Highway infrastructure: visions & challenges in the next decades

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Abstract. Malaysia has achieved a significant economic and social progress over the past several decades through the implementation of First Malaysia Plan (1966-1970) to Ninth Malaysia Plan (2006-2010). Further the Government of Malaysia aims at achieving high income nation status by 2020 through the introduction of Malaysia Vision 2020. The vision is crafted by the Fourth Malaysian Prime Minister to shape Malaysia as a developed nation not only in an economic sense but also in terms of social justice, political stability, government system, quality of life, social and spiritual values, national pride and confidence. The initiation of Greater Kuala Lumpur/Klang Valley (KL/KV) has resulted in rapid growth in urbanisation, transportation, infrastructure and construction industry sectors. Malaysian infrastructure development especially the transportation sector is going through rapid changes in terms of adapting state of the art construction technology, adjusting to industry evaluation, and use of intelligent transportation system to achieve the set goals for the future and equip the nation to brace the Industry Revolution (Industry 4.0). To stay relevant, the highway infrastructure need to be to be smart and green. The smart highway will provide better, safer and greener highway through digital and green technology through the introduction of Intelligent Transportation System (ITS). The idea of smart highway is not only limited to the application of technology but also to achieve the goal of sustainable and green environment. It is in line with the Green Technology Master Plan Malaysia (GTMP) 2017-2030 that outlines the strategic plans for green technology development to create a low-carbon and resource efficient economy. The challenges for smart highway implementation is waiting ahead. Issues related to technology acceptance, political will and policies, creativity and innovations, construction methods, ethics and changing in human values need to be discuss in depth.

1. Introduction
Malaysia has achieved a significant economic and social progress over the past several decades through implementation of various economic plans. Presently with more competitive and challenging global economic environment, Malaysia has reached a defining moment in its development path. Malaysia has embarked on comprehensive economic agenda to achieve the developed nation status and among top 20 countries in the world through various initiatives such as Vision 2020, Government Transformation Programme (GTP), New Economic Model (NEM), Economic Transformation Programme (ETP) and 10th Malaysia Plan [1].

The Malaysian infrastructure development especially the transportation sector is going through rapid development to equip the nation to brace the Industry Revolution (Industry 4.0) in terms of technology and innovation.
This paper aims at presenting the various strategies to overcome the challenges and key factors to be amongst the top countries in economic development, citizen well-being and innovation.

2. Malaysia Economic Planning
Traditionally, the progress in Malaysian economic and social development over the past several decades is through the implementation of First Malaysia Plan (1966-1970) to Ninth Malaysia Plan (2006-2010). Besides the Government of Malaysia also aims at achieving high-income nation status by 2020 (Malaysia Vision 2020).

Malaysian Vision 2020 was unveiled by the fourth Prime Minister of Malaysia, Tun Dr. Mahathir bin Mohamad at the inaugural meeting of the Malaysian Business Council on 28 February 1991. The Malaysian cabinet approved the Vision unanimously and mandated for an immediate national conference, which took place in December 1991 [2].

The vision is crafted to shape Malaysia as a developed nation not only in an economic sense but also in terms of social justice, political stability, government system, quality of life, social and spiritual values, national pride and confidence [3].

It is also a Malaysian Government desire to become one of the top 20 countries in the world in terms of economic development, citizen well-being and innovation. The Greater KL/KV is already on the global map as one of the iconic cities in Southeast Asia. It boasts world-renowned landmarks such as Petronas Twin Towers, a unique blend of diverse cultures and heritage, an extensive road network and high quality basic services such as water and electricity. However, it now faces fierce competition from neighbouring cities in development progress and attracting multinational talent. Its liveability lags many other Asian Cities, inadequate public transport system and many other natural assets remain untapped.

3. Malaysian Transport Infrastructure
The initiation of greater KL/KV has resulted in rapid growth in urbanisation, transportation, infrastructure, and construction industry sectors beside others. Availability of space in the urban environments is very scarce and hence the need for integration of infrastructure facilities and their coexistence.

Greater KL/KV regional connectivity will be enhanced and at the same time, intra city connectivity will be improved with light rail, mass rapid transit systems and upgraded pedestrian facilities.

The Malaysian transport infrastructure mainly comprise public transport systems like Light Rail Transit (LRT)/ Mass Rapid Transit (MRT)/ monorail/ inter urban bus and rail services and extensive highway network system besides other modes of transport like airways. Since the above existing transport system is still inadequate to meet the current demand as well the future, additional public transport systems are being planned and developed to enhance the capacity and meet the future demand such as Light Rail Transit (LRT 3), Mass Rapid Transit (MRT Line 2), High Speed Rail (HSR) and East Coast Rail Link (ECRL).

In the aspect of Malaysian highway infrastructure, Malaysia can be considered to be one of the best among developed nations. In Malaysia currently, there are about 31 inter urban & intra urban highways/expressways in operation, 6 are under construction phase and another 5 are in planning stage besides several other major arterial roads. This highway network system has been contributing significantly towards the country’s economic growth from time to time.

The North-South Expressway which is a brainchild of Malaysian fourth Prime Minister, is the Malaysia's longest access controlled highway with the total length of about 823km which connects Bukit Kayu Hitam near Malaysia - Thailand border on northern side and Johor Bahru at the southern portion of Peninsular Malaysia and to Singapore [4].

This expressway was fully operational in the year 1994, acts as a backbone connecting major cities and towns in Western Peninsular Malaysia and has spurred the economic growth significantly in the adjoining regions all along its route.
4. Challenges for Highway Infrastructure
Malaysian infrastructure development especially the transportation sector with the above large scale ongoing projects is presently going through rapid changes in terms of adapting state of the art construction technology, adjusting to industry evaluation, adapting to internet of things, and use of integrated transport information system to achieve the set goals for the future and equip the nation to brace the Industry Revolution 4.0 (Industry 4.0).

In line with the Industry 4.0, the concept of Smart City has been promotes through the globe even though the absolute definitions of “smart” is still questionable. However, the Smart City and Digital City are the most used terminologies in literature to indicate the smartness of a city.

Citing the definition by Washburn et. Al (1980) [5], Smart City is stated as “the use of Smart Computing technologies to make the critical infrastructure components and services of a city-which include city administration, education, healthcare, public safety, real estate, transportation and utilities-more intelligent, interconnected and efficient”. It can be imagined that smart city will be equipped with electronics data collections sensors to ease the traffic flow, made parking easier, improved the energy-efficient and comfort in building as well as the efficiency of public lighting.

In the coming decades, the Malaysian highway infrastructure shall face mainly the following challenges but not limited to:

a) Space availability for development and sharing of space for coexistence;

b) Utilisation of existing highway infrastructure to its maximum time & capacity

c) Upgrading to latest construction technology;

d) Adoption of intelligent transportation system;

e) Inclusion of Creativity & Innovation;

f) Understanding of internet of things and its application;

g) Integration of existing and planned public transport system;

h) Changing value and lifestyle;

i) Legal issues and risk factors; and

j) Policy framing and political will

The introduction of smart city concept also need to be considered by the highway industry in order for the highway infrastructure to be smart and green to complement the smart city. The smart highway will served as a connection from one smart city to the other smart city with the mission to provide better, safer and greener highway through digital and green technology.

5. Smart Highways
In relation to Smart City concept, there is no absolute definition on ‘smart’ when it comes to highway. Nevertheless, the introduction of Intelligent Transportation System (ITS) has given some light toward the implementation of a smart highway.

The terms of Intelligent Transportation System (ITS) has been widely promoted and recognized globally. ITS refer to integrated applications, employing combinations of information, communications, computing, sensor and control technologies and can be applied to various sectors such as transportation, building and vehicles. These technologies are already revolutionizing the way we live and work and they can equally well revolutionize the way that we travel.

In the transportation sectors, Intelligent Transportation Systems (ITS) aim to improve transport safety and mobility and reduce vehicle emissions [6]. Many such technologies have been developed to enhance vehicle safety, to prevent crashes, reduce trauma during a crash or to reduce trauma following a crash and used in mitigating traffic congestion. The ITS solution will enhance transport performance in cities which at the same time would not exclude further construction of roads and other transport infrastructure. Figure 1 shows the typical application of ITS.
Some ITS applications are already existence in Malaysia and could be mostly seen on the expressway. The applications are listed as follows:

- Use of state of the art Intelligent Transport Management Systems, Traffic Control & Surveillance System, Toll Collection System, and Emergency Response Plans.
- Progression of Malaysian highways to migrate from Touch & Go/Smart TAG systems to Radio Frequency Identification (RFID) in 2018 & Multi Lane Free-Flow (MLFF) in 2025. Figure 2 shows the RFID implementation and Figure 3 shows the MLFF gantry in testing phase;

![Figure 1. Typical application of ITS.](image1)

Efficient Use of Internet of Things, Big Data & Cloud Computing to make use in real time traffic management & surveillance. This includes traveller information system, advanced traffic information system, connecting vehicles, fleet management, congestion management, congestion pricing, real time traffic signal control system, parking management system, vehicle weigh-in-motion, vehicle entrance permission, vehicle on-board units (OBU), automatic enforcement system and efficient transport planning by public authorities (Refer to Figure 4)

![Figure 2. ETC System - RFID implementation.](image2)

![Figure 3. ETC System - MLFF Gantry in Testing.](image3)
The implementation of Intelligent Transportation System (ITS) are now globally accepted as the modern approach to solve issues related to highways infrastructure and traffic operations such as traffic congestion [7], traffic signals [8] and traffic lighting [9]. The ITS implementation are also made to meet the purposes to improved safety, higher productivity and efficiency, more environmental friendliness and enhancing for a better life quality [10].

The technologies that can be seen today has gone through a long journey to be developed. Definitely many ‘try and error’ experiments has been conducted for improvements. Looking back at the history, Saunders, N. as recited by A Martin, H Marini, S Tosunoglu (1999) stated that Japan in the year 1973 has already started a project related to Intelligent Vehicle/highway System (IVHS). The Japan’s Government through the Ministry of International Trade and Industry has been conducting an activity to develop and evaluate an on-board dynamic route guidance system, working in junction with the private sectors in different areas.

The effort to develop and evaluate IVHS continues with a strong support from the Japanese government. All this work was then unified in 1990 in a project called the Vehicle Information and Communication System (VICS). With all these projects under way, Japan has moved ahead in a number of areas. In 1994, Japan formed its Vehicle, Road, and Traffic Intelligence Society (VERTIS) [7].

Europe started the activity related to the Intelligent Vehicle/highway System (IVHS) back in the year 1988 with DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) followed by another programs called European PROMETHEUS Project (Program for European Traffic with Highest Efficiency and Unprecedented Safety) [7]. These two programs is reported have been working for about 12 years to demonstrate the necessity of viewing vehicles and highways as an integrated system.

A Martin et. al (1999) also recorded in their study that in the United States of America., the first efforts in the IVHS were undertaken by individual states and cities back in 1987 where ‘Mobility 2000’ was created to promote the creation of national programs in the field of IVHS. ‘Mobility 2000’ was a main factor in the completion of a set of planning documents to guide national support for the development of an IVHS program. In 1990 ‘Mobility 2000’sponsored the National Workshop in IVHS in which representatives of federal and state government agencies, industry and the academic community participated. There, the U.S. Department of Transportation (USDOT), through its Federal Highway Administration (FHWA), mobilized federal support for a nationally coordinated program. Representatives of the major automobiles, communications, information systems, transportation equipment, and consulting companies in the United States also attended the workshop. Mobility 2000 promoted the formation of the Intelligent Vehicle Highway Society of America (IVHS America).

Continuous research, development, and implementation of ITS in Japan, Europe and United States of America has given a big contribution to the world. It is believed that these developed countries are now adopting more and more Intelligent Traffic System on their highway infrastructure which will be as a model of reference by others.
It has to be noted that the idea of smart highway is not only limited to the application of technology through Intelligent Transportation System (ITS) but also to achieve the goal of sustainable and green environment. It is in line with the Green Technology Master Plan Malaysia (GTMP) 2017-2030 [11] that outlines the strategic plans for green technology development to create a low-carbon and resource efficient economy. In the first edition of the GTMP, six key sectors has been choose which are Energy, Manufacturing, Transportation, Building, Waste and Water. In the transportation sector, several approach has be taken such as:

a) Energy Efficient Vehicle (EEV)
In the National Automotive Policy (NAP) 2014, Malaysian Government has set Energy Efficient Vehicle (EEV) as the way forward for the national automotive industry. According to NAP 2014, EEV definition is applicable to any vehicle that fits the set of specifications in terms of carbon emission level and fuel consumption, and encompasses fuel-efficient vehicles, hybrid electric vehicles, full electric vehicles, alternative fuel vehicles etc. Driven by the EEV initiative, local car manufacturers Proton and Perodua have EEV models, such as Ertiga and Axia respectively (Figure 5). R&D&I on EEV should be continued to allow local automotive industry to move up the value chain in transport GT while positioning Malaysia as the local EEV hub.

![Figure 5. Perodua AXIA (EEV).](image)

b) Electric Vehicle (EV) Technology
For personal transport, there are several types of EVs available in the Malaysian market, ranging from Hybrid Electric Vehicle (HEV, which runs on both fossil fuel and battery, without external charging function, such as Toyota Prius and Honda Jazz), Plug-in Hybrid Electric Vehicle (PHEV, which runs on both fossil fuel and battery while allowing the battery to be charged externally, such as BMW 330e), Battery Electric Vehicle (BEV, which runs solely on battery, such as Nissan Leaf and Tesla Roadster) are also in the market. Figure 6 show the example of electric vehicle.

![Figure 6. Electric vehicle.](image)
c) Electric Motorbikes
In terms of electric motorbikes, local company Eclimo Sdn Bhd has been developing electric scooter that can cater local as well as regional markets. Moreover, Eclimo has been working with the Research Centre for Applied Electromagnetics (UTHM) and UM Power Energy Dedicated Advanced Centre (UMPEDAC, UM) to develop electric drive train for its electric scooter, as a move to localise the EV technology.

d) Ride Sharing and E-Hailing
The rise of ride sharing and e-hailing services such as Grab [12] and Uber [13] have brought a new mode of efficient “public transport” which substantially changed the way urbanites commutes. Ride sharing and e-hailing services are seen as the future trend in mobility and the services could potentially increase transport efficiency and mitigate congestion issues.

e) Bike Sharing
The smart bike sharing green system implemented recently viz., oBike [14] (Figure 7) is Malaysia's first and largest dockless system which uses technology. It allows commuters to travel – via bicycles located all over the city and across country to reduce congestion and pollution.

![Figure 7. oBike sharing.](image)

6. Future Trends for Smart Highways
Going into the future, transportation system and operations will be fully mechanized, automated and sustainable with the use of advanced sensors, user-friendly digital technologies as well as green technologies. The goal of the smart highway is to provide better, safer and greener highway through digital and green technology.
Change of mind-set is crucial among players in the highway industry in order to stay relevant in the coming decades. Continuous research is needed to invent new technologies. Some of the future technologies for use on road are already explored. The examples are elaborated as follows:

a) Interactive lights
Smart road lighting using relevant automated system and data connectivity offers lighting asset management (analyse, plan & maintain), remotelight management (monitor, manage & measure) that is safe and green. Interactive lights works in the sense that when a car approaches a particular stretch of a road, the motion sensors will light up only that section of the road [15]. The lights will grow brighter as the car comes closer and will slowly dim away as it passes. Figure 8 shows the concept of interactive light.
b) Glowing lines
Created by Daan Roosegaarde’s and Heijmans Infrastructure and introduced on a highway in Oss, Netherlands. Smart Highway Project combines green energy with safer driving and an art installation experience. It consists of glowing lines that are charged during day-time and glow at night for eight hours. The first pilot has been realised, and will further be developed and launched internationally. Figure 9 shows the concept of glowing lines.

Figure 9. Glowing lines.

c) Electric priority lane
Smart Highway also provides an extra Electric Priority Lane. Underneath the road surface, this priority lane is equipped with induction coils which enables electric cars to recharge as they drive over. Figure 10 shows the concept of electric priority lane.

Figure 10. Electric priority lane.
d) Intelligent (Networked) highway
Deployment of fibre optic cables along major road networks with high transmission capacities will contribute to future ITS systems development that requires rapid high-volume transmission and huge traffic data aggregation to regional or national data centres. (Eg. Asia Pacific Information Superhighway initiative). The concept may also be referred to roadside ‘listening’ stations that will link up with GPS receivers in cars to monitor traffic patterns and accidents.

e) Piezo-electric energy road
Piezo-electric crystal can generate energy from the vibrations generated by the vehicles. Focusing on the transition of energy to piezoelectric integrated roads, a renewable energy harvesting method, will lead the next power generation into a feasible and more reliable source of energy. Figure 11 shows the concept of Piezo-electric energy.

![Piezo-electric energy](image)

Figure. 11. Piezo-electric energy.

f) Illumination Traffic Sign/Bollard
Development of light-collecting illumination signs/bollard or visibility during night time and inclement weather. Figure 12 shows an example of illumination traffic bollard.

![Illumination traffic bollard](image)

Figure. 12. Illumination traffic bollard.

These innovations has to be cultured to ensure the highway infrastructure are moving together with the time. The implementation of new technology to highway infrastructure will result in benefits such as improving safety, reduce congestion, reduce emissions and use of fossil fuels, improve access to jobs and services, reduce transportation cost and improve accessibility and mobility. Thus the effort made has to be fully supports to cultivate many more innovators to contribute ideas for mutual prosperity.
7. Conclusion
With the desire and strong determination, Malaysia is in the right path to achieve the set goal to become developed nation status and to brace the challenges of Industry 4.0 in the coming decades. The Malaysian highways will surely emerge as a world class, fast, safer, convenient and intelligent system with fully mechanised, automated operations and sustainable with the use of user friendly intelligent transportation systems, digital and green technologies in meeting the present needs and without compromising those of future generations.

The steps towards the smart highway are already implemented phase by phase and at the mean time we are preparing for the future to come in. The technology bloom can’t be avoided thus well preparation has to be made to welcome it to be a part of us. The challenges for smart highway implementation is waiting ahead. Issues related to technology acceptance, political will and policies, creativity and innovations, construction methods, ethics and changing in human values need to be discuss in depth. Government roles is not only limited to provide infrastructure and access to technology but further extended to bond collaboration with the next generation of industry players, stakeholders and academicians in order to develop policies, clear frameworks and proper education to create a shared vision of the future without compromising the basic value of humanity.

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