Changing direction – rethinking urban bus design to attract the 21st century passenger

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Abstract

Society is demanding more accessible city buses, which provide a safe and comfortable environment for passengers. Typical current designs of urban bus have a mechanical layout arrived at over fifty years ago, when operating requirements were very different. This paper describes the LoBUS low floor bus concept which is designed for modern conditions. The major pre-requisite is that responsibility for fare collection is entirely removed from the driver, but this is how becoming commonplace in many cities.

The new design consists of a power module, attached to a passenger module. The power module contains a front wheel drive power train, and the driver's accommodation. This enables the passenger module to have a very low floor, with small trailing wheels, and a simple structure. There is enormous flexibility in door and interior layout. Whilst the most common variant is likely to be a 12 metre long single deck bus, double deck and articulated versions can be built.

The concept is feasible with available components, but manufacturers would face a series of challenges in order to create a practical vehicle with competitive life cycle costs.
Keywords: bus, citybus, LoBUS, low floor, public transport, urban transport.

1 Developments in urban travel

Efficient and attractive public transport is now recognised as essential to the economic and environmental health of our cities. In developed and developing cities across the world, new transit projects are used to regenerate blighted areas, spur growth in new expansions or improve the quality of life for citizens by curbing the otherwise relentless increase in car usage.

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Almost without exception, these new projects are based on rail – be that light rail or heavy rail. Rail is perceived by politicians and planners as having great impact and offering the chance to improve the environment through striking vehicle design and system architecture [1].

Bus transit is being left behind, although in terms of original and operating costs it is far cheaper than rail. Even in cities with extensive rail systems, buses will generally carry the majority of passengers, but they are not seen as so glamorous as rail when it comes to new projects. This paper contends that a major reason is that bus design has not seen the advancement found in rail, despite big changes in society's requirements and behaviour. The bus manufacturing and operating industries are conservative, yet a fundamental change in approach is needed if the bus is to be regarded by society as a progressive means of urban public transport.

2 What is wrong with bus design today?

Today's urban bus designs are based on running unit and interior layouts that were established in the 1930s, notably in the United States. The Yellow Coach type 720 double deck buses for New York and Chicago used a transverse rear engine to allow low floor lines and adequate headroom on each deck. They had an entrance ahead of the front axle, which would enable the driver to collect fares on later single and double deck designs and eliminate the need for a conductor [2].

Strip away modern materials and a contemporary appearance from today's buses and the resemblance to these buses built over sixty years ago is striking. Yet this basic design has many drawbacks. In busy traffic, the job of driving the bus and supervising fare collection is increasingly difficult. Having the engine so far from the driver can also lead to insensitive driving.

More important perhaps, buses are unattractive to passengers. There has been a great effort to get floor levels as low as possible, to speed up boarding and improve accessibility. But pushing floor levels down as far as possible actually leads to sub-optimal arrangements for people with impaired mobility. Often the first seat at floor level is more than three metres from the entrance. Towards the back of the bus, the floor level rises in awkward steps because major components are housed underneath, leading to poor seating arrangements. The overall effect is a more cluttered, confined space than found in high floor buses built forty years ago [3].

It is true that some variations on the basic design have been developed, such as buses with very low floors and side mounted engines. But these are still complex and continue to suffer from many of the same drawbacks for passengers.

The major reason why the current layout has been maintained (despite its disadvantages) is to allow the driver to deal with fare collection. Until recently bus operators were very wary of taking this duty away and opting for off-board fare collection. However, technology has advanced to the point where it is now accepted as the way forward, so long as adequate revenue protection measures

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can be put in place [4]. That means passengers do not need to pass by the driver as they enter the bus. The driver and passengers can be separated, and their respective environments can be optimised for how they use the vehicle.

3 The essence of the LoBUS concept

The LoBUS concept takes advantage of this opportunity, as illustrated in Figure 1 [5]. The essential layout of the concept consists of a 'power module' and a 'passenger module'. The power module contains the main running units and front wheel drive. It also houses a separate driver's compartment. The driver enters the LoBUS through a door on the front offside. The ergonomics of the cab are not compromised by the need for the driver to attend to fare collection, so all the controls are laid out for optimum comfort and efficiency [6]. On the nearside of the driver is the engine cover, and all round is deep glazing that - combined with a relatively high driving position - gives an excellent view of the road. There is no wide passenger door ahead of the front axle, so the windscreen can be raked back to deflect any stray light from the passenger module or elsewhere. This also means that the whole of the passenger space can be brightly lit without distracting the driver.

Figure 1: The LoBUS concept.

The heating and air conditioning can be set to suit the driver's own preferences, and there are no draughts from passenger doors frequently opening and closing. The driver can monitor the door areas via a video link and can also observe general activity throughout the passenger area on video screens. Two way audio communication allows the driver to make announcements and answer questions from passengers. There is also a permanent radio link with the operations centre. Recruiting good bus drivers is difficult – offering this kind of work environment should help to attract highly competent staff.

Behind the power module is the passenger module. In essence, this is a simple box, with as little component complexity as possible. There is no drive to

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the rear wheels, which are of small diameter for minimum intrusion into the passenger space. The concept envisages two rear wheel sets sufficiently separated to allow back-to-back seats to be placed above them. Back-to-back seats can also be used to provide space to enclose air and fuel tanks.

The floor height is a constant 300mm to just behind the rearmost axle, where it rises at five degrees to accommodate the departure angle. Ergonomics work in the 1970s demonstrated the benefits of low, step free floors. This research reported that 10% of all passenger accidents occur in the gangways, and steps and steep slopes are major contributing factors [7]. Having the passenger emergency doorway at a level only 300mm above the ground is another safety feature. Any extending wheelchair ramp can be very simple in design and operation - stowed under the entrance area, and deployed to create a gentle ramp from either pavement or ground level.

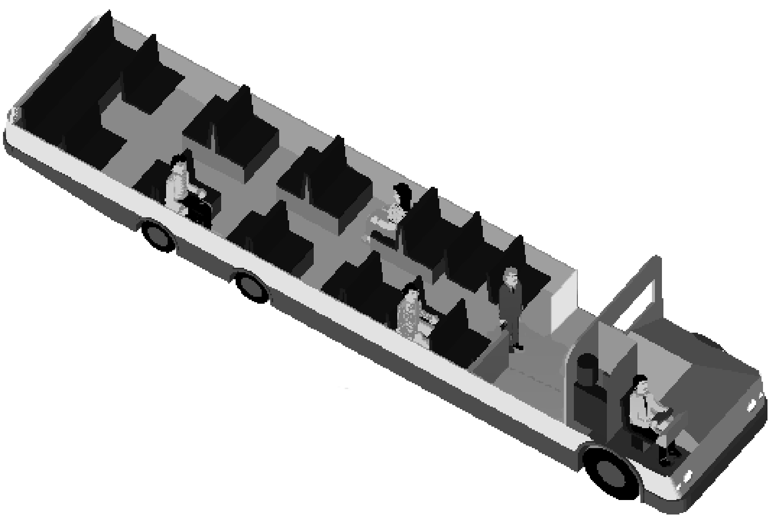

Figure 2: Possible seating layout.

There is enormous freedom in seating and standing space layout and the location of doorways. The constant floor height makes passenger circulation safe and efficient. It also means that designers do not have to contend with the interior steps, broken window lines and large amounts of interior wasted space that are a feature of too many of today's buses. Figure 2 shows a fairly conventional layout, with ample space for wheelchairs and buggies near the entrance.

3.1 Other variants

The LoBUS can be built in various lengths, with rigid buses 15.5 metres long being practical. Shorter buses could be built on the same principles, although the choice of drive train would determine how narrow particular versions could be.

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The very low floor line allows a four metre high double deck variant to be built with generous headrooms in both decks [8]. The relatively high driving position means that the upper deck cannot extend right to the front of the vehicle. This limits the top deck seating capacity, although the design actually achieves a good balance of seats between the two decks and avoids the problems with lower deck seating layouts found on some contemporary double deckers.

An articulated single deck variant is also possible, and was considered in the American Super Bus study of 1974 [9]. This would avoid the problems associated with having the power unit right at the back of the trailer, although transmitting the power to propel a 22 tonne vehicle through two single tyres at the front would present an engineering challenge.

3.2 Technical design

The practicality of front wheel drive for full size urban buses has been established for some time. The Super Bus project showed that (compared with rear wheel drive) front wheel drive would provide superior handling in snow, ice and other low traction conditions; more positive effort when pulling away from the kerb; and greater stability due to the forward weight distribution.

The LoBUS concept could be realised with a conventional components [10]. For example an 8.3 litre diesel engine, mounted with the flywheel at the front of bus, could drive through a transfer box to an automatic gearbox and thence by further transfer boxes and shafts to the front wheels. It would work, but it would be very inefficient and probably quite noisy. More promising alternatives are being investigated which can provide an efficient and quiet drive line within the two metre length to which the power module has been notionally restricted. These include diesel-electric and diesel-hydraulic drives.

On the other hand, there is much to be said for concentrating all the major units - together with the final drive - in one area. This has been the basis for most car designs for almost forty years, and has been hugely successful. Lengthy drive shafts are eliminated; the driver is more aware of any developing running unit problems; and having units concentrated together permits efficient noise encapsulation.

There are, of course, aspects of the design which present potential draw-backs compared with conventional designs. It would be more mechanically complex; the limited front wheel steering angles might restrict the turning circle; and heavier tyre wear could be expected. The LoBUS can accommodate some four seats fewer than current models within the same overall length, owing to the forward engine position. However this is a reasonable trade off, given the much improved passenger facilities. It is also the case that there is a trade off in the design between the best environmental solution and the realisation of the best passenger environment. Zero-emission drive lines usually require bulky batteries and other equipment that would compromise floor levels and seat layouts. The philosophy of the LoBUS is that by creating a more attractive form of transport, enough car drivers will be persuaded to switch to public transport to create a net emissions benefit.

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3.3 Industrial design

Some argue that a factor in declining bus use in many cities has been the poor quality of design found on modern vehicles – not helped by the complexity inherent in today's low floor models [11]. The simple layout of the LoBUS concept gives designers great freedom create a vehicle that is highly attractive to passengers and also has great street impact. This opportunity was exploited in two design course projects at Coventry School of Art & Design (part of Coventry University) in 2003. The school is one of the foremost teaching centres for automotive design in the United Kingdom.

Figure 3: Front wheel drive city bus. (Courtesy of Stephen Cooper/Coventry University.)

The first project considered a 12 metre long single deck bus that could go into immediate production (see Figure 3). The designer took advantage of the flexibility of body layout by opting for a wide central doorway, arguing that this would assist efficient passenger circulation. It also helps to create the look and feel of a metro rail vehicle, which in many people's minds has much greater appeal than a traditional bus. The overall shape suggested by the running unit layout also reflects modern metro practice.

The second project took a longer term view. The brief was to create a double deck bus for London that might enter service five or so years hence. The design team were asked to take risks in its appearance and layout, and come up with a solution that would be highly attractive to passengers as well as a powerful visual contributor to the city environment. The exterior takes full advantage of the LoBUS running unit arrangements to create a completely new shape for an urban double deck bus, as shown in Figure 4. The rounded front gets the bus well away from the 'dumb box', and the smooth sides offer the chance to fit extensive destination information and lively graphics.

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Figure 4: London double deck bus.(Courtesy of Coventry University.)

The interior is also radical. The aim is make the bus a more convivial place than it is today. Door and seat layouts are not hampered to the extent they are on current designs and the team explored arrangements that break away from conventional 2+2 seating. They created spaces where passengers could socialise or work on the move. Of course, safety legislation and the need for high passenger density means that such radical ideas would not all find their way into production, but they show how the LoBUS concept can be the basis for some fresh thinking.

3.4 Manufacturing and operating considerations

The LoBUS should be easier to manufacture than current designs. The power module and passenger module can be assembled separately, and brought together in the final stages of manufacture. This would permit proprietary bodywork to be fitted if required.

The constant body cross section and simple structure of the passenger module will simplify construction and reduce parts count. The concept does not enforce fixed bay lengths, which mean that buses can be built economically to suit various operating and regulatory regimes.

The simple body structure means that left and right hand drive variants would cause few problems. However, the power module would have to be built in left or right hand drive versions.

Operating the LoBUS will require a few changes to bus operating practice. However, if the benefits are worth having, this should not be a deterrent. After all, in several countries operators were prepared to replace open rear platform front engined double deck buses with rear engined front entrance ones in order to reap the economic benefits of single person operation in the 1960s – necessitating major alterations to operating and maintenance regimes.

The road infrastructure does not require major changes, although – as with all very low floor buses – a high quality level surface is essential. Bus stops need to

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be built to correspond with the chosen door location on the LoBUS. If operators opt for a forward entrance and exit then current designs would suffice. However, if they chose central and rear door layouts some rebuilding might be required.

Drive through bus stations are now much more common than those where the buses face the passenger concourse in a herring bone arrangement. This latter type is ideal for front entrance buses because the platform extends over the concourse apron. The LoBUS does not permit this, and so appropriate safety measures would have to be considered in order to enable people to enter and leave the bus safely at this type of bus station.

Maintenance of the LoBUS will be different to current vehicles. Any design with the engine mounted between the front wheels is going to be somewhat harder to service than most rear or side engined designs. There are various options for access to the running units. As far as possible, access from inside the vehicle should be avoided, in order to keep it clean. Routine servicing could be done through hatches. The power unit, transmission and front wheels could be mounted on a sub-frame able to be withdrawn in its entirety when major servicing was needed. Another possibility is a reverse tilt cab that sees the whole of the lower deck front skin and screens lift up to reveal the major components (see Figure 5).

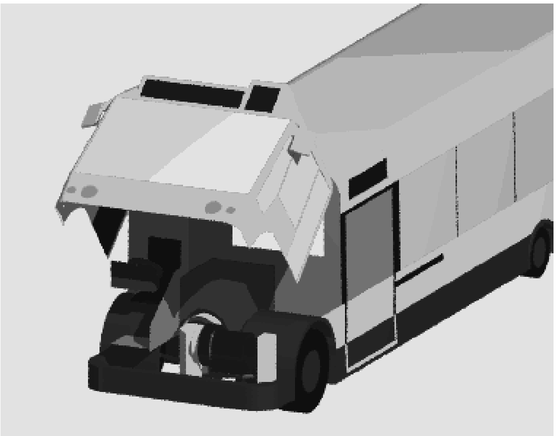

Figure 5: Full tilt engine access.

The rear wheel sets could be reached in various ways. One option is to have each set pivoted about the forward suspension anchor point. In this way, once the bus is hoisted slightly, the wheel set could be swung out to give access to the inner tyres, the brakes and the suspension components.

Body maintenance should be straightforward. The body of the passenger module does not have to bear significant loads from carrying heavy running units slung from well beyond the rear axle. This, combined with the constant body cross section, means that the structure can be simple and repairs can be quick and economical.

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The LoBUS concept envisages a heavy duty bus that will survive an operating life of around 15 years, covering well over one million kilometres. Today's buses generally see little more than an occasional repaint over that period, but the simplicity of the LoBUS passenger module lends itself to being regularly refurbished so that it maintains its attractiveness throughout its life.

Moreover, the best shape of bus for operating conditions can change a great deal over 15 years. The separate power module and passenger module concept – together with the simple design of the latter – means that the basic shape of the bus can be altered relatively easily. The length can be changed; doors can be moved around; seats and standing spaces can be arranged differently.

4 Design challenges

The LoBUS concept is radical as regards full size urban buses, but the individual elements of the design have been proven at the engineering and, in some cases, the operating level. Details of relevant design projects and vehicles put into production are described elsewhere [10].

The LoBUS offers many benefits to operators, drivers and, most especially, passengers. It is a practical solution to the need for a much more attractive urban bus, that will entice people out of their cars and provide a complement (if not an alternative) to new rail systems. In order to bring it to full production, several design challenges will have to be addressed.

The biggest one is getting suitable components to support the front wheel drive concept, with small trailing wheels. The technical targets are not overwhelming, but bus manufacturing volumes are quite low, and thus unit costs would be high unless standard components can be used or adapted.

Key areas for development include tyres. The concept envisages 12R x 20 tyres at the front and 10R x 12.5 tyres at the rear, which would be carrying high static and dynamic loads for these sizes. Tyre wear at the rear could be reduced by making the rearmost wheels self steering.

Space is limited for suspension and brakes. Active suspension might be considered, but this must be set against the desire to keep the overall design of the bus as uncomplicated as possible. Disc brakes seem the likeliest solution, and cooling of the rear sets would need particular attention.

5 Taking the concept forward

The LoBUS concept is not proprietary. It is being put forward in an effort to inject some fresh thinking into full size bus design which the author believes is long overdue. Off-board fare collection, advances in components and the means of propulsion make now the ideal time to go back to first principles. Manufacturers and operators must break away from their conservatism and create a new generation of buses which truly meet passengers' needs and match the appeal of modern rail and metro vehicles.

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Acknowledgements

The author would like to thank friends associated with various aspects of the bus industry for their help and advice in the preparation of this paper. He would like to emphasize that the views it contains are his own, as is responsibility for any factual errors.

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