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WHEN IS A BUS NOT A BUS? REDEFINING TRANSPORT TYPOLOGY.

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ABSTRACT

Recent system advances in the rapid transit sector have led to a position where the various modes are trying to look and feel like a mode which they are not - buses acting like trams, trams pretending to be metro or even heavy rail (tram-train). There are issues associated with this blurring of boundaries that makes the definition within the existing typology redundant. Added to this there is a proliferation of new and rather confused acronyms - LRT can be light rapid or rail transit and some terms, BRT (bus rapid transit), ULR (ultra-light rail), exist without apparent clarity of definition. There are potential implications for this indistinct situation for system promoters - the U.K. Safety Regulatory framework draws no distinction between forms of guided transit; hence any form of guided bus falls under the same onerous regulatory safety requirements for a rail-based system. The Health & Safety Executive is to revoke the existing safety framework and implement one based upon European directives allowing for system differentiation. The directive would be better placed to discriminate relative safety requirements provided there is a classification of the various modes. The deregulation of bus services introduced competitive-access implications - why invest in a capital-laden infrastructure with the threat that this could be operated upon by competitors? This would suit the new forms of guided-bus being distinguished from regular bus operations. The U.K. suffers from bus-apathy, based on the perception that the bus is a low-quality solution, and this situation is not helped by the use of regular buses on kerb-guided systems being classified as equivalent in definition as a magnetically or optically guided-bus or even the French tram-tyre solution. The forms of transit are re-defined in the existing typology to address transit modes that constitute heavy rail, metro, light rail and the various forms of bus-based transit. A simplistic decision-tree is used to classify the transit modes to demonstrate the typology in real-world application in an attempt to re-focus each type of emerging transit artefact.

KEYWORDS: Light rail, light rapid transit, bus, LRT, typology

1. INTRODUCTION

A research project is being undertaken to model cost and environmental performance of light rapid transit modes to enable comparison of alternatives to overhead line equipment (OLE) electrified light rail systems. The objective, and reason for the comparison, is to assess the relative performance characteristics for equivalent systems to conventional light rail.

There were a number of 'definition tests' defined early in the research project that would be used to determine whether a proposed alternative to a conventional light rail system could be considered to be an equivalent – i.e. the realisation of an alternative and not a substitute system. These tests were derived from considering U.K. conventional light rail systems such as those in Manchester, Nottingham, Sheffield and Birmingham:

- The capacity of the vehicle, or vehicles operating in multiple for usual operation, would be greater than 100 but less than 300.

  - System capacity is a function of vehicle number and capacity and operating headway (a complex function of control system, vehicle acceleration/deceleration and route dynamics). Light rail in the U.K. (whilst on-street) operates by line-of-sight control that would need to be maintained for equivalent vehicle; hence the rationale for vehicle capacity as the definition test.

- The system must have a capability for on-street running.

  - One of the key benefits purported for successful light rail systems is the ability to penetrate in to the centre of social, commercial and residential areas for maximised integration.

- The system must have a capability for non-discretionary guidance.

  - A development in bus technology, in attempting to imitate light rail has been the advent of more complex non-mechanical guidance. This adds to the feel of permanence associated with light rail steel rails and dismissed with painted bus-lanes.

Looking at worldwide systems, and the definitions applied to them by numerous authors and organisations indicates there are a number of common terms used to describe urban transit; however the use of these is somewhat inconsistent and apparently at times interchangeable. The use of acronyms allows for further confusion. LRT as Light Rapid Transit or Light Rail Transit and BRT (Bus Rapid Transit) apply different definitions that at times depends on the agenda of the author. The next section of this paper analyses some of these definitions.

2. THE BASIS FOR CONFUSION IN DEFINITION

Recently, there has been an upturn in the diversity of urban transit systems and these appear to be focussed on a merging of modes. The recurring theme is that transit modes are attempting to imitate the next mode up the 'transport-chain'. Consider the dimensions of transit modes offered by Vuchic (1999) of system performance versus investment cost; adapted for use in this paper and illustrated in Figure 1. Investment cost has been interchanged for complexity for the purposes of this paper. Note the diagram implies performance and complexity is a straight-line relationship, this is not the case. For the purposes of this paper the relationship adequately identifies the implication of the higher the transport system performance requirement the greater the necessary system complexity.

The complexity of a system is subject to many factors ranging from scheduling and regulatory aspects to more obvious, tangible control system, vehicle and infrastructure considerations. Necessarily, complexity correlates with system cost, drawing a parallel with Vuchic's version. The dimension of performance has been extended to consider 'mesh density' along with Vuchic's consideration to speed, comfort and capacity, i.e. the more complex the system the less dense the mesh-density becomes. This has further permitted the inclusion of inter-regional and international transport over and above Vuchic's model. In moving-up the complexity line, transit modes are attempting to move in to the markets traditionally offered by more complex modes. Consider trolley-buses and guided-buses imitating light rail and heavy rail focussing on inter-regional air markets with high-speed rail-links – the recent Virgin Pendolino train introduced in the U.K. has the feel of an aircraft with compact, table-less seating and small windows resembling an aircraft fuselage. The tram-train, for example, is the use of light rail vehicles on heavy rail or metro networks interfacing with 'conventional' light rail operation for example Karlsruhe and in the Netherlands between Rijn and Gouwe.

Light rail is perceived to be clean (and hence environmentally-friendly), modern, fast, efficient, safe and secure with state-of-the-art 'stops' (LRTA, 2003) – in fact everything that the stereotypical bus is not. Developments in bus vehicle and system technology have been focussed on making conventional buses look and feel like light rail systems on the basis that light rail appears a 'preferred' mode. Internal modification to the vehicles, to make them more akin to a light rail vehicle (LRV), includes seating arrangements, decals, passenger info and low floor configuration. Externally, wheels tend to be covered to give the illusion of an LRV. Bus propulsion systems are moving away from the conventional diesel internal combustion engine (ICE) - albeit slowly. There are changes to ICE fuel source (dating back many years) to use alternative fuels, also the use of overhead electrification (again very dated, trolley buses were common-place in the 20^{th} century) and more recent technological advances for example the rather embryonic and not-yet commercially viable fuel cell. Whilst the concept of sub-surface central guide rail dates back to the early 20^{th} century other bus-guidance systems have seen implementation, from the relatively common kerb-guidance to magnetic and optical systems. Configuration and capacity of vehicles is changing to provide a look and feel of an LRV – the 'bendy bus' was probably not intentionally made to look like an articulated LRV but has almost conveniently been able to take LRV form.

A key difference between bus and light rail operations outside of vehicle concerns is that of the infrastructure. Some complimentary measures have also been migrated to bus operations toward the permanence offered by light rail; for example in route prioritization and route characteristics with reserved running, guidance systems and prioritised signalling at junctions. Stations (stops) and other facilities have been updated, again modern decals being key. The provision of real-time passenger information displays, raised kerb stops and the design of shelters and ticket machines have aided the perception that the bus service is about permanence and a system does not need to have steel running rails to ascribe to this.

Individually the developments would still leave the look and feel of a conventional bus, but as part of an overhaul of the complete 'package' a system with an LRV feel begins to take shape. Some recent examples of developed systems are given in Table 1.

The issue that faces the research project begins to become clear – if a system defined as an equivalent is to be proposed, what is the impact on finding an equivalent in the merging of transit modes. In other words, when is a bus not a bus, and more precisely, when is a bus (equivalent to) a tram?

There are a number of authors that for different reasons (and particular system-promotion agendas) that have sought to define transit systems or by seeking to write about them have implied definitions. Some of these are considered here.

3. CURRENT DEFINITIONS OF TRANSIT SYSTEMS

Given the earlier consideration to Vuchic and the proposed model of his performance/cost characteristic it is appropriate to consider the wider views offered that lead to the graphical definition. Vuchic (1999) defines characteristics of 'urban transit systems', of which light rapid transit is a component. The need for classification is borne out of the requirement to understand performance and cost characteristics of the different modes to match them to local conditions for appropriate implementation. Furthermore, classification will provide an understanding of the regulatory basis and relevant safety regimes for system implementation and operation.

Vuchic (1999) recognises that classification based upon vehicle and technology does not suffice given the development in transit modes – including in 'light rail transit' and BTS – bus transit systems. The defining criteria detailed are:

- Right of way (ROW)
- Technology: infrastructure and vehicle
- Type of operation

The ROW is categorised in 3 ways:

Category A:	Low investment streets and roads without separation suitable for buses, trolley-buses etc – low performance/cost characteristic
Category B:	Partial separation – potentially using kerbs. Crossings are 'at-grade' with signal control and suitable for light rail and BTS with buses on transit-ways that exclude other vehicles.
Category C:	Fully separated for use by rail vehicles only. Higher cost systems due to separated tunnels, bridges, and stations and with appropriate guidance. Will generally offer high capacity and speed.

Performance and cost increases A through C.

Noted that Cat C is stated (by Vuchic) to be for rail vehicles only, yet in Essen, there is a bus operation that uses concrete running-ways set outside of the steel rails of the fully segregated sections (category C) of the light rail system. This light rail system also runs in grade-separated areas – approaching metro system provision.

The technology, both vehicle and infrastructure is usually a determinant of the ROW. As the ROW requirement increases A through C, (inherently bringing an increased performance requirement predominately for speed and capacity) this implies a greater technical dependency for operation and control. This is typically in the specification of power supplies, signalled-control and passenger interface. By example, a category A system using standard technology bus vehicles will be cheaper in capital investment and running costs offering lower performance (speed and capacity) next to a fully signalled, high technology, high capacity metro system operating on a Category C ROW.

A common (U.K.) theme in defining light rail is the tendency to include fully-segregated systems as light rail; whereas these are more akin to metro systems. By example, the U.K. Government National Audit Office (NAO, 2004) refer Docklands Light Rail (DLR) and the Tyne and Wear Metro (T&WM) as Light Rail systems; a view consistent with the LRTA, Taplin (1995) and Barry (1991). Barry uses the term light rail, as it 'simple and precise' and this is necessary as 'there is a lot of confusion about'. However, both the DLR and T&WM systems are fully segregated, fully signalled systems; the DLR necessarily so as this operates with a 750v d.c. third rail power supply. The overall system capacity also indicates metro operation – in 2002/03 the systems carried 37 and 46 million passenger journeys respectively. The next highest was the Manchester and Croydon systems with 19 million. Notably, the Manchester system operates over 39km compared to the (then) 27km DLR system (NAO, 2004). DLR seems actually to be a metro. The Light Rail Transit Association (LRTA, 2003) evokes the Talent Bombardier diesel unit as a light rail vehicle, but operating on heavy rail lines in Rostock diminishes the viability of this. However, a similar diesel-powered unit operating on-street in Zwickau can be considered light rail given the nature of operation on light-rail lines.

The US Federal Transport Administration (FTA) appear to have an obvious agenda to promote the bus, in whatever guise, as the choice for modern transit solutions. A report (Baltes et al, 2004) also sponsored by the US Department of Transportation seeks to assist transit solution decision-making by detailing the characteristics of Bus Rapid Transit. With characteristics come some useful or illuminating definitions.

An early definition in the report states that BRT is a 'flexible, high performance rapid transit mode' – quite vague, sounding like a vacuous blue chip company mission statement. The flexibility is dimensioned by stating that BRT has a variety of 'physical, operating and system elements. The use of the word 'variety' is a 'catch-all', with options provided for running ways, stations, and vehicles. By example, ROW can be from physical separation (guide-way) to differentiation through colour schemes (i.e. a simple, cheap, painted bus lane).

It continues (Baltes et al, 2004) to consider BRT attributes, 'in a permanent integrated system' and having 'unique identity'. Permanence and identity seem to be a popular consideration to why light rail is perceived as more attractive than conventional bus; however, the case studies presented in the report fail to bear this definition out. A number of systems are detailed in the report (Baltes et al, 2004) as BRT; however some of these are little more than regular bus systems with bus lane provision. The 'Chicago Express' is a 36.7 mile system with 36.7 miles of mixed flow traffic running, no guidance, traffic signal control and no running way marking - a regular bus service, then. Other quoted systems (Oakland, Los Angeles) are the same with only one from the ten systems considered having guidance (the optically guided Civis system in Las Vegas). The similarity to regular bus systems continues when quoting the vehicles. Again, of the ten systems, 8 are powered by internal combustion engine (7 diesel-fuelled). Only the Civis has an electrical final drive. All 10 are standard, articulated or stylised-standard configuration bus design – essentially a modern bus. Few case studies provide substantiation to permanence and identity.

Baltes etal continue, stations and platform definitions seem unreasonable – a bus shelter with a kerb is deemed a station – somewhat stretching the definition. Other areas considered are not BRT specific, for example, fare collection, passenger information and operational management. In summary the case for BRT, as a concept separate to bus and hence having different characteristics and permitting clear definition is not affirmed by this report. The systems purported to be BRT use phraseology implying a level of system complexity without employing many of characteristics of the suggested mode.

So what of Europe – are there systems worthy of separate definition to bus as BRT systems? The latest innovation from the Operator First and manufacturer Wright Group in the U.K. is the "ftr StreetCar" concept (Wright Group, 2005). At the Bus 2020 Conference (Daniels, 2005) held early this year in London, this was presented as the future of bus; in the context of the holistic system, not merely the vehicle. That said, although the needs for complimentary measures as a pre-requisite for operator provision were repeatedly alluded to these were never detailed. Another, provision possibly sought is less tangible – to be financially viable (i.e. to generate revenues consistent with the greater implementation and operating costs) ftr will seek exclusivity on route operations through the so-called Quality Bus Contract (QBC). The measures hinted at the need for segregation and identity, the light rail ideal of permanence. Furthermore, the synthesised photographs illustrating the vehicle in city centres appeared with no apparent demarcation or complementary system identification. Also, it must be said, the rear of the vehicle does look nothing more than like the back of a bus!

A key author in the field of rapid transit through recent times is Hass-Klau (2003). A significant piece of work, 'Bus or Light Rail: Making the Right Choice', as the title infers has a pre-requisite requirement to define the different transit modes if it is to differentiate between them for analysis and proposition of benefits and dis-benefits of each. Quite early in this text the definitions are drawn. Initially, this extends to light rail, busway and guided-busway. A further more detailed review is provided that infers a hierarchy (in the way it is listed) from urban surface or underground rail to light rail and tram and 'traditional' bus options.

The terms 'Tram' and 'Tramway' imply a historic system that can be upgraded to 'light rail standards' (Taplin, 1995), Hass-Klau accords with this and refers a definition of light rail (from ECMT, European Conference of Ministers of Transport (Hass-Klau, 2003) that provides a route for the staged development of transit systems from (historical, but modernised) tramway to light rail and furthermore to operations on fully-segregated, underground or elevated routes. In any case each stage should permit development to the next. Light rail and tram are interchangeable (and now 'technically inseparable') but distinct from metro, underground and subway as these are fully segregated and are usually powered from a 3rd electrified rail; whereas light rail systems are usually overhead electrified.

Guided bus is defined as being an intermediary mode between tram and bus, which is either always guided or fully autonomous running on a separate right of way. Vehicles can be diesel, electric or hybrid powered with guidance being mechanical, optical or electronic.

Systems have been introduced befitting this category with full guidance and overhead power supplies; for example Translohr and the Caen TVR.

Busways (or the US variant, 'transitways', or as Vuchic (1994) has it, 'bus transit systems') are reserved running lanes for conventional buses. These do not allow other traffic to enter the system given the degree of segregation and at times will have grade-separated crossings. Finally, at the bottom of the Hass-Klau pile is the bus lane. The segregation extends only to demarcation with colour-schemes for conventional buses using the 'system' and whilst protected by legislation, for example in the U.K., there is little to prevent other road users abusing the bus lane provision and using the bus lane.

Overall, it is clear that there are different views of what constitutes the varying forms of transit. This confusion has been exacerbated with the new forms of transit that are trying to look and feel like something they are not. This confusion cannot be helpful for system promoters and potential users; that depending on their agenda can seek to 'destroy' or promote systems. Whilst the debate may serve to provide some interest, are there issues of definition that have wider implications on the provision of transit modes?

4. WIDER IMPLICATIONS OF INCONSISTENT OR IMPROPER DEFINITION

Aside from the arguably negligible issue of semantics and calling a bus a tram and a tram a train; are there more significant issues associated with transit mode definition? It is believed that in the U.K. at least, there are wider reaching implications. There are two issues considered here: the definitional issue associated with safety regulation and a largely definition-context issue (particular to the U.K.) of competition regulation. The impact of both of these issues makes it more difficult to introduce intermediate transit systems, i.e. between bus and light rail, in the U.K.

4.1. Safety Regulation

The existing U.K. safety legislation for transit systems is being reviewed by the Health and Safety Executive – the Government appointed body for administering and enforcing safety legislation in the U.K. This has been considered in a consultation document by the Health and Safety Commission (HSC, 2004). Currently all guided transit modes are subject to the same onerous safety requirements as for heavy rail. In this form, guided transit systems are considered to be any form of rail-based vehicle (heavy, metro and light), any form of guided or trolley bus and even canal systems – covered under the term, 'railways and other guided transport systems'(HSC, 2004). A 225km/h tilt-active heavy rail vehicle operating on a fully signalled system is hardly comparable to a 60km/h line of sight operated light rail system; but this is exactly the case under current legislation.

Clearly, legislation common to the different transit modes is necessarily going to address the worst-case scenario in terms of mandated requirement; that will usually be the heavy rail systems, i.e. if the legislation is good for heavy rail then it should be more than adequate and indeed over-kill, for the other less complex, slower, public-highway integrated schemes.

To achieve compliance may import unwarranted costs thereby making systems unfeasible. The cost/performance ratio is weighted toward a higher cost for given system performance output. Even where compliance does not require additional protective measures manifested in infrastructure provision, the cost and time of demonstration can negate the benefit of implementing a lower performance system on the basis of cost and time to service.

The HSE has recognised the need to 're-shape' the safety framework in accordance with and as driven by EU (European Union) requirements. The proposed framework – the RSD, Railway Safety Directive, as mentioned, has been the subject of a consultation paper and consultation period. It is targeting a number of objectives, amongst which are (HSC, 2004):

- Commonality with EU Safety and Interoperability Requirements
- Streamlining of safety requirements to allow greater proportionality to risk and reduce costs
- To apply principles of regulation for non-interoperable (rail) systems but again proportional to risk and characteristics of the system

The final item is of particular interest. The covered systems by the RSD include tramways and other guided transport systems but specifically excludes any system that uses, 'trolley or guided buses'. The excluded systems will be legislated using the existing ROTS (Railways and Other Transport Systems) legislation as this includes: road-based with rail guidance, road-based with side-guidance and track-based with side-guidance (HSC, 2004).

The safety regulation of road vehicles is enforced by the DfT (Department for Transport) and there is an overlap between the DfT and HSE. Currently, the HSE approval of guided bus systems extends only to the approval of guide-wheels and guide-ways. All other aspects are the undertaking of the DfT. An 'untested' concept in the U.K. is that of optical or magnetic guidance, these do not have guide-wheels and the ROW can loosely be described as guide-ways – so where would the regulatory obligation lie? For trolley bus systems the HSE is only concerned with the power supplies and this role, according to the HSE appears to add to costs with little resulting benefit (HSC, 2004). A debate is ongoing between the HSE and DfT to remove the road-based systems from HSE governance.

4.2. Competition Regulation

U.K. bus services, for the majority of operations, were de-regulated in the 1980's and remain as such, only London and Northern Ireland operate outside of this regime. One of the motives for de-regulation was to promote competition between operators to improve passenger service and cost. Under a relatively open-access arrangement the viability of a service is dependant on the level of competition for revenue versus the cost to operate. This has seen the use in some cases of rather tired-looking buses being given extended serviceable life in order to reduce capital costs. This same rationale will extend to infrastructure provision and investment in new technology vehicles without an assured exclusivity of operation to maximise revenue, contrary to the open-access provision, why would an operator make such an investment? The lack of sub-definition to bus operating modes may cloud this issue when considering bus services. On one hand under current safety legislation a guided bus in considered to require similar provisions to a rail vehicle yet would still be subject to a competition framework for bus operations. There seems little motivation in the U.K. to introduce a system other than a regular bus service, with kerb guidance at best – at least this has precedence in the U.K. The case for the newer technology systems, intermediate systems for example Phileas and Civis, in the U.K., is unclear – a significant amount of time and resources (cost) would be required to demonstrate feasible implementation that would then be in competition with lower cost alternatives. This further supports the case for potential operators to seek exclusivity to maximise revenue to offset cost.

The need for exclusivity, in the form of a Quality Bus Contract (QBC) needs to have clear demarcation between modes. If legal constraints on competitive operations are to be implied then the definition of vehicle and operation type that are able to operate within, or be excluded from the QBC needs to be explicitly made.

The paradox is that with the current impasse on light rail schemes in the U.K. it could be argued that there is a case for intermediate transit system introduction yet the competition regulation makes this difficult to happen. The 'time to market' and implementation costs for light rail schemes are prohibitive yet the lower cost, quicker to implement intermediate systems are not given sufficient opportunity to be realised. Also, the nature of 'guided' or more specifically 'tracked' systems affects the public authority's ability to subsidise systems. Tracked systems are generally subsidisable whereas bus systems are not. Subsidy is appropriate to bus systems where this is a non-commercial service and if an unsubsidised commercial service is operating this disallows the running of a subsidised service in competition.

An issue that should not be understated, certainly in the U.K. is 'bus-apathy'. Buses are stereotyped as dirty, smelly, unreliable and with choking diesel fumes, not environmentally friendly. Bus patronage is continuing to fall except for London where the specific (private car) travel constraints and continued upgrade of bus fleets mean that the passenger numbers have increased in some areas. However, given the option of light rail of bus (guided or otherwise) without careful inspection, the general public would go for light rail every time. However, given the opportunity to introduce newer technology bus systems (as the ftr is alluding to do) and potentially further enabled by the changes to legislation, then a re-definition of certain bus operations may begin to change opinion. However, this will not be the case if the U.S. FTA (Baltes et al, 2004) version of bus rapid transit (bus stops and bus lanes) becomes commonly known as the 'new' alternative (equivalent) to light rail.

There is a growing recognition that the transit systems need to be differentiated in order to permit reasonable apportionment of safety approval, risk and cost. This may have the effect of making road-based systems more costs effective and attractive for U.K. implementation. This further indicates the requirement for transit mode definition as without this definition intermediate transit systems can be inappropriately classified thereby making implementation in the U.K. more difficult than need be.

5. THE NEED FOR TYPOLOGY DEFINITION

Given the confusion presented, the key objective of this paper is to propose a light rapid transit typology based upon specific definitions of system characteristics. There are two key themes emerging – the staged development of transit systems, gravitating to the mode 'next-up' in the chain. This is recognised and it appears as though the advocates of the different modes appear to talk-up the position of a given system (to the next mode) even though at times it does not appear substantive. The use of new and ill-defined terms, including existing typology definitions can confuse, sometimes suspiciously so, the issue. It is relevant to propose, not necessarily a new typology but a new set of explicit definitions.

The characteristics used to describe the different transit modes are relatively consistent in the application to infrastructure and vehicles for the differing modes. However, given that the objective is to define the characteristics in order to make the systems distinguishable for the purposes of identifying equivalence to a conventional light rail system is relevant (and efficient) to consider those elements that will differentiate between the modes. This has been based upon the three definition tests provided earlier:

- Has the capability to run on-street, non-segregated
- Has the capability to be non-discretionally guided
- Typically has a vehicle, or combination of vehicles with a capacity of greater than 100 but less than 300

There are a number of sub-characteristics within these definitions that need to be rationalised. Provided that a system has been defined as equivalent from the tests above the sub-characteristics of guidance means and power supply type (as these will be key determinants in the cost and environmental performance areas that the research project is addressing) can be further defined. There are many different modes and it was considered practicable to capture the definition means diagrammatically – in a decision tree.

6. LIGHT RAPID TRANSIT NODAL DECISION-TREE

The term, 'Nodal Decision-Tree' has been given to the design of the decision tree presented to support the definition of the transit typology proposed. The concept is very simple as can be seen from the decision tree presented in Figure 2. Each node (black dot) represents a characteristic selection to be made – by looking at the criteria presented at the left hand side of the tree aligned with the node. A characteristic is defined as being in place ('yes' – dashed line, to the left of the node) or not a characteristic of the system (a 'no' – solid line, to the right of the node). Using this from the first node allows the tree to be followed to provide the typology of any system defined by the tree.

As repeatedly mentioned the focus is on the light rapid forms of transit in seeking equivalence to light rail systems; hence the analysis is focussed in this area. The initial point in the analysis immediately determines the common characteristic of light rapid transit systems – the notion of a local, inter-urban service. The next test establishes whether the system is road or rail based with a qualification on rail-based services to understand whether it replaces a heavy rail operation. The concept of guidance is tested in two ways. The initial characteristic is used to determine whether the vehicle can be directed entirely at the driver's discretion. In the case of an overhead line power supply, the driver may retain full directional control but must stay within the limits of the overhead wire to maintain operation; hence cannot operate at their own discretion but are not guided per se. The latter test identifies whether there is any form of guidance control applied whether by physical, optical or magnetic means.

Finally, to determine equivalence, vehicle capacity is tested and if between 100 and 300 is considered equivalent. When the definition has been developed to the point that it is now in the area of equivalence to light rail there are a further five distinctions drawn on the nature of power supply and guidance to fully define the different sub-modes.

Consider a worked example, the Translohr system in Padua and refer to Figure 2. Translohr is not an inter-regional system and does not have steel running rails. The system is on-street capable and does not have full discretionary guidance, note that the first 'system' type dismissed here is the bus. Moving on, the vehicle capacity is less than 300 but greater than 100 and at this point has been determined as equivalent to conventional light rail. The use of overhead electrification means that it is fully non self-powered and as it uses a central guidance rail it is considered a tram-tyre system. Without guidance it would be considered a a straight-forward trolley-bus.

It is noteworthy at this point to consider the ultra-light rail (ULR) type systems. In developing the definitions this system type appeared to fit most definitions where capacity was less than 100 passengers per vehicle. There are few ULR systems that have been implemented, for example in the U.K., the 'Parry People Mover' ULR has seen numerous trials without full implementation. It is interesting to note that the ULR system option proliferates the tree; it is almost as if by alluding to be the best-fit option it lacks a degree of speciality; there will always be, by definition, a close-relative of the system that is more likely to be a proven solution. In other words, the only shape that fits all shaped holes is one that is too small.

Note, that wherever the end of the tree is reached by a triangle, this denotes that the system characteristics do not have a real-world example; effectively these are disallowed systems. There are six cases where these have been identified and these are provided in Table 2.

7. MODE AND SUB-MODE DEFINITION

The decision tree illustrates the route to defining the modes. To conclude this exercise it is practicable to draw together the different sub-modes into modes considered as the proposed typology. In order of increasing complexity (i.e. moving up the performance/complexity line in Figure 1) these are proposed as follows, for systems equivalent to (and including) light rail:

- **Guided-bus**: kerb-guided bus, non-mechanically guided-bus, guideway guided-bus and fully reserved guide-way bus.
- **Trolley-bus**: hybrid trolley-bus, hybrid guided-bus, trolley-bus and tram-tyre
- **Light Rail**: light rail (non-OLE), light rail (hybrid) and light rail (OLE/3rd Rail)
- **Tram Train**: tram train (non-OLE), tram train (hybrid), tram train (OLE)

A graphical representation of the proposed typology is illustrated in Figure 3. Note, that Figure 3 includes reference to BRT (Bus Rapid Transit) as all modes covered by guided and trolley-buses. Examples of each mode are provided in Table 3.

The defining criteria between these modes align with the incremental development of light rapid transit systems introduced earlier. From bus operation an investment in running way will lead to the guided-bus. The next step would require the introduction of overhead power supplies to become a Trolley-bus system. Further investment is then required to develop to the next system necessitating the implementation of steel-running rails. Note that system development can commence at any stage, so for example, the Zwickau system is a light rail non-OLE system and has not developed from trolley-bus therefore does not already use OLE. Finally, in this context, to develop from light rail requires integration with or in place of heavy rail operations. Taking the next development stage, but then becoming non-equivalent to light rail would mean segregated operation as a metro system.

8. SUMMARY AND CONCLUSION

This paper has identified that the current definitions used to describe transit systems are inconsistent and at times misleading. This is particularly the case where a lobbying group in support of development of the mode being discussed is providing the definition. The transit field would benefit from a clearer definition – in the U.K. the HSE is seeking to revoke existing safety legislation to provide a reasoned approach to regulation of non-rail guided systems. This may provide greater opportunity for the development of typically European systems (such as Civis, Translohr and Phileas) in the U.K. and may then begin to re-awaken the travelling public to the concept of modern buses, operating on infrastructure with a greater degree of permanence. Ultimately, this could lead to the promotion of more light rail equivalent systems thereby providing a modern, high quality transit solution – that could be implemented far earlier and more cheaply than a conventional light rail system. The incremental development of systems could then be implied given there is sufficient demand to develop the system accordingly.

The proposed typology for light rapid transit aligns with the notion of an incrementally developing transit infrastructure albeit this has had a focus on equivalence to conventional light rail in order to reach the definition proposed. There is value in providing a more robust definition of typology that enables a universal comprehension of system types – enabling lobbyists and those being lobbied to recognise appropriately the nature of any given system. The U.K. lags behind Europe in the development and implementation of new transit modes and the move by the HSE can provide the catalyst to more systems being promoted without the burden of unwieldy, unnecessary and costly safety regulation. With this legislation in place there is no middle ground – the systems in the U.K. are at-best guided bus with a large, expensive jump to light rail or at worst from scratch to light rail. BRT exists as the opportunity to bridge the development gap that this definition identifies. The U.K. privitised and de-regulated transport system has a clear need for 'intermediate systems', between conventional bus and light rail – more than most countries. However the current competition and safety regulatory constraints make it harder and more financially risky and hence prevent the implementation of the intermediate solutions.

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TABLES

System Name	System Examples	Key Characteristics
CIVIS	Las Vegas (U.S.), Rouen (France)	Optically guided, rubber-tyred, articulated vehicles that can have conventional ICE power source and electrical final drive. Fuel cell versions are in development. Raised-kerb halts with feel of tram-stop, not bus-stop.
PHILEAS	Eindhoven (Netherlands)	Magnetically guided vehicle with rubber tyres that can be operated driver-less, LPG ICE with electrical transmission and final drive. Vehicle internal layout (seating and materials used for interior design) modern and akin to LRV. Reserved running whilst remaining on-street.
TRANSLOHR	Padua (Italy)	Overhead powered rubber-tyred vehicle, with on-street running. Modern, articulated vehicles.
TVR	Caen (France)	Central rail guidance, rubber-tyred vehicle, overhead line power supply.

Table 1 - New Technology Bus Systems

Ref	Description of Disallowed Mode
a	On-street capable, steel rail system used as a replacement or interfacing to heavy rail with a vehicle capacity exceeding 300
b	As for 'a' except not used as a replacement or interfacing to heavy rail
c	Rubber-tyred vehicle with capacity >300
d	Rubber-tyred vehicle with no on-street capability and no guidance system
e	As for 'd' except capacity >300 per vehicle
f	As for 'd' except capacity <100 per vehicle

Table 2 - Disallowed Modes from the Nodal Decision Tree

Mode	Sub-Mode	System Example Name/Location
Guided-bus	Kerb Guided-Bus	Leeds (UK)
	Non-Mechanical Guided-Bus	Civis (Lyon, France), Phileas (Eindhoven)
	Guide-way Guided Bus	Essen (Germany)
	Fully Reserved Guide-way Bus	Fastway, Gatwick (England)
Trolley-Bus	Hybrid Trolley-Bus	Fribourg (Switzerland)
	Hybrid Guided-Bus	Phileas (not yet implemented)
	Trolley-Bus	Lyon (France)
	Tram-Tyre	TVR, Nancy (France)
Light Rail	Light Rail (Non-OLE)	Zwickau (Germany)
	Light Rail (Hybrid)	Bordeaux (includes 3rd Rail supply)
	Light Rail (OLE)	Manchester Metrolink (UK)
Tram-Train	Tram-Train (Non-OLE)	Camden-Trenton (US)
	Tram-Train (Hybrid)	Nordhausen (Germany)
	Tram-Train (OLE)	Karlsruhe (Germany)

Table 3 – Mode and Sub-Mode Definitions System Examples

FIGURES

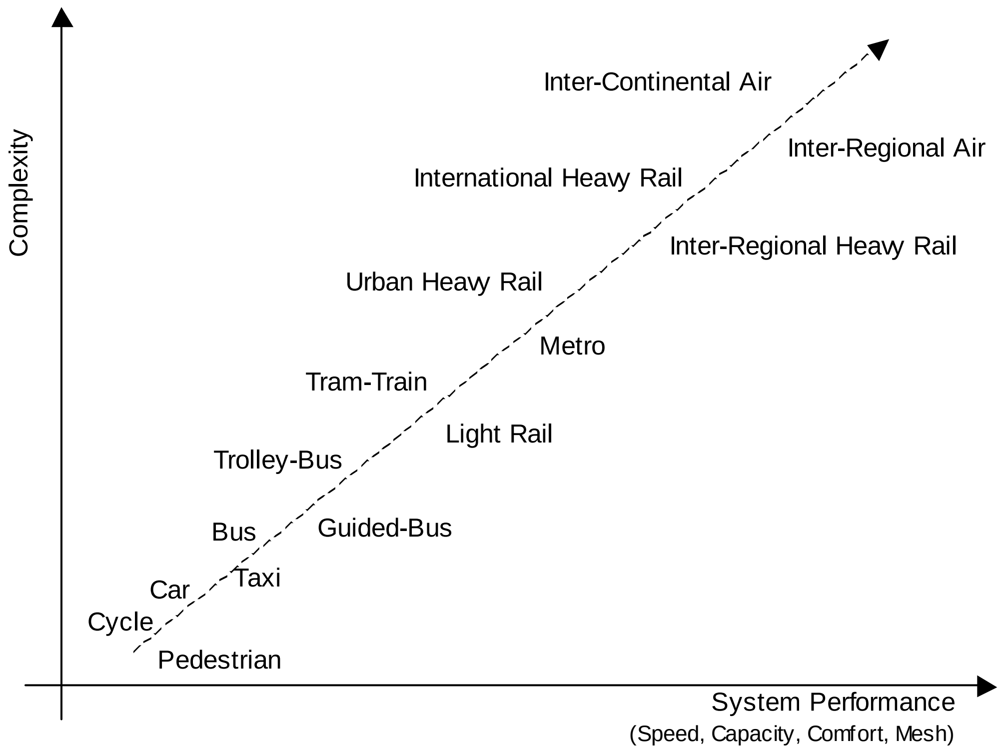

Figure 1 - Transport Mode as a function of Performance and Complexity

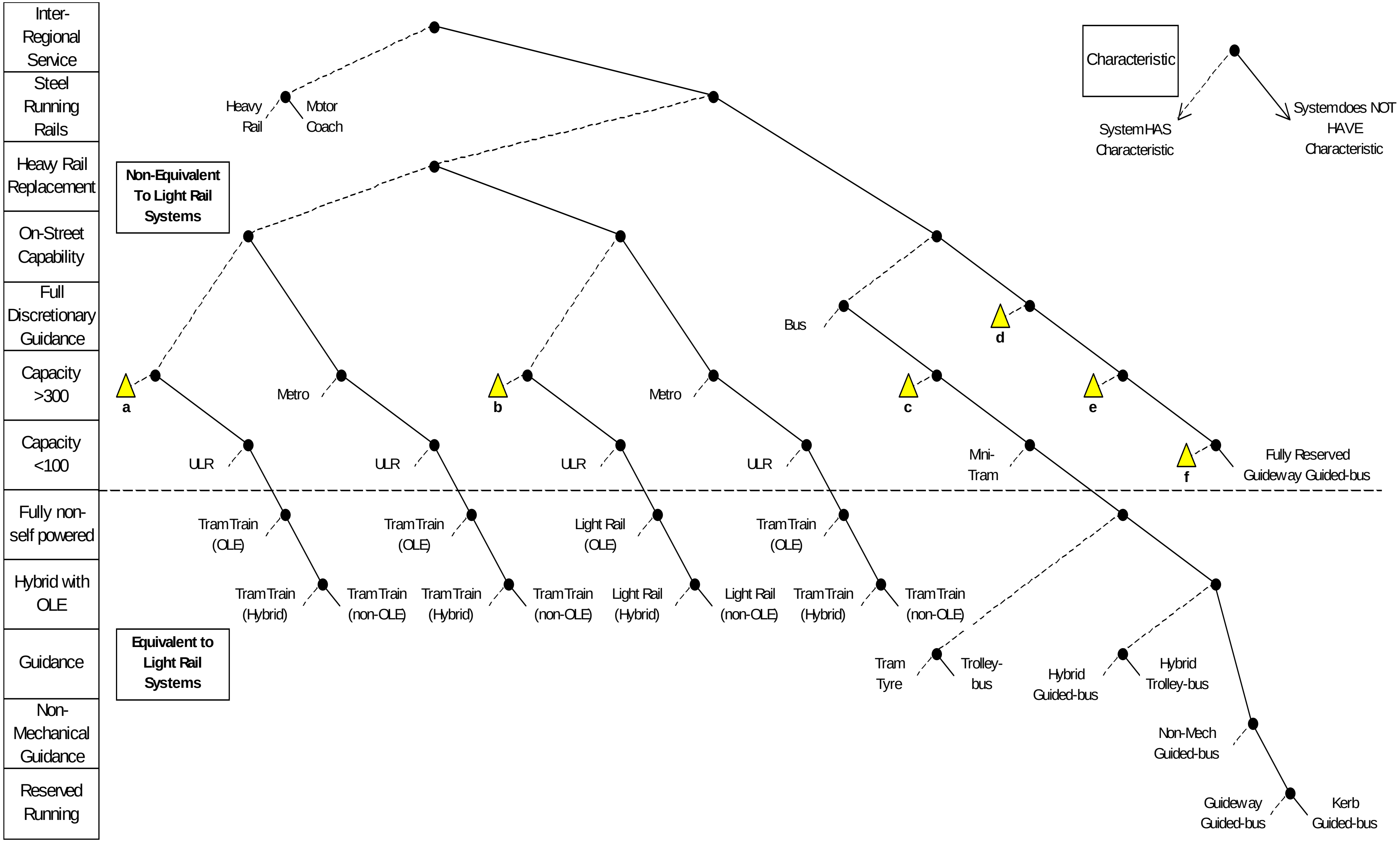

Figure 2 - Light Rapid Transit Nodal Decision Tree

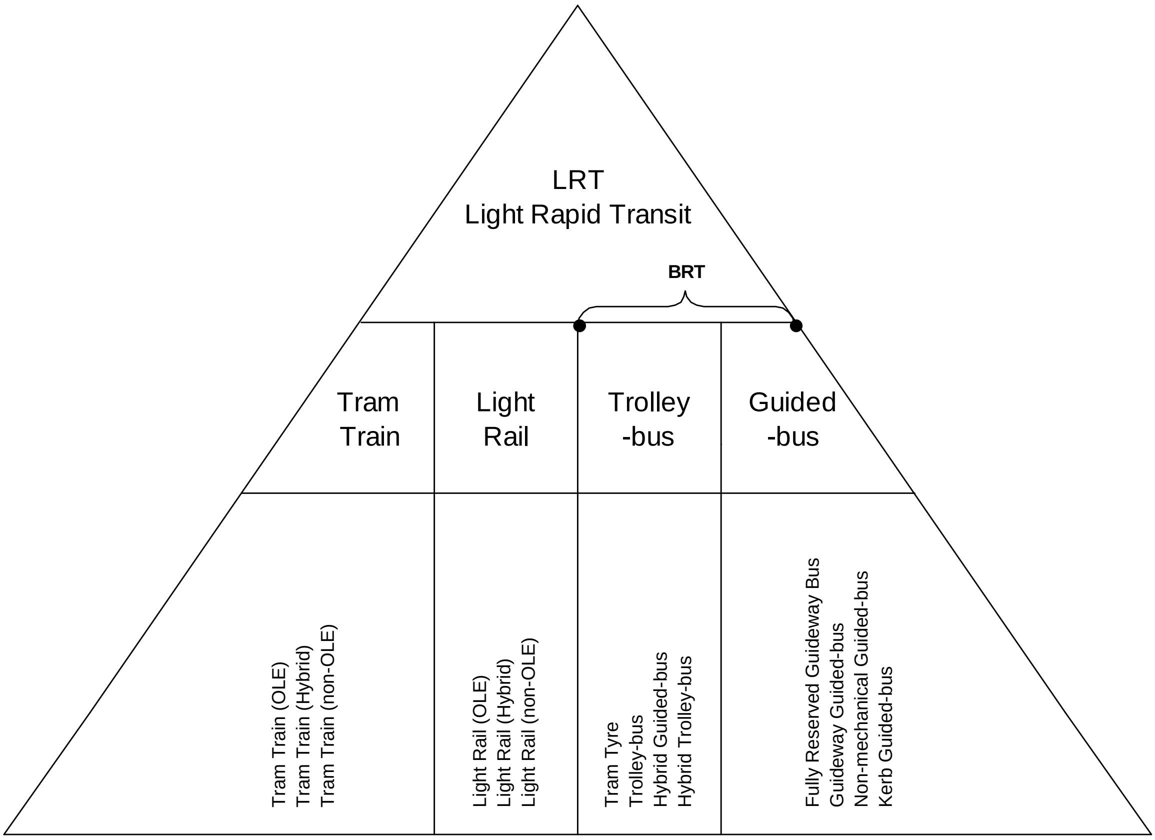

Figure 3 - Light Rapid Transit Typology Proposal