REVIEW OF THE MAJOR FACTORS INFLUENCING ROAD DEVELOPMENT DURING THE XXTH CENTURY

Dr M. G. Lay, AM
Director Royal Automobile Club of Victoria & ConnectEast
mmlay@bigpond.net.au

ABSTRACT

Taking an international rather than a regional perspective, the paper reviews the major factors which have influenced road system development during the XXth century. Whilst much of this development might be attributed to the introduction and subsequent widespread use of motorised vehicles, the paper discusses a range of other social, cultural and technical factors which also played significant roles. It begins by examining the inherited momentum of the XIXth century, establishes road-related social conditions and technological development at the beginning of the XXth century, and then explores subsequent changes. It focuses on overall trends but also nominates specific events and iconic occasions. The paper observes that the car powered by internal-combustion (IC) engines burst on the scene like a new puppy, with limitless energy and with little care for the consequences of its leaps and bounds. The paper concludes that the XXth century has put the IC engine to magnificent and extensive use and that, after a century, the current generation have learnt how to civilise the car and the truck, although many of these lessons have yet to be put into universal practice.

1. SETTING THE SCENE

The history of a period cannot properly be told by beginning on the first day of that period. As Ben Johnson said at the start of the XVIIth century “The present state of things is the consequence of the past; and it is natural to enquire into the sources of the good we enjoy and the evils we suffer.” Let us therefore take his time-tested advice.

As a consequence of European colonial activities and of the Industrial Revolution during XVIIIth century, the need for transport and accessibility grew with increasing rapidity during the following century. More land was being developed, more people were in continual transit, and more freight was being traded. Such changes placed heavy demand on national road systems. Fortunately, and concomitant with the Industrial Revolution, the technology of roadmaking had improved as a consequence of significant technical input from such pavement innovators as Trésaguet, McAdam and Telford. In addition, the power of the Revolution was being usefully applied via the use of explosives, mechanical excavators, stone-crushers and steam-rollers for roadmaking and basecourse compaction.

The Revolution’s power came largely from burning coal and producing steam. The engines needed were large and ponderous. Attempts to use them to provide motive power were rendered futile by the inability of the road system to carry the imposed loads. Steam-powered transport was thus to go its own separate way on specially provided iron rails and ballast. Coal burning also produced a flammable gas: known as “town gas”. It was widely used for street lighting and soon inventors were developing internal-combustion (IC) engines powered by the new gas. The engines were welcomed, but their power-to-weight ratios were still too low to make them useful sources of motive power. Furthermore, coal gas had many drawbacks for lighting, producing a faint flickering flame. Alternatives were needed.

Since Sumerian times, petroleum seepages had been in use for many purposes, but with the Industrial Revolution there were now tools to drill for petroleum and refine it into its various constituents. High-volume refining began in 1865. Initially, the most important product was kerosene which was used for lighting and heating. Two waste products were the light distillate known variously as petrol or gasoline and the heavy-end waste best known as bitumen (or asphaltic cement). A number of German engineers - particularly Otto, Langen, Maybach, Daimler and Benz - seized on the new petrol and took the earlier gas-powered IC engines to a new engineering level. They were also aided by the machining tools produced for cannon makers which had, coincidentally, made it possible to make pistons and cylinders to the precision required by the high rpm IC engines. The power-to-weight ratios of the new IC engines dramatically increased and by 1885 self-powered road vehicles were a practical reality.

Similarly, asphalt (a mix of stone and bitumen) was being used to obtain products for medicines, fuel and waterproofing and, beginning in 1837, French engineers – particularly Léon Malo - were successfully developing asphalt paving in Paris. By 1870 it was a technical if not a commercial reality. By the late 1890s, Richardson in Washington was producing “artificial” asphalt to appropriate technical specifications, by mixing bitumen with quarried stone. Finally, in 1902 Guglielminetti introduced the new technology of bituminous spray-sealing as a dust suppressant on the streets of Monte Carlo.

Steam power had other consequences for our turn-of-the-century scenario. The much-heralded arrival of George Stephenson’s steam-rail hauling Yorkshire coal meant that by 1850 many governments were making major reductions in public expenditure on roads on the basis that rail would meet all their community’s travel needs. At the best, roads would serve to take travellers and freight to and from railway stations. Previously well-maintained arterial roads rapidly sank into rutted and ruinous decay. In many jurisdictions, no new roads were built and few maintained for the entire last half of the XIXth century. In addition, since the beginning of the XIXth century many roads had been developed and enhanced as private toll roads. Such private investment stopped. For instance, there were 61 operating toll gates in Melbourne in 1874 [1]. All were closed by 1878.

Another transport child of the Industrial Revolution was the bicycle, first brought to commercial reality by the Michaux brothers in Paris in 1861. The bicycle introduced the democratic idea of travel for all citizens who then demanded good facilities, free access and, of course, useful road maps and road signs - an inheritance later to be enjoyed by the new motorists. There was a further major spin-off from the bicycle. Since the invention of the wheel some seven millennia earlier, a single pass of a heavily-laden wheel was sufficient to destroy a water-soaked road. The same event still happens today on primitive roads throughout the world. The core reason for this daily catastrophe is that the contact pressure between a solid wheel and a pavement can readily exceed 2 MPa which is three times the pressure between the pavement and a pneumatic truck tyre on a heavily-loaded truck. The pneumatic tyre which brings this gentler ride required vulcanised rubber and was first invented in 1845 but it did not reach practical application until redeveloped by John Dunlop in Northern Ireland in 1888 to meet the growing demands of the bicyclists.

Another factor working at a much broader scale was the “City Beautiful Movement” whose righteous philosophy was that the life and morals of citizens could be elevated by improving their physical surroundings and enhancing their “moral purity and harmonious moral order.” Perhaps initiated by the work of a sequence of Popes who reconstructed and recreated Rome and its avenues, it reached a pinnacle with the work of Baron Hausmann

who in the mid-XIXth century began reconstructed Paris to its current much-admired form (the work was not finished until 1920) – although with military as well as social motives. During the same period John Nash in London was creating such streetscapes as Regent St and Trafalgar Square by applying the principle of “picturesque beauty” [2].

In 1838 a Select Committee in London wrote: “...there were districts in London through which no great thoroughfares passed, and which were wholly occupied by a dense population of the lowest class of persons who, being entirely secluded from observation and influence of better educated neighbours, exhibited a state of moral degradation greatly to be deplored. It was suggested that this lamentable state of affairs would be remedied whenever the great streams of public intercourse could be made to pass through the districts in question. It was also justly contended that the moral condition of these poorer occupants would necessarily be improved by communication with more respectable inhabitants, and that the introduction at the same time of improved habits and a freer circulation of air would tend materially to extirpate those prevalent diseases which not only ravaged the poorer districts in question, but were also dangerous to the adjacent localities.”

The charter was to be carried into the XXth century, particularly via the urban “parkway”. The term originated in Williamsburg, Va., USA, in 1699 where it was applied to roads with wide, grassed verges. The concept was popularized by the development of Central Park, New York, in 1858 by the pioneer landscape architects, Frederick Olmsted and Calvert Vaux. Olmsted's design sank the main transverse traffic roads below ground level and used bridges to carry local surface traffic over these arteries. These surface parkways then crossed over a path network on a separate set of bridges.

2. AS THE CURTAIN RISES

So what do we see as the curtain rises on the XXth century? In wealthy communities such as Paris, London and Washington, street paving with stone setts, wooden blocks, asphalt, and/or concrete had reached the stage where sound, solid and waterproof surfaces could be produced. To our eyes they would be appear neat and walkable, but the macrotexture designed to provide purchase for the shod hooves of the horse would be rougher than today’s pavements. At the other extreme, the microtexture would be inadequate to meet the needs of vehicles travelling faster than a trotting horse. However, we would be most struck by the widespread horse excrement, and occasional horse carcases, lying on the road surface and by the associated muck and stench. The streets would seem most unpleasant places, unless there had been recent passage of a street-cleaning gang. The main noise would be of horses’ hooves and iron-tyred wheels bouncing and scraping along hard road surfaces.

Outside the towns many roads would be unsurfaced and the majority of the surfaced ones would have employed unbound stone surfaces, the better ones built by the methods of McAdam or Telford. Pavement edges would be poorly defined and roadside drains would usually be uncovered, relatively deep and unlined. Pedestrians would share the roads with wheeled traffic. More noticeable to our modern eye would be the many obstacles – trees, stalls, ditches, steps, etc – close to the roadside. The roadside signs that did exist would often require travellers to stop in order to understand their message [3]. Intersections and cross-roads would be frequent and poorly marked. The traffic would be predominantly horse-drawn jigs, cabs, coaches, slow carts and ponderous wagons. In the countryside we would also meet heavily-laden wagons pulled by large teams of oxen and travelling at less

than human walking speed. In the towns, jigs and coaches would reach speeds of up to 20 km/h and present real threats to pedestrians.

There would be the occasional self-powered car and truck. They would be objects of great interest and concern as they scurried about at high speed, scaring both horses and people. The occupants of the cars would clearly be of the upper classes indulging in yet another form of conspicuous consumption. At the beginning of the XXth century the world – with a population of over 1 500 000 000 people - had just 11 000 cars, all produced on a one-by-one basis. The situation was not without concern. Traffic fatalities were continuing to increase and it was becoming clear that animal-powered traffic was almost unsustainable. The streets were clogged and congested and there was just not enough farm-land to breed and feed all the animals needed to service the transport task. The associated pollution was becoming intolerable. The urban world had reached horse capacity. Perhaps more ominously than predictions of unsustainability was the fact that by 1895 popular publications were carrying articles showing that the car was cheaper to operate than the horse.

The problems created by the horse often seemed insurmountable, and the new motorcar was viewed by many as their solution. The following resolution from Britain's 1898 Annual Municipal Engineering Conference illustrates a widespread faith in salvation via the car: “That this Conference of Municipal Engineers assembled in connection with the congress of the Sanitary Institute...is of the opinion that the introduction and use of efficient motor vehicles should be encouraged by county, municipal, urban and other authorities, in view of the fact that the extended use of such vehicles would contribute to the general improvement of the sanitary condition of our streets and towns.” But as the curtain rises on the new century, the most passionate advocates of new and better roads were not the car owners who were still almost entirely the rich and the privileged, nor were they the cowering horse owners. Instead those advocates were the bicyclists who had democratised travel over the previous decade and the independent farmers whose very subsistence relied on ready access between farm and market. Their prelude heralded a new century in which daily travel was both a right and an obligation for every citizen and business and where a normal life was impossible without access to a good system of roads and streets.

Public attitudes were also influenced by steam rail which had by then been around for a half a century. Although far more expensive than the bicycle, rail had introduced people to the importance of travel speed – speed that meant that the next town was not a strange place a daunting day’s journey distant [4]. Karl Marx commented on how the XIXth century railway caused the “*annihilation of space by time*” and cultural historians and sociologists have noted how the dramatic change in travel created whole new forms of consciousness – fertile fields indeed for the users of the new car [5]. But a prime difference between steam rail and the IC car was that initially the car did not need to create its own, dedicated infrastructure [6]. Instead it increasingly consumed existing street- and road-space.

3. THE FIRST DECADES OF THE XXth CENTURY

Roads are for nothing if there are not vehicles to use them. As the century began, the car and the truck were already rapidly making their presence felt. By the end of the XXth century, the fleet had grown at an annual nett rate of over 12% to about 500 million on the world’s roads. The critical feature of this growth was that it changed the role of the IC vehicle from a toy of the wealthy to a daily tool for all people. Of course, there are still large parts of the world where the ordinary people do not have access to a car or truck.

A prime initial concern was with the speed of the new vehicles. Police unsuccessfully pursued careering cars on foot and on bicycle. In 1905, Logan Page – Director of the US Office of Public Roads – perceptively wrote “If we cannot control the speed of motor traffic in the infancy of the motor era, how can we expect to cope with it in the future?” The new vehicles also disturbingly increased the “wear-and-tear” on the old roads. But perhaps the worst of all their initial impacts was the dust they caused. On unsurfaced roads each car created a cloud of all-consuming dust. Similar clouds arose in the cities where citizens soon realised to their displeasure that much of it consisted of powdered horse excrement. Rudolf Diesel, inventor of the truck engine, was also an avid long-distance motorist. In his 1905 diary he describes how he was travelling down an Italian valley and looked back to see an astonishing scene - his car had filled the whole valley with a wondrous white cloud of swirling dust. But let Diesel tell it himself [7]: “What a dust storm we stirred up leaving Italy! Powdery limestone dust lay 50 mm thick on the street. (We) raced through the Piave Valley, and behind us there swelled a colossal cone. This white cone rose in the air and expanded to infinite proportions. The entire Piave Valley was thick with the fog, a white cloud lying over the valley all the way to the mountain ridge. We outraged the pedestrians with gas attack - their faces pulled into a single grimace - and we left them behind in a world without definition, in which the fields and the trees in the distance had all lost their colour to a dry layer of powder.“ There was a desperate search for countermeasures and dust was a key issue at the first PIARC World Road Congress in 1908 [8, 9]. Guglielminetti’s invention of spray sealing arose in just this context. There were also rapid improvements in the plant used for asphalt and concrete paving. Producing a good road surface soon became a matter of finance rather than of engineering.

The Congress’ Compte Rendu [8] also noted that one of the other impacts of the new cars had been to restore roads to their pre-railway level of importance. Thus, a major new event that occurred during this period was the re-invention of the parkway. The initial stages of the Long Island Motor Parkway in New York State were built on private land in 1906 as a single asphalt carriageway, 10 m in width and 10 km long. Its initial purpose was to serve as a motor racecourse for the Vanderbilt Challenge Cup, first run in 1904 catering for motorists as a wealthy elite. However, the rapidly changing market led to it being opened to the public in 1908 as a toll road for cars only. Construction continued and by 1910 some 80 km were available for public toll use. It was the first public road to eliminate intersections and the first to employ banking on curves, a provision that had not been needed in the low speed pre-car days. The road was not successful economically and its sharp curves led to its waning popularity. Nevertheless, it operated as a toll facility until 1937. Of itself, it had little impact, but it was a forerunner of major future developments.

A core new concept introduced in the parkways and subsequent motorways was that adjoining land-owners had no rights of access to the road. Access was only possible at specially designed, grade-separated intersections. Access restrictions had not been necessary along the pre-IC roads (except immediately adjacent to a toll-gate). The concept was strongly resisted by influential sectors of a generation of road engineers, although it could be justified by reference to the rail systems which already had protected rights-of-way.

IC trucks had first been used in the Boer War late in the XIXth century. The years preceding the First World War had been a time of military preparation. France began equipping its army with trucks in 1907. A major impact of the First World War was the acceptance of the IC engine as a practical, useful operating device. This particularly applied to the truck which by then was carrying freight at costs per tonne-km which were a

quarter below those of rail and which took only a third of the road space of the equivalent horse-drawn wagon. After the War, Marshall Ludendorff of the German Army declared "victory in 1918 was the victory of French trucks over German railways."[10]

There was little road development during the decade of the War, but at its end the world had a surfeit of trucks and of young men whose only peacetime skill was to operate and maintain trucks. As one consequence, the US gave 24 500 trucks to its State highway agencies for use in road construction. Further, to demonstrate the peacetime effectiveness of the truck, in 1919 US General Pershing organised a convoy of 79 trucks and 300 soldiers including Dwight Eisenhower to undertake a demonstration drive across the USA. They proceeded at an average speed of 80 km/day.

4. BETWEEN THE WARS

When the First World War was over, the initial surge in development was in the US, by then the world's industrial and rural powerhouse. Car manufacture, which had begun in Germany, transferred to France with its better roads, was now centred in Detroit where Henry Ford's cheap, mass-produced T models were providing cars for all. Their price bottomed at $260 in the mid-1920s. From being a transport mode for the elite and the dilettante, the car and truck were now available to all and were an essential tool on every farm. Ordinary voting citizens were converted from car-haters to car-lovers [11]. There was thus a widespread emphasis on applying a hard and wide pavement surface to the existing two-way road network. Before long, most of the USA was linked by an all-weather road system.

Furthermore, there were some with grander plans. A number of fine landscaped parkways were built in New York and Washington in this period. They were effectively linear parks containing a road built for non-commercial traffic. In many ways these roads were similar to today's motorways, but were usually designed for lower speeds and thus had less generous alignments and permitted some side access to the roadway. The first of this series was the 27 km Bronx River Parkway, recommended primarily to clean up the banks of the Bronx River and protect animals in the Bronx Zoo from water pollution. The original design was based on the XIXth century parkways. It consisted of four unseparated lanes with no intersections, and crossroads passing over the Parkway. The design speed was 60 km/h and no trucks were permitted. The Parkway was widely acclaimed by the local community and set road design standards for the next 30 years. By 1932 the region boasted some 270 km of parkway.

Robert Moses, said by some to be the XXth century's greatest road builder, began building parkways as Commissioner of the Long Island Parkway Commission, a post he held from 1924 to 1963. He deliberately kept the overpasses on his early parkways low to keep out the buses used by the lower-class travellers. The parkways today provide a fine heritage of attractive, landscaped roads.[12] Further parkways were built by the US Federal Government as job creation schemes during the Depression, beginning in 1932 with the initial 24 km Alexandria section of the George Washington Memorial Parkway along the palisades of the Potomac. The parkways soon became a significant part of American travel mores.

The Depression had a major impact on XXth century roads. Road-making has always been a source of work for the otherwise-unemployed and so the Depression saw increased road construction throughout the world. On the other hand, many governments were concerned by the impact of motor transport on their rail networks and began introducing a range of

legislative measures penalising motor transport [10]. At the end of the century, remnants of this legislation could still be found in many countries.

Between 1913 and 1921 a private German group called AVUS - Automobil Verkehrs und Uebungsstrasse - built a straight, dual carriageway, controlled-access road of about 10 km in Berlin between Nikolassee and Charlottenburg, running through Grunewald Park. If it had not been for the narrow unprotected median between the two carriageways, it would have been the world's first motorway. The expanded road remains in operation today as part of the E51's entry into Berlin. The AVUS experience in providing for the new IC vehicles led to the establishment in 1924 of a German society devoted to the study of roads designed for the car – SUFA - which five years later presented plans for a 22.5 Mm network of special roads. The development of the Italian autostrada followed a similar course. In 1922 Piero Puricelli formed the Autostrade Societa Anonima which opened its first road from Milan to Varese in 1924. Like the AVUS, it had an unprotected median. In 1925 Mussolini described it as a “great Italian accomplishment” [13] and in 1926 he chaired the closing session of the Vth PIARC Congress in Milan.

The AVUS idea captured the German imagination, particularly as the construction of these autobahns also had the potential to alleviate massive local unemployment. The autobahn's chief advocate was Fritz Todt, engineer-manager of a Munich construction firm and close confidant of Hitler. A design team travelled to America to inspect its new parkways, returning to Germany intent on building Germany’s new roads to a grander, straighter scale. For example, autobahn design speeds were set at 165 km/h, about double the values by then in use on the US parkways. However, other aspects of the alignment - such as ramp geometries - were below modern motorway standards. Indeed, these later standards were raised by US engineers, on the basis of the short-comings of the original autobahns. The first autobahn was a 20 km stretch from Bonn to Cologne which was built in 1929-32. Construction was controlled by the Cologne Mayor, Konrad Adenauer, who was later to lead post-war Germany with distinction. The road had two lanes in each direction separated by a coloured line and probably just qualifies as the world's first motorway [13].

The Third Reich under Adolf Hitler took over all autobahn construction in 1933, despite his party's prior objection to the concept. In May of the same year, he announced that highway building would unite, preserve, and expand the Reich and then implemented a scheme to build 7 Mm of autobahn. A road between Frankfurt and Darmstadt opened in 1935 and met all the criteria for a full motorway. The autobahnen and the associated motorization rapidly became major items in the Nazi PR campaign and a key part of the infrastructure of the German war machine. Idealistically, autobahn construction was viewed as a trial mobilization and as embodying Nazi ideals of national character, spirit, strength, and beauty. More pragmatically, it was seen as relieving unemployment, encouraging the car industry, and promoting tourism. Retrospectively, Sachs [7] sees this period as a watershed, with the motivation for road-building changed from serving the sectional interests of carmakers and road-builders, to being seen as a proper and effective investment for developing a national economy. Construction was aided by the diversion of unemployment funds, the direct appropriation of land, and the use of forced labour. As a result, about 1 Mm of autobahn were built by 1936 and 4 Mm by 1942, with another 2.5 Mm under way when construction ceased at about that time. In 1950 - as an aftermath of the War - only 2.2 Mm were still in operation.

While the idea of high quality inter-city roads seems unquestionable today, in that period of nervous nationalism between the Wars, many thought it was far from a good idea. Baldwin

[14] notes that although “continental” delegates at the Vth PIARC Congress proposed a resolution which supported special inter-city roads, the British and American delegates reduced the motion to a meaningless platitude.

Traffic regulation in the motor car age mainly developed in the between-Wars period. Speed regulations were inherited from the horse-drawn era and were one of the first tools used to attempt to control the car. The concept of design speeds for roads was formalised during the 1930s with the realisation that the new cars could easily “out-drive” existing road alignments. As a consequence minimum curve radii on new roads gradually increased from the 50 m endorsed at the first PIARC Congress [8] to 150 m in the 1920s to 500 m or more at the end of the century. This one change meant that, at a grand scale, the new XXth century roads bore little visual similarity to their predecessors. Traffic signs and road marking practice were developed in the 1920s and were internationally codified in a 1968 United Nations convention produced in Vienna. A very visible feature of the century’s roads has been the roundabout which developed from the grand spaces of XIXth century urban design. In 1903-7 it was given traffic sense by Eugène Henard in Paris, by Holroyd Smith in London and at the Columbus Circle in New York. However, it was made a major and commonplace traffic tool by British engineers from the 1930s onwards.

5. RECOVERING FROM WORLD WAR II

America had been planning a national road system prior to the out-break of the Second World War. In 1937, President Roosevelt had called Bureau of Public Roads chief Thomas MacDonald into his office and handed him a map of the United States on which the President had drawn six criss-cross lines representing a national road system. MacDonald was presidentially told to study the program and reported back in 1939 recommending that a national highway system be constructed. Roosevelt appointed a National Interregional Highway Committee in 1941 with MacDonald as chairman. With confident foresight, part of Roosevelt's charter to the Committee was to study "the possibility of utilizing some of the manpower and industrial capacity expected to be available at the end of the war." In 1944 its International Highways report recommended a National System of Interstate and Defense Highways. The concept first appeared formally in the 1944 Federal Aid Highway Act and had a strong military basis. The Keynesian foresight was not restricted to the US, for in the same year Churchill gave a British cabinet minister the task of planning for transport in the reconstruction of Britain following the War [14].

The end of the war was followed by another period of post-War redevelopment, again led by the US powerhouse. In fact, France opened its first motorway near Paris in 1946, however work on that project had begun in 1936, but been halted by the War. In the US, the immediate post-war years created other demands for public and political attention and the idea of an Interstate System went into hiatus. Some roadmaking effort did go into toll roads, beginning with the Maine Turnpike in 1947 and there was a strong feeling in the American community that better roads were essential. For example, a paragraph on page 25 of the March 1952 issue of that mirror of American attitudes, the Ladies Home Journal, noted that: "some of our more frugal taxpayers at the club jump me when I argue that we need more four-lane highways in our State. ‘Too expensive they say....’ They forget how our narrow roads frazzle every motorist's nerves and ulcerate his disposition."

In 1952 and 1953 General Motors ran an elaborate national essay competition on ‘How to plan and pay for the safe and adequate highways we need’. The two winners were General Lacey Murrow from the American Association of Railroads and Robert Moses. The next motorway stage began soon after this seminal event, as lobby groups began to

encourage a political vision of a nationwide road network. The involvement of Moses is interesting because, as his career was ending, New Yorkers were increasingly observing that traffic congestion had not disappeared following much road construction and “that the movement of people and goods required a balanced transport system in which the construction of transit systems kept pace with the construction of roads.”[12, p897].

In 1954 President Eisenhower appointed a committee under General Lucius Clay to study American highway needs. It has been suggested [15] that one of Eisenhower’s motivations were his memories of how much better were the German autobahns of his wartime experience than the American roads he had attempted to use in 1919. Clay was an ex-military engineer and hero of the Berlin airlift in the Cold War, and then a board member of General Motors (GM). Eisenhower's Secretary of Defense, Charles Wilson, was also from the GM stable and he had appointed a personal confidant, Francis du Pont, to succeed MacDonald as head of the Bureau of Public Roads. Du Pont just happened to be a member of the family that “owned” GM. In retrospect, the influence of ex-military technocrats was possibly stronger than that of the car industry, although the two groups had been intimately linked in the USA since World War I. The Clay Committee advised Eisenhower that an Interstate System was needed. There has been strong debate over the years as to whether in this period GM and its partners deliberately destroyed much of the non-motorized urban transport in the United States or, alternatively, took reasonable commercial advantage of the situation in which they found themselves. The general consensus now favours the latter view and observes that GM merely aided and abetted the rush to low-density suburban living that was already in place.

Arguments over alternative road funding methods - e.g. tolls, loans, and pay-as-you-go - delayed early passage of the necessary US legislation. The successful advocacy of the pay-as-you-go concept was due to “States’ rights” Senator Harry Byrd and the subsequent outcome was described by the Clay Committee Secretary, Francis Turner, as a system of national highways rather than a national system of highways. Pay-as-you go has been universally applied – it simply means meeting each year’s road expenditure from that year’s revenue. It works seamlessly provided there is sufficient revenue to permit many projects to proceed simultaneously.

The Interstate System was signed into law by President Eisenhower in 1956. The legislation required the system to be designed for traffic forecast to occur in 1975 and, in an exceptional move, authorized the initial funding for twelve years to 1969. The Federal Government was to meet at least ninety percent of the cost from a Trust Fund maintained by motor vehicle taxes, predominantly a petrol tax, and based on an existing Californian model. A new Act in 1968 added 2.5 Mm to the proposed network. Although initially scheduled for completion in 1972, the Interstate System continues as a work-in-progress. In 2006 it has a length of 75.4 Mm. It has been by far the world's largest public works program and has become the largest earthmoving project in the history of the world. Nevertheless, in terms of technical difficulty, the achievement of the Japanese system of National roads (Kokudou) deserves special mention, although in extent it is much smaller than the Interstate.

6. NEW URBAN ROADS

The Interstate was not as successful or as well-regarded in urban areas as it was in the countryside. Mumford [16] commented that "when the American people, through their Congress, voted (for the Interstate program) the most charitable thing to assume about

this action is that they hadn't the faintest notion of what they were doing." A story is told that suggests that even Eisenhower fell into that same category as, upon seeing the construction of the first urban motorway entering Washington, he telephoned officials expressing disbelief that such roads could be part of his Interstate System. He was soon to learn precisely what he had initiated some three years earlier. Indeed, somewhere between 1944 and 1962 a new urban direction had been subtly added to the Interstate philosophy. The first mention of urban routes was in 1947. By 1956 about twenty percent of the system length was in urban areas. Lewis [17] suggested that the urban extension had strong congressional support as it was seen as a major job creation measure.

The urban motorway was introduced at the same time as the Urban Renewal Act permitted the demolition of urban “slums”. The process had much in common with the City Beautiful movement discussed earlier in the paper. The dimensions of the urban motorway took it beyond the human scale and dramatically altered urban environments – often to their detriment. In a memorable quote Robert Moses stated that “when you operate in an overbuilt metropolis, you have to hack your way through with a meat axe.”[12] As an alternative to the meat-axe solution for burgeoning urban road traffic, the 1920s had seen many fanciful schemes for multilevel cities with layers of subterranean roads.

One of the inherent problems with the initial approach to urban road development was that it transferred rural design standards to urban areas, as if there was some overwhelming virtue in being able to travel uninterrupted at 100 km/h through inner city areas. Vast amounts of urban space were needlessly consumed. The major move towards rational design standards for urban areas came from Japan where many projects in Tokyo and elsewhere demonstrated how design for lower operating speeds permitted quality motorways to be tightly fitted into existing urban areas. A fine example would be the Kahei spiral ramp pair at the junction of MEX 6 and RR 7 in Tokyo.

Cities throughout the world watched the aftermath of America’s new urban freeways, noting both the good and bad points. One key lesson was that the land-take associated with freeway nodes, particularly if serving a set of radial routes, was so enormous that such nodes would eliminate an entire down-town area. A turning point occurred in 1959 when citizens of the beautiful city of San Francisco halted construction of the Embarcadero (I 480) Freeway – an elevated structure along the San Francisco waterfront. Their actions were successful and the last remnants of the motorway were removed in 1991.

Formal transport planning began in the early railway era. Between the Wars, there was a steady increase in traffic counting and in traffic censuses. Aided by growing computer-power, predictions from the data were being applied to planning inter-city roads. The application of such numerate planning to cities began in the 1960s but was thwarted by some key problems. For instance, the initial software took no account of capacity constraints, leading to overly optimistic designs. The data used was also far from adequate. For example, the key variable set in the first models was future population prediction and retrospective analyses have shown that the predictions were often grossly in error. The models were also over-calibrated and tended to enhance, rather than manage, any profligate current trends. Another problem was that many early models inadequately allowed for traffic generated by the proposed new roads. By the late 1970s the models were beginning to deliver more credible outputs.[18]

An associated issue at mid-century was the view that local intersection problems could be solved by independently grade-separating each intersection. The best-known example is the series of projects in Paris along the Seine pursued under the patronage of President

Pompidou in the early 1970s. In retrospect, such projects had two flaws. First, at great cost they simply transferred most of the traffic problem to the next intersection. Second, unless done with great design sensitivity (and not involving elevated overpasses) they produced urban blight in a large area around the treated intersection. The Parisian scheme did not have this second flaw. These problems are now tackled on a larger and more system-oriented scale.

The urban road debate raged for the remainder of the century and it was not until the large-diameter urban road tunnel became feasible that cities once again began to have some confidence in urban road-building. For example, when the CityLink motorway opened in Melbourne in 2000 with 5 km of urban tunnel it was arguably the first urban motorway in the world to noticeably alleviate existing traffic problems without creating any new traffic concerns.[19] Similarly, the mammoth Central Artery/Tunnel Project recently completed in Boston was the world's most expensive road project. Its primary purpose was to remove the elevated Central Artery which had dominated the Boston streetscape since it opened in 1957 and created huge traffic problems. The replacement tunnel has removed the eyesore, improved traffic flow, opened up the city's waterfront and riverside, reduced community severance and provided citizens with new parks and open space.

7. THE LAST THIRTY YEARS

7.1 Road Building

The last portion of the XXth century was marked by continued growth in road use, by spectacular road building, and by some strident resistance to new road building. Whilst citizens have always resisted losing their land to road building and objected to "outside" traffic – Juvenal complained vigorously about the cart noise in Rome in 100 AD – the more recent complaints have had a broader, more philosophical basis. They gained strength through Lewis Mumford's articulate criticism [16] of the American urban motorways in 1957 and were more recently compounded by widespread concerns about pollution and sustainability. Whilst the road-makers have to varying degrees heeded these criticisms, the underlying concerns have been fuelled by the continuing personal and commercial attractiveness of road transport. In the early 1980s I coined the First Law of the Car – if you have a car, you will use it wherever and whenever possible. The observation was first articulated by Buchanan in the 1960s [20]. A corollary of the Law is that people who don't use a car are those who are physically unable to do so. This imbalance in favour of the car has led to considerable community schizophrenia over the issue, viz:

* we need motorways, but not in my backyard, and
* the problem would be resolved if my neighbours would use public transport, and thus leave more road space available for my needs.

In urban areas the immediate demand for transport has continued to exceed supply. And when more transport has been provided, the community has used it to improve accessibility rather than to satisfy demand. Thus a significant consequence of the provision of radial urban motorways has been to increase the length of daily commuting trips. Nevertheless, as cities around the world observed the worst excesses of the early urban motorway programs, a new level of design sophistication and environmental awareness arose and as a result many more recent projects have been sensitive and compatible parts of the urban environment. The main productive tools have been planning to increase urban population densities and to provide higher levels of public transport service. However, the lure of the car has meant that many of these schemes have struggled to succeed [21]. A basic method of car management has been to exclude the car

from some areas otherwise devoted to human movement. The first pedestrian mall was opened in Germany in 1929. In the 1930s, Alker Tripp – a London police commissioner – began to stridently advocate the separation of cars from pedestrians and cyclists. His advocacy was biased towards the car and had some impact on Buchanan's work. More recently, there has been a far more positive attitude to walking and cycling and a consequent resurging growth of paths dedicated solely to these modes.

An interesting facet of road development has been the urban by-pass. By-pass roads do not occur naturally and, before the car, all towns were essential stopping places. There were few incentives from either travellers or townsfolk for roads to by-pass towns – indeed, the reverse was usually the case. Some towns used their city walls as sites for ring roads. When by-passes such as Route 128 around Boston were built in the 1960s their core purpose was rapidly defeated as new growth congregated around the by-pass. The lessons finally learnt were the need for strict land-use control to prevent the by-pass being consumed by the expanding town (as with London's M25 motorway) or to create a series of ring roads as the city expands, as has happened in Beijing. In many circumstances, the development of peripheral road systems and their associated land-use controls have taken priority over urban arterial roads.

Interurban roads – particularly when linked to the peripheral roads discussed above - have been more warmly welcomed, with the main sustainability concern being their propensity to lure further users away from more "acceptable" modes such as rail. The roads have been particularly attractive to freight traffic due to their ability to provide point-to-point delivery and to meet the logistics needs of their customers.

The road-building task in itself became technically easier but administratively more difficult as the century progressed. In a review of the period, Gerondeau made the simple but perceptive remark [10] that roads can only be built on reservations provided by the wise actions of earlier planners. There have been recent administrations which have not been prepared to take such action. It can also be observed that countries that have achieved a comprehensive set of national roads (such as USA, Japan, France and Italy) have done so via a long-term commitment to an agreed network and to a stable system for funding and managing the network. Once the policies have been established, political direction has been at the margin rather than at the centre of any decision-making.

To take this theme of road administration further, it has been "normal" for road administrations to grow outwards from small local bodies concerned with local issues. However, as indicated in the preceding paragraph, leadership is required at a larger scale in order for workable road networks to arise. At the turn of the XXth century, the French system provided practical evidence of the success of the large-scale approach, but the message was only slowly heeded in many jurisdictions. A similar centralising move was happened in the USA as the century began and continued through the era of the Interstate. In more recent years the European Union has used its supra-national powers to encourage the development of a trans-European network. The hurdles that this project has had to overcome since it commenced in 1977 are evidence of the usefulness of large-area road administrations. Indeed, the latter part of the century has seen the World Bank, the Union and many nations use road-building as a prime way of enhancing a region's economic performance and social well-being. In contrast, it is interesting to observe that through much of our previous history roads were built to permit empires to subjugate distant regions.

Toll roads were widespread in pre-rail portion of the XIXth century. There was a resurging growth in the second half of the XXth century, particularly in France, Spain, Italy and parts of the USA. Motorway tolls were first authorised in France in 1955 and it now has 8 Mm of toll road [22]. A major drawback was the fact that toll-collecting plazas required about five times the normal width of the toll road, making them inappropriate in many locations. However, the development of electronic tolling in the last decade of the century removed that impediment and has particularly made urban toll roads feasible. Electronic toll collection began in the 1990s, commencing on a large-scale with Route 407 in Toronto and City Link in Melbourne. The technology used in Melbourne was based on systems developed to allow airfield defences to detect whether a rapidly approaching jet fighter was friend or foe. In addition, pension funds seeking long-term secure income flows began to see toll roads as an ideal investment, providing major new sources of capital.

The fundamental argument against toll roads has consistently been that roads are a public good, and should therefore be operated and maintained for the public purpose. In recent times the argument has been eroded by the growing application of “user pays” principles to public goods, both to at least cover operating costs and to restrain economically unjustified usage. Furthermore, electronic tolling opens the practical door to general road pricing. Road pricing as a means of managing road use according to economic principles was first proposed by Arthur Pigou in 1920 in his landmark work “Economics of welfare” [23]. However, by the end of the century only the island state of Singapore had (in 1975) implemented a comprehensive working scheme. Nevertheless, many communities have realised that increasing road-space is not the only way to manage the demand for road transport.

At another scale, the devil is in the detail and there are many examples where road projects have been delayed or defeated by a local opposition whose needs have been ignored or overlooked. For instance, Baldwin [14] observes that in the development of British motorways their opposition was “often a reaction to an apparently arbitrary exercise of central authority over local opinion.”

I have said nothing so far about bridge building in this review, as it is a “subservient” part of the road system. But mention must be made of the wonderful new bridges on tall piers which allow roads to rise above the tree tops, both preserving the local visual and human environment whilst giving road users a spectacular and quality ride. Great examples are the H3 in Hawaii, the Europa in Austria and the Millau in France. Many roads and bridges can now be regarded as positive features of the landscape – a role once reserved for a few iconic bridges and tourist roads. Another important side issue is the important role that XXth century roads have played in providing access corridors for public and private utilities such as electricity, water, sewage, gas and telecommunications.

7.2 Traffic Control

One of the key facets of the development of motorised road traffic has been that it has occurred with little external input and almost no external control. Effectively, total reliance is placed on drivers who have minimal training, monitoring or operating assistance. At an international conference in 1981 tis author described the system as “primitive and unsophisticated” [24]. and has noted [28] that a visitor from out-of-space might have compared our traffic system to “a swarm of bullets, potentially lethal and intermittently manoeuvred by distracted and less than fully alert drivers making apparently random choices and judgements.” Only as the century ended were there signs that circumstances were changing for the better.

Traffic signals were an adoption of 19th century railway signalling practice and were first used for road traffic in 1868 in London. Vehicle actuation of signals was introduced in Baltimore, USA, in 1928. Recent times have seen a far greater use of information technology in road operations. A major break-through in signal timing and coordination began in the 1960s in Sydney, Australia, with the application of queuing theory created to service the Berlin Airlift during the Cold War. Traffic-responsive signal systems like SCOOT and SCAT developed rapidly during this time. Much effort towards the end of the century was being devoted to intelligent transport systems although their initial impact was scarcely discernible. The first operating systems provided advice on weather and road conditions. But as Sachs [7] asks “”Is the microchip not for our children what the engine was for our grandfathers?”

One terrible consequence of our rapid adoption of motor vehicle technology without concomitant control processes has been the annual number of road users killed or injured. For much of the century road managers were comforted by the dispassionate view that deaths per distance travelled were falling, ignoring a proper concern with the total number of fatalities. Thus, it is still surprisingly difficult to find even an estimate of the total number of people killed on the world’s roads each year. For just the last year of the XXth century, the number killed appears to lie somewhere between 540 000 and 1 120 000 people. The best of some very poor estimates is that the half million per annum figure had been exceeded as early as 1987. By comparison, about 60 million people were killed in World War 2. There is no room for complacency in such estimates of the road deaths.

Whilst the prime causative factors in road crashes were seen to be stem from human error, engineers came to realise that the cost-effective way of treating this problem was to improve the safety of the vehicles and the roadside. The last 30 years has thus seen a quantum improvement in vehicle safety and in the safety of the roadway. Particular and effective emphasis has been placed on seat belts, air bags, pavement edges and removing or protecting roadside objects likely to be impacted by an errant vehicle. Another lesson has been that there is little to be gained by higher and higher operating speeds. These have now peaked with a change in emphasis from speed to throughput (capacity) and safety. Furthermore, studies of unexpected capacity drops on major operating freeways have shown that these frequently stem from instabilities in the traffic flow (the butterfly effect) and so greater emphasis is now placed on removing the causes of such instabilities (e.g. poor merging and diverging) rather than on automatically building more capacity.

Throughout the century, traffic demand has consistently outstripped capacity and therefore traffic congestion has been commonplace. Davison [25] sees it as a Faustian bargain – we were offered the car with all its wonderful advantages, so wonderful indeed that the promised advantages were destroyed by the rush to collect them. From time to time it has been argued that congestion would be a meter that controlled traffic [14]. However, congestion has rarely destroyed the attractiveness of the car and the consequence has been the wasteful personal and social costs of growing delays. Another outcome of the Faustian bargain was that further road building attracted more users, destroying many of its intended benefits. The lessons slowly learnt have related to the need to manage the entire transport and land use system in a coherent and cooperative way and to provide appropriate alternatives to car and truck travel.

8. INTERLUDE

Although this paper and its surrounding conference are about roads, it would be a sine qua non without comment on the leading role played by the IC vehicle fleet. These vehicles have provided their users with historically unprecedented and unforeseen levels of service, availability, comfort, weather protection, pride of ownership, low perceived cost, convenience, security, timeliness, privacy and safety [26, pages 1088-9] – all at speeds that people had never experienced in the days of the horse and carriage {in 1911 a Blitzen Benz took the world speed record to 235 km/h}. To the above already-large list of car virtues, Sachs [7] and Davison [25] have added the extra, exhilarating dimensions of independence, status, power, style, love and danger. Bayley [27] noted that powerful cars "are not transport; they are aphrodisiacs." To Davison the "car became a mechanical extension of the self, conceived as an autonomous, rational, self-actualising individual -- a triumph of liberal democracy." Not surprisingly therefore, in the developed world, car numbers have now reached "effective" saturation, in that everyone who wishes to drive a car has access to one.

In his pivotal work in 1963 Buchanan observed [20] that the car had moved from "being the privilege of the minority, to the expectation of the majority." He drew the further conclusion that as car ownership became "universal", the majority of voters would be car-owners and that "governments would be increasingly pre-occupied with the wishes of car-owners." Gerondeau [10] perceptively noted that "once countries reach a certain level of development, cars are no longer the prerogative of the most favoured, but become a means of transport for almost all, including members of even the most modest social classes." In many less developed countries it is instructive to observe how the IC engine has been skilfully used to power a whole range of small vehicles and how the motorcycle and moped can provide efficient means of personal transport.

A different change occurred in the 1930s. Grübler [6] observes that up to then the car was competing with the horse for its market niche, which was short-distance travel by cab, coach or wagon. By the 1930s the car and the truck were able to compete in the long-distance travel market previously the preserve of inter-urban rail and coastal shipping, whose service was often markedly inadequate. Another German commentator [7] notes that by the 1930s "a totally new type of road was needed to make space penetrable by-passing (urban and rural) impediments." This explains the new interest in long-distance roads (typically motorways) which occurred from that time.

Trucks have proved particularly adaptable as they have carried heavier and heavier payloads at high speeds. Road trains in Australia now routinely pull loads of over 100 t. This has been possible because the wheel loads and pneumatic tyre pressures have remained effectively constant. Larger loads are carried by adding more pneumatic wheels. Thus the truck is still less damaging than its iron-tyred predecessors.

Over the course of the XXth century, cars and trucks gradually became more fuel efficient, less polluting, less noisome and safer, although – because of their ever-growing numbers – their aggregate contributions to greenhouse effects and human death and damage remain high. There has also been an increased awareness of, and accounting for, the indirect costs of vehicle operations on the communities in which they operate.

9. CONCLUSIONS

Roads have been with us since the first pathways arose following a major retreat of glaciation in about 10 000 BC. The invention of the wheel in about 5 000 BC literally added a new dimension to the path network. In the 18th century, the Industrial Revolution dramatically raised the demand for transport and hence for effective roads. However, all these changes are dwarfed by the impact of the internal-combustion car and truck during the XXth century – the era which is the subject of this paper and of this conference.

The story of roads in the XXth century has been based on the dichotomy between the enormous advantages of the car and the truck on the one hand, and on the other hand their peripheral - yet often overwhelming - effects on all other aspects of XXth century society. The Industrial Revolution had had many prior major impacts and so perhaps we should have been better prepared for the consequences of the work of two Germans – near-neighbours Karl Benz and Gottlieb Daimler – who found a practical use for one of the by-products of the new oil refineries. We should also not have been surprised by the influence of war on XXth century roads. These new cars with their rapidly changing and ever-improving technologies, encountered a road system which was old, ponderous and difficult to change with even the best of intentions. Within the century, enormous tensions were created and then largely resolved. Davison [25] has commented: “The history of our times is written not only in words, but in things….Every age takes pride in the things it makes and invests them with more than material significance.” In this context, the XXth century’s mark has been the wedding of the ancient road and the new-found facility of petroleum-powered internal-combustion. It is fair to conclude this review by saying that the XXth century has reason for Davison’s pride as it has put the IC engine to magnificent and universal use. Furthermore, after a century, we of the current generation have learnt how to civilise the car and the truck, although many of those lessons have yet to be put into universal practice.

It is indeed a message which has a larger compass, as the world debates the sustainability of the planet. The effect of the IC motor vehicle on XXth century life and our various responses to its benefits and disbenefits have been discussed in this paper. In many ways they are a microcosm of the wider challenges that the world now faces. We have seen that the car has brought enormous benefits, but that it has also been over-used and misused. The best of our road systems have shown that humankind has the ingenuity and skill to achieve wise outcomes. Perhaps most importantly, those wise outcomes have without exception been the consequence of a clear vision and strong long-term planning.

REFERENCES

Note that references are not given to “familiar” aspects of road history in the text above. These are covered in detail in the author’s Ways of the World [28].

1. Lay, M. 2003. Melbourne miles. Melbourne: Australian Scholarly Press
2. Ackroyd, P. 2001. London: the bibliography. London: Vintage
3. Lay, M. 2004. History of traffic signs, Chapter 2, The human factors of traffic signs. C. Castro & T. Horberry (Editors), Boca Raton: CRC.
4. Lay, M. 2005. The reality of historic roads. Corrugations Conference, International Commission on Monuments & Sites, Melbourne, later republished as The cultural heritage significance of roads, Road & Trsp Res, 15(3): Sept, 2006, 63-79
5. Schivelbusch, W. 1979 (German Edn 1977). The railway journey – the industrialisation of time and space in the 19th century. Berkeley: University of California Press
6. Grübler, A. 1990. The rise and fall of infrastructures. Heidelberg: Physica Verlag

7. Sachs, W., 1992 (German Edn 1984). For love of the automobile, Berkeley: University of California Press
8. La Commission d'Organisation 1909. Compte Rendu: 1st Congrès Internationale de la Route. Paris: Lahure
9. PIARC 1997. A brief historical chronicle of PIARC. Routes/Roads, 296(IV):76-9, October
10. Gerondeau, C. 2001. Millennium book. Paris: RGRA
11. Finch, C. 1992. Highways to heaven - the auto biography of America. New York: Harper Collins
12. Caro, R. 1974. The power broker – Robert Moses and the fall of New York. New York: Knopf
13. Rallis, T. & Helk, U. 1993. The story of the motorways. J European Asphalt Pavement Assocn & Tech Univ Denmark, paper 1993-6
14. Baldwin, P. & R. 2004. The motorway achievement. London: Thomas Telford
15. McNicholl, D. 2003. The roads that built America. New York: Silver Lining Books
16. Mumford, L. 1964. The highway and the city. New York: Harcourt Brace Jovanovich
17. Lewis, T. 1997. Divided highways: Building the Interstate: Transforming American life. New York: Viking
18. Lay, M. 2005. The history of transport planning. in Handbook of transport strategy, policy & institutions (Button, K. & Henscher, D. Eds). Amsterdam: Elsevier, pp 157-174
19. IEAust 2002. Journey and arrival. Melbourne: IEAust
20. Buchanan, C. et al 1963. Traffic in towns. London: HMSO
21. O'Toole, R. 2001. The vanishing automobile and other urban myths. Oregon: Thoreau Institute
22. Gandil, P. 2004. Creation of an agency for transport infrastructure funding in France. Routes Roads 325, Oct, p41-5
23. Pigou, A. 1920. Economics of welfare. London: McMillan
24. Lay, M. 1981. Roads into the future - designs for the evolution of road traffic. Papers IXth International Road Federation (IRF) World Congress, TS2:13-26
25. Davison, G. 2004. Car wars. Crows Nest: Allen & Unwin
26. Lay, M. 1998. Handbook of road technology, 3rd Edn, Vol 2, New York: Gordon & Breach
27. Bayley, S. 1986. Sex, drink and fast cars. New York: Pantheon
28. Lay, M. 1992 (German Edn 1994). Ways of the World. New Brunswick: Rutgers University Press