

Analysis of Road Network Efficiency by Using Freight Vehicles'

Probe Data

Takahiro Tsukiji^{1*}, Shoichi Suzuki¹, Yukio Shikatani¹, Hiroshi Makino¹

1. ITS Division, National Institute for Land and Infrastructure Management,
Ministry of Land, Infrastructure, Transport and Tourism, Japan

1 Asahi, Tsukuba, Ibaraki, Japan

TEL: +81-29-864-4496

E-mail: tsukiji-t92ta@nilim.go.jp, suzuki-s92tg@nilim.go.jp, shikatani-y924a@nilim.go.jp,
makino-h87bh@nilim.go.jp

Abstract

An analysis was conducted in this study to attempt to evaluate the level of development of the access roads around a physical distribution base using ETC2.0 probe data. ETC2.0 probe data are obtained from a pilot program for freight trucks being conducted by the Ministry of Land, Infrastructure, Transport and Tourism. The results indicate that the level of development of the access roads affects the speeds of trips to and from the base within certain distance ranges. As issues that should be taken into account in the future analysis, supplementation of data, precise segmentation of trips, and exclusion of unreliable data are cited.

Keywords: freight truck, access road, ETC2.0 probe data

Introduction

Amid economic and social globalization, the improvement of our local competitiveness is needed. As part of this effort, it is necessary to improve the functioning of international strategic ports and other physical distribution bases [1]. In Japan, transportation by freight trucks accounts for more than 90% of freight transportation (as measured by weight) [2]. Therefore, the functional improvement of physical distribution bases requires the development of access roads connecting production and distribution bases. In developing these access roads, the access needs of freight trucks that use the distribution bases and the usage conditions of the access roads must be identified to clarify where roads should be developed and what types of roads should be provided.

Until now, the travel patterns of freight trucks had been determined from information

collected in the Road Traffic Census [3] and Nationwide Freight Flow Survey [4]. They are conducted at intervals of several years. The information from these surveys cannot be used, however, to determine detailed travel records for freight trucks, including travel speeds, times, and routes. Previous studies have analyzed freight trucks travel using data from cell phones equipped with global positioning system (GPS) locators or GPS on-board units (OBUs) mounted for purposes of probe investigation [5][6], freight truck probe data obtained from private companies [7], ETC data [8][9], and data from questionnaires completed by truck drivers [10][11]. However, each of these study approaches has limitations. Probe investigations are limited in that they cover limited periods and areas. Road administrators do not have free access to freight truck probe data from private companies. ETC data and questionnaire data cannot be used to determine travel speeds and other travel record details. In contrast, ETC2.0, the new system being promoted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) of Japan, is capable of continuously collecting probe data. The ETC2.0 probe data include travel speeds, location information, and other travel record details from vehicles equipped with OBUs. The use of ETC2.0 probe data will make it possible to examine the details of vehicle travel throughout the year.

This paper presents an analysis conducted using ETC2.0 probe data to evaluate the level of development of access roads to and from the Port of Kobe based on the travel details of freight trucks. Because the access roads to the east and west of the port differ in their degree of development, trips to and from the east side of the port might involve different travel speeds than trips to and from the west side of the part. Clarifying the travel speeds of these trips by radius for the purpose of comparison of the access roads on the east and west sides could help identify the areas and radii within which access must be improved and the types of roads that must be developed.

Characteristics of ETC2.0 probe data

The ETC2.0 probe data consist of travel records, behavior records, and other data for vehicles equipped with ETC2.0-compatible OBUs. The travel records include the time of day and the latitude and longitude coordinates from which the travel routes of vehicles can be identified. The latitude/longitude data are obtained through the global navigation satellite system (GNSS) positioning function of the OBUs. A travel record is accumulated when a vehicle travels at least 200 m from the point at which the previous data were collected or when the travel direction of the vehicle changes by 45 degrees or more. ETC2.0-compatible OBUs can retain travel records over travel distances of 80 to 100 km. ETC2.0 probe data are uplinked to an ITS spot when a vehicle passes the communication region of the ITS spot's roadside antenna (the 20-meter area directly below the spot). The uplinked probe data are aggregated and saved in the integrated probe server and become available for use by the road administrator.

While no individual vehicle is currently identifiable from ETC2.0 probe data, MLIT is conducting a pilot program. In the program, MLIT is collecting ETC2.0 probe data that can be used to identify individual vehicles from among approximately 2,600 vehicles belonging to cooperating logistics companies. The analysis described in this paper was conducted using the probe data obtained from these 2,600 vehicles.

Development of access roads to the Port of Kobe

Figure 1 shows how access roads have been developed around the Port of Kobe. The port of Kobe is the westernmost of five ports designated by MLIT as international strategic ports (those of Tokyo, Yokohama, Kawasaki, Osaka, and Kobe). Therefore, the Port of Kobe is intended to extend the functions as the gate port supporting the industrial activities and international logistics of western Japan [13]. However, the Port of Kobe is located in the area of Rokko Island and Port Island, far from the inland area, which means that the port is not readily accessible by expressways. The access roads on the west side are less developed than those on the east. Several east–west road networks stretching toward Osaka and Akashi (e.g., the Hanshin Expressway, ordinary roads) experience chronic traffic congestion.



Figure 1 - Development of access roads to the Port of Kobe [12]

Method of analysis

Process of analysis

In this study, the operation of a freight truck from the time at which it departs from its trip origin to the time at which it loads and unloads cargo at its destination was defined as a trip to analyze the travel speed and travel distance of each trip. With regard to trips to and from the Port of Kobe, the distributions of trip lengths and trip directions were initially clarified according to the trips to and from the port. Next, assuming that the speed of each trip can be represented by the slope of the graph of the relationship between the time required and the travel distance (the length) of each trip, the average speed of each trip was calculated at 100-km intervals from the Port of Kobe. The speeds of trips to and from the Port of Kobe over each distance were compared according to the directions of the trips (on the east or west side of the port) to clarify the locations and radii around the port at relatively low speeds. This analysis was conducted using ETC2.0 probe data collected between November 1 and November 30, 2014. Table 1 shows the number of vehicles and trips used in the analysis.

Table 1 - Number of vehicles and trips

	Trips to the Port of Kobe	Trips from the Port of Kobe
No. of vehicles	144	146
No. of trips	350	348

Method of trip extraction

Travel records obtained from the ETC2.0 probe are uplinked as a series of data. This means that the threshold of a time interval when a travel record is interrupted must be set to identify where cargo is loaded and unloaded. A long-distance trip could involve a long stop for a rest or a nap in addition to loading or unloading. Therefore, the time interval threshold must be long to thoroughly extract long-distance trips to and from the Port of Kobe. In contrast, trips to and from the points around the Port of Kobe could be circular or shuttle transport trips in which cargo is loaded or unloaded within a short period of time. Thus, such trips must have a shorter time interval threshold. In this analysis, the time interval threshold for extracting a long trip was set to 360 minutes and that for extracting a short trip was set to 30 minutes. The trip extraction process consisted of the steps described below.

(Step 1) All travel records obtained from the ETC2.0 probe data for analysis were segmented using a time interval threshold of 30 minutes. The origins and destinations of the records were displayed using geographic information system (GIS) software. An area

containing circular and shuttle transportation around the port was designated as the “Peripheral area” (Figure 2).

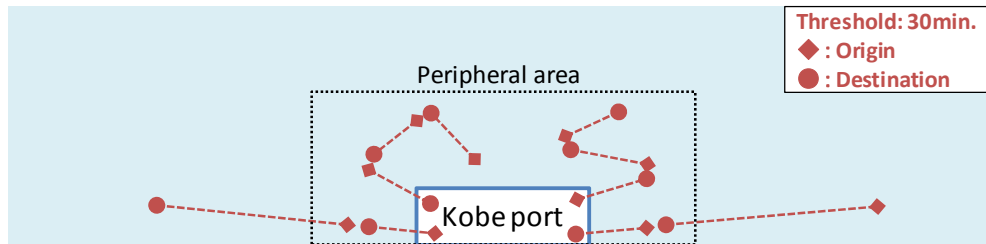


Figure 2 - Image of Step 1

(Step 2) All travel records obtained from the ETC2.0 probe data for analysis were segmented using a time interval threshold of 360 minutes. The trips for which either the origin or the destination was at the port and the other was outside the peripheral area were extracted as long trips (Figure 3).

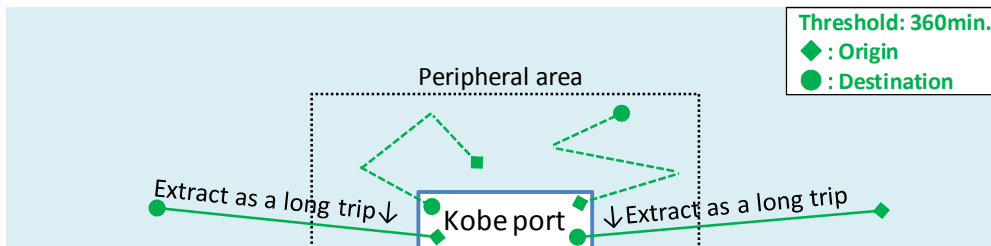


Figure 3 - Image of Step 2

(Step 3) Other trips were segmented using a time interval threshold of 30 minutes. The trips for which either the origin or the destination was at the port and the other was inside the peripheral area were extracted as short trips (Figure 4).

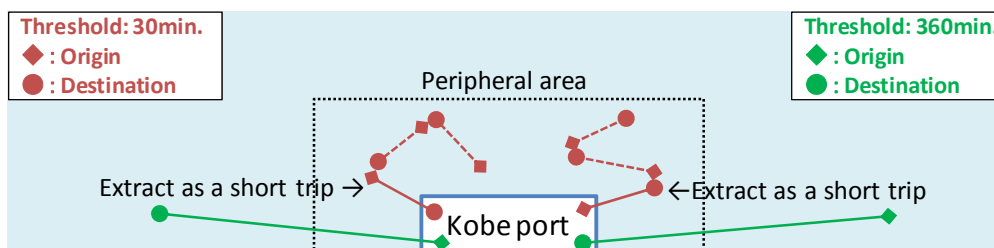


Figure 4 - Image of Step 3

Figure 5 shows the boundaries of the peripheral area of the Port of Kobe.

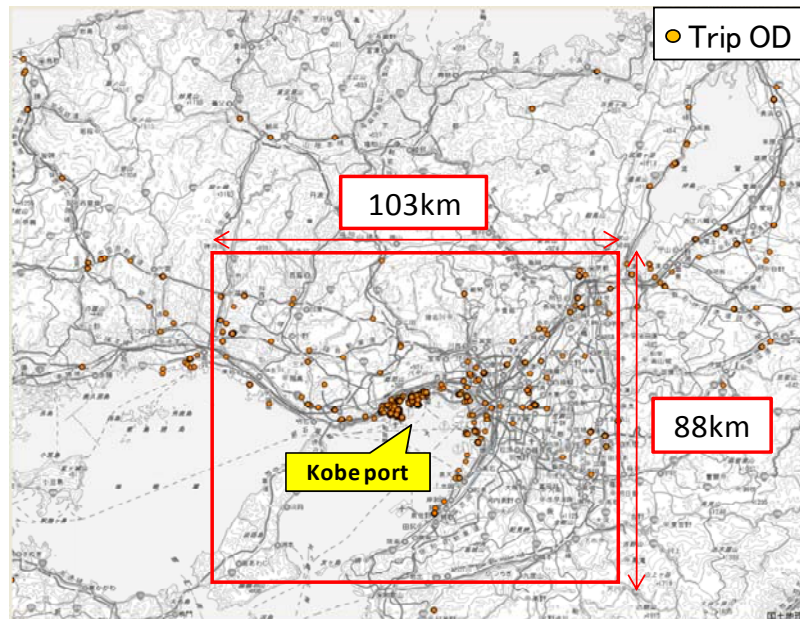


Figure 5 - Peripheral area of the Port of Kobe
(Map source: Geospatial Information Authority of Japan)

Trips to and from the Port of Kobe were extracted as follows. First, a rectangle containing the port was defined by latitude and longitude for the purpose of mechanically extracting the travel record data corresponding to the rectangular area (Phase 1). The travel record data extracted in Phase 1 were displayed in the GIS software. A rectangle containing the wharf was defined for the purpose of extracting the travel data corresponding to this area and excluding points along the coast or on expressways that were neither origins nor destinations (Phase 2). Figure 6 illustrates how trips to and from the Port of Kobe were extracted.

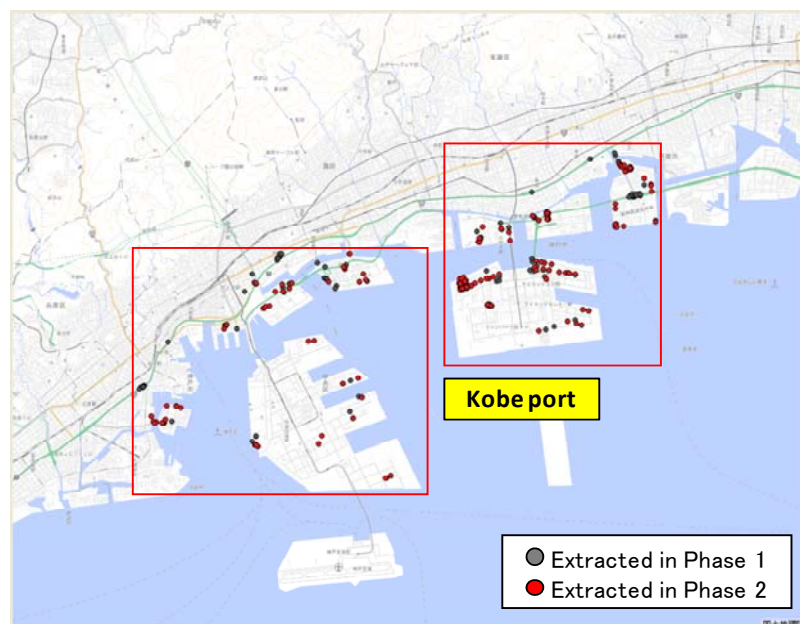


Figure 6 - Image of extraction of OD at the Port of Kobe
(Map source: Geospatial Information Authority of Japan)

The trips were classified by direction. As illustrated in Figure 7, the islands of Japan were classified as being east or west of the Port of Kobe. Trips with origins or destinations on the east side were defined as eastern trips, and those with origins or destinations on the west side were defined as western trips.

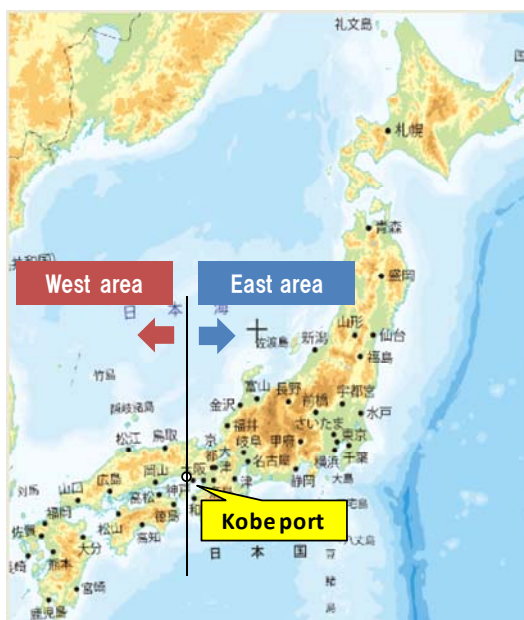


Figure 7 - Image of area classification

(Map source: Geospatial Information Authority of Japan)

Results of analysis

Based on the data for the eastern and western trips to and from the Port of Kobe, Figures 8 and 9 were prepared to show the distributions of the lengths of trips and the directions of trips to and from the port, respectively. Figure 8 shows that the largest number of trips to and from the port fell into the length range of 0 - 200 km long for both the eastern and western trips, followed by trip lengths in the range of 200 - 400 km and trips greater than 400 km long. The subsequent analysis focused on trips shorter than 1,000 km, as there were very few trips to and from the port that were longer than 1,000 km. Figure 9 shows that the distribution of the direction of trips to the port was approximately equal to the distribution of the direction of trips from the port and that the majority of trips were to the east.

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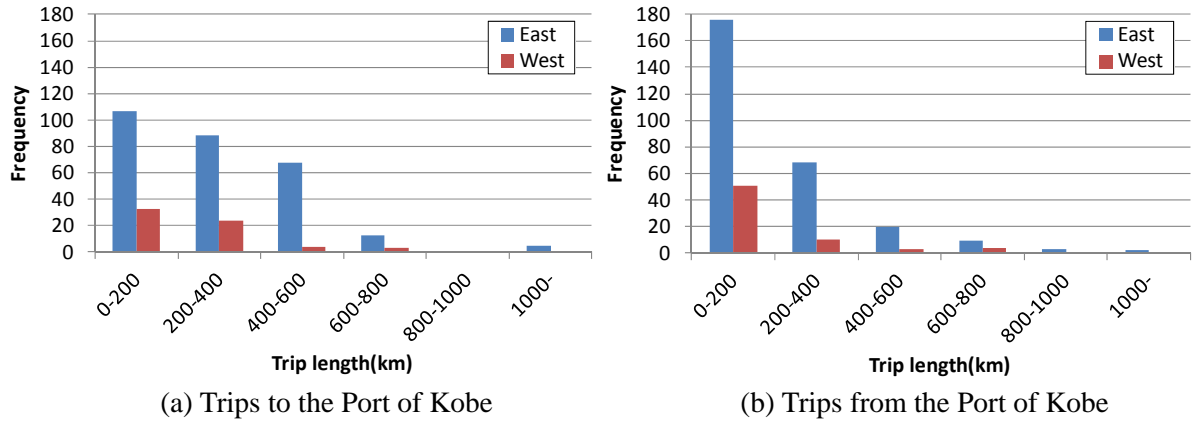


Figure 8 - Distribution of trip length

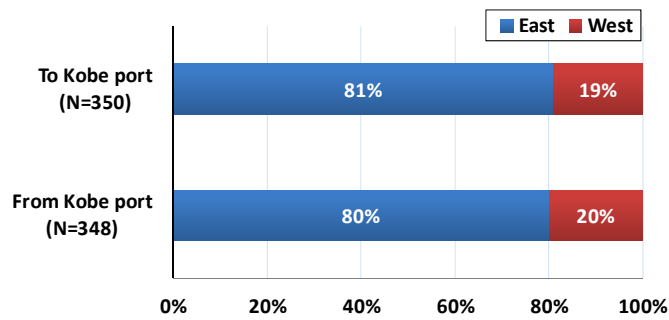


Figure 9 - Distribution of direction of trips

Figure 10 shows the relation between the time and distance of all trips shorter than 1,000 km to and from the Port of Kobe. The average speed of trips from the east to the port was 42.0 km/h, and that from the west to the port was 34.1 km/h. The average speed of trips from the port to the east was 42.1 km/h, and that from the port to the west was 34.5 km/h. These average values indicate that the trips to and from the east were faster than those to and from the west, with little difference in speed between the trips to and from the port in either case.

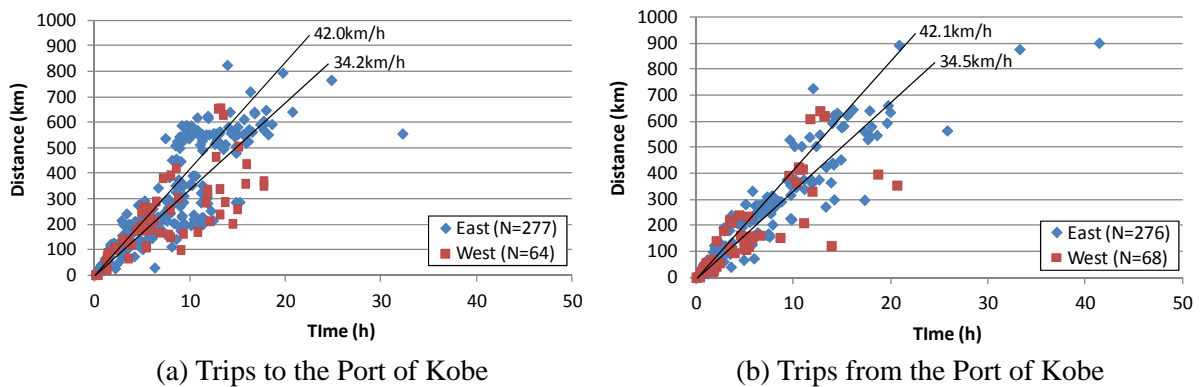


Figure 10 - Relation between time and distance

Figure 11 shows the calculated average speed of trips to and from the Port of Kobe at 100 km intervals to the east and west of the port. The trips to the port in the area within a radius of 600 km were faster in the east than those in the west. As for the trips from the Port of Kobe, the trips to the east were faster than those to the west within the distance intervals of 0 - 200 km and 300 - 400 km. In contrast, the trips to the west were faster than those to the east within the distance intervals of 200 - 300 km, 400 - 500 km, and 600 - 700 km.

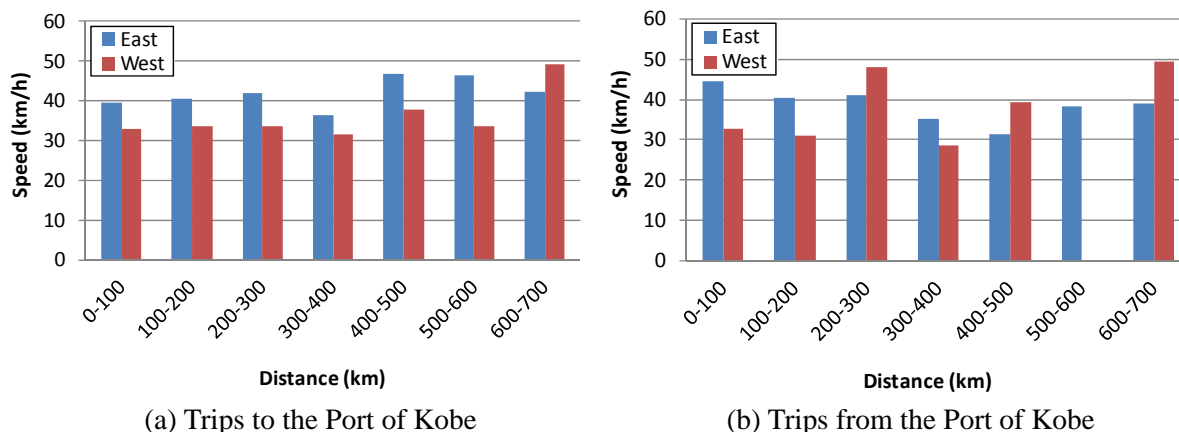


Figure 11 - Average speed by distance from the Port of Kobe

Consideration

The analysis of the directions of the trips revealed that there were many more trips to and from the Port of Kobe on the east side of the port than on the west side. From the result of the freight flow survey among prefectures (2010.10.19-21) in the Nationwide Freight Flow Survey in 2010, the ratio of freights to Hyogo Prefecture, where the port of Kobe is located, from eastern prefectures was approximately 51%, while the ratio of freights from western prefectures was approximately 49% by weight basis. Also the ratio of freights from Hyogo prefecture to eastern prefectures was approximately 73%, while the ratio of freights to western prefectures was approximately 27%. From these results, although the port of Kobe seems to serve well for the eastern region than for the western region, it is considered that the data used in this analysis have a bias.

The analysis of the trip speeds in each distance interval revealed that the trips both to and from the Port of Kobe in the interval from 0 to 200 km were slower in the west than those in the east. Figure 12 shows the radial limit of area within each distance interval of the Port of Kobe. As shown in Figure 1, while the area on the east side of the port has easy access to the Meishin Expressway, the area on the west does not have convenient access to the Sanyo or Chugoku Expressways, which explains the lower trip speeds in the west. This means the highways that enable smooth access to the Sanyo and Chugoku Expressways would need to be developed as access roads on the west side of the port. The average speed of trips to the west in the interval from 200 to 300 km was higher than that of trips from the west in the

same interval of distance. However, the number of trips to the west was only 4 while that of trips from the west was 15, and some unique trips seem to make the average speed high. One of the causes of the fact that the average speed of trips to the east was low in the interval from 400 to 700 km is the effect by the trips to Kanto region. Congestion frequently occurs in the Tomei Expressway and Tokyo Metropolitan Expressway, which are used by vehicles heading for Kanto region. That seems to be why the average speed of trips to the east was low in the interval from 400 to 700 km.

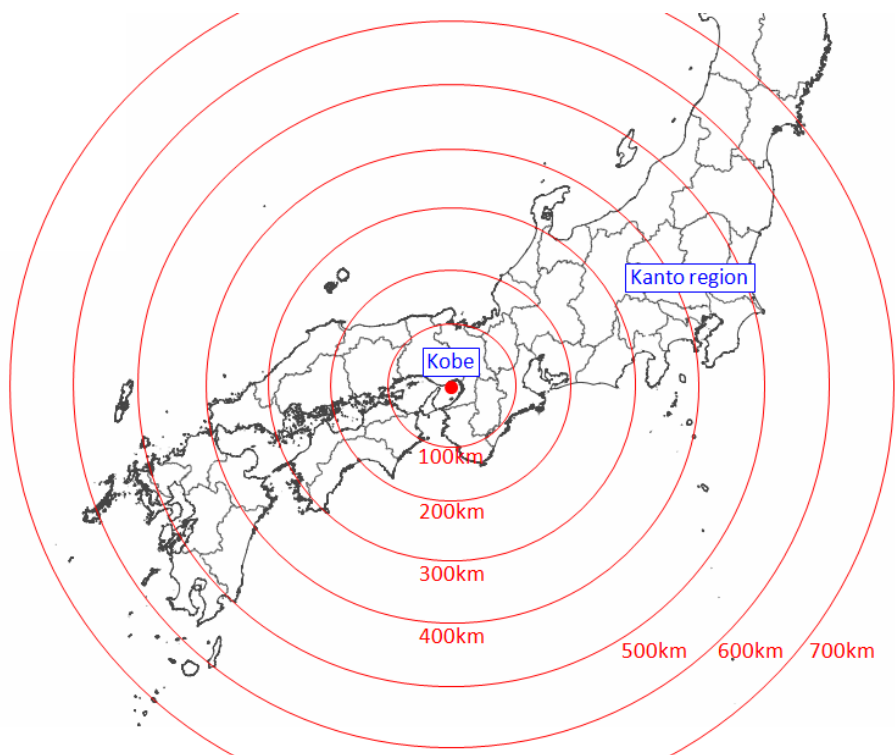


Figure 12 - Radial limit of area within each distance interval of the Port of Kobe
(Map source: Geospatial Information Authority of Japan)

Issues for future study

An analysis was conducted in this study to attempt to evaluate the level of development of the access roads around the Port of Kobe, using ETC2.0 probe data obtained in a pilot program. The results indicate that the level of development of the access roads affects the speeds of the trips to and from the Port of Kobe within certain distance ranges. Issues that need to be taken into consideration in future analyses and assessments of the accessibility to physical distribution bases using ETC2.0 probe data are summarized below.

One issue is that only a limited set of vehicles were considered in this analysis. The analysis did not address all freight trucks departing from or arriving at the Port of Kobe but rather a specific set of vehicles equipped with ETC2.0-compatible OBUs as part of a pilot program. In addition, multiple trips by the same vehicle could be included in the scope of the analysis.

When ETC2.0-compatible OBUs become more common and ETC2.0 probe data are used for analysis of accessibility, etc. in the future, this issue must be taken into account and appropriate measures like combining analysis of probe data with Road Traffic Census data or other road traffic data should be taken.

The second issue pertains to trips not being precisely segmented. In this study, trips were segmented on the basis of loading and unloading of cargo. However, the resulting trips extracted do not necessarily represent the operation of freight trucks in a proper manner. Questionnaire surveys of drivers conducted in previous studies [10][11] suggest the possibility of better characterization of trips based on loading and unloading of cargo. This would require combining analysis of probe data with questionnaire data.

The third issue is the influence of the characteristics of the ETC2.0 probe data. The location information in the ETC2.0 probe data is acquired through the GNSS positioning function for map-matching on a digital road map, but the accuracy of the GNSS positioning function could be degraded. That could prevent the proper identification of travel routes with tunnels, in sections with elevated roads running alongside local roads, and sections where multiple paths are generated by high-rise buildings. In addition, the origins and destinations of trips are not properly extracted in the extraction of trips to and from physical distribution bases. Future analyses would need to take these data characteristics into consideration to secure a sufficient volume of data and exclude unreliable data.

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