Urban Transportation Planning for a Vibrant and Distinctive Singapore

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Abstract

Singapore's Economic Strategies Committee in early 2010 issued a series of recommendations towards making Singapore a "vibrant and distinctive global city... open and diverse, the best place to grow and reach out to a rising Asia, and a home that provides an outstanding quality of life for our people." This paper explores the role of urban transportation planning as one of many factors that could contribute to this vision.

Singapore's well-articulated plans to test-bed electric vehicles dovetail well with its vision for a "smart energy economy" – an example to Asia. We will focus primarily on the pros and cons of vehicle electrification; issues more complex than is often simplified by purveyors of new technologies.

Introduction

Singapore, with its Rapid Transit Systems (RTS), buses, taxis, its control of private vehicle ownership and usage through the Electronic Road Pricing (ERP) scheme, vehicle tax schemes and the annual quota for growth of the private vehicle fleet, is to be lauded for striking an appropriate balance between economic efficiency, satisfying demand for better transportation and managing traffic congestion.

In fact, the ERP systems in place in Singapore, the signboards of the parking guidance system, the speed-trap cameras, the proliferation of GPSs, in totality, all provide the foundation for an Intelligent Transport System (ITS), which could in the future:

- Reduce accidents, by enabling vehicle-to-vehicle (V2V) communications
- Allow for individual vehicles to communicate seamlessly with traffic signals, i.e., vehicle-to-infrastructure (V2I) communications, enabling smoother traffic flows [these may be based on Dedicated Short Range Communications (DSRC) technologies]
- Provide real-time relevant traffic and weather data to all vehicles (also V2I), and
- Enable data capture for traffic management, over time, to assess and improve upon multi-modal transportation performance.

Beyond the safety aspects, such systems provide environmental benefits in reducing tail-pipe emissions from idling vehicles and thus improve overall energy efficiency and fuel savings.

Exploring vehicle electrification

The Energy Studies Institute (ESI), Singapore is committed to researching all forms of energy usage in the regional landscape. The recent interest in electric vehicles (EVs) (*Figure 1*) has been analysed by Wong Yuk Sam. He has offered a series of observations on the EV phenomenon and how it would impact our energy environment. Here are some conclusions from his studies (Wong 2009).

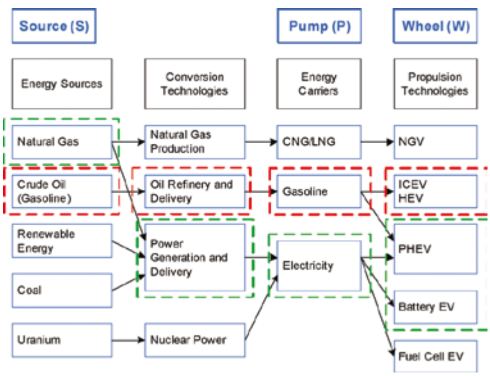
Figure 1: Electric Vehicle on sale (Mitsubishi iMiEV)

Energy consumption and CO_2 emission reductions are achieved by (1) reducing energy demand and (2) improving system efficiency. Among land vehicles in Singapore, Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and EVs are viable to replace gasoline Internal Combustion Engine Vehicles (ICEVs) to reduce total energy consumption and CO_2 emissions from land vehicles. While electricity harnessed from solar and wind in Singapore would theoretically be zero-carbon, it would not be sufficient to feed PHEVs and HEVs, given the small land area in Singapore. However, given that most of Singapore's electricity is generated from Natural Gas (NG) in Combined Cycle Gas Turbine (CCGT) power plants, switching some fraction of the automotive fuel diet from petrol and diesel to electricity (hence natural gas) would effectively reduce carbon emissions, as natural gas is a cleaner burning fuel. More importantly, it moves the various fugitive point source emissions to those at the power plants, allowing for easier carbon capture by CO_2 smoke stack scrubbers, thus effectively reducing the amount of emissions.

In 2008, the total energy consumption from gasoline cars is 327 million gge (gallon gasoline equivalent) and the CO_2 emissions total 3.24 million US tonnes. HEVs can reduce the energy consumption by up to 39% and reduce the CO_2 emission by up to 39%. PHEVs can reduce the energy consumption by up to 46% and reduce the CO_2 emission by up to 54%.

The graphic (*Figure 2*) taken from Wong's (2009) study represents our continuing studies at ESI to further analyse all types of energy sources for propulsion systems, including the future role of nuclear electricity in providing zero-carbon electricity for power generation

Figure 2: The energy supply chain for vehicle electrification



and for the EVs (*Figure 3*) of the future. In a separate study by Michael Quah (2009), bio-mass sources for the production of bio-diesel and hydrogen fuel cell vehicles are further considered (Quah 2009). The key lessons from that study are the following:

Figure 3: Renault Fluence Z.E. Concept, an electric vehicle

- in the quest for energy security, energy diversity is key, and in the future, all possible sources of energy must be taken into consideration
- for urban populations, there may be no need to move to fuel cell vehicles (as in the case of large countries, such as the US) because such power sources are more suited to long-range driving to minimise time between fuelling up
- for urban populations with short-distance driving patterns as in Singapore, EVs (from PHEVs to HEVs to full EVs) may be the best options for private vehicles, although further improvements in energy storage systems, such as batteries and capacitors, and charging stations need to explored.

Hence, the many test-bedding programmes being currently conducted in Singapore will help contribute to our holistic "systems of systems" approaches to meeting the challenges of the future. For example, the Experimental Power Grid Centre (previously known as SINERGY Centre) at A*STAR, focusing on intelligent grids, micro-grids and Distributed Energy Resources (DER), will provide plug-and-play capabilities and core research competencies in analysis and modelling, interconnection technologies, and advanced system control and management. These disciplines are critical to supporting the EV programmes as well as the vehicle-to-grid (V2G) and V2I interactions of the future. Similarly, the Energy Market Authority (EMA) Pulau Ubin project on micro-grids will assist in understanding system interactions vital for a future "smart energy system" in Singapore. And so will the Energy Research Institute at NTU (ERI@N), with its work on energy storage, modelling, advanced metreing, and command and control systems.

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What is impressive is that the variety of science and technology programmes (both fundamental and applied, as in test-bedding programmes) taken as a whole provides Singapore the tools to further advance urban transportation innovations and implementations; but, as in all "systems of systems" approaches, we must consider the pros and cons of policy implementation.

Vehicle Electrification: Potential pitfalls versus technology advantages

With the underlying assumption that Singapore is beginning to test-bed the use of EVs, as being jointly driven by the EMA and the Land Transport Authority (LTA), we will examine the pros and cons of the transformation in the vehicle powertrain. We assert that this transition would be no simple task given the complex interactions among:

- consumer preference and choice
- public transportation policy
- corporate and industrial pressures for governmental subsidies for new technologies (as is evident in the West) and
- advocacy from renewable energy sector private investors interested in public funding.

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The potential rewards are understandably satisfying:

- a partial divorce between road transportation and dependence on the "liquid" fossil fuel diets (and hence the oil markets)
- a decrease in Singapore's net emissions (because of Singapore's primarily natural gas sources for power generation) and
- new technologies and new business sectors for economic growth.

With increasing electrification and the ITS innovations described earlier, centralised control of traffic flow and more efficient urban policies can all stem from success in electrifying the vehicle fleet. Equally importantly, mass increase in EVs provides a tantalising test-bed for a series of innovative energy generation and storage options: Singapore could become the region's first successful example of a truly distributed energy network with a flourishing private power generation market which accommodates both legacy power plants and private individuals. Such a "systems of systems" integration could not be achieved without government establishing a framework for market interactions. But a whole-of-government approach is essential for leadership in establishing new industrial policies, balancing sophisticated technology investments without the government picking the winners in a complex network of vendors. Behavioural economics will have to come into play, where consumers may begin to consider that all types of EVs are safe, user-friendly and superior to the internal combustion engine (ICE): a formidable challenge for public-private sector collaboration.

Behavioural Economics: Do people really prefer electrons over petrol or diesel?

The lessons learned from the adoption of electric two-wheelers (E2W) in China and Taiwan might be crucial. A number of factors contributed to the demand in metropolitan China: the rapid increase in per capita income, rising concern of the pollution levels from ICEs, traffic congestion and the official ban on fossil-fuelled two-wheelers in metropolitan zones within China (Wienert 2008). The last factor is widely understood to be crucial to the rapid increase in demand for electrical replacements; consumers are simply turning to the most viable alternatives. This is a tough lesson for other countries seeking to adopt EV fleets: is the law as a stick the best encouragement for change?

How would Singapore do? The China and Taiwan approach is likely to be unpalatable to proponents of market-based solutions who prefer to see consumers switching to EVs on their own accord (Wienert 2008). A legal ban on ICEVs on segments of Singapore roads would raise many questions (and many possibilities.) But a multi-government agency with a whole-of-government approach would have to be first established to provide options, e.g., rapidly engineer the electrical-charging infrastructure necessary to keep the EVs and electric bicycles on those segments of road. While the EV test-bedding programme is a good start, the entire car re-sale market would have to be actively tweaked by the government in order for existing car owners to gradually phase out their current vehicles; an ample adjustment period to alleviate any economic woes caused by the new policies is needed. Major car-dealers and parallel importers would have to be persuaded to market EVs (*Figure 4*). And how is this to be achieved? We suggest that a study of the politics of subsidies and incentives and economic policy be expedited to ensure mass consumer confidence in new products, new systems, new technologies, given that there remains many rate-limiting steps, such as improvements needed in energy storage systems and systems for better monitoring and control of power flows within the vehicle and from grid-to-vehicle (G2V) and from V2G (Anderson 2009). Singapore could emerge as an international leader in the implementation (test-bedding) of EV technology with its attendant corporate consulting benefits and R&D leadership. However, the social-economic costs in doing so must be well-considered.

Figure 4: Electric Vehicle on sale (Nissan Leaf)

In Singapore, the current view is that through a system of government-sponsored and private sector-driven corporate incentives, the sticker price of any EV (HEVs, PHEVs, or EVs) would decline to levels palatable to the average motorist. The Chinese experience with E2Ws indicates that short of an outright ban on ICEVs, the public was unprepared to accept EVs as a general rule; one author has termed it “a policy accident, rather than success” (Yang 2010). In Taiwan, motorists were not prepared to accept EVs even when prices were on par or below that of conventional cars, motorbikes and scooters (Yang 2010). The PHEV combines the positive attributes of EVs and the ICE, but in the event where the driver forgets to charge the vehicle over-night, the efficiency factor of a PHEV plummets as the battery on board simply becomes a dead weight to the conventional engine and consumes unnecessary fuel (Yang 2010). Even the most efficient lithium-ion batteries used in today's cutting edge car models like the GM Chevrolet Volt have much less energy storage capacity compared to traditional ICE cars. Although urban transportation patterns seem to indicate that most people would drive much less than the total energy requirement for EVs, breaking established patterns on car-refuelling might prove to be the Achilles heel for road vehicle electrification. Consumer behaviour related to driving habits, re-fuelling and the willingness of drivers to re-charge their cars regularly, all have to be examined much more closely in the Singapore context before policies can be implemented (Yang 2010).

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Perhaps the most difficult component would be the paying of subsidies for the EV roll out in Singapore. There is much international chatter with regards to governments offering partial financial assistance to car companies, infrastructure providers, electrical utilities companies and, ultimately, consumers, to commercialize EV technology on a mass scale (Anderson 2009). Once again, in the Singapore context, this approach runs counter to current policy on curbing private vehicle usage and establishing an unfettered market on energy. In addition, there has to be a sustained political will to withstand the costs of doing so; an entire bevy of international consultants, financiers, researchers, policy makers and scientists will stand to gain a financial windfall from any local government largesse. The political endorsement for such a move has to be sustained for an indefinite period before we see the results.

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But Singapore is well-recognised for its commitment to industrial policy and growth development. EVs are now fashionably touted in the international arena and in the US, the lobbyists for vested interests in this arena are plentiful. We contend that a holistic "systems of systems" technological and economic study be conducted to make the public fully aware of the social and economic cost of implementing such policies as well as the potential economic benefits of new industrial innovation in Singapore.

Carbon pricing, by rewarding Singapore for the offset of CO_2 emissions from road vehicles, coupled with any additional tax revenues from road pricing, could help to pay for the current added costs of EVs (Anderson 2009). As mentioned earlier, there has to be a large degree of flexibility and strong public-private sector co-operation in order for this project to come to fruition. Singaporeans have to actively "buy-in" to the rewards of EVs and their attendant benefits. One of the low hanging fruits would be the creation of the first consumer-oriented market place for carbon emissions in the world; it is possible that private equity, whether from Singapore or other financial centres, can be used to lubricate the transition process and help to pay for the government investments in the transition to EVs. The potential job and revenue spin-offs from participating in the carbon markets have been addressed by Tilak Doshi (2009). But once again, there has to be a concerted political effort to analyse the macro-economic impact of implementing a carbon marketplace/taxation effort. But as we work the carbon tax or cap-n-trade issues, consider its impact (negative?) on Singapore's petro-chemical and international logistics sector which generate a majority of the carbon emissions in operations and bunkering while contributing tremendously to the island-state's economy.

Changing the industrial architecture of road vehicle electrification

The much touted association between EVs and renewable energy sources, such as, wind and solar lies in the usage of the electricity storage capacity of these vehicles when they are at rest, known as V2G (Anderson 2009). Essentially, the vehicles absorb the electricity generated by renewable sources and re-distribute it through the national grid; this helps to offset the peaks and troughs for renewable energy generation at all hours of the day.

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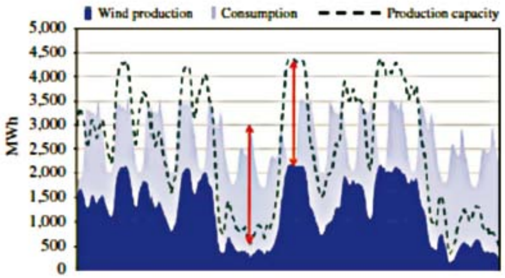
Figure 5 illustrates the uneven nature of energy generation of the wind energy sector in Denmark, which theoretically could be offset by V2G technology.

The complication lies in the implementation of this technique in Singapore. The amount of electricity generated by renewable energy remains negligible in the domestic Singapore electricity market, as mentioned earlier; natural gas powered turbines which are much more regular in energy generation remain the status quo. Hence, implementing a V2G solution would have much more different implications for the supply and demand structure of the power grid locally.

Singapore is accustomed to separating the energy demand for transportation and electrical power. Combining these two areas means that an entirely new perspective on energy has to be formed; we will be witnessing a rapid increase in demand for electricity at all hours. The market case for renewable energy sources remains to be proven in the Singapore context and further investigation into its reliability in providing concentrated power for distributed, private transportation remains to be seen. LTA could collaborate with public infrastructure providers or with customers with large roof areas to encourage the re-sale of excess electricity from vehicle owners, thereby creating a new market for small scale private holders in the domestic scene. However, ensuring that there is sufficient power for vehicles at all hours of the day would involve complex software and hardware co-ordination along with centrally allocated electricity blocs throughout the island. From a common sense perspective, motorists might not be able to use their vehicles at all hours of the day, given such an arrangement. Hence, consumer behaviour has to be changed, either through market persuasion or government regulation.

Figure 5: Wind energy and electricity consumption in Western Denmark power grid



Wind energy production and electricity consumption in Western Denmark power grid, over 2 weeks in December 2006. * The period was December 2–17 2006 Source: DONG Energy.

Excerpted from Paul H. Anderson (2009) p.2484

These are basic hurdles which have to be examined more thoroughly. A first step to solving this conundrum would be to electrify the road vehicle fleet of the 2 major public transportation providers; the fixed schedules of the various buses would be a much more predictable format for initial field tests of V2G. Financing the public transportation companies to make the switch from diesel and petroleum would be another attendant issue.

This focus on vehicle electrification serves to illustrate four major points of our paper:

- such transitions would provide major economic benefits to Singapore in its re-engineering to participate in new technology innovations and hence new business and economic developments
- however, the socio-economic costs near-term and the remaining technological and system infrastructural challenges must not be underestimated,
- hence, a holistic "systems of systems" analysis/study is paramount, because
- in meeting the above challenges, Singapore could take the lead in vehicle electrification business developments, while striking the balance between private vehicles and the importance of public transit.

LTA has shown that meeting urban transportation challenges today with a grand vision for tomorrow will indeed catalyse economic growth, and technological innovation with minimal environmental impact.

Conclusion

Given the above programmes in Singapore (the balance of promoting public transit versus the "control" of the growth of private vehicles, the decision to gradually electrify the automobile to reduce emissions, and the advancement of "smart energy systems" leading to future intelligent transportation systems), we contend that this nation has begun the journey towards emerging as a leading test-bed for innovative energy solutions for the transportation industry. Keeping in mind Singapore's physical constraints and the imperative for innovation and continuous improvement, there emerges one important conclusion: a holistic "system of systems" integration across multiple disciplines (and thus agencies) must be further strengthened to achieve success. LTA has shown that meeting urban transportation challenges today with a grand vision for tomorrow will indeed catalyse economic growth, and technological innovation with minimal environmental impact. As such, we are on our way to becoming a "vibrant and distinctive global city." Indeed, if our urban environment could evolve to the standards set by Changi airport, then Thomas Friedman's quotation, when he described his trip from New York's JFK airport to Changi as "like we had just flown from the Flintstones to the Jetsons," (Friedman 2008) may also apply to Singapore's urban transportation system.

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