

Route bus transport – stakeholders, vehicles and new design directions

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Abstract

In providing a review of the Australian bus industry, this paper describes some of the key issues that are affecting route bus public transport; a complex array of stakeholders and a key tool – the route bus – which exhibits considerable variation in specification. Information gathered by empirical means and through literature suggests that the stakeholders are many, their roles complex and intertwined; yet the overall goal of providing successful transportation services to the public is fundamentally clear. By examining the roles of operators, governments, manufacturers and the end users this paper identifies the nature of some of the problems facing the route bus transport task, refining the possible contribution of design in such an environment.

The current state of the Bus Industry is the result of the relationships between the stakeholders as much as their input to the provision of transport. Specifically, the information indicates that Industrial Design is not an active discipline within the Bus Industry and is veiled by the actions and mechanics of those involved in bringing a bus into its service life.

Further to the stakeholder review, an analysis of route bus specifications provides an overview of the state-of-the-art of this principle industry tool whilst testing some common beliefs regarding functional specification. In light of the stakeholders and their roles, specification analysis enables the identification of trends and subsequent problems; providing specific areas for the development of research and possible solutions.

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1.0 Introduction

The FutureBus project is focussed on improving route buses for the provision of public transport. Industrial Design has several opportunities for input into this field, which can be brought together by studying the product specification of the tools – the route bus. There are complications however; buses are complex, both in a vehicular and an administrative sense, a complexity in many ways created by the business environment shaping and operating the bus. Bus specification and stakeholder priorities are intertwined, co-dependent subjects and as such are difficult to examine if removed from the context of one another.

Part Two of this paper provides a review of the stakeholders and their roles in bringing route bus transport into service, giving an overview of their roles and the affect this has on the overall transport goal. Route bus specification is then examined in Part Three to highlight the ways stakeholder relationships are manifested in a sample of the physical product, to test existing assumptions in the industry and to inform design directions for new route bus vehicles.

2.0 Stakeholders and Relationships

Despite an ultimate aim of transporting customers, there are evident several degrees of separation between stakeholders in the bus industry and this end. Beginning with the passenger, the product they purchase is dominated by the service or utility of transport, offered by the government through the operator. There is a tendency in the industry to see ‘the bus’ as the end product in the chain, which although accurate from several stakeholder perspectives undermines the notion of transport being *experienced* by passengers, not just provided and endured (Bunting 2004). It would be more accurate of the public transport system to describe the bus as a tool. A broad view of the bus industry is taken, indentifying a collection of areas for the improvement of bus transport through the discipline of Industrial Design.

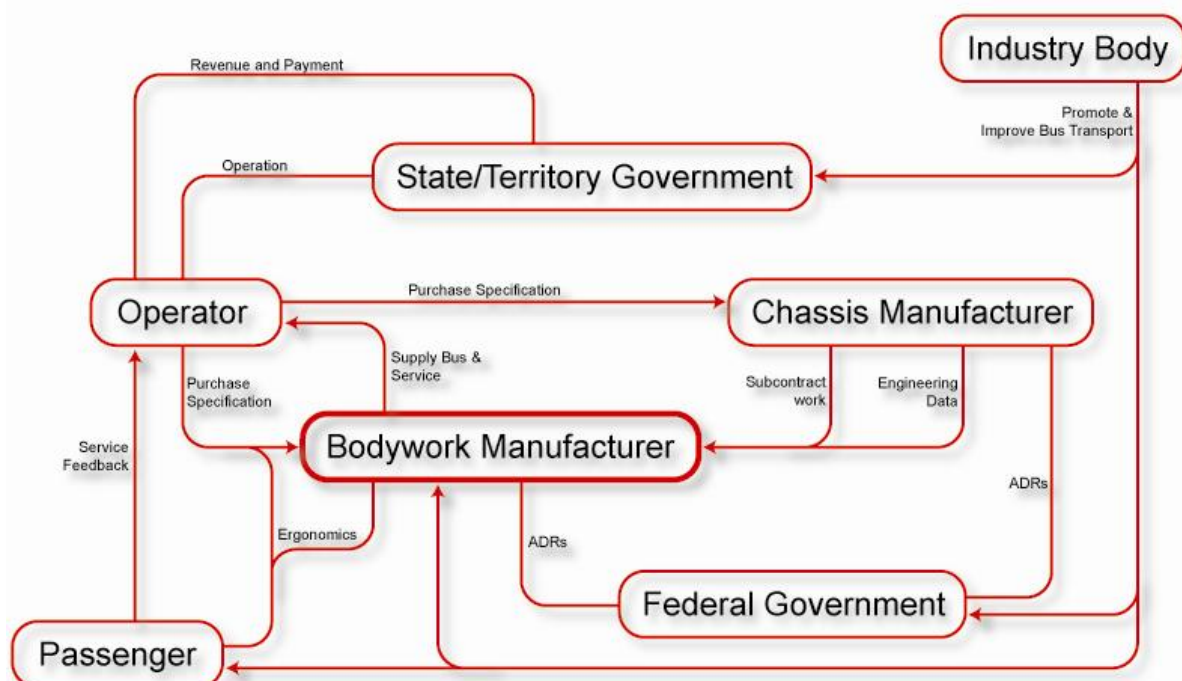


Figure 1 – The Stakeholders and Relationships. Developed from Millar and Moynihan (2007)

2.1 Operators

The most outwardly visible role of the operator is just that; operation of transport services. These services take place to fulfil a contract with the government for transport provision on specific routes. Services are also operated by charter, providing a school bus service for example.

The nature of route contracts varies between states and territories, especially in terms of revenue streams, vehicle ownership and organisational structure. For private operator to government relationships the contract is usually based on a concept of payment in cents/km, a fuel rebate and meeting agreed standards for quality of service, such as on-time performance and cleanliness. Operators are responsible for the maintenance and fuelling of the vehicles, which weighs upon some of their choices in new vehicles – namely chassis, where engine and transmission maintenance may require marque-specific infrastructure or skills. This is also a point of contention in the current climate with some Euro4 compliant chassis requiring Urea refilling infrastructure for the Selective Catalytic Reduction (SCR) process.

Discussion of the type of company that an operator might be is beyond the scope of this study, but it is important to note that typically they are smaller private companies, some with a fleet of one bus, and there is a tendency for them to be family owned. As such; experience, fleet particulars and procedures are often engrained. This can be reflected in a particular choice of chassis, bodybuilder or air-conditioner. The bus industry is in a state of growth but the number of operator companies is in decline; recent observations show a tendency for larger operators to take over their smaller counterparts (Smith 2007).

Importantly, operators are the 'face' of the transport service, despite operating routes determined by external agencies – for better or worse - and administering fares that only reach the operator indirectly. Bus drivers are employed by the operator and are an integral feature of the face, and their accessibility by the public in terms of human interaction is an important strength of bus operation (Tse et al. 2005); this equips buses to potentially offer better, or more holistic 'service' when considering additional inputs from the driver such as local information, safety and security.

Given the intimate relationship between the operator and the route(s) they administer, operators have a solid case for a high level of involvement in the design and manufacture of their essential tool; the route bus. Dependant on local administration, this may not be possible. Perth's Public Transit Authority (PTA) controls a bus fleet of one specification driven by various operators; but this is an exception. A more normal case is that operators tender for buses of their specification, or a basic specification is arrived at through dialogue with manufacturers – chassis and bodybuilder. A key issue in the bus procurement process is customer sacrifice, the gap between the operator's wants and what the bodybuilder can supply (Gilmore & Pine 2000). The bus bodybuilding industry is intensely customer-focused and through careful design and engineering the customer sacrifice gap has been significantly closed, however two core issues remain; that the bodybuilder is being left out of the design process by being presented with a set of *wants* rather than a set of *problems*, and that the preferences of each operator create considerable divergence in the product range, increasing time and costs in all stages of manufacture. The bodybuilder is therefore effectively shut out of the problem set experienced by the operator, despite them having good intentions in providing clear specification. These issues are discussed further in sections 2.4 and 3.

2.2 Government

The relationship with the bus industry is different for Federal government and State/Territory governments. The Federal Government, through the Department of Transport and Regional Services (DOTARS) publishes the Australian Design Rules (ADRs) which set out requirements for buses, generally concerned with occupant safety, accessibility and emissions. DOTARS is responsible for keeping the ADRs up to date and also for inspections to ensure they are being adhered to. This is achieved partly by an examination of the engineering drawings and production methods at the bodybuilder. There is a cause for some concern in this method, as DOTARS can cover a higher number of bus units by conducting inspections at larger manufacturers, often neglecting smaller

manufacturers and importers – a contentious issue because the larger companies typically have greater resources with which to implement ADRs, have more to lose if risking non-compliance and are more visible to DOTARS, a formula that may result in smaller companies being more likely candidates for non-compliance. In addition to this, the ADR compliance methodology is to test buses at point of manufacture, disregarding modification once the vehicle has entered service.

In addition to ADRs the contribution of DOTARS is through the development of strategies to deal with transport related issues; for example within DOTARS is the operationally independent Australian Transport Safety Bureau (ATSB) whose role is the development of transport safety through investigation, analysis and reporting on a variety of transport issues (Australian Transport Safety Bureau 2007).

State and Territory governments have more of a direct operational relationship with the bus industry, utilising several different approaches. Victoria's Department of Infrastructure (DoI) carries responsibility for route design, timetables, bus stops and fare structures for the provision of services, operating the bus routes through contracts with operators, as described above (Department of Infrastructure 2007). Servicing the contract will incrementally pay the operator for the purchase of the vehicle up to a ceiling price predetermined by the department. The DoI, like its counterparts in other states and territories also specifies minimum functional requirements for new vehicles - beyond, and somewhat more specific than the Federal ADRs – stipulating for example low-floor vehicles, the provision of air-conditioning and security measures such as CCTV.

Although fundamentally targeting the same goals of transport provision, there are noteworthy variations in the departmental structure of state and territory governments. The NSW Ministry of Transport (MoT) has contracts with several transport operators, the largest of which is the state-owned State Transit Authority (STA); the MoT administers transport and is progressively gaining more control over bus operations. The Australian Capital Territory Internal Omnibus Network (ACTION) was until recently a government authority, now a government owned operator of buses in Canberra wholly responsible for the operation of routes in the ACT. Between these two administrative margins is Western Australia's Public Transport Authority (PTA). Perth's bus operators are contracted to operate routes, but do so with vehicles supplied and specified by the PTA. This raises an interesting point for the issue of customer sacrifice; a collective of operators that despite having their own set of values and experiences are servicing their contracts with identical buses. This is clearly an area for further investigation.

Public transport is funded in part by its own ticket box revenue and by government subsidy – this can be observed internationally in public transport in varying proportions. The level of subsidy provided by government is an area of some political debate; suffice it to say that views on the level of subsidy that should be provided range from 100% (free for passengers) to 0% of running costs. There is also variation in the amount of subsidy within networks – the NSW state owned STA receiving more government funding from the MoT than private operators.

Variation in contract can become evident in the specification of buses. New South Wales specifications have historically been based on the number of seats in a vehicle, as this was a principle means of calculating contract payment. Despite changes in how contracts are paid, there is a consequence that NSW buses are frequently specified to have as high a seated capacity as possible. Victorian routes have been subject to different performance indicators and therefore display different seating characteristics. Industry debate continues as to whether *seated* or *overall* capacity is more important, with consideration also falling to route attributes such as the average passenger's journey length.

2.3 Chassis Manufacturer

Comprising of the floor frame, power plant, transmission, brakes, driver instrumentation and the associated systems such as engine management and braking control, the chassis is a major choice for the specification of the bus. There are several major marques with the majority being designed and manufactured in Europe and imported to Australia. The primary contract for the supply of a

vehicle is between the purchaser and the chassis manufacturer, who then sub-contracts the bodywork to a chosen manufacturer, supplying the chassis along with a suite of bodybuilding information for works to commence. Notably, this contract structure does not limit the communication between bodybuilder and purchaser, an issue to be explored in section 2.4.1. Typically each marque will offer a discrete range of chassis products, with variants to accommodate requirements such as route bus, articulated and bi-articulated buses, double deck et cetera, and within these choices offer a selection of power plant options to accommodate different power requirements and fuel choices, the majority of which are diesel or compressed natural gas (CNG) in the current market.

Chassis products are offered 'off the shelf' to a purchaser, a direct contrast to the body product which offers far more scope for customisation. The centralised nature of chassis manufacturer, with only a handful of marques responsible for producing most of the global market is also contrasted by the dispersed bodybuilding industry. These contrasting business strategies are somewhat reliant on one another; a customer can accommodate the limited variety in chassis by virtue of the variety available in bodywork, while at the same time a standardised chassis design will enable a certain level of standardisation in bodybuilding, especially in structural areas.

The operator's choice of chassis is governed by several key points. Although typically manufactured to a high standard in a competitive marketplace and therefore exhibiting considerable functional overlap, there are differences in engine and transmission design impacting on bus maintenance. There are no observable patterns; some operators prefer to use one chassis marque, others are happy to operate with many. One example of chassis differentiation is the method for achieving Euro4 emission targets, the playing field being divided between Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation, with one manufacturer offering either. There are the aforementioned infrastructure issues with SCR, and EGR engines possess their own set of maintenance considerations.

Chassis manufacturers - whilst working well in conjunction with bodybuilders - have nevertheless been a major driving force behind innovation in bus design. The introduction of low-floor vehicles was dependent on the supply of appropriate chassis designs. Similarly, current innovations in the introduction of new fuel sources such as hydrogen internal combustion, hydrogen fuel-cell and hybrid power plants are developing as chassis projects, the technology to support these innovations – such as roof-top hydrogen storage - being developed on a needs basis by the other manufacturers in the supply chain.

The European majority of chassis manufacturers and their strong role in innovation leads to stakeholders, especially operators, looking towards Europe to set the standards for many elements of vehicle design. Elements such as information systems, appearance, comfort and performance are often influenced by what is available in other countries, and many of the suppliers of such products are themselves European.

Whilst the chassis is a collection of several key elements that make the bus as we know it, there is an important point to be made regarding visibility. Passengers - ultimate end users - perceive the 'bus' visually almost entirely through the bodywork. Their ergonomic relationship is also largely with the bodywork and associated details such as seating and handrails. Conversely, the fundamental functional attribute of the bus is *motion*; provided by the power plant and transmission. What's more, as the majority of buses display the badge of the chassis marque, they are perceived as being that 'type' of bus. This issue of perception and visibility is explored in further depth in section 2.7.

2.4 Bodywork Manufacturer

As shown in figure 1, many of the constraints and pieces of information from various stakeholders come together in the role of bodywork manufacturer, or bodybuilder. This congregation of needs identifies bodywork as having great potential for input from the field of Industrial Design; a strength of which lies in the synthesis of disparate information (Lawson 2006).

2.4.1 Sales

The primary role of the sales department is communication. They process a large amount of information that needs to be translated from the customer further downstream to manufacturing. Initial customer communication is usually with a bus operator; depending on the size of the operator company this might be someone in a specific procurement role, or at the other extreme the business principal. Outline bus specification is created in response to a tender or expression of interest. This quotation document is submitted to the customer, covering some overall bus features such as size, seated capacity, chassis and price. Upon receiving a favourable response to the quote, further dialogue between sales and the customer will yield a specification document, a much more specific - but not exhaustive - breakdown of the physical elements.

This process gives cause for some concern. The quotation fulfils its role in securing business and establishing broad parameters in an admirably efficient manner, and it contains information of a simple enough nature to be transferred to the next stage, specification. However specification is something of a grey area, the methods involved in reaching a specification are considerably diverse. Some customers show certainty in their requirements, whilst others, usually those with smaller fleets and correspondingly fewer experiences in procurement exhibit more flexibility.

Specification as a process is largely conversational, with many points assumed to be 'standard' unless otherwise mentioned, a process often leading to a raft of alterations coming into the project after specification signoff. Crucially, throughout this process there is little dialogue regarding functional attributes as discussed in section 2.1. It would seem that the design process is written out of specification because of the authority of the customer, or irrelevance to them of a particular issue. That is to say either a functional issue with bus design has arisen and the operator has dealt with it through their experience – a potentially rich source of information whose depth and potential is by no means condemned – and subsequent specification or that such an issue has never arisen and therefore warrants no discussion. Moreover, each customer situation is different in this regard given its basis in personal experience. Communication with engineering before specification signoff is somewhat informal, which partly explains the restricted role of that area.

2.4.2 Engineering

The primary role of the engineering department is to implement the specification received from sales into a manufacturable bus. This is done while maintaining or improving production time, quality and adherence to ADRs. The requirements spelled out in the specification are broken down and dealt with in different portions of the bus. The amount of work required in engineering varies depending on the nature of the specification. Some component changes are simple to implement, whereas others create knock-on effects for other areas of the bus which appear completely separate to the consumer or operator. Modular elements are implemented as a method for dealing with specification diversity, but are only functional in foreseeable circumstances. There are regions of the bus body where a modular approach is inappropriate because of the sheer diversity of specification.

The bus is divided using a manufacturing methodology - strongly tied to the sequence of manufacture - illustrating the general approach to bodybuilding; that this is a manufacturing/engineering challenge rather than an ergonomics/usability one. This methodology gives cause for concern; whilst a professional overlap between engineering and design exists very comfortably, by having only one field represented the bodybuilding process can often neglect more qualitative issues such as comfort and convenience (Archer 1979; Booz Allen & Hamilton 2000). In this situation, engineering is being asked to fill out the role of design, a role well within its capabilities in this instance because the design process has been co-opted by the customer as discussed above in 2.4.1. Certainly, an engineering approach is justified, but there also exists a clear case for the input of industrial design into this team. The engineering department currently projects a character of being the department of 'making it work' caused in no small part by an innate ability to do just that. One opportunity within engineering is to incorporate more interaction with sales and open up more design-like approaches to enable the bodybuilder to question specification, drive design direction and take more control of the at times ad-hock approach to manufacturability, usability or functional elements.

The specification is interpreted into engineering information, a Bill of Materials comprised of a drawing pack and a complete breakdown and cost of the bus specification which returns upstream to sales and the customer. The drawing information and associated process manuals are passed on to manufacturing. The flow of this information and the media used is identified as an area for improvement; in quotation and subsequent specification the hypothetical 'bus' is described only through text, a difficult medium for customers to understand and visualise the ramifications of their choices. At this stage the customer would need an ability to read engineering drawings and interpret complex terminology to build an accurate 'picture' of their bus. In addition to the quality of the communication to different parties, the current system requires double-handling of information in the journey from customer to production.

The proportion of work required by engineering is not directly linked to the profitability of any given project; an order size of one bus might require redesign of the entire bus frame for example. This is bound to happen in such a customer-focussed, customisation environment. It is important to note that in this customisation procedure there remains no 'standard' bus, despite there being some functional areas which have been narrowed down to only two options. The nature of the production environment is such that it displays neither the characteristics of fully-customised products nor those that are simply mass produced. Kotha (1996) discusses the co-existence of mass-production and mass-customisation under the umbrella of one company, and the flow of innovation and market trends from one arm of the business to another; bus bodybuilding as it currently operates introduces new innovations in bus design osmotically from customer specification and their resultant engineering solutions.

2.4.3 Production and Logistics

From the quotation stage, production scheduling is an important issue, sometimes determining whether or not a quote is successful. Whilst specification is being worked on by engineering, long lead time items such as glass, doors and air-conditioning units are ordered for the bus(es) awaiting manufacture. The production schedule is filled many months in advance; an Australian built bus is typically a long lead time acquisition.

A major cause of the long lead time is the level of customisation demonstrated in production. The process of bus manufacture is divided into physically different areas sequenced from structure-to-skin. Several processes, such as roof fabrication, are conducted off line and then come together with the chassis and sidewalls before panelling. Refinements of this nature have reduced the product cycle time to around 40 days whilst accommodating a high level of customisation. This production methodology is largely dependant on skilled tradespeople and their experience, developing the skill to 'read between the lines' of the specification – knowing that one specification leads on to another sub-specification whether it is itemised or not.

The present system accommodates different products flowing though the production stream, even if they are adjacent to one another. Whilst the flexibility of the production line and the skill of the tradespeople yield almost limitless customisation opportunities, this is at the sacrifice of further reductions in cycle time. Streamlining the product range as discussed above, and therefore limiting the bus variations possible would have positive outcomes for production; reduction in cycle time and improvement in quality control by establishing quality baselines that are more universal.

2.5 Service Administration

The administration of a service ensures passengers and potential passengers have access to information and ticketing so that they may conduct a journey by bus, or other mode of public transport. The structure of administration varies but generalisations of description in the literature and press tend towards byzantine (McMullen 2007; Millar & Moynihan 2007); Melbourne for example has two central bodies, the Dol's Transport Ticketing Authority (TTA) and Metlink, representing all the operators of public transport in metropolitan Melbourne. The role of the TTA is to oversee transit

ticketing through a contract with the private sector, which at present also includes the introduction of a new smartcard ticketing scheme (Transport Ticketing Authority 2006). Metlink is the 'face' of public transport (Metlink 2007), providing information for passengers to navigate the system, and also administering the ticketing and revenue. This is not a typical example however; Sydney Buses operate routes, administering their own information, with ticketing controlled to some extent by the STA. ACTION buses in the ACT also manage information and ticketing internally.

The administration of the public transport system is an important factor in usability. In attracting new passengers to bus transport the vehicle must of course be clean and effective at performing its task, but of equal importance, the system must be cognitively accessible. Vehicle design by the bodybuilder and chassis manufacturer is separated from the system by the bus operator, and attempted to be re-connected by communication added to the vehicle such as stickers, maps and advertising. This is potentially a growth area, already visible in schemes such as Melbourne's SmartBus, using existing vehicle electronics in concert with informative bus stops showing live information. Considerations of *system* usability are identified as a method for the holistic improvement of bus transport.

In addition to cognitive accessibility, the transport system should be administratively accessible. There is a public perception of the public transport sector possessing an impenetrable bureaucracy, concerns and complaints from passengers are not reported because the passenger simply does not know who is accountable (Millar & Moynihan 2007).

2.6 *Industry Bodies*

Each state has an industry body, member organisations all of which are themselves members of the Bus Industry Confederation (BIC). Their goals, despite being at different levels, are similar – to increase public transport use. Cited reasons for this include reduction of the social impacts of congestion and car-dependence, but clearly these goals are parallel with the overall development and long term prosperity of the bus industry. To achieve these goals the industry bodies bring together the efforts and expertise of different parties such as operators, manufacturers, legislators, lobbyists and researchers; with the resultant activities being diverse, examples including television advertising or conferences. Industry bodies also assist their members in meeting legislative requirements such as ADRs or Disability Discrimination Act (DDA).

2.7 *Passengers*

The actions of various stakeholders ultimately take the passenger into consideration. The passenger is the stakeholder at the top of the industry, yet direct contact is only made through the service administrator and the operator. Other stakeholders, while sensitive to passenger needs are somewhat removed from the implementation of their actions. For example, many ADRs are ratified to protect the bus occupants from unsafe vehicles, but these rules are acted upon by the chassis manufacturer and bodybuilder. They are communicated to the passenger by means of the vehicle itself. These communication streams are strongly one-way, how does a passenger relate to such an invisible force? The passenger is removed from the remainder of the bus industry, unaware of the organisations behind it, yet crucially affected by their collective actions.

The information flow is further weakened as a result of segmentation by the stakeholders. A passenger might communicate a usability issue with a particular new vehicle to the bus operator. The operator then reflects this feedback in their new specification to the bodybuilder, but has the idea been lost in translation? An opportunity exists for gathering and acting upon information from each stakeholder, in order to offer increased benefit to the passenger.

If the feedback mechanism for the passenger is invisible, then so too is the product or service they are paying for. The issue of perception is very important to what the passenger receives in return for their fare – the utility of transport is the foundation for this, but consideration must also lie in the

passengers' reason to engage in that particular mode of transport over the others which may be available (Curtis & James 1998; Griffin et al. 2005). Importantly, buses have the potential to be iconic, a provider of a rich experience beyond that of movement from A to B. These factors are primarily expressed in the psyche of the passenger, but they are no less important to the successful implementation of bus transport than any other requirement.

Any further generalisations about passengers are to be avoided; when considered individually we are reminded that this is *public* transport, accordingly, passenger diversity is evident in physical, social and journey senses, factors overlooked in some parts of the industry. Each stakeholder is a link in the chain to the passenger, but some only think as far ahead as the next few links, rather than how their actions might affect change at the end.

2.8 *Summary of Part Two*

It is clear that in some regards the bus industry is a victim of its own complexity. The stakeholders have independent sets of priorities, resulting in actions which are at times incompatible. Some positions, such as that of transport operator, are subject to further difficulties in being a bridge between transport policies from the Government and implementation to the passengers for whom they are representative. The net result for these situations is one of compromise, as evident in the customer sacrifice necessary in the specification and manufacture of a route bus vehicle.

Administratively, the areas which bridge between policy and enactment are fraught with difficulties. In order to enforce ADRs a more widespread approach is clearly necessary, but limited resources make this difficult. Legislation and contract requirements for operators are also impacting on vehicle specification, at times positively, and at others creating trends in new vehicles which may be at odds with the fundamental goal of providing the best transport service possible. The goal itself is also area for debate as businesses must maintain profitable operations as well as fulfil their obligations under contracts or law.

Passengers fit into the industry in a way that suggests a lack of priority. The needs of this group are co-opted by other stakeholders; their safety in the vehicle ADRs, their need for certain levels of service by contracts with government, their ergonomic requirements spoken for largely by the operators who are specifying the buses and those manufacturing them. It is a matter for further research as to whether this current system is adequate. An understanding of the more psychological requirements of the passenger is also required as a part of implementing route bus transport.

3.0 *Quantitative Specification Analysis*

Given the discussion of the stakeholders and their roles in the provision of route bus public transport, an examination of the bus vehicle will facilitate an understanding of some of the effects of this business environment. Within the bodybuilding industry there is a common belief based on experience and anecdotal evidence that bus specification is unnecessarily diverse, given that the role of a bus in providing public transport is considerably more finite. Observations from inside the industry indicate that there are correlations between some specifications. The purposes of this analysis are to offer a test to the hypothesis that specification is too diverse. Also, to seek out any manifestations of the stakeholder relationships examined above and to find functional areas of the bus vehicle that are in need of standardisation will suggest avenues of enquiry for the studio based research.

3.1 *Scope*

Having above discussed the role of Industrial Design in the field of public transport, and furthermore the discipline's possible contribution to bus bodywork manufacture, the scope of this analysis is identified as specification of route buses manufactured by the facilities of an Australian company, for a predominantly Australian market. This discrete study is part of a greater investigation into the history and state-of-the-art of route bus vehicles.

3.2 *Study Sample*

The data range is 24 consecutive months from October 2005 to October 2007. There are two overall points for interpretation in the study sample range. The first is Bus specifications (n=81), representing the decisions made for an order of vehicles, for which the average is 6.11. The second is interpretation by vehicle, representing what is manufactured (n=495) and put into service.

The sample is taken from the production schedule of the Australian bodybuilder with the largest market share (Australasian Bus and Coach 2007). The manufacturing capability of the company is broad, offering a high level of customisation in bus and coach vehicles accommodating many variables. An open approach to product specification – although part of what this study aims to examine – results in the sample being representative of customer needs and market forces. Manufacturing is carried out at five facilities, two of which are in the United Arab Emirates and Malaysia. Between the facilities production runs range from large orders to single buses, the range of order sizes being 150.

3.3 *Information Sources*

Two internal documents have been identified to describe the route buses in question. One reflects the final vehicle specification that is fed into the engineering department. Two is the resultant Bill of Materials (BOM) for a particular series of bus. The production series can contain one or more buses, the quantity itself being a point in the data collected. The relationship between the two documents is important; sales specification is generated by the customer and the sales department, reflecting more functional and visible elements of the bus, the BOM is a completely comprehensive breakdown of the components and processes that are used to realise the sales specification. The documents are identified as suitable for this study because:

1. The Sales Specification contains 'high level' specifications and is thus a concise source of critical information.
2. The Bill of Materials is completely comprehensive, showing all components and processes that contribute to the bodywork manufacture, filling any gaps that might be left in the sales specification.

3. The BOM is the final piece of communication to production, eliminating ambiguity and any specifications that may have been delayed and therefore not present in the sales specification document.
4. Both Sales Specification and BOM are subject to quality control procedures and therefore contain accurate data and are archived in an accessible manner.
5. In terms of manufacture, the two documents are first and second order in the process, with the physical bus vehicle being third. Therefore they are not susceptible to inaccuracies or misinterpretations of a report created by sighting and reporting on a bus that already exists.

Comparison points for the study have been selected to represent important functional aspects of the route bus. It is reiterated at this point that the route buses of different specification perform the same fundamental task; transport provision, a broad research theme of which this study is one part. The data points represented in the analysis have been selected for the following reasons:

6. They are pivotal decisions from an assembly point of view; accommodating the choices has an impact on several more downstream items on the BOM.
7. They have been identified as having a questionable functional difference to the provision of transport; the choice of 'x' does not represent a worthwhile gain in function over 'y' and thus identifying a trend or correlation will prove or disprove these minor hypotheses.
8. The data point will enable interpretation of other points by building a 'picture' of a particular bus. This supporting data - whilst not especially significant on its own – may be required to provide the basis for functional trends in the analysis stage.

3.3 Results

The information was systematically processed into a spreadsheet, with the following attributes being used for the comparison of specifications and bus vehicles:

State (Geographical)	Doors (q)
Marque (s)	Hoppers (y/n)
Chassis (s)	Seat Cantilever (s)
Artic (y/n)	Cantilever (y/n)
A/C Unit (s)	Forward Facing Pairs (q)
Length (mm)	Perimeter (q)
Wheelbase (mm)	Rear Facing Pairs (q)
Order Qty (q)	Back Row (q)
Seat Stanchion (q)	3/4 Forward Facing (q)
Handrail Colour (s)	3/4 Rearward Facing (q)
Floor Material (s)	Total Seated Capacity (q)
Window Tint (s)	

The type of information recorded was either a specification choice (s) represented by an index number, a figure (q), (mm) representing quantity or measure, or a numerical record of yes or no (y/n). This type of data logging allowed averages to be calculated for quantity measures and for yes/no measures, as seen in Figure 2, with percentages referring to 'yes' specifications. Comparison between the averages for specifications and actual bus units is intended to give an indication of the difference between decision making processes in bus procurement – whether a particular specification is favoured by more operators, as shown in specification averages, or by more bus units, and arguably passengers and end users, as reflected in bus unit averages.

Average	Spec	Seating															
		Peeper Screens (y/n)	Desto Locations (s)	Buzzer Cord (y/n)	Bell Pushers (q)	Seat Stanchion (q)	Window Tint (s)	Doors (q)	Hoppers (y/n)	Cantilever (y/n)	Forward Facing Pairs (q)	Perimeter (q)	Rear Facing Pairs (q)	Back Row (q)	3/4 Forward Facing	3/4 Rearward Facing	Total Seated Capacity
		Unit	9%	1.6	25%	8.8	6.9	1.3	1.8	52%	19%	15.8	5.5	0.01	5	1.9	0.3
		31%	2.4	11%	13.6	7.0	1.1	1.7	21%	67%	16.0	6.1	0.01	5	1.9	0.1	45.1

Figure 2: Specification and Unit Averages

Several large differences are immediately apparent. Firstly, Peepers windscreens are present on only 9% of specifications but 31% of bus units manufactured. This, along with Cantilever seat supports, hopper windows and buzzer cord is explained by several large orders evident in the production schedule. Whilst this difference is easily explained, it represents an important difference of perception, given that the same sales spec and bill of materials is created by Engineering for a run of any number of units, the perceived frequency of occurrence for a particular detail is considerably different for Engineering than for Production, or the passenger on the street. Destination indicators are another important functional area where a disparity emerges between the averages. The average specification is 1.6, demonstrating an almost even split between single front display and a side display. In bus units the average is 2.4, the average being pulled up by the large order of 3 position systems. This carries consequence because similar to other examples where a significant difference is found it suggests an inconsistency in the underlying knowledge and subsequent requirement for the specification – an avenue for additional research. The significance of these disparities between averages are considered to be worthy of design attention because it represents an anomaly in the knowledge base used to specify the vehicles; be it from a legislative, experiential, financial or historical perspective.

The difference in averages is also an indication that there is room for standardisation with regard to that particular functional element. Where averages are close to one another, the statistics are indicating a common thread in the decision making of the various operators, as seen in window tint for example. From a selection of none (0) single (1) or double (2) tint the averages for specification and bus units are 1.3 and 1.1 respectively, showing that single tint is the most popular choice given that there were no zero values recorded.

Analysis was carried out to determine whether any correlations could be drawn between attributes. Historically, the Australian industry has viewed a second door on a rigid vehicle as a sacrifice to seated capacity, traded off with the aid to access and egress. Comparison between the seated capacity of a bus and its length to initially test this hypothesis returned a correlation 'r' value of 0.86, indicating some correlation between the two. Seated capacity and number of doors returned a correlation coefficient of 0.06, essentially no correlation – positive or negative – between the data, where a negative correlation would be expected if industry mood towards high passenger capacity was to be followed (State Transit Authority of New South Wales 2007). Whilst not indicating a causal relationship, these values refute to some extent the common hypothesis that door quantity is a large determinant of seated capacity, the latter an important performance indicator for the operation of transport. The lack of correlation shows that the situation is not as simple as we may perceive; disaggregate analysis of 11.9M and 12.5M length buses as a sample group also suggest the hypothesis is incorrect, too simplistic to be an accurate guide for the specification of bus vehicles, see Figure 3. In the group of 11.9M buses, the sample returned all 11.9M one door buses having a seated capacity of 45, where for 2 door buses of the same length the seated capacity ranged from 39 to 46 – one seat more than the single door of the same length. According to the hypothesis, a 12.5M bus with one door should have the highest seated capacity, yet the range of 45 to 50 seats for this category overlaps by a value of one with 11.9M 2 door – theoretically the lowest. Finally, the difference between 12.5M one door and 12.5M two door maximums in the sample is only one seat.

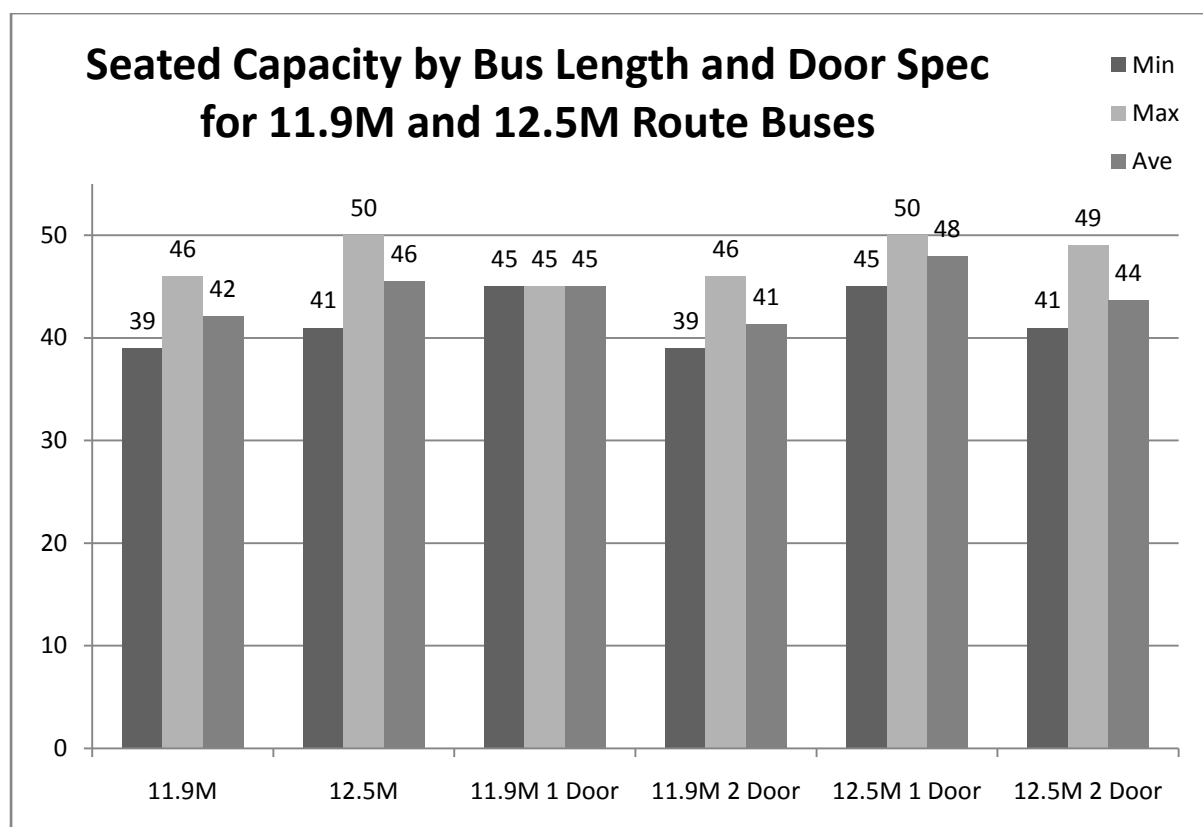


Figure 3: Seated Capacity of Buses – disaggregate scores for 11.9M and 12.5M buses in the sample.

The difference in the averages is 4 seats, which may explain how the hypothesis was formulated in the collective minds of the industry stakeholders, but clearly the situation is too complex to use this common 'rule of thumb'.

Specification trends for the data recorded by numbered index have been analysed by studying the frequency distributions of functional elements, particularly when a specification decision is made from an array of possible choices. Several are conspicuous simply by virtue of the number of options represented in the sample, such as Air Conditioning Module (A/C). 10 different modules were represented in the sample, a significant finding given that the interface between A/C and roof carries with it considerable ramifications for the framing of the bus body. Taken by specification, there are three A/C modules making up 60% of the field, with a range of 25% to 2%. The distribution by bus vehicle is far more skewed, with one module specified in only 2% of cases found on 52% of all buses in the sample. A similar case is found in the specification of floor material – 15 possible choices dominated by four favoured materials. Broad, flat distributions such as A/C and floor material can be interpreted as areas where standardisation could be successfully implemented; several distributions show heavy weighting towards one choice; single-pane windscreens and yellow powdercoat on handrails both being examples where clear trends are exhibited.

Mere demand for a particular specification does not however make it the best choice from all perspectives. As discussed above in Part 2, the stakeholders have varying positions on what constitutes an ideal bus, or bus service, and this is reflected in the specifications. One example is the specification of a demisting solution for the windscreen – a distribution with only three possible choices; in-dash, overhead ducted, and both. In-dash is the most common choice in both specification and vehicle units but it is unknown whether this is due to it being the simplest and cheapest option, or because of superior performance. Decisions of this nature are not made without reasoning, analysis of the specification rationale would in this situation, as in others, aid the design of one functionally superior solution to meet the varied needs of the stakeholders.

3.4 Discussion

Bus vehicles are highly modular; standardisation of functional areas and component choices is well underway in some parts, and left wanting in others. Importantly, some of the functional areas analysed above are suited to different types of modularity. Ulrich (1991) quoted in Pine (1993) identifies 5 key types of modularity, with Pine (*ibid*) adding Mix Modularity:

Component Sharing Modularity	Sectional Modularity
Component Swapping Modularity	Bus Modularity
Cut to Fit Modularity	Mix Modularity

These types of modularity can be applied when determining approaches to issues of standardisation. For example, windows of either tint choice are manufactured off site; the fitting process for windows does not vary significantly as a result of this specification – it is component swapping modularity. Coupled with the fact that the windows are not manufactured internally, the resulting specification can be managed successfully without the need for standardisation. A similar situation is observed with floor materials – this time with considerably more diversity in the sample. In these circumstances of component swapping modularity some reduction in diversity may be desirable from an administrative perspective, especially considering that the diversity is in part due to cosmetic choices of a very fine difference.

Air conditioning modules are manufactured off-site, but their incorporation into the bodywork is a matter of some difficulty as the A/C modules require mounting in a fashion unique to the model. Here, as in other functional areas of the bus we can adopt different approaches. Modification of the A/C units to fit a common roof is an example of bus modularity, the creation of a common interface best demonstrated through Universal Serial Bus (USB) connections between computers and peripheral components. Whilst this may offer an effective end result, some difficulties would be expected in the cooperation of several A/C manufacturers and their product ranges. A second option may be to modify the roof to accept various A/C modules as with component swapping modularity; whilst administratively more simple than Bus Modularity, this would be a significant technical undertaking and indeed the end result may not be possible.

The passenger saloon is one area that is difficult to define in a statistical fashion. The industry has several key indicators of this area which are important to functional requirements; seated capacity, door specification and overall vehicle length being three of these. Further analysis of this area indicated that broad rules such as ‘long vehicles with few doors have the most seats’ are at best overly simplistic and at worst wrong, considering the variety of designs found in the sample. This result indicates that further work in this area would be profitable, in order to explore the options and make recommendations based on various functional priorities.

4.0 Directions

Given the stakeholders, their relationships and the associated specification of bus vehicles, a general lack of design leadership in the industry has been observed. It is clear that each of the stakeholders hold their own set of skills and knowledge and that any new or refined process for the creation of route bus transport should aim to tap into this information. The isolation of certain stakeholders from one another leads to disparities in approach, philosophy and more finite examples of work such as bus specification – caused by differing solutions to constraints such as legislation, experience or finance.

An initial area of development for design is in the synthesis of this rich, but disparate suite of information. There is an opportunity for vehicle design – by virtue of the position of the bodybuilder in relation to other stakeholders – to assume a leadership role in improving route bus transport. A clear strength of this position is in the manufacture of the bus as a key tool, but this is reinforced by the central position bodybuilding plays in the industry landscape. To be most beneficial this work should aim to be collaborative and consultative, using each of the various areas of expertise to its best affect. It should be made clear at this point that vehicle design is not intended as a substitute for the

vast experience of the stakeholders in their respective positions, but rather as a conduit to achieve better ends by successfully utilising available skills and knowledge.

This approach is one method of closing the customer sacrifice gap, whilst also dealing effectively with specification diversity. In this regard, the approach is concerned as much with product as it is with process. The communication of information throughout the specification process is in need of streamlining, and the addition of feedback into the system could provide a more timely indication of results.

The bus chassis is offered 'as is' within a market of several choices. The standardised nature of the chassis leads to a requirement for flexibility in bus bodywork, in order to achieve the outcomes desired by the market. It remains to be determined what level of standardisation or customisation would be appropriate in this situation. The problem is best approached from both sides – managing with increased knowledge the amount of customisation 'needed' by the industry and thus reducing desire for customised products to a more absolute need, whilst also making efforts in product design to accommodate those customised elements which are deemed absolutely necessary.

Finally, it should be recognised that the bus industry does not operate in a vacuum; that the problems encountered in these enquiries are not unique to this industry. An avenue for further work is to look for solutions in analogous situations and test their application to the design of route bus vehicles.

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