Applicability for Green ITS of Heavy Vehicles by using automatic route selection system

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ABSTRACT

When persons intend to let the heavy vehicle that its size or weight is exceeding the legal limit for free running on roads run in Japan, persons who operate such vehicle have to select the route by themselves, and have to receive the permits from the road administrators of the routes. They can let such vehicles run on roads actually after the permission. From such a background, it is difficult to evaluate the validity of the route. Therefore, the result of the design and development work of the system which makes it possible to select the most suitable route for the heavy vehicle under given conditions automatically is reported.

Keywords: Heavy Vehicle , Automatic Route Selection , Green ITS

1. INTRODUCTION

Heavy vehicles which exceed limits on vehicle dimensions or weight, called special vehicles, travel on roads only after receiving the permission of the road administrator. Normally, the individual who wishes to operate the vehicle (hereinafter referred to as applicant) prepares the route of passage by referencing the road data manual, after which the road administrator makes a decision, based on the specifications of the vehicle, to either allow or deny travel on the route based on vehicle data and the geometric structure of the roads, and a permit is issued based on the results of the decision.

Under these regulations, one issue is that comprehensive evaluation is difficult, such as whether the requested route is the shortest distance, the safest route to travel, and whether the route has the minimum effects on road structures. For that reason, a system was designed and developed by unifying the algorithms used for judging, and for selecting the shortest route, in order to allow heavy vehicles to automatically select the optimal travel route. Here, we compare the routes created manually with routes generated by this system, and report on the comparative results of the above, such as the reduction of route length.

2. BACKGROUND TO THE DEVELOPMENT OF THE AUTOMATIC ROUTE SELECTION SYSTEM

2.1 Overview of the travel permit system for heavy vehicles

2.1.1 Travel permission system

Road structure is designed so that vehicles within a specified standard can travel them safely and smoothly, and vehicles which exceed that standard run the risk of causing a negative impact to the road structure or traffic.

For that reason, it is prohibited to allow vehicles which exceed the government mandated limits on weight, width, height, length, and minimum turn radius, shown in Figure 1, to travel on roads (Article 47 Section 2 of the Road Act).

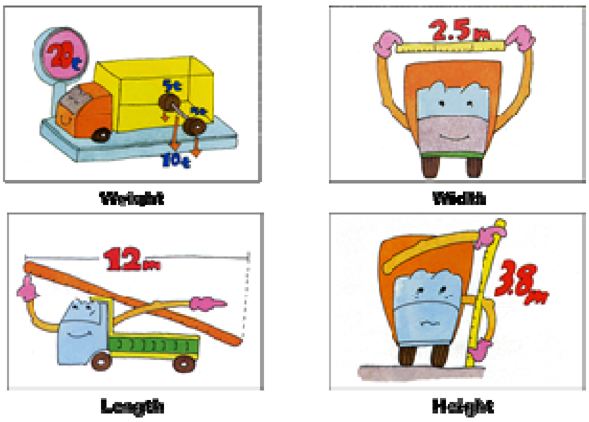

Figure 1. Vehicle Standards

However, only when the road administrator acknowledges that it is necessary or cannot be avoided, it is possible to permit travel by a vehicle that exceeds the maximum limits, providing road structure is maintained and conditions to prevent dangers to traffic are met (slow speed, traffic restrictions, use of a pilot vehicle, designation of transit time, etc.) (Article 47 Section 2 Paragraph 1 of the Road Act)

Here, the person wishing to operate a vehicle exceeding the maximum limits must write the vehicle specifications, cargo content, transit route, and transit date on the designated form, submit it to the road administrator, and receive a transit permit, after which they can operate the vehicle in transit.

2.1.2 Transit judging methods

As shown in Figure 2, factors used in transit judging include determining the possibility of transit versus the load bearing ability of bridges, the internal height of tunnels, turning ability at intersections, and the width of straight and curved sections of road. A calculation method is specified for this transit judging based on the transit permission program. All road networks in Japan with a width of 5.5 meters or greater are registered in the database which

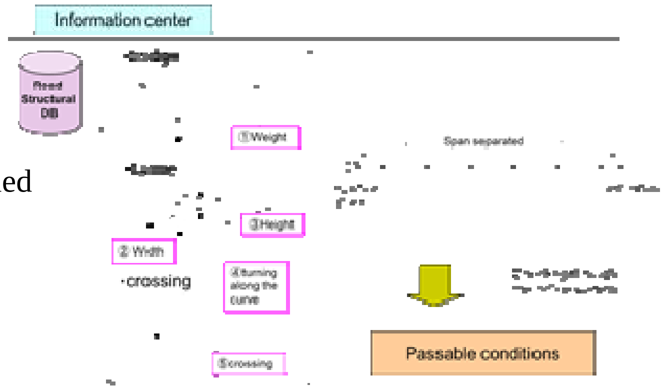

Figure 2. Vehicle Standards

includes as master data all data necessary for transit judging for almost all directly managed national roads and primary regional roads.

2.2 Issues for route selection in Japan

2.2.1 Road network conditions

Road networks which see frequent transit by heavy vehicles are listed in the road data manual. Among those, weight designated roads (allowing transit of up to 25 tons total weight without approval) and height designated roads (allowing transit of vehicles with heights up to 4.1

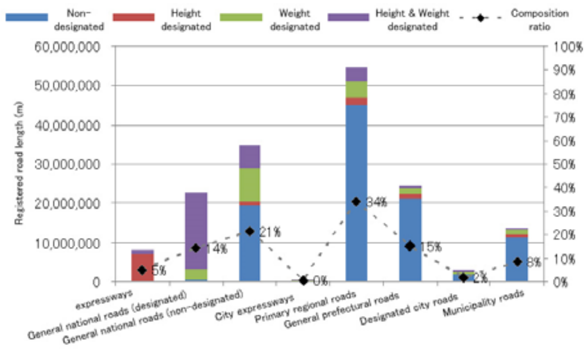

Figure 3. Road data manual

meters without approval) are established as roads on which international maritime containers may transit easily.

Broken down by road type, the type of road with the highest ratio recorded in the road data manual is primary regional roads, comprising over 30%. This is followed by general national roads (non-designated), comprising about 20%. Looking at the designated road category, weight and height designated roads are the most common. Over 90% of directly managed national roads are weight and height designated roads.

2.2.2 Issues for route selection

Although the aforementioned road network exists, and limits for determining the possibility of transit, such as road width, are made public, the applicant was still required to prepare their own route while referring to this data. As a result, the reality is that applicants prepared their routes through trial and error and a reliance on experience regarding past successful transit. Thus, a significant amount of effort was required for route preparation.

Further, an issue remained such that neither the applicant nor the road administrator could determine whether the route prepared by the applicant on their own was the optimal route or not (for example, whether it was the shortest distance or featured the best transit conditions).

2.3 Requirements for an automatic route selection system

It is apparent from questionnaires and interviews of applicants carried out previously that there was a need for a system that allowed selection of the optimal transit route after setting the starting point and destination, as is done with car navigation systems.

Further, there is a need among road administrators who, from the standpoint of maintaining roads and securing safety, wish for routes on roads with high standards to be used as much as possible.

3. OVERVIEW OF THE AUTOMATIC ROUTE SELECTION SYSTEM

3.1 SYSTEM OVERVIEW

The necessary conditions for generating routes appropriate for the transit of heavy vehicles were considered and organized in order to compile the functional requirements for the system. Note that examination and coordination was done with consideration given to the manual of permitted limits for heavy vehicle transit.

3.1.1 Requirements for generating routes appropriate for the transit of heavy vehicles

To consider the details of the functions needed for route generation, the relationship between the system to generate transit routes (hereinafter referred to as the automatic route selection system), and systems related to heavy vehicles, were organized, as were the basic functions that should be handled by the automatic transit route generating system.

In order to accurately define routes appropriate to transit by heavy vehicles, the necessary requirements and basic judgment methods to achieve them, as well as the data available for that judgment, was compiled, and a route generation method aimed at maintaining road structure was considered.

Note that for the specific processing methods used in the system, feasibility was evaluated based on the necessity of the requirements (priority) and the state of organization of the data available for use.

3.1.2 Understanding the state of transit route generation

Past heavy vehicle permission data was used to determine the respective ratio per vehicle type and the ratio per type of road on the transit routes. As a result, the distribution of dimensions and weight for each vehicle model and axle classification was categorized to organize the vehicles into groups. Further, the ratio of directly managed national roads and expressways (designated roads) was high at 96%, showing that it is likely that many heavy vehicles are traveling on high standard roads. As a result, it was confirmed that the appropriate selection of routes to reach directly managed national roads and expressways is important from the standpoint of road administration.

3.1.3 Consideration of transit route generation methods

Transit route generation methods were considered in light of 3.1.1, and the most feasible road administrator requirements were selected to reflect in the routes. Further, the generation method was selected in consideration of the applicant needs organized in 3.1.1.

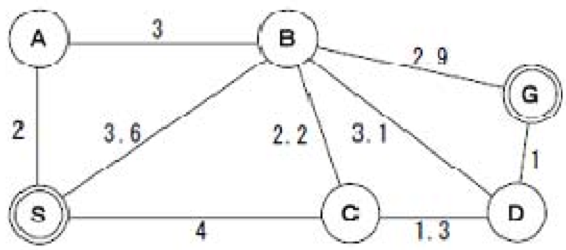

Figure 4. The basic logic

For route path finding, time and distance costs were associated with each link between nodes on the road network, and Dijkstra's algorithm (proposed by Edsger Dijkstra in 1959) was adopted as the algorithm to use to select the optimal route by minimizing those costs (Figure 4).

In order to generate a route based on the conditions organized in 3.1.1, the route generation pattern varies depending on whether the conditions that are set change according to the vehicle specifications or not.

3.2 Requirements in generating routes appropriate for the transit of heavy vehicles

3.2.1 Method for setting transit permission conditions

The transit conditions of weight (bridges) and dimensions (width, height, curves) based on the heavy vehicle transit permit program are shown in Figure 5. Transit is permitted for four weight types and three dimension types of heavy vehicles that exceed the limits.

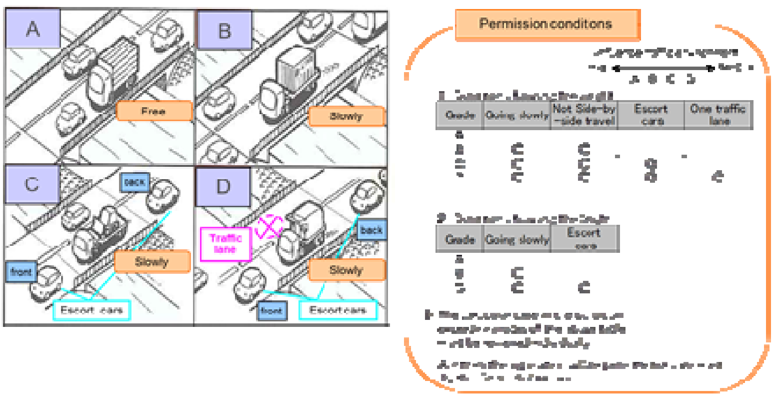

Figure 5. Transit permission conditions

3.2.2 Organizing routes appropriate for the transit of heavy vehicles

It is believed that applicants can make use of better transit conditions by traveling on routes that use weight and height designated roads appropriate for heavy vehicle transit. Further, there are merits for both parties such that, from the standpoint of the road administrator, having heavy vehicles travel on higher standard roads benefits road maintenance, while traveling on weight and height designated roads for longer periods is also advantageous regarding the effect on the roadside environment.

The generation method is described below in detail.

1) A transit route is generated from the departure point which is either the shortest route, or has the best transit conditions, to reach weight and height designated roads.
2) A route using weight and height designated roads is generated up to the vicinity of the destination.
3) A route is generated from the designated roads to the destination using either the shortest distance or the best transit conditions.

3.3 Setting route generation conditions based on an understanding of the state of heavy vehicle transit routes

When the ratio per road type and usage conditions for weight and height designated roads was examined to test the hypothesis in 3.2.2 based on actual data from heavy vehicles which had been given permission, it was found that 90% were expressways and directly managed national roads, and 98% were designated roads.

3.4 Transit route generation methods

3.4.1 Organization of route generation conditions

The route generation pattern varies depending on whether the conditions that are set change according to the vehicle specifications or not. This is because the conditions for generating a route are different as shown in Table 1.

Table 1. The route generation pattern

Case of variation upon vehicle spec	Case of non-variation
・ Transit conditions	
・ Unavailable transit (upon vehicle spec)	・ Unavailable transit
	・ Environmental road pricing
・ Weight designated roads	
・ Height designated roads	
	・ Weight & Height designated roads
	・ Distance (span length)

When conditions change according to vehicle specifications, route selection can be carried out using the vehicle specifications of the registering vehicle during route generation, but this creates the issue that when calculations are performed each time, route path finding will require time as well. As an alternative to this, the heavy vehicle approval data was analyzed and organized according to each representative vehicle type

and specification (Figure 6, 7), and the resulting conditions were used to calculate the transit conditions for all spans across the road network in advance to reduce route generation time.
Further, transit conditions were analyzed for each vehicle and obstacle type to organize the cumulative number of vehicles approved as shown in Figure 8. Based on these results, 13 models of vehicles were defined and the cost values were set based on the transit conditions for the entire network using total weight, axle weight, width, length, and height.

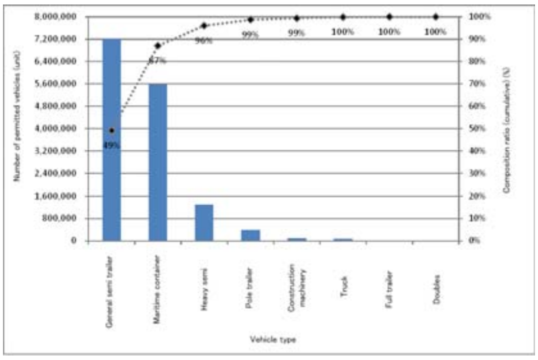

Figure6. Vehicle type

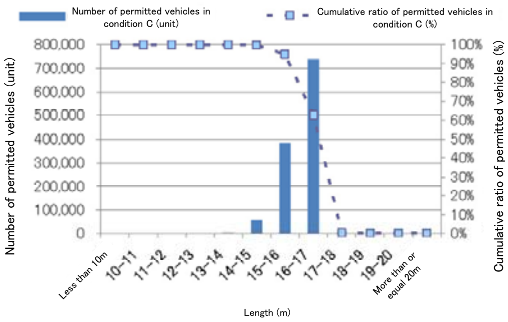

Figure 7. Permission units

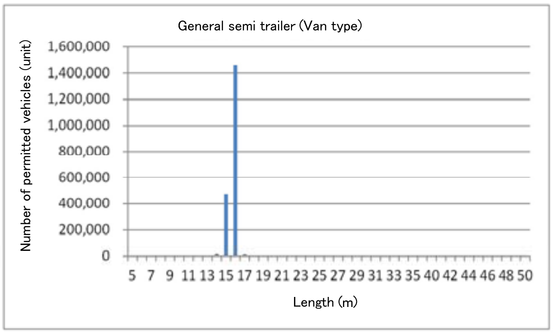

Figure 8. The length of the vehicle type

4. Development of the automatic route selection system

4.1. Overview of the automatic route selection system

Figure 9 shows the composition of the automatic route selection system.

4.2. Validation results of the automatic route selection system

The results from validating the automatic route generation conditions in advance using the developed system, showed that the appropriate transit route was selected automatically, as shown in Figure 10.

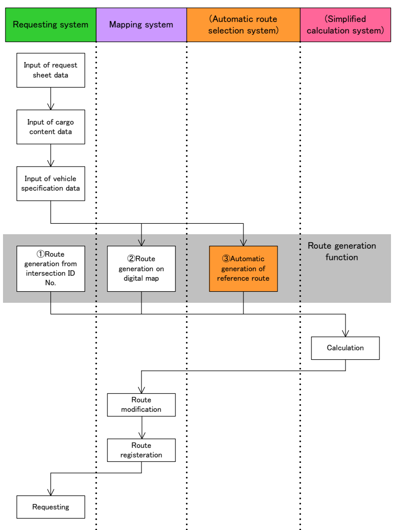

Figure 9. Automatic route selection system

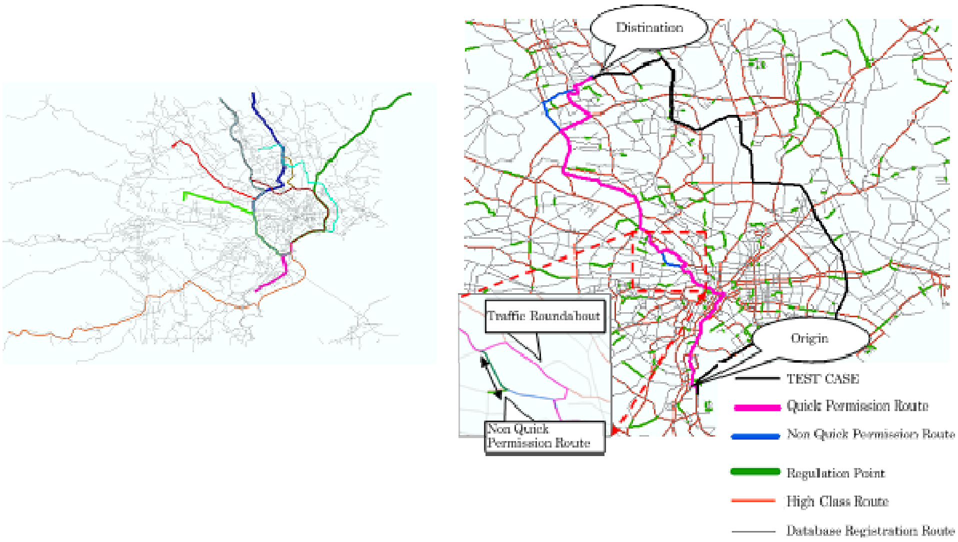

Figure 10. Travel route automatically generated case

5. The example of selecting the route automatically

5.1 Optimization of time required for preparing registration paperwork

5.1.1 Time required to generate a route using the former system

The former route generation system used a Web GIS system, much as the new system, to allow the applicants themselves to select the intersections along the route to register from the departure point to the destination to generate the route.

5.1.2 Time required to generate a route using the automatic route selection system that was developed

The automatic route selection system allows the applicant to generate routes automatically for three cases by setting the departure point, destination point, and if necessary, midway points. (Table 2)

Table 2. The case of route selection

case	Requirements for route generation	Specific conditions
1	Route of model vehicle transit as condition C or more	Except respective judge/condition D
2	Route of model vehicle transit as condition D or more	Except respective judge
3	Route excluding model vehicle unavailable transit	Route of the shortest distance

5.1.3 Time reduction effects

Compared with 5.1.1, using the new system under 5.1.2 allowed the applicant to generate a route with better conditions in one third of the time it took previously. (Measured using an average length route: hand selection: 8 minutes, automatic selection: 3 minutes)

There are approximately 300,000 cases of heavy vehicle permits given per year. While approximately 30% of those are cases where the registered details are simply updated from a previous case, the remaining 70% are for applicants creating new routes.

For that reason, this system can be utilized for approximately 210,000 applicants.

5.2 Reduction of effects on road structures by prioritizing the use of high standard roads

Routes which direct transit over weight and height designated roads (expressways, directly managed national roads) as much as possible are generated through the use of the automatic route generation function, and the effects thereof were compiled from multiple samples. In the future, there are plans to obtain a more detailed result by accumulating one year's worth of route data.

5.3 Contribution to environmental measures by prioritizing environmental road pricing zones

Currently, there are two environmental road pricing zones on the road network upon which heavy vehicles travel. Current cost settings generate routes which avoid the Residential area to use the shoreline zone. As a result, it was confirmed that applicants are able to select routes that are inexpensive to travel and that put less burden on the roadside environment.

5.4 Contribution to Green ITS as a result of travel distance reduction

5.4.1 The relationship between this system and CO2 reduction efforts

According to the results of questionnaires and interviews carried out hitherto with applicants, transport companies provide incentives for drivers who consume less fuel when traveling. This has the combined effect of reducing transportation cost while reducing the transport company's CO2 emissions. If travel distance can also be reduced, than these effects can be further improved.

5.4.2 Analysis of travel distance reduction

Table 3 shows the result of a simulation of the travel distance reduction effect provided by the automatic route selection system using approved routes created in the past.

Here, a model route was created based on the average approved route length for heavy vehicles of 270 km one way, and the results were examined.

While there is some fluctuation due to road type of the transit route, and between routes, it was confirmed from the simulation results that the travel distance is reduced when a vehicle traveling the average one way distance uses expressways or beltways.

Note that the plan is to obtain statistics for the coming year to clarify the trend.

Table 3. Analysis of the effect of mileage

No.	Assumed route (departure～destination : used road type)	Previous Route (km)	Automatic route (km)	Distance + − (%)
1	Along the comparatively similar route (Ooi Wharf～Shiomizaka, Hamamatsu :general)	270.0	299.8	+ 11.0 %

2	Along beltways partially (Ooi Wharf〜Shinshu-Nakano toll : highways)	270.0	257.0	-4.9 %
3	Available use of Jobando & Tohokudo highways (Ooi Wharf〜Miharu-Nishi bypass : highways)	270.0	271.0	+ 0.0 %

6. FUTURE OUTLOOK AND PLANS

6.1 Confirmation of usage conditions

The number of times this system is used per month is being analyzed to understand the usage conditions. The results show that, compared to April 2013, 150 percent the number of routes were generated in June.

6.2 Awareness of transit route generation conditions and review of route selection conditions

It has been made possible to accumulate a log of each vehicle's specifications, departure point, destination, and automatically generated route in order to enable detailed analysis of the effectiveness of this system. For that reason, the log data for FY 2013 (April 1, 2013 to March 31, 2014) will be analyzed. Specifically, an analysis of the automatically generated routes will be carried out in order to examine the validity of the cost values and model vehicles. Further, remaining issues with the system will be identified by comparing the above with routes used for actual registration.

6.3 Further expansion to a transit route display system

As it is possible to automatically display the transit route after selecting departure point and destination on the in-vehicle unit by using the automatic transit route generation function, the system can be used as a guide for the permitted route by displaying the GPS based current position on that permitted route.

7. CONCLUSION

An automatic route selection system was developed and validated by using Dijkstra's algorithm, commonly used in car navigation system route path finding, and the approach of the manual of permitted limits for heavy vehicle transit already used in route judging for heavy vehicles, as cost values for each span of road. This system has been in general use since April 2013.

Automatic route generation according to the given conditions (example: allows nighttime transit, shortest route, etc.), which were hitherto set by applicants based on previous transit route selection experience, makes it possible to greatly increase the convenience of registration. Further, it is believed that analysis of the route data that will be accumulated from this point onward will make numerous types of analysis possible and allow for the provision of transit routes for heavy vehicles that are more convenient, and have less impact on road structures and the environment.