Australasian Transport Research Forum 2013 Proceedings
2 - 4 October 2013, Brisbane, Australia
Publication website: http://www.patrec.org/atrf.aspx

# Design of a new route bus for Australia – Investigating the value, contradictions and cost implications of vehicle improvements.

Dr Robbie Napper[1], Peter Elliott[2]

[1]Department of Design, Monash Art Design & Architecture, Monash University

900 Dandenong Road, Caulfield East, Vic, 3145.

[2] Toyota Motor Corporation Australia Ltd

61 Bertie St, Port Melbourne, Vic, 3207.

robbie.napper@monash.edu

## Abstract

This paper presents a case study of the development of a new route bus for the Australian market. The work describes a project undertaken between 2009 and 2013 in Melbourne, Australia. The project is divided into three stages; the product design specification (PDS), the concept design stage, and the detailed design, marketing and prototype stage. Four discoveries pertinent to public transport research are made.

The PDS shows that in the face of immovable legislative and mechanical constraints there is still significant scope for improvement to Australian route buses; drawing a hypothesis that pragmatism and safety need not preclude an attractive, user-centred design.

The concept design stage refutes the view that in order to be superior, contemporary route bus aesthetics should be derivative of light rail vehicles. A second discovery in the concept design stage was the potential discord between contemporary appearance and what is viewed in the market as a pragmatic, repairable and rational product.

The detailed design, marketing and prototype stage is concerned with the execution of the design concept. Component analysis in this stage reveals that improvement of technical performance, usability and aesthetics can be achieved with a cost saving. Engagement with eventual vehicle purchasers in marketing activities shows the importance of aesthetic improvement.

The case study uses the rare opportunity of complete vehicle redesign to improve knowledge of the value of design in the route bus, and broader public transport context. The findings of this research improve our understanding of vehicle design and public transport user experience.

## 1. Introduction

Route buses are an important part of our transport system. The ubiquity of roads means buses can offer an inexpensive and versatile means of public transport (Griffin, Catling et al. 2005). Bus vehicles are capital goods, machinery used to produce a commodity (Acha, Davies et al. 2004). Manufacturers make buses – operators provide transport. The nature of bus operators varies from government organisations to small family businesses; they are typically responsible for the operation of buses in a defined geographical area to create transport service. Operators must work within their locale and business strategy; reflected in varied methods of operation and marked physical variations in bus vehicles.

Economies of scale in modern production systems allow less expensive manufacture and assembly of complex, identical goods which would otherwise be more expensive. Heskett (1980) describes methods of manufacture as evolving from maker-as-user to a form of mass-craft manufacture applied by Josiah Wedgwood in the manufacture of ceramics.

Industrialised mass production was eventually accepted culturally as a reasonable method of manufacture and developed separately to bespoke methods, which continue as a manufacturing method in their own right. Existing ideas of mass production were brought together in the Model T Ford, in combination with the innovation of compartmentalised manual tasks in production. Henry Ford's notion of standardisation offered customers *"...any colour that he wants so long as it is black."* (Batchelor 1994).

Ford's often quoted yet reputedly never uttered phrase (*ibid*) nevertheless neatly summarises the beauty and boundaries of mass production – the system will work if consumer demand is limited to the product in standardised form. In the Model T case, the efficiency of manufacture led to such an affordable product that customers overlooked deficiencies; as despite shortcomings the Model T still represented a significant advance from the horse. Mass production endures as the basis of efficient manufacture, the fundamental attributes being the repetition of tasks and components.

In the 1980s the modern system of mass-production fragmented into the postmodern system intending to satisfy smaller markets for goods and services, more in-tune with consumer needs (Day 2007). For a manufacturer to survive in a fragmented market requires either high cost bespoke manufacture, small overheads and market share, or a manufacturing strategy affording economies of scope, such as Mass Customisation (Pine 1993) envisioned by Stan Davis (1987).

One of the most important competitive platforms in the bus industry is the opportunity for operators to customise their vehicle; itself illustrating that operators don't actually *desire* customisation, but rather they desire what they perceive is the *right* bus for them. Since almost any bus vehicle can be considered to provide an essential basic function, we consider the customisation competitive platform to be an "attractive" quality, rather than the "must be" qualities (Kano 1984) of durability, capacity, cost and other mechanically quantifiable attributes.

This research was carried out under contract for Volgren Australia Pty Ltd, between August 2009 and February 2013. The research was ostensibly tasked to redesign Volgren's main product – the route bus – to improve manufacturability while maintaining or improving Volgren's sustainable competitive advantages of low life cycle cost, safety and repairability.

The commercial setting for this research provides the testing platform for the design, with the eventual bus build and factory production switch forming part of the proof for conclusions drawn. In order to protect commercial interests in the project, the present research reports on the process at the very end of the design cycle; where the product has been commercially released into service. The present case is thus offered as a platform upon which conclusions are drawn, affecting the public transport sector as a whole.

This paper describes the problem of improving an already market leading product in terms of manufacturability, with the strict requirement of no reduction in the existing Sustainable Competitive Advantage (SCA) of the company. Sections following the brief introductory matter describe how this was carried out; the aim of this paper being to describe four areas of new knowledge discovered in, and demonstrated by, the new design.

With the above competitive environment in mind, the present research first undertook a large data-gathering task in order to fully understand the constraints of the project. This research was presented to the client as a product design specification (PDS).

## 2. Methodology

The pervasive method throughout this research is experimentation by design studio research. Design is a process of research resulting in the creation of artefacts. Design, like research, sets out to discover and create *"that which does not exist"* (Nelson and Stolterman 2003). Whether knowledge, products or indeed both are sought, the aim of the process is the same. The creation of new artefacts results in new knowledge. As the process of designing requires that decisions are made based on existing knowledge, the design process encompasses information gathering, reflection and synthesis into a statement of direction prior to the development of concept designs. The ideas are benchmarked against the constraints discovered early in the process and those which are coming to light as part of the ideation process, and finally a conclusive position is reached where products might be manufactured, and the process may seek improvement through iteration.

Within the context of this experimental process, data were also gathered through focus group research and interviews. A total of five focus groups were conducted in the concept design stage, with 16 participants in each. A total of 3 interviews were conducted with industry stakeholders. Information gleaned from both of these methods was used as a basis for further design iteration and development.

The process of business case analysis (BCA) was applied in the project to measure the quantitative – primarily economic but also mass and quantity – attributes of new components as compared to those they replaced. This process is discussed more in section 6, with an example BCA form (blank) shown in Figure 5.

## 3. The product design specification

Completion of the PDS enabled the design research team to fully understand Volgren's SCA, and project constraints. The first part of this research examined Australian Design Rules (ADRs) (for example, Australian Government Department of Infrastructure Transport Regional Development and Local Government 2006), chassis, and the interior and exterior design relevant to the Volgren bus, and buses in the market.

PDS research was carried out as a desktop exercise by reviewing relevant literature, an in-depth artefact study of the vehicles, and interviews with Volgren staff. The simplest, and yet one of the most extensive, parts of the research was the study of relevant ADRs. ADR data are communicated to users in a largely textual form, and the PDS undertook to interpret these into graphical and 3D mediums to enable the generation of future design concepts "on package" from the beginning.

A comprehensive study of buses on the production line was carried out to gather knowledge about the production process. Although in itself thoroughly documented and controlled by Volgren, process weaknesses are only evident in observation of the work being carried out. In doing so, a conflict between the SCA and project objectives was discovered. Volgren's approach to repairability has resulted in assemblies of many smaller parts – offering the benefit of replacement only when necessary and normally limited to the area of local damage, but conversely requiring many more hours of skilled labour in the build process.

An examination of Volgren's product also revealed in detail what was anecdotally known – that the design of components for the vehicle, especially those manufactured in-house from sheet metal resulted in parts of low cost, aesthetic and functional value. While pragmatic and helpful to the SCA of low life cycle cost, these components were observed to be limited to a single function – for example a simple bracket – subsequently attached to another functional part, for example a driver's coat-hook. Such "simple mapping" (Eggen 2003) is observed to be typical of engineering-focussed companies and while perfectly functional it is also component intensive. The PDS therefore identifies the conflict between a rational approach to manufacturing and Volgren's existing "repairability" competitive advantage.

In examining the product from a sales and customer perspective, the PDS identifies that a key competitive advantage for Volgren is the flexible specification of their product – bus operators enjoy a range of options and generally speaking, get what they want. However, this is in direct conflict with efficient manufacturing, and a mass-customisation approach was agreed to be applied throughout the vehicle following experimentation in the driver's area (Napper 2010).

The degree of customisation to be offered was a matter of contention within Volgren. The production and engineering teams sought a reduction in options, whereas the sales team desired the opposite. Following approaches developed with Volgren over the preceding years, the options list was reduced by removing those with no profit, and the PDS further recommended that the function provided by important options be maintained where possible by designing a range of functional options into a single, standard component.

Curiously, bus design in Australia is not particularly in-tune with passenger requirements. Vehicle performance – for example power, passenger capacity or fuel economy – are considered from an operational perspective as evidenced in tenders (for example, Wales 2007; Government of Western Australia 2010), but vehicle improvement for their eventual end user is uncommon (Napper, Burns et al. 2009). With the exception of complaints to bus operators and the election of governments, passengers have no direct means of affecting change in the bus industry. The PDS therefore undertook a review of passenger-focussed issues to determine passenger requirements

Review and inclusion of passenger requirements based on previous research in the PDS revealed an opportunity for the Australian bus industry, summarised as the following (ibid);

1. Ease of cognitive and physical access.
2. Personal and vehicular safety.
3. Comfort.
4. Flexibility in using their transit time.
5. An aesthetically appealing environment.
6. Cleanliness.
7. Suitable space for a comfortable and useful journey.

Passenger requirements have been served at a basic level through ADRs ensuring a threshold of passenger amenity and safety – for example by the implementation of minimum seat pitch (ADR 58:13.2, in Australian Government Department of Infrastructure Transport Regional Development and Local Government 2006). When coupled with state regulations such design rules provide a functional vehicle, but in the view of this research, an unattractive one. The design approach to this research affords an holistic view of what the vehicle should provide to stakeholders, and indeed who those stakeholders may be. The improvement in providing passenger requirements is an area of significant opportunity for improvement in the Australian route bus market.

The final, and perhaps largest contribution of the PDS research to Volgren's competitive advantage was the examination of exterior styling applied over previous models, often referred to as "visual DNA". Facelift styling of interior and exterior are a requirement of this project but up to the present there has been no design intent used in the generation of Volgren's "look". Contemporary Australian buses tend to exhibit a staid, conservative appearance – a result of demands in a conservative industry perhaps, but also one that does not willingly accept the notion of buses having a strong identity (Schwartz 1980; Scherer 2010). The PDS examined past Volgren exteriors to determine whether there are any strong visual cues to associate with the brand. Although a capital good, buses have prodigious street-presence and there is some unquantified evidence suggesting the importance of a unified, pleasing appearance, for example the red used in London and Bogota. The PDS found that although Volgren's exterior designs have wavered significantly over the last 25 years, the mechanical characteristics of the bolted aluminium body have provided strong visual links – mainly in the form of immovable horizontal lines – for application in the development of new styling.

The PDS encourages a thorough understanding of Volgren's competitive advantage, sets out basic requirements, and identifies conflicts. Importantly, the results of the PDS are not communicated in isolation, but rather as a cohesive, interdependent whole. This mirrors the design approach taken in the following stages where one issue cannot be solved in isolation lest a manufacturing solution have a negative impact on sales for example. The PDS was tabled to the project steering committee and Volgren were asked to undertake several internal activities to resolve specification issues prior to the design stage.

## 4. Concept design

Whereas the PDS communicated existing, albeit unknown conditions, the concept stage is where the new work contribution of the project began. The task of this stage was to determine at a broad level what the key visual and functional characteristics of the new product would be. It is a precursor to the more technically demanding detailed design stage where the concepts are executed. The work in this stage was broken into two functional areas – interior and exterior.

With the discoveries and forced decisions of the PDS as constraints, concept sketches were developed to explore the range of possibility for both interior and exterior. The research in this stage set out to determine the best visual treatment for the new product. The methodology used was concept development for focus group research, with concepts presented to project stakeholders and decisions made based on their input.

The subject matter of the bus as capital goods, and its setting in a conservative industry is re-emphasised at this point as a key element of the focus group methodology. Owing to the commercial nature of the project, participants for the focus groups were drawn from within the project team – both the host organisation Volgren and the research team from Monash University. The participants represented different elements of the project; engineers, engineering managers, sales team, sales managers, managing director, CEO, after-sales service managers, manufacturing team leaders, process engineers and industrial designers.

Although focus group attendees were all vocal, forthright experts in their respective fields, the discussion of styling and aesthetics was difficult to initiate. As identified by Archer's (1979) seminal work "*predominantly quantitative considerations*" can sometimes overrule those of aesthetic, or user-centred focus simply due to paucity of language or lack of metrics by which to compare them. Add to this a reluctance to discuss "soft" considerations because of cultural mores, and it becomes clear why professionals in the bus industry are not accustomed to discussions for which there is no empirical, quantitative base. The observation is made from this focus group that it does not suit the predilection of most heavy vehicle professionals to robustly debate aesthetics. The presentations throughout this stage commenced with a long presentation of concept work, and only when the design team themselves commenced the process of constructive criticism did the stakeholders join in. While every Volgren vehicle has had a "look" of some description over the company's history, they were treated as more a foregone conclusion once drawn, rather than something which could, and should, be debated to arrive at a perceived "best" position.

Exterior concepts were broadly categorised into one of three types on a continuum – "contemporary", "progressive" and "ultra-modern stretch" as shown in Figure 1. Each concept was prepared using regulatory and functional requirements as a base – in this case a visual underlay for sketching – to ensure basic validity of the design. Some 100 concepts were presented in the first round review, with subsequent reviews narrowing down to 50, 12 and 3 concepts. The first review revealed the most data from the focus groups, pointing towards contemporary exterior styling as almost unanimously preferred. As illustrated in Figure 2, the concept development process for the exterior became more detailed as the scope of options became smaller.

**Figure 1: The continuum of exterior concepts, showing from left to right, "contemporary", "progressive" and "ultra-modern stretch" approaches to styling.**


**Figure 2: The increasing detail in exterior concepts, showing drawings two drawings and a basic CAD surface model.**


As the focus group participants became more familiar with the discussion on styling, and as more finely developed concepts were generated, a conflict emerged between the need for facelift styling and Volgren's existing SCA. A reputation as robust, repairable and resilient product, and especially as a heavy-duty long-lifespan capital good, has resulted in market resonance for conservative designs with little or no aesthetic sensibility. It is not poor styling but rather a lack of it which has come to be identified as a "necessary" corollary to a functionally superior product. This association is deeply rooted in the bus industry, and is somewhat strengthened by the counter-example of heavily-styled low-durability imported vehicles. The sales team participants suggested any new appearance with an increase in styling content may be viewed in the market as functionally inferior. The link exists in perception rather than material, but as perception plays a role in the sales process of a product, this became a new consideration of exterior design development. The need was for a superior appearance, but not to the extent where it would be viewed in the market as the only improvement. Conversely to this conflict, work in the sale of this new vehicle in subsequent months identified a key advantage to superior styling described in section 6.

Once a design direction was established for the exterior, secondary approval was sought with major stakeholders in the project – bus operators with long-term contracts of vehicle supply. This step was contractually necessary and also served as a method of very early marketing, promoting customer buy-in and to provide assurance to the project committee that the design direction was suitable to the market.

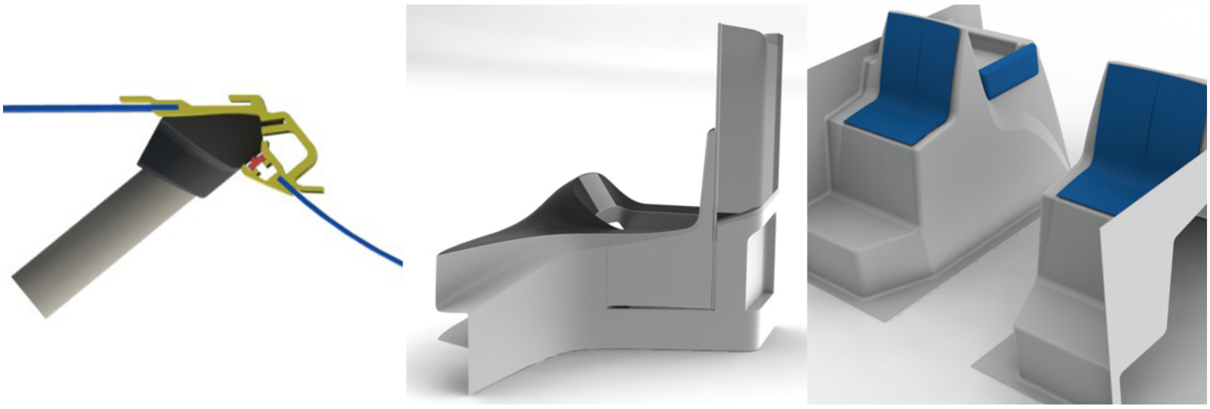
Drawing on a range of aesthetic inspirations such as the history of the bus market and other stylistic and materialistic trends, the pursuit of an appropriate appearance "theme" for the bus was the main purpose of the exterior development. The literature contains few references to stylistic directions appropriate to bus transport – those that do exist are biased towards Bus Rapid Transit (BRT) as the value of styling in BRT is deemed more important than in regular buses (Zimmerman and Levinson 2004; Bus Rapid Transit Institute (BRTI) 2009). The BRTI report (ibid) posits that functionally a BRT system would do well to emulate the functional characteristics of light rail transport (LRT) vehicles. The extrapolation of this notion to suggest that bus vehicles should stylistically emulate LRT vehicles is also made in the report. While this work makes the excellent point that vehicle image is a critical part of transport performance, the conjecture that "rail-like" (ibid) vehicles are the only successful way to improve bus image is refuted by the example generated in this project. A rail-like appearance has been shown to work; the present research shows that a successful styling theme can be created which is not derivative of other modes.

The interior concept development began with a similar approach to exterior – discussion around a range of concepts to determine a styling theme. The approach initially failed, with no favourable concept being selected. It was determined in the ensuing discussion that an aesthetic approach to the interior was flawed, as the interior of a bus is an intensely functional space comprised of many hundreds of functional components. As the interior of the bus is the most component- and therefore labour-intensive area to manufacture, a more component-focussed approach was taken. The unifying aesthetic was to be developed following the component design.

To facilitate this new approach, the interior was divided into smaller functional areas and each of these tackled as projects in their own right. This approach is somewhat retrograde when considering the aim of concept development, however a functional approach was agreed on in each area of the interior, the principle themes being of component reduction by combination, value adding to components to reduce labour cost, and a general "clean-up" by relocation of visible fasteners.

Despite initial difficulties, the interior design concept stage made a contribution to a new competitive advantage by approaching the components with a more holistic, or designerly perspective – weighing up the legislative and mechanical requirements normally focussed on at Volgren, with those of sales and passenger requirements. An excerpt from interior concept development is shown in Figure 3 to illustrate the difference in approach from the exterior design.

**Figure 3: Interior concept development, showing handrail clamp, driver's area and wheelarch seating concepts.**



Both the process and results of the concept review focus groups show that design made a significant contribution to Volgren's competitive advantage. Throughout the focus groups, it became clear that a contemporary approach to styling as opposed to a retrospective or futuristic approach would be most appropriate. This was not known at the project outset. The decisions made in the interior design, while not indicative of design identity, show that the introduction of new aspirational constraints – in this case a cleaner appearance – is an achievable goal for a company with existing market strength.

Work in the concept stage successfully developed a new competitive platform for Volgren. Updated styling could have been achieved without this research, however it is postulated as a result of this work that a design approach to styling development resulted in a visual and material treatment more sensitive to cultural and aesthetic constraints. The development of a successful aesthetic for buses which is not derivative of light rail is in itself new knowledge.

## 5. Detailed design, marketing and prototype build

The third and final stage of the project was concerned with the detailed design of all components, manufacture of parts, and assembly of two prototype vehicles. This was the most resource-intensive stage and was conducted over 18 months to February 2013. In total some 750 components were developed and manufactured. The completion of this stage ended the research project; the development programme of the vehicle continued on from here.

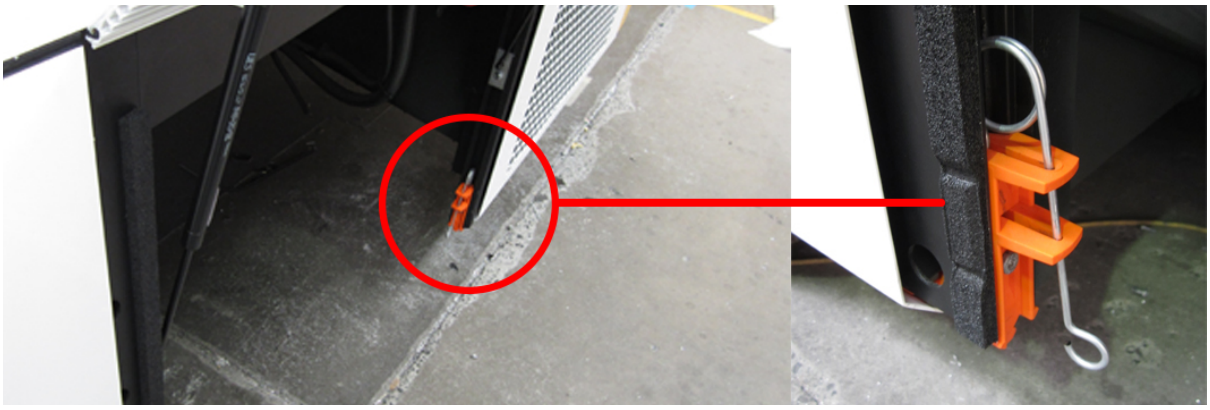
Beginning with the agreed concept, the design intent now had to be expressed in three-dimensional geometry ready for manufacture. This "core" of the design execution task poses a significant challenge in maintaining the integrity of the agreed concept. In the case of the exterior styling, the exterior surfaces had to be maintained while developing robust details in the scope of rigorous tolerance control. In the case of interior components, the functional characteristics agreed in the concept stage had to be expressed in components – as few as possible.

While challenging at the best of times, detailed design of components also affords the designer an opportunity to build in more value. As described above, execution of agreed design intent is the first requirement, but in detailed design there is an opportunity to implement further principles of design to add supplementary value, and competitive advantage.

One example of the additional value-add possible in detailed design is the creation of a seemingly innocuous clamp component pictured below in Figure 4. Charged with the design intent of concealing mechanical fasteners from the vehicle's side, a lateral thinking approach posited that this component could be used to secure both hinged and fixed panels, and therefore become standardised on every panel. This standardisation has tremendous value for product assembly; part standardisation leads to process standardisation, reduced labour and improved quality. Tests of the part in glass-reinforced nylon revealed ample strength at low cost, resulting in a total saving per bus of $602, for a component cost of $1.35.The tooling investment of $8775 is recovered in the production of 15 vehicles (11 days production). A no-cost colour option was exercised to have the part in Pantone International Orange 021C, making it more visible in the bus and therefore offering better usability to assembly and maintenance staff.  This example illustrates a functional improvement through a positive closure method for exterior panels; a process improvement through standardised fitment and visibility; and a cosmetic improvement through the elimination of visible exterior fasteners; improvements made at a cost saving.

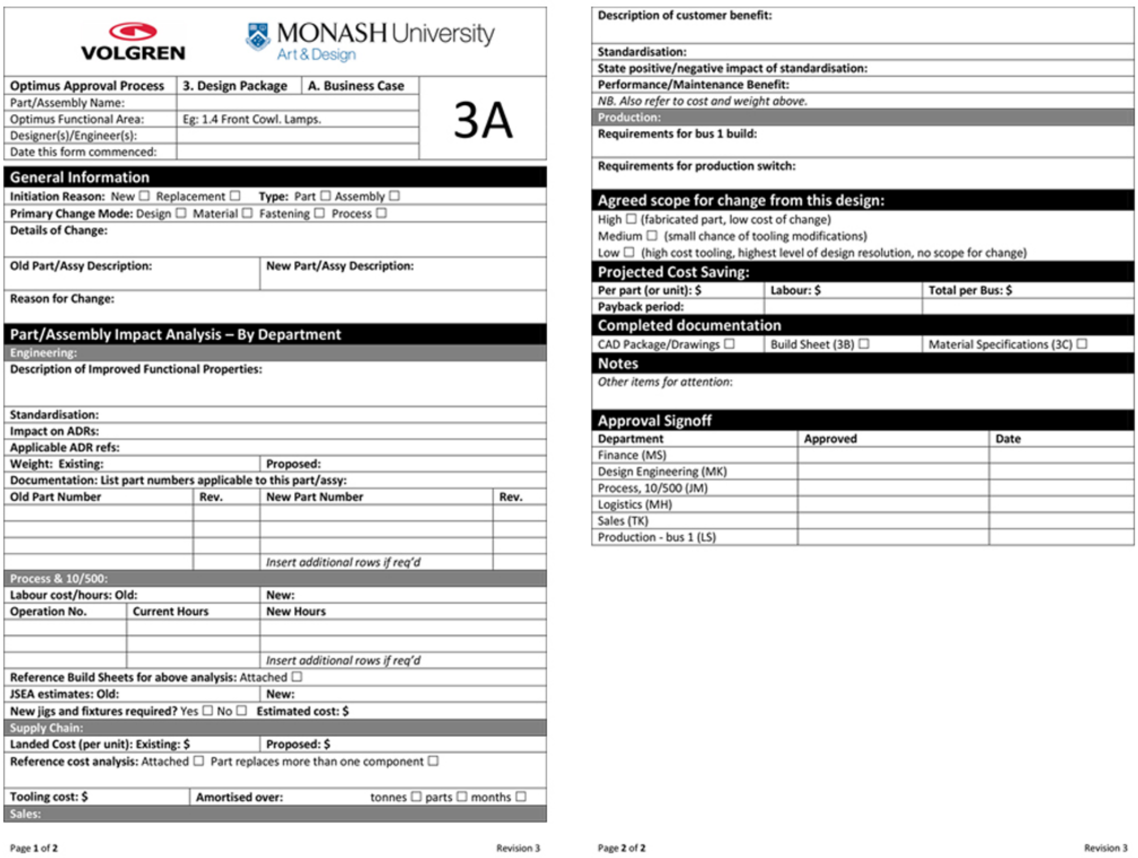
The readiness of components for manufacture was determined by business case analysis (BCA). In the BCA, a like-for-like comparison was undertaken between the new component and those which it replaced. The BCA was written by the design team and populated with data from each department within the business. Design engineering, process engineering, supply chain, sales, finance and senior management were then required to assess and either approve or reject the change based on their own requirements. Examples of BCA rejections include those made on the basis of technical performance, warranty availability and duration, labour, and stability of supply chain.

**Figure 4: Exterior panel clamp, showing context on the left, and detail on the right.**



While part and assembly cost formed the foundation of the BCA, it is interesting to note that in contrast to the clamp example above, several high-cost components were approved without a direct economic benefit as they were viewed to offer the vehicle design some intangible value – such as improved styling and the creation of product identity. The process for validation in these qualitative instances was made later and therefore at some risk in the customer-specification stages; the launch of marketing activities for the new vehicle prior to production.

**Figure 5: Business Case Analysis Form**



VOLGREN

MONASH University
Art & Design

| Optimus Approval Process | 3. Design Package | A. Business Case | 3A |
|---|---|---|---|
| Part/Assembly Name: | | | |
| Optimus Functional Area: | Eg: 1.4 Front Cowl. Lamps. | | |
| Designer(s)/Engineer(s): | | | |
| Date this form commenced: | | | |

**General Information**

**Initiation Reason:** New ☐ Replacement ☐ **Type:** Part ☐ Assembly ☐

**Primary Change Mode:** Design ☐ Material ☐ Fastening ☐ Process ☐

**Details of Change:**

**Old Part/Assy Description:** | **New Part/Assy Description:**

**Reason for Change:**

**Part/Assembly Impact Analysis – By Department**

Engineering:

**Description of Improved Functional Properties:**

**Standardisation:**

**Impact on ADRs:**

**Applicable ADR refs:**

**Weight: Existing:** | **Proposed:**

**Documentation: List part numbers applicable to this part/assy:**

| Old Part Number | Rev. | New Part Number | Rev. |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | *Insert additional rows if req'd* | |

Process & 10/500:

**Labour cost/hours: Old:** | **New:**

| Operation No. | Current Hours | New Hours |
|---|---|---|
| | | |
| | | |
| | | *Insert additional rows if req'd* |

**Reference Build Sheets for above analysis:** Attached ☐

**JSEA estimates: Old:** | **New:**

**New jigs and fixtures required?** Yes ☐ No ☐ **Estimated cost: $**

Supply Chain:

**Landed Cost (per unit): Existing: $** | **Proposed: $**

**Reference cost analysis:** Attached ☐ Part replaces more than one component ☐

**Tooling cost: $** | **Amortised over:** tonnes ☐ parts ☐ months ☐

Sales:

Page 1 of 2 Revision 3

**Description of customer benefit:**

**Standardisation:**

**State positive/negative impact of standardisation:**

**Performance/Maintenance Benefit:**

*NB. Also refer to cost and weight above.*

Production:

**Requirements for bus 1 build:**

**Requirements for production switch:**

**Agreed scope for change from this design:**

High ☐ (fabricated part, low cost of change)
Medium ☐ (small chance of tooling modifications)
Low ☐ (high cost tooling, highest level of design resolution, no scope for change)

**Projected Cost Saving:**

| Per part (or unit): $ | Labour: $ | Total per Bus: $ |
|---|---|---|
| Payback period: | | |

**Completed documentation**

CAD Package/Drawings ☐ | Build Sheet (3B) ☐ | Material Specifications (3C) ☐

**Notes**

*Other items for attention:*

**Approval Signoff**

| Department | Approved | Date |
|---|---|---|
| Finance (MS) | | |
| Design Engineering (MK) | | |
| Process, 10/500 (JM) | | |
| Logistics (MH) | | |
| Sales (TK) | | |
| Production - bus 1 (LS) | | |

Page 2 of 2 Revision 3

The route-to-market for a bus is different to those of consumer goods. As a complex product system (Hobday 1998), and capital good (Suomala, Sievanen et al. 2002; Acha, Davies et al. 2004) an amount of pre-sale customer involvement is useful, and in the case of long term supply contracts in the bus industry – contractually necessary. Interviews with major contract holders for the supply of vehicles were conducted throughout the design process in order to pass the concept design through to the next stage.

Interviews with contract holders were used to gather qualitative information leading to the approval of parts with intangible value. The interviews showed an approval, through stated willingness to pay, for the new look of a vehicle. Interviewees from government operated fleets stated that the political capital in a new, improved look will be worth a small cost impost – a statement made without knowledge of the project aim to keep the improvements cost-neutral or cheaper.

As components and assemblies were approved, the supply chain department commenced procurement of initial sets of components. A prototype programme was agreed with a local bus operator to fund the supply of two chassis for the build of two vehicles. Bus 1 was assembled as components arrived and were approved against engineering data. Bus 2 was assembled in production sequence to test process engineering improvements. At the close of this stage, two complete buses had been assembled and were ready for dynamic and static testing. The testing programme's main aim is to ensure the mechanical integrity of the product, ensuring legislative and market compliance.

## 6. Discussion

This paper describes a case applying three existing design techniques – PDS, concept design and detailed design and prototyping. The design approach to research led to the expected documentation of technical and legislative performance requirements; but importantly also determined at a macro-level some contradictions in the product. A key competitive advantage – repairability – was in this case discovered to be in conflict with a desired project outcome – rational manufacture. A further advantage of a design view in this desktop research stage is the creation of new knowledge for the client in the form of a statement on product styling DNA. The inherent characteristics of the PDS as an illustrated written report aids dissemination in the company and required little design acumen in interpretation.

**Figure 6: The finished vehicle – exterior and interior photographs.**

The PDS afforded an outside-in view of the bus and the manufacturing business. This view was integral in discovering the scope for improvement in the vehicle. The current product leads the market primarily by means of mechanical design. The view of the project team, and moreover that of the authors was that the scope of performance of a route bus is founded in such mechanical characteristics but extends far beyond. In the design process many parallels were drawn between the bus and other contemporary products with which the public interacts; in particular the private car. Although tempered by the fact that a bus has far different duty cycle and economic factors, this view was integral in pushing usability and styling as areas for product improvement.

Conversely to the PDS, the concept stage was expressed in a medium more familiar to designers, so a steep learning curve was experienced by many of the client participants. The concept stage primarily dealt with the theme of competitive advantage by breaking into new territory – the development of contemporary market-focussed styling and the beginning of a rational component design approach. While the existing product is a market leader, it led through superior mechanical engineering. The concept stage was careful to offer new competitive advantages which didn't diminish those in existence; carried out by styling development and the consolidation of several functions and components into single part concepts. The concept stage was characterised by the high-level creation of new content, in preparation for detailed design.

The subsequent market testing in stakeholder interviews confirms the above view; public transport in Australia is competing with other modes, in particular the car. The recognition of political capital in a new public transport vehicle suggests a link to public demand for better services in addition to what is already well documented in the transport planning literature concerning the demand for more, and more reliable services.

The exterior styling improvement achieved in this project also demonstrated that in order to be attractive, buses need not be derivative of LRT vehicles. Buses are recognised as occupying the "bottom rung" of qualitative desirability in public transport (Bunting 2004) and the notion that buses should be stylistically derivative of LRT vehicles relegates the mode to a position of imitation. Even an excellent execution of styling a bus to appear "tram like" would place the bus as at best a second-rate substitute in an attempt to be something it is not. The creation of a design theme which is – according to focus group and interview results – stylistically attractive and suitable to the bus archetype allows the mode to have its own appearance and stand on its own merits.

The creation of a new design theme and repositioning of the bus as a vehicle of enhanced appearance led to the discovery that the general pragmatism – founded in the vehicle's performance according to repairability, safety and durability – of a bus is linked in a marketing sense to the vehicles bland appearance. This suggests that operators are willing to forgive or overlook poorly developed styling in exchange for performance against their contractual performance indicators. The way a new appearance needs to be sold into the market is generally against these indicators, so a new interior for example is generally designed and sold around themes of cleanliness – a factor measured in transport operation contracts. The creation of a new vehicle with improved styling sets a task to ensure that the new styling is not wrongly perceived in the market as being detrimental to technical performance.

The improvements made to the vehicle in the present case have been offered to the bus market with no additional cost to the superseded vehicle. This offers two important outcomes, for the manufacturer and as new knowledge. Firstly, a strong market position as leader can be maintained. Secondly, the ability to improve the vehicle for no net increase in cost to the operator demonstrates the value of a design approach and should broaden the view of design's application in the public transport field. As demonstrated by the BCA, expenditure on new tooling was amortised by consolidating many components into one, standardising assembly processes, and reducing labour either in primary work or remedial quality controls. The importance of this economic view is to show firstly that design is not merely the application of styling to a product; the execution of that design into production parts allows the design team to seek value for the product. Secondly it demonstrates that although component may or may not have a desirable stylistic sensibility it must be manufactured, and the embodiment of some superior design content into that component can be had at no cost increase. At a higher level, the creation of a new vehicle identity with better passenger amenity for no cost increase demonstrates that the design of public transport vehicles is not an added extra to be contemplated as an option; but integral to the success of a vehicle in a manufacturing, operational, and contemporary culture context.

Despite the improvements being made with no cost increase, the final discovery of this work was evidence in interviews of a willingness to pay for aesthetic improvement. The notion that attractive vehicles usually attract political capital (or votes) is not new (for example, in Hensher 1999) and we must remain aware that best practice dictates mode selection based on technical performance. In this instance, an attractive bus may well level the playing field of vehicle perception in a world where rail modes are perceived as more attractive even if not functionally appropriate, and therefore conducive to extended political office.

The detailed design stage dealt with competitive advantage by creating the necessary geometry to execute concepts, and also exploit opportunities in component-level detail to achieve improvement. Whereas the concept stage dealt with broad issues such as styling and usability, the detailed design stage is the opportunity to apply more "typical" approaches to competitive advantage such as design for assembly or component/system usability. As this stage is necessarily taken one-part-at-a-time, the opportunity to imbue the product with value is great. Testing of detailed designs by business-case analysis placed the burden of proof on the design team to show how, and to what extent a component or assembly had met the project goals; with two important cost-based discoveries. First, a component with "high" levels of cosmetic and usability treatment can cost less to manufacture than a mechanically serviceable component of useability and cosmetic inferiority. Second, those components of high value both functionally and cosmetically may offer the business a somewhat intangible return – for example in "street presence" – and therefore justify a higher cost, particularly when at a strategic business level the decision has been made to improve appearance.

## 7. Conclusions

Taking the project at a holistic level, a design approach has created an opportunity to see a complex product not as a collection of different value-adding activities such as engineering and production; but as a singular piece of design. This thinking has led to the consolidation of new and existing innovations into a next-generation product. The design viewpoint also offers the opportunity to bring new thinking to product performance – in the case of buses and capital goods this was achieved by considering not just the purchaser of the bus, but the passenger as end user.

At an application level, this research illustrates some of the value of "design" in public transport – a word used in this case to describe the viewpoint of enquiry, catalyst for discussion, intellectual content related to form and function, and actual physical geometry. In these senses design can and should be applied by the myriad commercial ventures for whom competitive advantage is familiar ground but not in the designerly sense. Seeking new competitive advantages is one method to consolidate current leadership by discovering untapped strengths and putting them to work in new ways.

In this theoretical context, this research has made several contributions to the often ignored field of public transport vehicle design. The methodology of design studio research, coupled with more traditional investigations such as economic analysis shows that the value in a design process repays the cost investment. In particular, this research shows:

1. A pragmatic, functional vehicle design and an attractive, user centred vehicle design can co-exist.
2. Contemporary bus aesthetics need not be derivative of light rail in order to be attractive.
3. There is a discord in the bus industry between perceived reliability and contemporary aesthetics.
4. That design improvements extend beyond the visual, leveraging functional advances to achieve an overall cost saving.

This research has demonstrated through a case study of vehicle redesign that there is a complex array of issues to be overcome in the creation of new vehicles. The discoveries made strengthen the notion that vehicle improvements can be made beyond the scope of mechanical performance; and that in the view of many stakeholders in the transport system these are becoming more important as elements of our transport system, and in particular of the public transport user experience.

## References


Acha, V., A. Davies, et al. (2004). "Exploring the capital goods economy: Complex product systems in the UK." *Industrial and Corporate Change 13*(3): 505-529.

Archer, B. (1979). "Whatever became of design methodology?" *Design Studies 1*(1): 17-20.

Australian Government Department of Infrastructure Transport Regional Development and Local Government (2006). Vehicle standard (Australian Design Rule 58/00 – Requirements for Omnibuses Designed for Hire and Reward) 2006, Federal Register of Legislative Instruments. *58/00*.

Batchelor, R. (1994). *Henry Ford, mass production, modernism, and design*. Manchester: Manchester University Press.

Bunting, M. (2004). *Making public transport work*. Montreal: McGill-Queen's University Press.

Bus Rapid Transit Institute (BRTI) (2009). Quantifying the importance of image and perception to bus rapid transit, United States Department of Transportation, Federal Transit Administration, Office of Research, Demonstration and Innovation.

Davis, S. M. (1987). *Future perfect*. Reading, Ma.: Addison-Wesley Publishing.

Day, P. (2007). The heartbeat economy: Surviving in a global world. *Smartworks*. Sydney, Powerhouse Museum.

Eggen, Ø. (2003). Modular product development, Department of Product Design, Norwegian University of Science and Technology.

Government of Western Australia (2010). Supply and delivery of buses to the Public Transport Authority of Western Australia (Request for Tender). Public Transport Authority. Perth.

Griffin, T., D. Catling, et al. (2005). *Public transport - Mode options and technical solutions*. Oslo: HiTrans.

Hensher, D. (1999). "A bus-based transitway or light rail? Continuing the saga on choice versus blind commitment." *Road and Transport Research 8*(3): 3-21.

Heskett, J. (1980). *Industrial Design*. London: Thames and Hudson.

Hobday, M. (1998). "Product complexity, innovation and industrial organisation." *Research Policy 26*(6): 689-710.

Kano, N. (1984). "Attractive quality and must-be quality." *Journal of the Japanese Society of Quality Control April*: 39-48.

Napper, R. (2010). "Implementation challenges in mass customisation: route bus design." *International Journal of Mass Customisation 3*(3).

Napper, R., K. Burns, et al. (2009). Bus design guidelines: Complementing planning with vehicle design. *32nd Australasian Transport Research Forum*. Auckland.

Nelson, H. G. and E. Stolterman (2003). *The design way : intentional change in an unpredictable world : foundations and fundamentals of design competence*. Englewood Cliffs, N.J.: Educational Technology Publications.

Pine, B. J. (1993). *Mass customization: the new frontier in business competition*. Boston: Harvard Business School.

Scherer, M. (2010). "Is Light Rail More Attractive to Users Than Bus Transit? ." *Transportation Research Record: Journal of the Transportation Research Board 2144*(2010): 11-19.

Schwartz, M. L. (1980). "Motivations and Barriers to Riders' Acceptance of Bus Transit." *Transportation Journal 19*(4): 53-62.

Suomala, P., M. Sievanen, et al. (2002). Customisation of capital goods - Implicatiopns for after sales. *Moving Into Mass Customization*. C. Rautenstrauch, R. Seelmann-Eggebert and K. Turowski, Springer**:** 231-.

Wales, G. o. N. S. (2007). STA 2007/17 Supply of high capacity buses to the State Transit Authority for a super metro bus system trial in the Sydney metropolitan area [Tender Document]. State Transit Authority of New South Wales, STA.

Zimmerman, S. and H. Levinson (2004). "Vehicle selection for BRT: Issues and options." *Journal of Public Transportation 7*(1): 83-103.

## Acknowledgement

This research project was funded by Volgren Australia Pty Ltd. The authors thank the reviewers of this paper for constructive input. All errors and omissions remain the responsibility of the first author.