environment, craftsmanship is assessed in linguistic terms [13, 21]. To be able to have an audit that is related to the "needs" and "wants" of the customer, initial assessment of the product should be qualitative, i.e. "too rough" or "high effort". This assessment should then have a quantitative value placed against it relating to severity, to allow a numeric value to indicate the quality of the product. A customer-focussed target can then be set and aimed to be achieved during the NPI process.

Case study research carried out at the IARC has found that many automotive firms operate an audit system similar to the one described. This audit is utilised throughout the lifetime of the vehicle model from identifying concept risks early on in product development. Through to highlighting product concerns and potential areas of customer dissatisfaction on the physical product from prototype production until the end of the product lifecycle. One of the OEM's that adopts this methodology is Jaguar – Land Rover (JLR). The firm uses an audit process known as the Ford Consumer Product Audit (FCPA) [22]. The FCPA process identifies product concerns using the "Does it Look Right?" principle, shown in Figure 1. This is where vehicle attributes are measured against a nominal standard if the trained auditor, acting as a critical customer is concerned about its appearance or function.

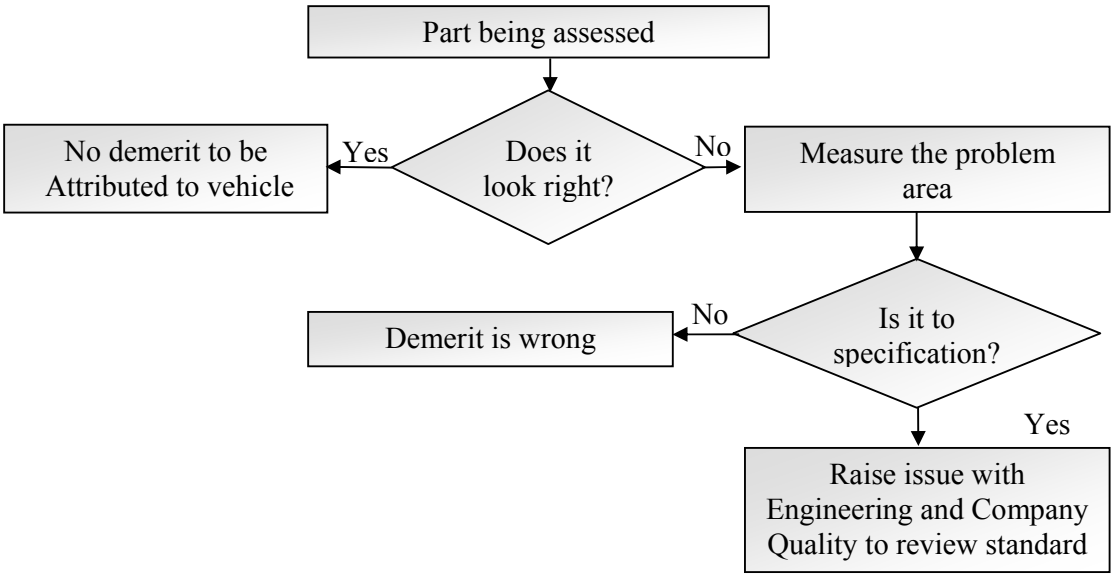

Figure 1: The "Does it Look Right?" Audit Process

The nominal standard that the vehicle attribute is measured against is known as the Quality Standards Manual (QSM). This manual is used as a reference by the auditors to provide a basis for process performance and supplier measurement and evolves in detail throughout the NPI process. There are a number of typical areas for measurement within the audit.

- Nominal Gaps and Profiles.
- Weld Standards.
- Paint, Glass and Chrome Outer Surface Standards.
- Exterior Ornamentation Standards.
- Interior Trim Standards.
- Functional and Operational Standards.
- Switch Harmony.

This list provides an indication of the types of attributes that are defined in the standards manual, which where possible provides allowable deviations or tolerances for defined nominal conditions. Where variation away from the nominal condition, within the specified conditions will not cause any effect to the style and design of the vehicle and will not attract any customer dissatisfaction. Examples of concerns caused by poor execution of craftsmanship are shown in Figure 2.

Figure 2: Poor Examples of Craftsmanship Execution

There are a number of elements to the product audit, designed to check specific functions and areas of the vehicle. Once these elements of the audit have been completed, all the numeric values of the concerns identified are totalled together, producing an overall score. This indicates the quality level of the vehicle. This total is aimed to be improved throughout prototype production until a target level is reached, where the vehicle is deemed fit for launch.

Expansion of product audit into the supply base

As identified in this paper the role of the supply base is crucial to achieve high product quality and craftsmanship at market launch. This makes research into extending product audit methodology throughout these suppliers during the delivery phase necessary, so that product concerns can be detected and matured. It is clearly shown in Figure 3 that components produced in the third tier of the example supply chain have critical customer interaction and therefore the audit methodology must reach this level of the chain, as well as the higher tiers.

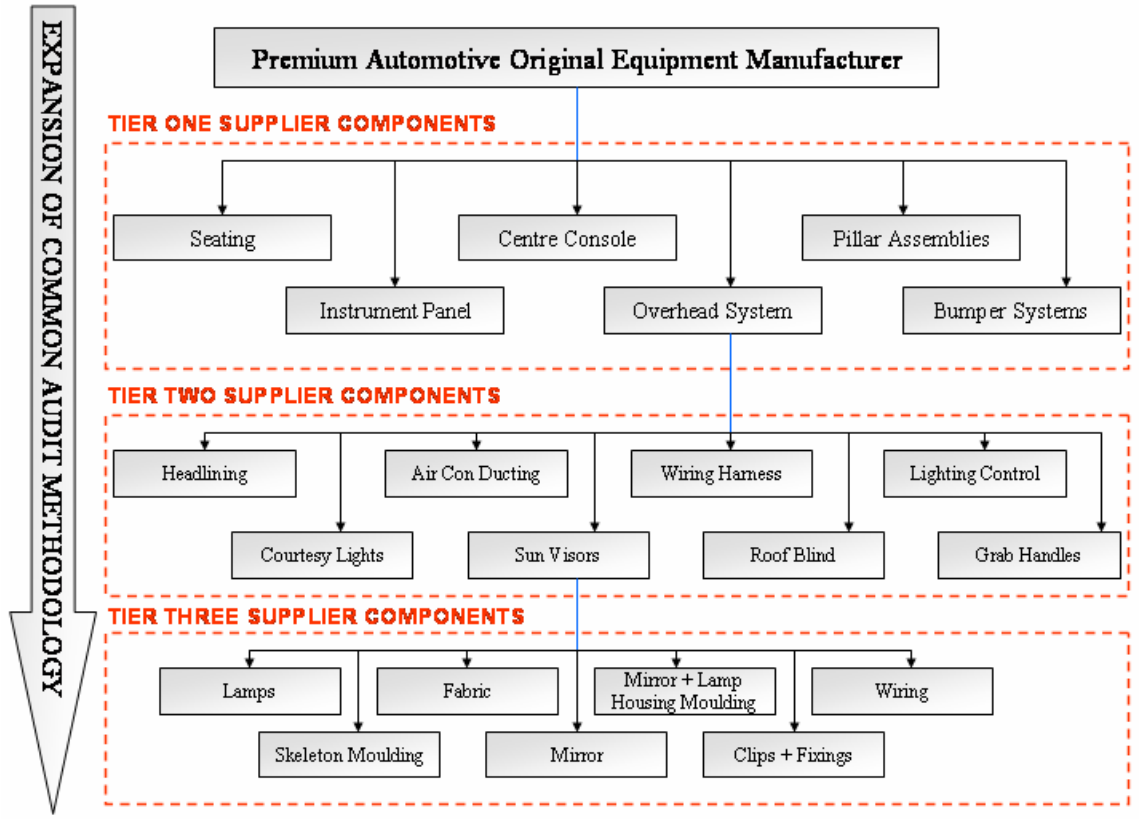

Figure 3: Expansion of Audit Methodology

Major tier-one suppliers to JLR were identified for initial research to implement audit processes and systems to produce common metrics, which can be used to communicate deviations from the quality standard. Two of these companies produce major modules to the new Land Rover Discovery 3 model, launched in November 2004. The companies were SAS Automotive who produces the Instrument Panel and Centre Console modules and Grupo Antolin who manufacture the Overhead System and Pillar Trim modules.

The IARC has developed a database based on Microsoft Access technology to capture product concerns on each of the modules. The database stores the Bill of Material (BOM) that make up each of assemblies and a defined list of product concerns that can appear on a product. This allows a deviation away from the standard to be highlighted in any location of the vehicle and rated for severity.

Deviations from the standard are rated using a structured scoring system, where concern score is dependant upon the type of fault identified and its severity. Concerns are grouped into four different classifications.

- Blitz Concerns: - These are safety related concerns and have the highest severity rating.
- A Concerns: - These are concerns which the majority of customers would notice and complain to the dealer about.
- B Concerns: - These are concerns which the models target customers would be able to identify, although only the "fussiest" customers would formally complain.
- C Concerns: - These concerns are items which are extremely difficult to notice, but absence of these concerns give the vehicle a well engineered "feel" with attention given to every feature of the vehicle. These types of concerns have the lowest severity rating.

"Blitz", "A" and "B" concerns are related to all the concerns on the vehicle that are perceived by the customer as "Things Gone Wrong" (TGW) and therefore is traceable from Customer Feedback and Warranty Data. "C" Concerns are those concerns which would cause a negative quality impression, so they are small defects and craftsmanship issues that would prevent the vehicle from achieving a "premium feel".

Faults which are identified are logged into the FCPA Input Form of the Graphical User Interface (GUI) of the Database, which is selected from Front Overview Form. This is shown in Figure 4.

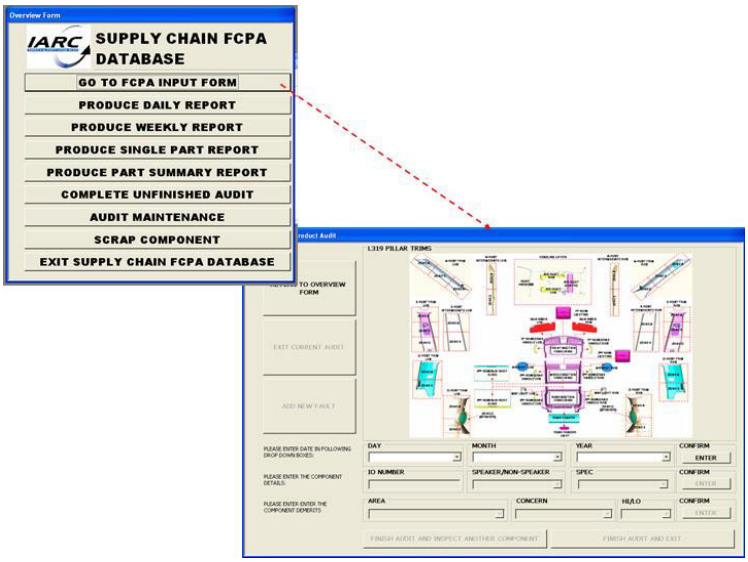

Figure 4: Audit Database Graphical User Interface (GUI)

The FCPA Input Form also records the date of the product audit, a unique assembly identifier and the variant description. Once the audit is complete this information is stored and allows a total FCPA score to be assigned to the module. This score is based on the severity and amount of concerns identified. A range of common reports can then be produced, which include basic quality statistics, such as a Pareto of concerns or the trend of FCPA scores over a weekly basis. These reports can plot a range of data from single assemblies to showing the trend of all the components that have been audited. Figure 5 shows the range of reports.

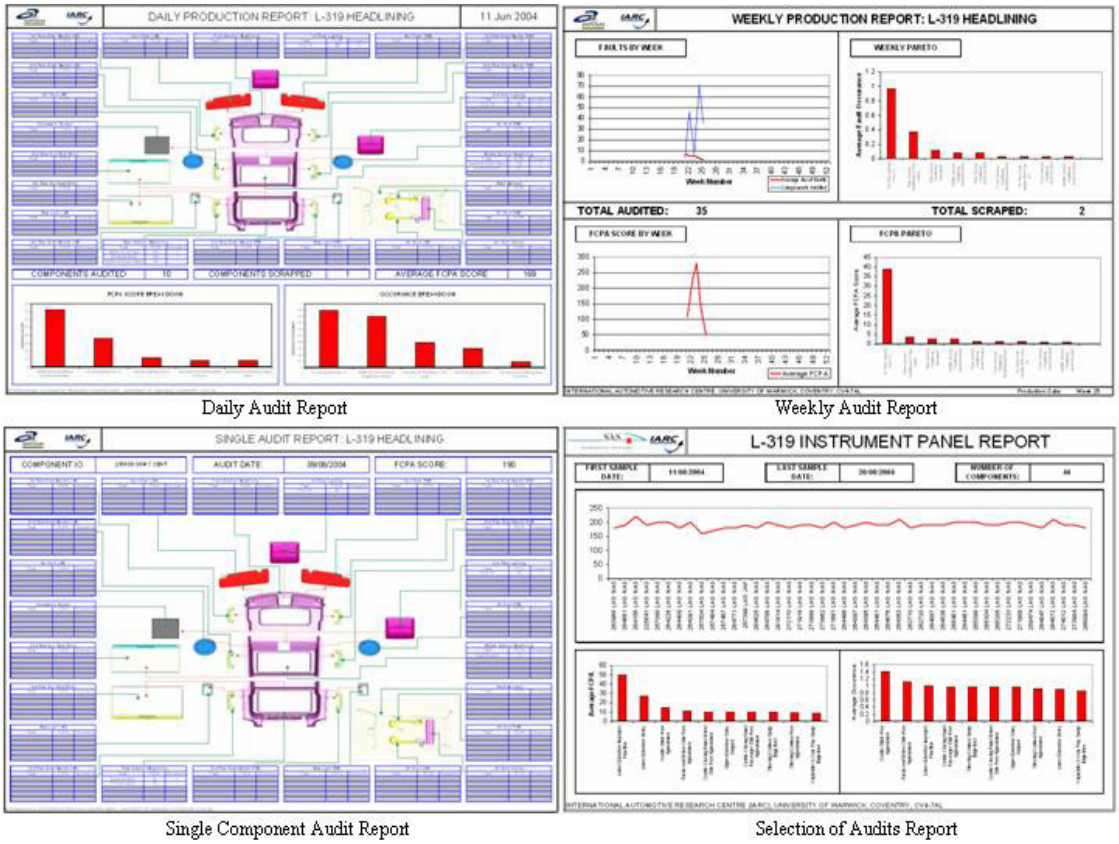

Figure 5: Range of Database Reports

The FCPA database was designed so that it can be easily implemented into a common PC desktop environment so that no hardware or software cost was incurred by the supplier. This allowed for the trial research to take place and the reports produced to be easily circulated around the company as well as communicated to its sub-tiers and to JLR.

As the product audit attempts to capture customer perception in linguistic terms, the assessment of the product can therefore vary from auditor to auditor. Training was provided by the IARC as well as JLR to the company's to explain the different product concerns and the level of detail that the product is required to be inspected too. This should allow a similar level of auditing to be achieved between the OEM and the suppliers. The audit databases were installed during the hard tool prototype build phase of the Ford Product Development System (FPDS), which is in the middle of the delivery phase.

Initial results

The database was utilised by the suppliers from installation through to market launch on the Land Rover Discovery 3. Figure 6 shows the audit results of the two companies, where the graphs plot the average product audit score on a weekly basis. This shows the maturation of the products in terms of quality and craftsmanship delivery as it progresses through to product launch.

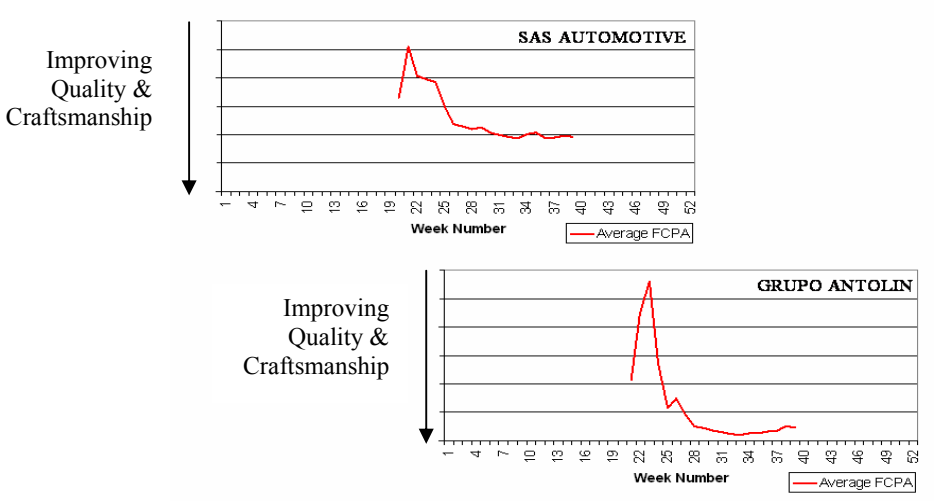

Figure 6: Audit Results of Collaborating Suppliers

Discussion

The results in Figure 6 show that both of the suppliers had an initial rise in their audit score, until it reached a peak. Grupo Antolin's score increase was sharper than SAS Automotive. This initial rise was found to be due to a familiarisation period in audit methodology by the product auditors. The auditors' awareness rose from identifying at first "A" and "B" class concerns to increasing the level of attention the product was assessed too. This meant that more "C" concerns which were previously undetected were being recorded by auditor. Therefore concerns which would have an affect on craftsmanship were being detected much earlier in the NPI process.

Following the peak audit score being reached at the companies there was a period of improvement activities as the metrics were communicated throughout the company and focus was given to the critical quality and craftsmanship concerns. At Grupo Antolin the metrics were used as the focal point of their Quality Reviews. During this period engineering changes and manufacturing process improvements took place. These improvements would have been more costly to the business if they were identified during volume production, as the cost of change is more at this stage [23]. Customer perception would have also been affected if the concerns were allowed to reach the market.

Engineering and Manufacturing maturation was conducted on a priority base, where the issues that were tackled first were the regular severe concerns, highlighted by the audit metrics. Once these had been resolved the next set of priority issues were addressed until craftsmanship concerns and faults which appeared at irregular intervals began to be solved. Therefore a whole range of potential sources of customer dissatisfaction were being rectified.

After the period of quality maturation there began a period of stability which continued until product launch, where the metrics were used to monitor process stability. SAS Automotives score stabilised at a higher average than Grupo Antolin due to the assembly being more complex and the auditors at the company inspected the assembly to a more critical standard than JLR. Grupo Antolin noted similar issues to JLR. These FCPA scores were used at evaluation gateways within FPDS, to set realistic "glide path" improvement targets for the next prototype build phase, until product launch.

The initial results have shown that having customer orientated metrics installed at the supply base of a premium automotive manufacturer, can facilitate more critical product assessment and significant maturation activities. This study contributed to the Land Rover Discovery 3 having the lowest FCPA score at product launch across all previous JLR programs.

Improvements and further work

The initial results have shown that implementing audit systems in the supply base can yield fast product maturation rates. There are however improvements which could be made to the audit methodology to enhance its effectiveness. One improvement would be to reduce the variation in the level of detail that the product is assessed too. Developing a more detailed quality standard with input from the supply base would help to minimise this variation. At present standard development is very detailed for aspects such as dimensions and functional elements. However, for features such as surface conditions and harmony between components, which cannot be easily measured, the standards are less clear. Input from the supply base to the standards manual would increase detail because they are responsible for the majority of the development and manufacturing of the component. Therefore have more understanding of the specification to be able to characterise product attributes.

Incorporating continuous improvement activities into the audit process, once the period of rapid product maturation has elapsed, would help maintain focus on quality and craftsmanship throughout the product lifecycle. This focus is important because from the initial results, both company's experienced stagnation or slight decline in their audit scores. Gradual process enhancements will allow the company's to achieve excellence in their manufacturing processes which will improve product performance, and customer satisfaction.

A detailed audit process outlining how each attribute or component of the assembly is to be viewed and what features, which are critical to the customer, to inspect would be a further improvement. This will allow an assembly to be audited consistently every time and help make sure that auditors inspect to the same standard without missing vital elements of the product. Increasing the repeatability and reproducibility of what is a subjective measure because auditors have to view the component as a critical customer. Advice on how the audit metrics should be communicated throughout the supply chain is required. This will allow the full benefits of having a common metric to be reached and allow concerns to be addressed in the most effective manor.

The initial results have proved that implementing audit mechanisms into the supply base can achieve rapid product maturation. This methodology now needs to be expanded down the supply chain. This work has already begun at the IARC and the results are being investigated to see whether it has resulted in more rapid maturation or allowed the audit to reach a lower score before stabilisation. It is envisaged that the audit system will be expanded across the entire supply base having the metrics formally integrated within the self-assessment or gateway stages of the NPI process.

Finally it has been shown that suppliers have the knowledge and expertise to deliver a product to a standard, once it is known. If the audit methodology was used in the supply base during the Design and Development stage of the NPI process to identify concerns in the virtual environment, engineering concerns can be resolved at much lower cost before a physical

product is produced, leaving the delivery phase free to hone manufacturing processes to deliver a product with excellent perceived quality.

Conclusions

The initial results have shown that a customer orientated product audit can be successfully implemented into a tier one supplier. This, after a period of familiarisation, allowed the full range of product quality and craftsmanship concerns to be recorded and identified for maturation. It also allowed the suppliers in the study to understand the expectations of its customer, JLR, and also the "needs" and "wants" of the end-user. This allowed resources to be focused at developing the product at source to satisfy both groups. The study also showed that supplier expertise can achieve rapid quality and craftsmanship improvement once expectations have been understood and communicated. The study now needs to be widened to incorporate more of the supply base, taking into account the improvements and further work identified within this paper.

References

[1] Calantone, R., Dröge, C., Vickery, S., "Investigating the manufacturing-market interface in new product development: does context affect the strength of relationships?", Journal of Operations Management, 20, 2002, 273-287.

[2] Wheelwright, S.C., Clark, K.B., "Accelerating the Design-build-test Cycle for Effective product Development", International Marketing Review, 11, 1, 1994, 32-46.

[3] Cooper, R.G., Kleinschmidt, E.J., "An Investigation into the New Product Process: Steps, Deficiencies and Impact", Journal of Product Innovation Management, 3, 1986. 71-85.

[4] Cooper, R.G., Edgett, S.J., Kleinschmidt, E.J., "Benchmarking Best NPD Practices – II", Research Technology Management, May-June 2004, 50-59.

[5] Gardiner, G.S., Gregory, M.J., "An audit-based approach to the analysis, redesign and continuing assessment of a new product introduction system", Integrated Manufacturing Systems, 7, 2, 1996, 52-59.

[6] Tennant, C., Roberts, P., "The creation and application of a self-assessment process for new product introduction", International Journal of Project Management, 21, 2003, 77-87.

[7] Boyer, S.M., "Total Quality Management and New Product Development", Total Quality Management, 2, 3, 1991, 283-289.

[8] Cooper, R.G., Kleinschmidt, E.J., "Stage Gate Systems for New Product Success", Marketing Management, 1, 4, 1993, 20-29.

[9] Williams, M.A., Kochhar, A.K., "New product introduction practices in the British manufacturing industry", Journal of Engineering Manufacture Proceedings Part B, 214, B10, 2000, 853-863.

[10] Lukas, B.A., Menon, A., "New product quality: intended and unintended consequences of new product development speed", Journal of Business Research, 57, 2004, 1258-1264.

[11] Clark, K.B., Fujimoto, T., "Product development performance: strategy, organisation and management in the world auto industry", Boston: Harvard Business School Press, 1991.

[12] Law, B., "WP1a (Definition): Scoping the Problem", International Automotive Research Centre, University of Warwick, 2004.

[13] Wolek, F.W., "Ye olde quality management", Total Quality Management, 10, 7, 1999 1077-1084.

[14] Holden, J., Wang, J-H., "Role of Craftsmanship in Product Design", Proceedings of the 14th International Forum on DFMA, Newport, Rhode Island, 1999.

[15] Birou, L.M., Fawcett, S.E., "Supplier Involvement in Integrated Product Development: A Comparison of US and European Practices", International Journal of Physical Distribution & Logistics Management, 24, 5, 1993, 4-14.

[16] Karlsson, C., Nellore, R., Söderquist, K., "Black Box Engineering: Redefining the Role of Product Specifications", Journal of Product Innovation Management, 15, 1998, 534-549.

[17] Petersen, K.J., Handfield, R.B., Ragatz, G.L., "A Model of Supplier Integration into New Product Development", Journal of Product Innovation Management, 20, 2003, 284-299.

[18] Wu, T., O'Grady, P., "A Network-Based Approach to Integrated Enterprise Concurrent Engineering", Journal of Advanced Manufacturing Systems, 2, 2, 2003, 187-200.

[19] Chen, C-C., Yeh, T-M., Yang, C-C., "Customer-focussed rating system of supplier quality performance", Journal of Manufacturing Technology Management, 15, 7, 2003, 599-606.

[20] Leonard, F.S., Sasser, W.E., "The incline of quality", Harvard Business Review, September-October 1982.

[21] Vasudevan, A., Wang, J-H., "Developing a Craftsmanship based Product Evaluation System", Proceedings of the 15th International Forum on DFMA, Newport, Rhode Island, 2000.

[22] Attridge A., Williams M., Tennant C., "Achieving craftsmanship targets across the UK automotive supply base, through the use of quality maturation tools and processes", Proceedings of the SAE 2005 World Congress, Detroit, Michigan, 2005.

[23] Tennant, C., Roberts, P., "A faster way to create better quality products", International Journal of Project Management, 19, 2001, 353-362.

Glen Turley
University of Warwick
International Automotive Research Centre
Coventry
CV4 7AL
United Kingdom
Tel: +44 (0)24 7657 5374
Fax: +44 (0)24 7657 5365
E-mail: glen.turley@warwick.ac.uk