Public Goods Pricing, Roads and Technology

February 2013

Mr Alex Li-Kim-Mui, for Infrastructure Australia

About the author:

Alex Li-Kim-Mui is a current Bachelor of Engineering and Commerce student at the University of Sydney.

John Maynard Keynes, one of the most famous economists of the 20th century, is reported to have said:

"When the facts change, I change my mind. What do you do, sir?"

Summary

The pricing of public goods has been a difficult proposition for governments over the years, due mostly to the interpretation of the non-excludable and the non-rival characteristics of public goods.

Roads are an example of something that has been assumed to be a public good based on these two characteristics. However some roads exhibit 'excludable' characteristics such as congestion or vehicle restrictions.

Road pricing has been limited by technological constraints among other things, but recent advancements in technologies have eased these.

To tackle problems such as an increasing number of road users, congestion, road wear and negative externalities, governments and road authorities could look at technology-based schemes that enable them to create property rights for road use, via identification and separation of vehicles.

More basically this raises questions as to our mindset about roads and public goods, and the desirability of approaching modern transport issues in a multi-disciplinary framework.

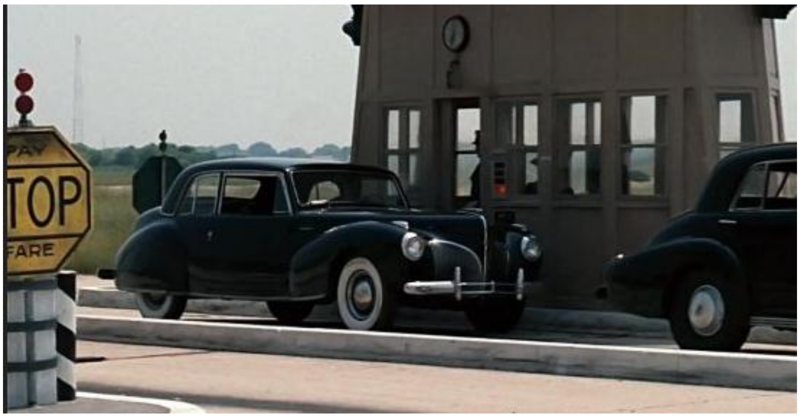
Introduction

Long-standing economic theory defines a public good as having two important characteristics: being non-excludable and non-rival. From an engineering-commerce perspective it is important to understand the underlying physical logic of this theory.

The common definition of matter states that it is any substance that occupies space and has mass. It follows then, without entering the realm of quantum mechanics, that two pieces of matter cannot occupy the same place at the same time. When an object does occupy a space it excludes other pieces of matter from occupying the same space. It would be a ‘private’ good as distinct from public good.

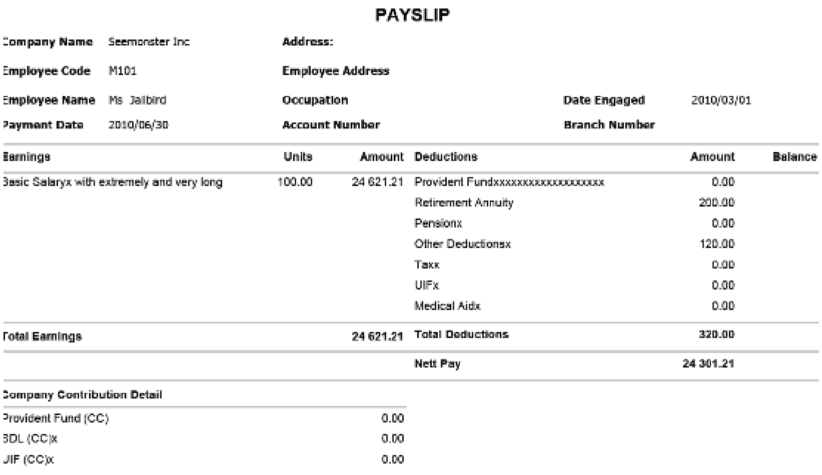
This same principle can be applied to what are commonly considered public goods such as roads. Because road space is not matter it does not fit the definition of occupying space or having mass. Roads have thus been assumed to be public goods since matter cannot be excluded from occupying it. In fact this may be more a matter of convenience than theory – it may be too difficult or too costly to attempt to preclude use of road space.

More specifically, the issue behind the public good assumption may be the inability of road providers to identify or separate vehicles at an optimal rate. An example of identification and separation is tolling where a physical gate is used to prevent use of a road unless a charge is paid. The approach of a physical gate was necessary because of an absence of direct links from the financial sector to the toll plaza – many transactions were in cash.



Top: This scene from the Godfather shows the old approach to tolling – payment from cash in the hand. Sometimes the costs are unexpectedly high! (Singh 2013)

Bottom: People received their wages in hand via physical pay packets. (The Guardian 2008)



PAYSLIP

Company Name	Seemonster Inc	Address:			
Employee Code	M101	Employee Address			
Employee Name	Ms Jailbird	Occupation		Date Engaged	2010/03/01
Payment Date	2010/06/30	Account Number		Branch Number	

Earnings	Units	Amount	Deductions	Amount	Balance
Basic Salaryx with extremely and very long	100.00	24 621.21	Provident Fundxxxxxxxxxxxxxxxxxxx	0.00	
			Retirement Annuity	200.00	
			Pensionx	0.00	
			Other Deductionsx	120.00	
			Taxx	0.00	
			UIFx	0.00	
			Medical Aidx	0.00	
Total Earnings		24 621.21	Total Deductions	320.00	
			Nett Pay	24 301.21	

Company Contribution Detail	
Provident Fund (CC)	0.00
SDL (CC)x	0.00
UIF (CC)x	0.00

Top: The advent of electronic devices allows wages to be paid electronically and tolls to be deducted without a physical barrier. (Stevens 2009)

Bottom: How wages are received today – straight into banks.

Engineering developments - the development of various technologies - has raised the potential to provide more accurate pricing opportunities, by increasing the availability of information. Importantly this allows road providers to more accurately measure and account for maintenance costs and (negative) externalities. It is possible that, within the foreseeable future, the well-established assumption that roads are public goods will be challenged with implications for views on the optimal pricing and provision of roads.

This paper attempts to fuse some concepts of engineering and economics by using observations from transport with potential long term applications to transport policy.

Public and Private Good Pricing

As stated, public goods are defined by two primary characteristics. They are non-excludable, meaning that the use of the good by one person does not preclude anyone else from using the good, and non-rival, meaning the use of one good by one person does not diminish the utility of another person consuming the good (Cowan 2002, Kaul 2000). A lighthouse is the classic example of a public good.

A lighthouse is the classic example of a public good.

The accessing of information or knowledge, such as news, is a public good. It is non-excludable, since one person's accessing of the news does not prevent anyone else from gaining the same information, and non-rival, because one person's reading of the news does not reduce the amount of information that is available to another person. It would follow that the definition of a private good is a good that is excludable and rival. Private goods are more commonly found, with examples including clothing and food.

The public goods problem is underproduction. With the difficulty of levying charges, financing public goods can largely rely on taxation. With tax collections under pressure, there are strong reasons to seek to charge directly for all goods. In transport the most obvious issues relate to the use of roads.

Unsurprisingly the pricing of private and public goods differ. In business terms, private goods are typically priced based on a minimum of their input costs, that is the sum of the costs of goods (or services) required to make the final good. For instance, the selling of a piece of clothing may require the seller to account for the cost of fabric used, labour costs and any additional premiums such as branding or the cost of selling and marketing the product.

Private goods are also priced with a profit in mind and hence the selling price may be much more than the cost of production. In economic terms, the price of private goods, or equilibrium price, is determined by the forces of demand and supply (in a market economy). This is found when the price that suppliers are willing to sell at matches the price at which buyers are willing to buy. In essence, pricing helps limit demand to suitable level where suppliers do not over- or under-supply their goods.

The mechanics behind private good pricing have inherent links to the managing and exercising of property rights. For private goods, property rights cover (1) the right to choose the use of the good, (2) the right to earn income from the good, and (3) the right to exchange the good based on a mutual agreement (Alchian 2008). In the case of roads, the ability to implement the second attribute has been limited, mostly due to the infeasibility of rolling out the appropriate technology – it would require providers to identify which vehicles are utilising the road and to enforce a separation between vehicles.

There have long been attempts to charge for public goods. These attempts usually relied on a physical barrier. A well-known example is a fence-entry system to a sporting stadium.

ANZ Stadium: an example of a fence-entry system (Destination NSW 2012)

Foxtel: an example of where electronic technology and non-physical barriers lead to exclusion (Foxtel 2013)

More recently, the advent of information and electronic technology has allowed for non-physical barriers – such as the use of codes to gain access to entertainment.

Compared with private goods, the pricing of public goods is not usually determined by market forces. This is largely due to the fact that public goods are provided by government since the provision of the good by one entity is substantially more efficient than the provision of the good more multiple firms[1] (Productivity Commission 2006). However,

[1] Increased efficiency implies that the establishment of technologies or infrastructure to exclude consumption of a good is very costly, costs which can only be balanced by government revenues.

exercise of monopoly power over consumers (other than by under-provision) is relatively unlikely since governments do not necessarily operate for a profit. A more likely pricing structure would be to charge nothing for usage, as is the case with national defence, parks or roads[2].

However by not charging a price for usage, governments face a funding problem[3] especially if demand increases which it well might if consumers see the services as being free.

Governments are in the unique position to use taxes to fund public goods but this generates additional issues such as limited investment signals to private entities and the potential for poor resource allocation. This problem could occur in the provision of roads, as will be discussed in later sections. Finding an appropriate pricing structure for public goods is in the interests of governments in order to attract private investment and improve resource distribution.

Matter, Information and Transaction Costing

In engineering terms, all matter has at least some form of information attached to it. This may range from written descriptions to visual images. For businesses selling objects, price is a key gauge for prospective buyers to see whether the good is beyond their willingness to pay. In general, by using information, markets are able to operate more efficiently – for instance, if a business did not advertise its selling price, a long bargaining process could ensue if a customer wishes to purchase it.

The concept of transaction costing, developed by Ronald Coase (1937) outlines that there is a disparity between the cost of obtaining a good or service and its selling price. Coase proposed that there were additional costs to buyers, such as information and search costs among others. For example, if a person is wishing to buy a good that has many suppliers around the world, the person would incur significant personal cost (such as in time expended in searching) if he or she were to investigate every single alternative. Instead Coase's transaction costing principle implies a person is more inclined to forgo a potentially more valuable or worthwhile good in order to limit their transaction cost of searching for information.

Coase's ideas were developed with respect to the purchase and sale of goods and services. Could they be extended to the costs of excluding consumption such as those of fencing near

---

[2] In saying governments place *no* charge for usage if public goods, they may place other fees such as registration fees, taxes or excises or tolls (in the case of roads) to help fund and maintain these goods.

[3] In addition to posing funding constraints with respect to public goods, there are economic implications such as the free rider effect. This is where users of a good do not pay their share and can lead to a situation where valuable goods, which people would otherwise pay for, are not being produced. Although it is highly unlikely governments will refuse to construct new roads in the future, the free rider effect emphasises the mentality towards the treatment and valuation of roads by individuals.

football fields, or of barriers and ticket collecting in public transport? Further, if the costs of exclusion fall, do Coase's ideas imply that some things considered public goods, because of the impracticality of exclusion, become increasingly like private goods?

So how does this relate to public goods and the provision of information? Simply put, the more cheaply that information is made available, the lower the transaction cost of exclusion. Two types of information may be relevant to exclusion costs; detection, analysis/enforcement. Advances in (remote) sensing, vehicle separation and processing of large amounts of data may reduce these costs.

For roads, as the cost of acquiring and using information regarding congestion on a particular road falls, then the cost of excluding additional vehicles from that route is lessened.

Theories of Public Goods and Exclusion: Engineering and Economics

As mentioned before, engineering principles are based around the existence of matter. Matter constitutes all objects which have mass and occupy space. By nature of physical exclusion, the notion of 'public' goods from an engineering standpoint cannot exist.

Economics is not, however, restricted to the existence of physical goods. In fact, much economic theory is based not only around goods themselves but the benefits (or costs) they bring; this is brought about by how individuals or firms utilise the goods at their disposal. Services and externalities are examples of the consequences goods can bring.

Exclusion requires the prevention of usage by at least one person from a good. Usually it was used for goods that experienced significant demand, mostly because it was most economically viable in these circumstances. In transport, exclusion took place by placing physical or hardware barriers, such as fences or gates. For trains and other types of mass transit, ticket barriers were used; for roads, toll plazas with boom gates ensured drivers paid the toll.

"In transport, exclusion took place by placing physical or hardware barriers [including] ticket barriers [and] toll plazas with boom gates"

In recent times though, electronic or software barriers have allowed methods in exclusion to change. Introduction of electronic payments and banking has facilitated this.

For instance, television signals have typically been considered as a public good (assuming everyone has a television and antenna) – at least during the early days of television, it would have been difficult to prevent someone from watching a particular program. However the development of electronic paying devices has seen the rise in pay television networks, and consequently it is appropriate to treat this form of media as a private good.

Roads as Public Goods

(ABC News 2010)

Roads have often been considered as public goods and it is, at first glance, a reasonable assumption to make. Roads are non-excludable because if one person begins driving on a road, another person is not prevented from also driving on it (of course assuming the additional person has a vehicle to travel in, sufficient fuel, etc.). They are also non-rival because one person driving on a, say, scenic route does not reduce a driver behind that person from enjoying the route. These assumptions stay true in most cases, most notably in free flowing traffic.

The only condition where these assumptions fail, especially the non-excludability principle, has been identified when a road becomes congested (Darganzo 1996). In this situation, if a road is blocked with traffic and no vehicles are moving, an additional person is precluded from entering the congested road space because there is no road for it to drive on! To an extent, the non-rival attribute also collapses since there is likely to be a loss in utility (in the form of time savings and personal satisfaction) if one is stuck in a traffic jam as opposed to being on a traffic-free road. Therefore a situation arises where the original assumption that roads are public goods does not hold.

"Congestion occurs when the demand for road space by vehicles travelling on the road exceeds the available road space"

Yet roads themselves have limited supply, namely the actual road space which is divided into lanes. Congestion occurs when the demand for this road space by vehicles travelling on the road exceeds the available road space. When traffic is heavy, vehicles are more inclined to travel slowly in order to accommodate vehicles changing lanes or additional traffic. The impetus to respond to road congestion in Australia is present: the State of Australian Cities Report (2010, p.53) warns of a $20.4bn cost by 2020 if congestion is not addressed.

In engineering terms, roads and road space are private goods, even when it is inconvenient for economic systems to treat them in this manner.

There are various public-goods options for governments when trying to tackle road congestion. Such options include increasing supply by building wider roads or more alternative routes, providing non-private vehicle alternatives such as public transport, or setting a charge on road usage through the implementation of tolls or congestion pricing. However technology developments might play a role in employing a cost-effective pricing scheme and this will be the focus of later sections.

As mentioned before, the aim of pricing is to limit demand so that suppliers do not over- or under-supply their goods. For roads, pricing relates to the valuation of the road by road users. Since they have typically been considered as a public good though, roads have often been considered as an undervalued good. 'Exclusive' roads have already been utilised, albeit on a relatively small scale. These would include toll roads whereby users must pay an access fee. The economics behind this thinking is to do with the valuation of the toll road by individual users – that is, the cost-benefit analysis between time, monetary and additional utility gains (or losses). Moreover the use of special transit lanes such as high occupancy, bus and cycle lanes (monitored by cameras at times) is another example of 'exclusive' roads.

In addition to these initiatives, road freight[4] pricing is also being utilised. In Australia, charges have been primarily based on, but not limited to, a Pay-As-You-Go (PAYGO) system where the cost of road service provision is estimated from the average of expenditure on roads from the three most recent budgets (Australasian Railway Association 2010, Productivity Commission 2006) and prices charged to heavy vehicles (used in freight transportation) are determined from these costs. However this can lead to skewness in the amount of payments charged if road expenditure changes widely between budgets making the PAYGO system less effective in accounting for road costs from particular vehicle types[5].

However, the most important factor for 'freight pricing' is very practical and based in engineering. A truck is easily detected from its shape, and excluded from road use. People can usually distinguish between a truck and a car. This also suggests why there is a difficulty in 'pricing' for all freight movements including that freight carried in vans/cars – it is not easy to discern which car-shaped van is carrying light freight and which van is carrying passengers or nothing!

[4] Freight is the term used to describe the transportation of goods by container or non-container traffic. This includes the bulk goods such as commodities including grain, coal, iron ore and fuel, and non-bulk goods which are usually processed products such as food, clothing and furniture (Australian Competition and Consumer Commission 2013).

[5] It should be noted that the vehicles that contribute the most damage to roads are typically heavy vehicles (Viton 2011, Hjort, Haraldsson and Jansen 2008). Therefore it would be appropriate that any pricing initiative is targeted towards the movement of freight, and not so much passenger vehicles.

Technology in the Pricing of Public Goods

A reason for road pricing has not extending beyond tolling and road freight charges is that the implementation and maintenance of the infrastructure to monitor, collect and enforce these charges, such as through cameras, sensors and computerised systems have been very expensive in the past. Hence such technology is only deployed on the most highly used roads.

Iit has been relatively impractical to install technology that would monitor and enforce the property rights of road providers (as mentioned earlier). However it has been recognised for many years that the opportunity to price roads is there if technology develops to a cost-effective level.

For the case of roads, there is already a lot of technology used in the *management* of the infrastructure network. On the smaller scale, simple detection techniques such as induction loops coupled with the electrical systems that function traffic lights help conduct traffic at busy intersections. Cameras that target speed and the missing of red lights or act as surveillance over busy segments of road serve as safety enforcements and traffic management tools. Then on a broader level, traffic management centres which use real time camera feeds, manipulate traffic flow using complex computer programs (such as the Sydney Coordinated Adaptive Traffic System) and warn drivers through electronic signage are examples of how technology has already aided in improving the functionality of the road network.

Research has already been conducted into the pricing of road freight via mass-distance-based and location-based charges and the use of weigh-in-motion technology (WIM)[6], where the mass of a vehicle is determined as it passes a particular section of road.

Apart from infrastructure based technology, there also is a new wave of in-vehicle technology including sensors such as odometers, or hubodometers, telematics[7]/telemetrics and block boxes on vehicles. These might be compared with traditional approaches such as log books and weighing. However, some years ago the Productivity Commission (2006) concluded these may not help road providers know specifically *which* roads are being utilised more by passenger and freight vehicles and therefore there would still be difficulty in determining which roads require greater funding (proportionate to their usage).

Location-based charges could be assisted by global positioning systems (GPS) in conjunction with telematics. This would enable road providers to formulate a usage profile for any

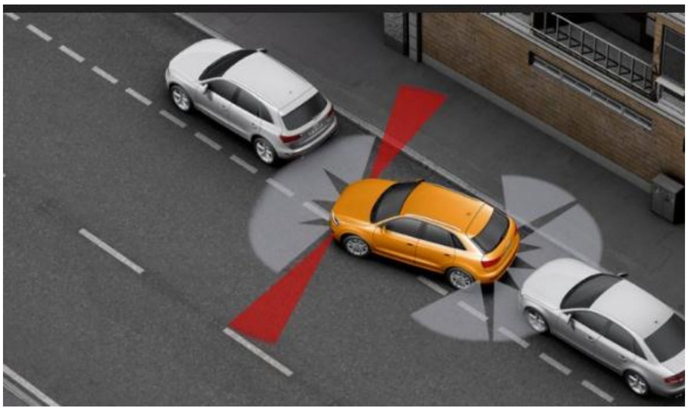
[6] WIM is already being utilised in Australia. However, numerous variations of the technology are being employed with mixed success.

[7] Telematics is the term given to electronic devices which combine both communication and the conveyance of information. Devices that may be considered as telematics include global positioning or navigation systems, or remote control or mobile technologies.

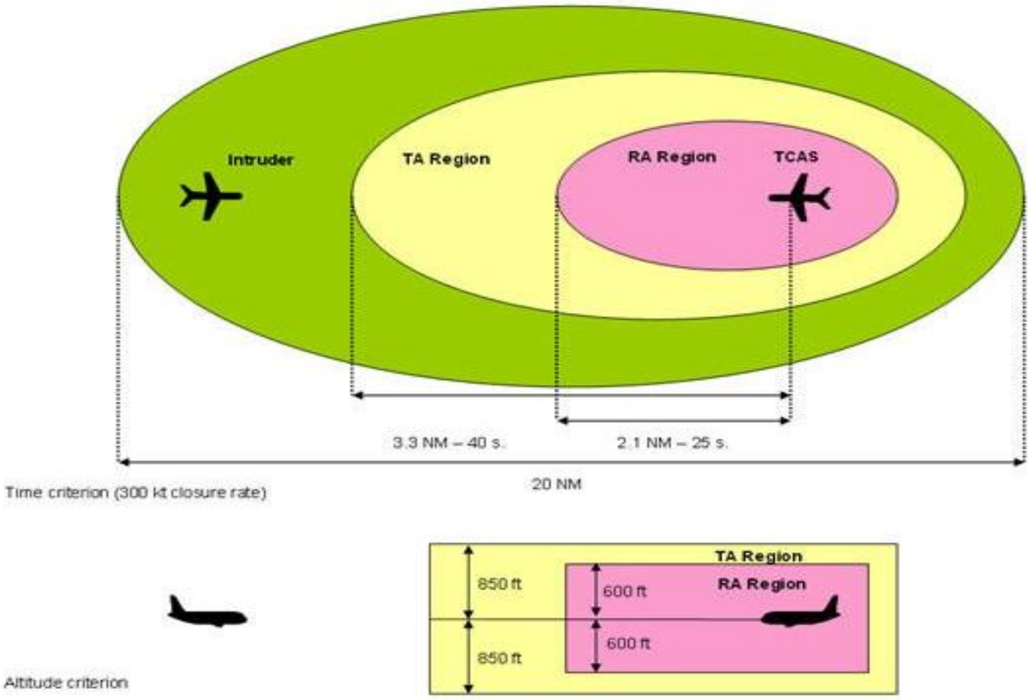
particular road outlining the types of vehicles that use it as well as the volume of these vehicles at various points during the day. Technological advancements especially with respect to mobile communications would be most useful in this application and help governments model and plan for future transport movements when identifying new suburbs or commercial centres.

Delivery of all this technology into all vehicles, especially retrofitting, would face problems. The program would be expensive at first and would require long term foresight and planning. Not only would the costs of implementing these technologies in vehicles be high, but also there are costs of providing, upgrading and unifying the infrastructure[8] around the country.

At the other end of the spectrum, there is interest in the emergence of automatic road vehicle control technologies such as radars, hazard avoidance and parking assistance.



Above: Rear parking technology in cars. Below: A pictorial demonstration of how TCAS operates.



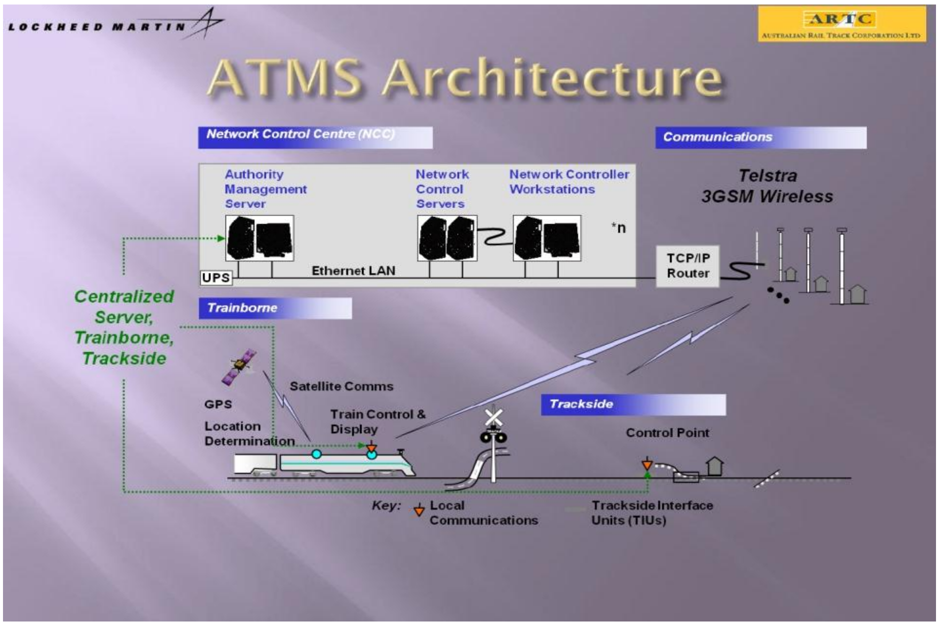
[8] Such infrastructure may include mass detection systems like WIM, various sensors and detectors both road side and on vehicles to measure distance, mass and/or location, and camera and computer systems to implement and monitor the pricing scheme.

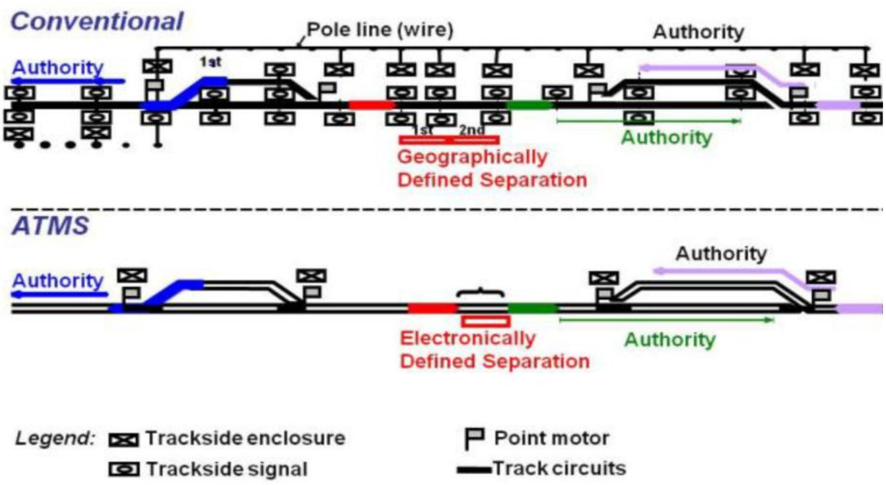
In parking assistance, avoidance of collision is not by the operator but is electronic - by vehicles sensors and controls. These automatically separate vehicles on road space and allow for vehicle identification.

This type of technology is used in other transport industries for which there is no 'public goods' assumption, or view as to wholesale funding from taxes. An example is the Traffic Collision Avoidance System (TCAS) of aircraft collision avoidance using electronics. The diagrams above shows clear analogies between this system and parking assist.

Also of interest is train control and signalling. Traditionally use of rail track was considered to be within the field of private goods because fixed line-side signals kept trains physically apart. That is, trains occupied clearly and discrete geographic segments of track with various forms of enforcement.

However, automatic train protection systems modify this. For example the Advanced Train Management System (ATMS) being deployed by Australian Rail Track Corporation uses satellites to electronically separate trains with electronic enforcement of separation. The basic architecture and comparison with conventional signalling is shown at the right.





The significance is that rail access prices are set for when a train occupies a track as if it continues to be among the class of private goods. There has been no consideration of moving away from rail access prices because separation may be electronic rather than geographic. ATP uses a technique of rail vehicle separation that is similar to that emerging for road vehicles.

Transport policy in many countries has been confounded by different approaches to the charging of roads and railway infrastructure. This is seen as especially problematic where the modes compete – major urban commuting and line haul freight.

There is some degree of technological convergence between road and rail technologies via electronics. Real-time information from sensors, detectors and cameras enables information about the respective transport networks to be displayed and relayed to central processing areas with access to electronic based finances.

By providing and analysing more information, these new technologies may challenge conceptions as to the extent of public goods attributes within transport. Such a challenge may have implications for pricing, economic efficiency, congestion, amenity and government finances.

Possibly technological convergence should be accompanied by efforts to achieve convergence in charging policy.

The facts behind the old approach to roads may be changing. Should we change our minds too?

Conclusion and Recommendation

This paper shows the value of a multi-disciplinary approach to transport issues – such as roads - in the public goods context. The question of the impact of modern technologies on the theory and application of public goods is worthy of further study in an engineering and commerce framework.

References

Alchian, A. 2008, *Property Rights*, Concise Encyclopedia of Economics, 2nd ed., viewed 13 February 2013, <http://www.econlib.org/library/Enc/PropertyRights.html>

American Association of State Highway and Transportation Officials 2007, *America's Freight Challenge*, Washington, D.C., viewed 6 February 2013, <http://www.transportation1.org/tif3report/driving.html>

Australasian Railway Association 2010, *Road Pricing Reforms in Australia*, Canberra.

Australian Consumer and Compeitition Commission 2013, *Definition of Terms*, Sydney, viewed 11 February 2013, <http://www.accc.gov.au/content/index.phtml/itemId/54229>

Austroads 2000, *Weigh-In-Motion Technology*, Sydney.

Buchanan, J.M. 1999, *The Demand and Supply of Public Goods*, vol. 5, Liberty Fund, Inc., Indianapolis, Indiana, viewed 4 February 2013, <http://www.econlib.org/library/Buchanan/buchCv5Cover.html>

Cowan, T. 2002, *Public Goods and Externalities*, Concise Encyclopedia of Economics, 1st ed., viewed 4 February 2013, <http://www.econlib.org/library/Enc1/PublicGoodsandExternalities.html>

Darganzo, C.F. 1996, 'The Nature of Freeway Gridlock and How to Prevent It' in Lesort, J.P., *Transportation and Traffic Theory*, Pergamon, Lyon, pp. 629-646.

Hjort, M., Haraldsson, M. and Jansen, J.M. 2008, *Road Wear from Heavy Vehicles – an overview*, Nordiska Vägtekniska Förbundet Committee Vehicles and Transports, Borlänge, August, viewed 8 February 2013, <http://www.nvfnorden.org/lisalib/getfile.aspx?itemid=261>

Infrastructure Australia 2010, *State of Australian Cities 2010*, Major Cities Unit, Infrastructure Australia, Canberra.

Kaul, I. 2000, 'What is a public good?', *Le Monde diplomatique*, June, Paris, viewed 5 February 2013, <http://mondediplo.com/2000/06/15publicgood>

Lane, P. 2012, 'A sense of place', *The Economist*, London, 27 October, viewed 9 February 2013, <http://www.economist.com/news/special-report/21565007-geography-matters-much-ever-despite-digital-revolution-says-patrick-lane >

Productivity Commission 2006, *Road and Rail Freight Infrastructure Pricing*, Report no. 41, Canberra, December.

Pan, Q., Gordon, P., Moore II, J. and Richardson, H.W. 2011, 'Modeling the Effects of Peak-Load Pricing on Metropolitan Network and Activities', *The Transportation Research Board 90th Annual Meeting*, Washington, D.C., <http://www-bcf.usc.edu/~pgordon/pdf/TRB_SCPM_PEAK-LOAD_PRICING_FINAL_REPORT_JAN_13_2011.pdf>

Riley, G. 2006, *Public Goods*, Tutor2u, Eton, viewed 1 February 2013, <http://www.tutor2u.net/economics/revision-notes/a2-micro-public-goods.html>

Singh, K. 2013, '1914 Lincoln continental coupe and customs limousine from 'The Godfather' goes for sale', *Bornrich*, viewed 14 February 2013, <http://www.bornrich.com/1941-lincoln-continental-coup-custom-limousine-godfather-sale.html>

Stevens, M. 2009, 'RTA NSW Exploring Wider Use For E-Toll System', *The Motor Report*, viewed 14 February 2013, <http://www.guardian.co.uk/money/blog/2008/jan/14/week>

Sydney Coordinated Adaptive Traffic System 2013, *Sydney Coordinated Adaptive Traffic System*, Sydney, viewed 11 February 2013, <http://www.scats.com.au/>

The Guardian 2008, *Money Blog*, London, viewed 14 February 2013, <http://www.guardian.co.uk/money/blog/2008/jan/14/week>

Viton, P.A. 2011, *Understanding Road Wear and its Causes*, Ohio State University, viewed 7 February 2013, <http://facweb.knowlton.ohio-state.edu/pviton/courses2/crp776/776-roads-beam.pdf>

World Bank 2011, *Railway Reform: Toolkit for Improving Rail Sector Performance*, Washington, June.