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CASE STUDY

Integration of transportation and energy data management systems to lower traffic congestion and emissions

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This case study discusses Toyota Motor Corporation's demonstration project on integration of the transportation data management system (TDMS) with the energy data management system (EDMS) to increase utilisation of public transportation systems to lower emissions as well as traffic congestion.

This project dubbed "TDMS-EDMS" was part of the Toyota Smart Community project, one of the four smart community projects funded by the Japanese government, in collaboration with the private sector. This project was active from FY2011 to FY2014.

THE CHALLENGE

According to the United Nation's Intergovernmental Panel on Climate Change (IPCC), greenhouse gas (GHG) emissions from the transport sector in 2010 had already reached 7 $GtCO_2eq$ ie, 23% of global energy-related CO_2 emissions (Reference 1). GHG emissions from the transport sector have more than doubled since 1970, outpacing the growth rate of all other energy end-user sectors, with 80% of this increase coming from road vehicles. In 2014, IPCC projected that without "aggressive and sustained mitigation policies" GHG emissions from the transport sector could reach 12 $GtCO_2eq$ by 2050. One of the mitigation approaches recommended by the IPCC is "*modal shift to lower-carbon transport systems — encouraged by increasing investment in public transport, walking and cycling infrastructure, and modifying roads, airports, ports, and railways to become more attractive for users and minimise travel time and distance".* Toyota's TDMS-EDMS project aimed to achieve such a modal shift by making it easier to utilise the local public transportation system instead of (or in combination with) private vehicles.

Another recommendation by the IPCC is increased utilisation of alternative drivetrains eg, electric vehicles. While battery electric vehicles do not directly emit any emissions, in most countries, the electricity generation process itself is still heavily reliant on fossil fuels such as coal and natural gas. As a result uncontrolled charging of electric vehicles may limit their contribution to lowering GHG emissions. In the TDMS-EDMS project, controlled charging of electric vehicles was implemented to ensure the charging process does not take place during peak-demand to lower the resulting GHG emissions.

WHAT THEY DID

Figure 1 shows the basic system configuration of the Toyota Motor demonstration project. The Traffic Data Management System (TDMS) controls transportation demand/supply and the Energy Data Management System (EDMS) controls local power demand/supply. The integrated platform plans and controls travelling routes as well as charging schedules of electric vehicles to lower GHG emissions and increase the efficiency of both the local transportation system and the local power system. Commuters can use the system via a mobile app as well as a web platform. The integrated system has five functionalities:

1. **Transportation and supplementary information collection:** TDMS collects real-time data on traffic flow, parking area vacancies, and bus/train itineraries as well as passenger flows. It also collects information on the weather as well as local events such as festivals.

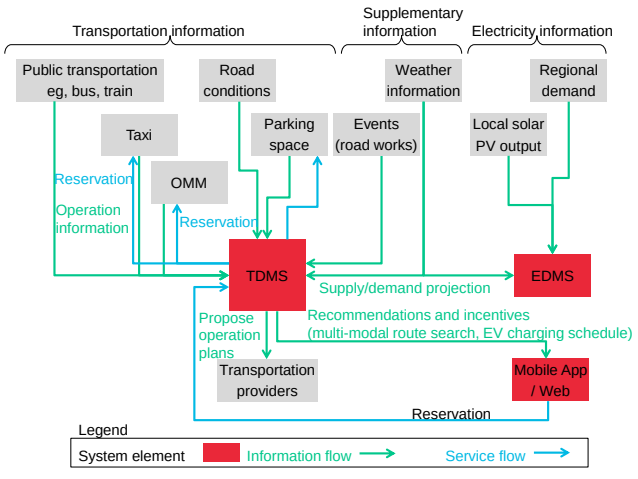

Figure 1: Toyota's integrated TDMS-EDMS platform
Source: Toyota Motor Corporation, Mitsubishi UFJ Research and Consulting. Note: OMM stands for One Mile Mobility system, Toyota's ultra-compact electric car sharing platform.

2. **Transportation supply and demand projection:** Based on the aforementioned information TDMS collects, it projects transportation supply and demand.
3. **Optimal route/transportation mode suggestion:** Based on the predicted transport supply and demand, the integrated TDMS-EDMS proposes optimum multimodal transport combinations for commuters based on travel time, cost, and associated GHG emissions. Users are presented with the top three results under each category of travel-time, cost and GHG emissions, which they can choose from. In the event the EDMS requests lowering electricity demand, for users who own electric and plug-in hybrid vehicles, the TDMS prioritises usage of public transport. It also sends demand response requests to both charging infrastructure as well as stationary storage systems in the region not to charge during these times, if possible.
4. **Provision of incentives:** Along with providing optimum multimodal transportation routes, the system enables third parties to provide users with incentives to choose the lowest GHG emission options as well as cooperate with demand response requests.
5. **Operation plan feedback for transportation business:** The integrated system also provides feedback to local transportation businesses such as taxi fleet operators and city bus operators. The system provides these entities with information on how much and when to increase or decrease their fleets.

OUTCOME

Toyota had initially aimed to achieve a 10% modal shift from private passenger vehicle usage to public transportation based on its prior experience from car-sharing experiments conducted in 1999 (Crayon project). However it has not been able to confirm the final modal shift rate. If Toyota's 10% modal shift target is achievable, preliminary calculations by Mitsubishi UFJ Research & Consulting based on data provided by Toyota show that a city with similar characteristics to Toyota City ie, a population of 500k and daily average passenger vehicle trips of 760k would be able to reduce its transportation GHG emissions by 18.5%. If CO_2 were priced at \$10/t[1] this would translate to \$1.37m. Additionally 18m hours of commuting time per year would be saved. Based on Japan's Ministry of Land, Infrastructure, Transport and Tourism's analysis of value of lost time to commuting (Reference 2), this would translate to JPY 49bn (\$420m).

While the results of the modal shift are unclear, the project was successful in demonstrating the integrated TDMS-EDMS platform could perform all its aforementioned five functionalities. The system was able to provide multimodal route suggestions to users as well as operation plans to transportation business operators based on its transportation supply/demand projections. Its suggestions included the relevant combination of multimodal transport options as well as incentives to encourage utilisation of the lowest GHG emission choice. The demand response functionality controlling charging of electric vehicles as well as stationary energy storage systems also performed as designed.

FUTURE PLANS

Figure 2 shows the future operating scheme of the TDMS-EDMS platform based on Toyota's experience thus far. The platform operator would provide services such as route/transportation mode suggestions to users and receive payments for those suggestions. The operator may also be able to generate ancillary revenues from the local utility via participation in demand response, as well as the local municipality that would be benefiting from lower congestion and better air quality and hence, enhanced economic activity.

Transportation service providers can be either owners of this platform or users themselves. In Figure 2, transportation service providers are considered as users. Traffic service businesses receive the benefit of a rise in income with the increase in public transportation usage as well as increasing operational efficiency through the operation plan suggestion service based on the platforms supply/demand predictions. Fuel consumption and GHG emissions of the transportation service providers could increase depending on the composition of their transport fleet.

Commuters would have to pay to use the service. However, they would benefit from savings associated with reduced usage of their own private vehicle as well as time-saved due to lower average commute time. Additionally they could benefit from the incentives offered by the TDMS-EDMS platform, if they can comply with the route suggestions and DR events.

[1] Reference carbon price considered by the Electricity Generation subcommittee convened by Japan's Ministry of Economy, Trade and Industry (Reference 3)

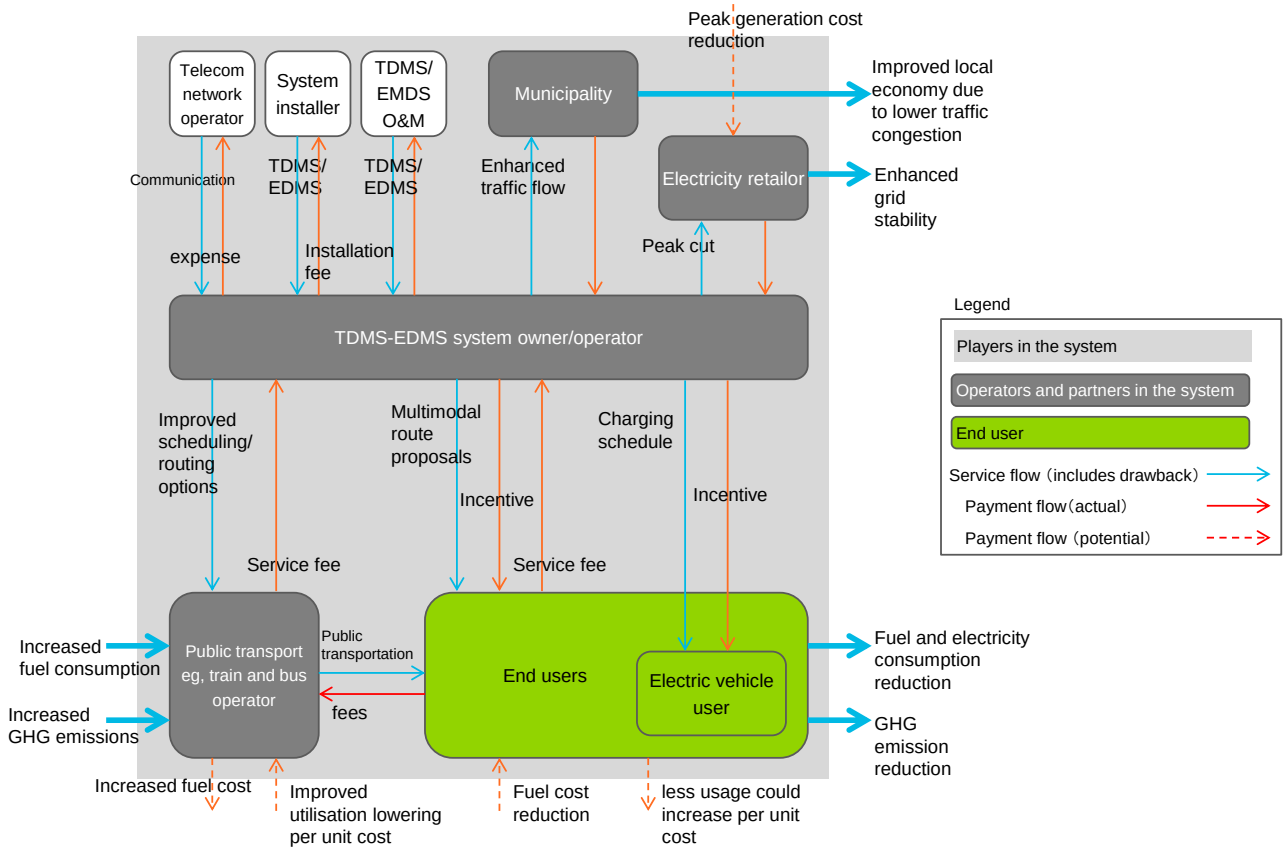

Figure 2: TDMS-EDMS operation scheme
Source: Toyota Motor, Mitsubishi UFJ Research & Consulting.

Future deployment targets

Since modal shifting from personal vehicles to public transportation is the main goal, the targeted regions need to have pre-existing public transport infrastructure. Toyota Motor expects a certain balance of existing private passenger vehicle traffic volume as well as availability of public transportation alternatives eg, buses and trains would be optimum. Toyota is currently evaluating which domestic and international markets would be best suited for commercial deployment of the system, prioritising developed countries until 2020 and developing countries post 2020.

How would the economics improve?

Based on data provided by Toyota, Mitsubishi UFJ Research and Consulting estimates the introduction of the TDMS-EDMS platform to a city with a population of 500,000 would cost about JPY 10m ($85.7k), while annual O&M costs also would be roughly JPY 10m ($85.7k). Comparing these costs with the potential value of annual GHG emission reductions it can achieve – about $1.3m if CO_2 is priced at $10/t – the economics seems attractive. The system would also increase the return-on-asset for the existing public transportation infrastructure. The cost of the system itself may come down further as a result of advances in cloud computing.

FINAL THOUGHTS

The integrated TDMS-EDMS platform can reduce congestion as well as GHG emissions, thus contributing to the quality of life in the region of its deployment. The integration of the local Traffic Data Management System as well as the Energy Data Management System also offers clear ancillary benefits to both the electricity grid as well as the local transportation infrastructure.

While the Toyota city demonstration experiment was aimed at passenger vehicle usage, the system can be adopted for other applications such as fuel cell buses. Toyota expects the integrated TDMS-EDMS platform can enable opportunities presented by the greater interaction between the electricity grid and the transportation infrastructure as a result of uptake of alternative vehicles such as battery-powered and fuel cell vehicles.

REFERENCES

1. Climate Change 2014: Mitigation of Climate Change, Transport Chapter, IPCC.
2. Database of Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan.
3. Electricity generation cost sub-committee, convened by Ministry of Trade, Economy and Industry, May 2015.