HIGHWAYS AND PRIVATE MODES OF TRANSPORTATION

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Summary

This article begins by defining highways and paths, pointing out that they satisfy the majority of human needs for transport. It then considers their planning, design, construction, operation, and maintenance. Their legal, economic, and social bases are also explained, and methods of funding their construction and maintenance are outlined. The article also discusses the various modes of private transport that use highways and long-distance paths. These include their use by pedestrians, bicycles, motorcycles, cars, taxis, and trucks. A *private* mode of transportation is one in which the vehicles are individually owned and operated. An objective review of driver characteristics and traffic behavior is given. The emerging field of intelligent transport systems is also discussed.

1. Highways and Paths

Most human mobility is satisfied by movement on foot or by independent wheeled vehicles. These movements commonly take place along prepared surfaces, ranging in scale from footpaths to motorways. This article concerns *highways* and long-distance paths: primarily, these are major routes linking significant origins and destinations for travelers. Highways are sometimes also called *arterial roads*, and their most advanced form is the *motorway* (or *freeway*). Users can only enter or leave a motorway via high-speed ramps. All cross-traffic is eliminated, and the motorway's curves and slopes can be safely negotiated at high speeds. The article does not concern streets and local roads, which primarily provide access to individual properties.

Paths have been a part of human society since the retreat of glaciation in about 10 000 BC. The development of roads followed the invention of the wheel, and dates from about 4000 BC.

2. Highway Law

The strip of land required for a highway is sometimes called the *right of way*. This term stems from the legal origins of modern highway in the laws of the kingdoms that followed the decline of the Roman Empire. Property then was largely in the hands of the king and his followers, but to ensure that the passage of the king and his armies was unimpeded he was granted the right to travel where he pleased. In other words, he had the "right of way" throughout the countryside, and no one could impede him. Of course, it was easiest to travel on roads, and these were kept in reasonable repair in order to keep the traveling king and his followers from destroying profitable pasture.

This concept of universal right of way came to be extended to all travelers. It was a very democratic concept for feudal times. The right to travel on roads without obstruction has continued in both law and common practice to the present day. It is the prime legal characteristic of the road, and has ensured its continued development as an integral part of society.

The road normally exists within a planning reservation, and an alternative name for the land used by a highway is a road *reservation*. Planning well ahead allows the land required for a highway to be obtained with minimal disruption. Long-term reservation of land can be counter-productive, however, by causing planning blight in an area.

The ownership of land abutting a highway is also important, as the type of roadside access to a highway can dramatically affect its traffic capacity, operating speed, and safety. This is most dramatically seen in the higher crash rates seen on motorways compared with other road types. In law, the owner of a property abutting a roadway usually has access to the road immediately adjacent to the property, but not to every part of the roadway. In addition, the public's right of way—the right of public passage—usually takes precedence over the rights of the abutting property owner. These two principles allow effective control of access to public roads. The extreme case is the *motorway*, where direct access from all adjacent properties is denied.

3. Highway Planning

Highways make travel more attractive than it would be otherwise. Hence, a new or improved highway will generate new traffic. Most highways significantly enhance the wealth of the community, an effect that is seen most directly in increased land values. However, the highway also competes with other land-uses and creates social severance within a community, while it and its users consume resources and degrade the environment. Thus highway developments are not universally welcomed.

A good highway produces the following key direct benefits:

- it minimizes vehicle operating costs,
- it minimizes overall travel time,
- it reduces the variability in travel time,
- it reduces road crashes, and
- by reducing stop/start traffic, it reduces emissions and fuel consumption.

These benefits can be eroded, however, by extra traffic attracted to a new or improved highway.

The creation of a new highway can cause much short-term disruption as a result of land acquisition, property demolition, construction, community severance, and the establishment of a new set of local travel and traffic patterns. Planners therefore tend to provide facilities to meet anticipated future travel demand, to avoid having to cause frequent further disruption whilst upgrading a facility.

The highway occupies a long and relatively narrow strip of land. Its width must be sufficient to accommodate the number of lanes required by the traffic flow, road shoulders to provide for stationary and straying vehicles, pieces of flat land (verges) permitting vehicles to run off the pavement without damage, and other land that might be needed for intersections, toll plazas, landscaping, rest areas, noise amelioration zones, and/or cuttings and embankments. Thus the width required might vary from 1 m for a narrow footpath to 100 m or more for a motorway. Most highways are of widths beyond the immediate human scale, and therefore create significant social and visual barriers.

The landscaping beside the road is an important part of a modern highway. It must reinforce the drivers' expectation of the road alignment. Often the strip of land beside a highway contains the surviving remnants of an area's native flora and fauna.

The siting of access points from properties or from the existing road system will often pose problems, and will depend partly on the highway's classification. The situation may range from that of a motorway with full access control, to an arterial road with service streets, through to a residential street with no access limitations: the first two road types are clearly highways. Access control is one of the most important planning and design features affecting a road's safety performance.

A common practical constraint on the use of a highway is the capacity of the facilities allowing vehicles to enter and leave the highway system. For this reason, the highway has been cynically described as the shortest route between two traffic jams.

Congestion is a key issue for modern highways. On a large scale, it is a result of demand (actual traffic) exceeding supply (traffic capacity). However, in urban areas operating experience shows that the majority of congestion arises from local incidents (breakdowns, illegal parking) that reduce capacity. Technically, congestion is said to arise when delays continue to lengthen. This subtlety of definition is necessary as delays are inevitable in any highway system with same-grade intersections. Often congestion can be allowed to "manage itself," with travel times increasing until some travelers begin using travel alternatives. It can also be managed positively by metering the traffic that enters the system, and limiting the number of vehicles that can join a highway by:

- allowing an entrance queue to form,
- charging for entry, or
- requiring users to pay tolls for using a length of the highway.

These measures may only be needed at peak periods of the day.

4. Highway Design

In most countries, individual highways form elements of an interconnected network of roads. Knowing how many people will travel on a particular highway is a matter to be considered by transport planners (see *Transportation Engineering*). Travel demand will typically have morning and evening peaks in opposite directions along the highway.

Once the number of travelers likely to use a highway in some future design year (the demand) is known, the number of lanes required can be estimated by dividing the demand by the capacity of a single lane. Typical lane traffic capacities range from about 3500 persons per hour for a footpath to 2500 vehicles per hour per lane on a high-standard motorway. In most developed countries, car occupancy averages about 1.2 people per car. Traffic capacity depends on car-following behavior, and this in turn depends heavily on how a driver reacts to the behavior—particularly the braking—of the vehicle ahead. Improvements in inter-vehicle communications via intelligent transport systems could therefore lead to major improvements in traffic capacity.

The number of lanes required will partly determine the width of the highway. Whether the lanes in each direction need to be separated by a central median, creating a divided roadway (or carriageway), will depend on the speed and frequency of oncoming vehicles. Broadly, this is the case if the anticipated traffic exceeds 10,000 vehicles per day. Motorways with controlled access are typically considered if the anticipated traffic exceeds 30,000 vehicles per day.

Cars are usually up to 2 m wide, and trucks up to 2.5 m wide. Road shoulders are typically 3 m wide. Lane widths on highways vary from 3 m to 3.7 m. The wider lane width is needed if high lane traffic capacity is needed. Safety requirements could mean that median and/or roadside verges, if they are needed, are 8 m wide. A busy urban motorway carrying 30,000 vehicles per day will require at least four traffic lanes, and so could have two 12 m carriageways and be at least 50 m wide (2[8+3+7+3+4]).

Vehicles traveling at high speed also need very gentle curves. For example, a 1 km horizontal radius is required for a design speed of 130 km h^{-1}. A key factor here is the speed for which the highway is designed. If the design speed is only 60 km h^{-1}, then the minimum radius is only 150 m. As this speed is far below the capacity of the modern car, it would only be used for highways in mountainous terrains. A similar minimum radius of about 500 m is required for vertical curves at high speed in order to prevent uncomfortable vertical accelerations. These gentle curves are also needed to give drivers sufficient forward sight distance to see hazards ahead in sufficient time to avoid them safely. Long straight lengths of highway are also undesirable as they encourage driver fatigue: perhaps a third of highway fatalities are caused by loss of driver attention. Finally, on two-way highways it is necessary to provide sufficient sight distance and lane space for vehicle to overtake slow vehicles impeding their progress safely. All these factors make it difficult to fit a modern highway unobtrusively into an existing landscape.

Intersections are important elements of a highway. Intersections on major highways must be designed to ensure that there are no crossing traffic flows. This results in the large cloverleaf and diamond interchanges commonly seen on motorway-to-motorway connections. These are very expensive to create, and the need for large curve radii means that they require a large amount of land. Where the highway meets the ordinary road and street system, long ramps are needed at entrances and exits to allow vehicles to accommodate the great changes of operating speed between the two classes of facility. Lightly trafficked highways used intersections (or junctions) controlled by traffic signals, stop and give way (yield) signs, and/or road rules determining priority.

All the above factors, combined with the variations encountered in any local terrain, mean that there are usually a variety of highway solutions that will meet demand for a new highway. These options must be explored technically, financially, environmentally, and socially. The process will include a range of informal and formal public consultations, and approvals from authorities charged with ensuring that environmental and social controls are met.

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Biographical Sketch

Dr. Max Lay is a Principal of Sinclair Knight Merz, and has been Independent Reviewer for the Melbourne City Link Project from 1996 to the present. In August 1999, the Institution of Engineers, Australia, named him Victorian Professional Engineer of the Year. On 12 April 2000, the Australian Road Research Board named its library the M.G. Lay Library to honor his "passion for the dissemination of high-quality professional information." He was Director of Major Projects with VicRoads from 1993 to 1996, Director of Quality and Technical Resources from 1988 to 1993, Executive Director of the Australian Road Research Board from 1975 to 1988, Engineering Research Manager at BHP from 1968 to 1975, and Engineer-in-Charge, Major Steel Structures, SECV from 1966 to 68. In 1988 he became a Professorial Associate of Melbourne University, and in 2000 was made a Professorial Fellow. He has been appointed an Honorary Fellow of the Institution of Engineers, Australia. He is a Fellow of the Academy of Technological Sciences and of the Chartered Institute of Transport. He is a Life Member of the American Society of Civil Engineers, a Member of the Australian Institute of Company Directors, and a Member of the Chartered Institute of Arbitrators. He has been a director of RACV in Victoria since 1985 and Deputy Chairman from 1997 to 1999: he became Chairman in July 1999, and became President and Chairman in 2000. He has been Vice-President and became President of the Australian Automobile Association in 2000. He was President of the Royal Society of Victoria in 1995 and 1996, and was a Councilor for 20 years from 1982 to 2002. He was founder of the Intelligent Transport Society of Australia, and served on the World Board of such societies. In 1999–2001 Dr Lay was Chairman of Intelematics Australia, a manufacturer of ITS equipment for motorcars adopted as "original equipment" in current General Motors' cars. He remains a director of the company. Dr Lay was educated at Melbourne and Lehigh University and holds the degrees of B.C.E. (hons), M.Eng.Sci. (hons), and Ph.D. He has been awarded the Monash Prize of the Victoria Division of the Institution of Engineers, Australia (IEAust), the Moisseif Medal of the ASCE, the Warren Medal of the IEAust, and the Transport Medal of the IEAust. He has authored the following books on roads: *Source Book for Australian Roads* (3 editions); *Handbook of Road Technology* (2 volumes, 3 editions); *History of Australian Roads*; *Ways of the World*, a world history of roads, bridges and cars (2 printings, plus a German edition); *Encyclopedia Britannica* entry on roads; and *Australian Encyclopedia* entry on roads. He has also authored over 700 publications on a wide range of topics, and has just written a soon-to-be-published history of metropolitan Melbourne's streets and roads called *Melbourne Miles*. Dr Lay and his wife, Margaret, have four children and nine grandchildren and live in Melbourne and Ocean Grove.