ABSTRACT

After the turn of the century, growing social attention has been paid to environmental concerns, especially the reduction of greenhouse gas emissions and it comes down to a personal daily life concern which will affect the purchasing decision of vehicles in the future.

Among all the sources of greenhouse gas emissions, the transportation industry is the primary target of reduction and almost every automotive company pours unprecedented amounts of money to reengineer the vehicle technologies for better fuel efficiency and reduced CO2 emission.

Besides those efforts paid for sheer improvements of genuine vehicle technologies, NISSAN testified that “connectivity” with outside servers contributed a lot to reduce fuel consumption, thus the less emission of GHG, with two major factors; 1. detouring the traffic congestions with the support of probe-based real-time traffic information and 2. providing Eco-driving advices for the better driving behavior to prompt the better usage of energy.

This article explains how the connected vehicle via network realized the reduction of fuel consumption and, thus, CO2 emission in real-life deployments in Japan and China.

INTRODUCTION

Nissan is pursuing technical developments and commercial deployments of various kinds of Telematics solutions for the improvement of environmental concerns toward ecological use of energy and less emission of CO2.

This article refers to the effectiveness of Dynamic Route Guidance (DRG) and Eco Drive Advice (EDA) deployed for CARWINGS, a Japanese commercial implementation of Telematics, and DRG for the world's highest density real time traffic information based on taxis in Beijing, China.

CASE STUDY #1: CARWINGS IMPLEMENTATION IN JAPAN

In Japan, governmental agencies gather traffic data mostly from infrastructure-based sensors and provide traffic information through VICS
t for the use of general vehicles. In addition to this governmental traffic information, with consents from vehicle owners, major Japanese vehicle companies gather, mostly via either customers' carry-in cellular phones or embedded cellular phone modules, and analyze anonymized probe data, which contains location-related data with time stamps, to obtain broader, detailed, and nearly real-time traffic information.

With using probe data in conjunction with VICS data, NISSAN started commercial implementation of DRG, with statistical analysis to forecast the near-future traffic congestions in 2006. Based on our experiments in Kanagawa Prefecture in Japan, we obtained the data which showed that a vehicle with a DRG-enabled Navigation System increased the average speed by 25% and reduced the emission of CO2 by 17%, when compared with a plain vanilla Navigation System without any traffic information as shown in Figure 1. (Red bar v.s. Green bar)

In addition to these DRG effects, NISSAN provides Eco-Driving Advice (EDA), as shown on Figure 2 and Figure 3, for drivers and proved that further improvement of fuel consumption would be attained. This is an implementation based on our findings that the differences of customer's driving habit yield diversified levels of fuel efficiency.

For the reference of drivers, we report the up-to-date status of EDA result on drivers' Web site as well as on Navigation
since July '07 in Japan as a packaged service of the Eco Management System (EMS).

Such a daily awareness through Eco-related activities will contribute a lot for the improvements of real life Eco Management. As a result of those EMS activities, we testified through our examinations that EDA would bring in additional 18% of improvements, even after DRG, on Fuel Efficiency among controlled group.

As shown on the right side of Figure 2, NISSAN proved the effective solutions toward Green Driving with those combination of A: DRG and B: EDA and was awarded with two major ECO prizes from Ministry of Land, Infrastructure, Transport, and Tourism in 2007 and from Ministry of International Trade and Industry consecutively in 2008, 2009, and 2010.
In the year of 2006, NISSAN started to discuss with Beijing Traffic Information Center (BTIC) regarding the use of taxi-based real-time traffic information to improve the traffic and environmental conditions in Beijing. Within this collaboration, BTIC provided their traffic information processing technology with the world's highest density traffic information gathered from taxis, while NISSAN provided Traffic Forecast Technology based on our cutting-edge Navigation & Telematics Technology.

Through this collaboration, NISSAN testified that 18 percent of travel time was reduced on average in the real traffic conditions in Beijing in July 2007 and demonstrated this total solution, named as STAR WINGS, at Beijing ITS-World Congress in Oct. 2007.

At the Beijing Motor Show in Apr. 2008, NISSAN announced the Navigation System with STAR WINGS, which utilized the BTIC's Traffic Information received via FM multiplex broadcasting, with a capability of DRG to avoid congestions, and then commercially launched NISSAN's new passenger vehicle called TEANA with the DRG-enabled the Navigation System in China. (Figure 3)

In addition, in Sep. 2009, NISSAN explored the possibility to apply EDA in the Chinese market and implemented an educational driving course for trial in Shanghai to find 15%, on average, of improvements of fuel efficiency among those who took the course.

**TRAFFIC FLOW SIMULATION FOR 2020 IN BEIJING**

In the real market, penetration of Navigation Systems with DRG capability takes a long time, because the take rate of those devices at the point of new car sales would be just a small percentage, especially in a non-Japanese market, and
any vehicle stays in the market for about a decade. So, in order to evaluate the long-term effectiveness of DRG, we simulated the effects of DRG for the improvements of traffic flow in Beijing by analyzing the situation of available road network, congestion rate of vehicles, driver’s route selection behavior, and market penetration rate of DRG-enabled Navigation Systems to receive traffic information such as STAR WINGS toward 2020.

We defined the effect of improved traffic conditions as:

\[
\text{Effect of improved traffic conditions} = \text{available road network} \times \text{congestion rate of street} \times \text{driver’s route selection behavior} \times \text{penetration rate of DRG-enabled Navigation Systems}
\]

Here;

- **Available road network** has been forecasted based on the Beijing’s Future Road Plan in 2020. The improved road infrastructure provides more available alternative routes for the better traffic conditions.

- **Congestion rate of street** was assumed from the increasing rate of 5% per year considering Beijing’s policy to shift for public transport system.

- **Route selection behavior** was analyzed from the interviews of two thousand professional taxi drivers in Beijing.

- **Penetration rate of DRG-enabled Navigation Systems** is set as variable.

As shown in Figure 4, we simulated how the traffic information will disperse the traffic congestions depending on the market penetration rate of DRG-enabled Navigation Systems among total vehicles.

We conducted the simulations in four selected areas in Beijing as shown in Figure 5. For this simulation, Beijing University of Technology and Hiroshima University are joining in STAR WINGS project, within which Beijing University of Technology, in collaboration with BTIC, provided us with traffic flow analysis and its forecast; NISSAN provided our expertise in DRG technology using real-time traffic information; and Hiroshima University provided us with the analysis of driver behavior and its modeling.

The in-vehicle system is rather simple and shown below in Figure 6. Most of the data processing and analysis would be done on servers on the network.

**Result of the simulation**

Based on our simulation in the area of CBD (Figure 7), those vehicles using DRG experienced the improvement of vehicle speed by 12km/h on average. This improvement level was almost constant and independent from the penetration rate of DRG-enabled Navigation Systems. On the other hand, the average speed of vehicles even without traffic information will also be improved due to the broader optimization of traffic flow. As for the average, if the penetration rate of DRG-enabled Navigation Systems exceeds 30%, overall traffic speed will be improved from 9km/h to 15-20km/h.

A similar effectiveness was found with the simulation in the area of Zhong Guan Cun as shown in Figure 8. Improved vehicle speed was 7km/h for the vehicles using DRG-enabled Navigation System and also would improve the vehicle speed for the vehicles not using traffic information as the penetration rate of the devices goes higher. 30% penetration of rate of DRG-enabled Navigation Systems contributes effectively to improve vehicle speed from 10 to 16km/h in overall.
Summery of the simulation
We verified that STAR WINGS is effective to improve traffic flow and, with 30% of penetration rate of DRG Navigation Systems, overall traffic flow would reach an optimized level.

SUMMARY/CONCLUSIONS
- Dynamic Route Guidance (DRG) helps drivers to avoid traffic congestions and results in shorter travel time up to around 20%\(^2\) with better fuel usage and, thus, reduction of CO2 emission.

- If the penetration rate of DRG-enabled Navigation Systems exceeds 30% among the total number of vehicles, overall traffic flow will be optimized.

- Eco-driving Advice (EDA), which changes the human factor of vehicle driving, has been proved efficient for the better fuel efficiency and ecologically friendly driving in Japan and China. With more penetration of navigation systems and communication devices worldwide, further implementation of Green Driving would be pursued.

REFERENCES
1. VICS: Vehicle Information and Communication System. “VICS is an innovative information and communication system, enables you to receive real-time road traffic...
2. The density of traffic information availability is 70% in Beijing, while 24% in Tokyo and 23% in Paris.

3. Japanese traffic information service, VICS, took 12 years to reach the penetration rate of 27%.

4. Through the interviews, we found that, if the travel time forecast suggests 10-15 mins of trip time reduction, drivers will use traffic information and take alternative route. My additional calculation resulted in as follows; \( Y = 8.56 \times \log(X) \), where \( X \) is a number of minutes to make a trip on a given route and \( Y \) is a number of expected minutes when alternative route would be taken. If \( Y \) is smaller than \( 8.56 \times \log X \), drivers may take the alternative route.
5. 30% of penetration of traffic information receivers is equivalent to shipments of three million units.

6. NISSAN made similar experiment in the US and obtained the reduction of travel time by 16% and fuel consumption by 8% on average. The experiments were done in Michigan and Virginia in July and August in 2008 and California in September 2009.

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DEFINITIONS/ABBREVIATIONS
CARWINGS
NISSAN'S Telematics service started in 2002 in Japan. CARWINGS service is available for NISSAN customers who purchased Make-option Navigation Systems for free of charge, except for Operator Service which are free only for the first three years.

BTIC
Beijing Traffic Information Center
CBD
Central Business District

DRG
Dynamic Route Guidance

EDA
Eco-Drive Advice

EMS
Eco-Management System

GHG
Green House Gas

VICS
Vehicle Information and Communication System