



IDENTIFICATION OF IMPORTANT ROADS FOR SWIFT ECONOMIC RECOVERY OF LOCAL INDUSTRIES AFTER EARTHQUAKES

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Abstract

This study aims to identify important roads for swift economic recovery and resumption of local industries after gigantic earthquakes. By having a clear indication based on quantitative analysis of commodity flows before a disaster, priorities on which road to clear & repair are identified. This will give efficiency to the recovery works.

The experience of the Great East Japan Earthquake, demonstrated the importance of roads in disaster countermeasures. The Chubu Regional Bureau of the Ministry of Land, Infrastructure, Transport and Tourism developed an emergency road restoration plan for rescue and transportation of minimal provision of relief goods as one pillar of the Nankai Trough Earthquake countermeasures. After the immediate life-saving phase, comes the livelihood recovery phase. Economic recovery is a must for the disaster affected areas. Otherwise the affected population will not be able to regain income to sustain their living. "Important commodity distribution roads" are designated with the aim to quickly restore the roads necessary for industries. If these restoration plan and road designation does not meet the reality of the commodity input/output distribution of the local industries, there is a risk that the economy cannot be recovered quickly.

In this study, a research was done to reveal the actual commodity flows among the local industries in Aichi prefecture which ranks first among the 47 prefectures in Japanese manufacturing produce. Nishimikawa area in Aichi prefecture is known as the heart of the Japanese automobile industry. Toyota Motor Corporation is supported by supplies from a large number of companies in this area. Telephone survey was conducted to 1,842 companies in this area, which revealed the business relationships and supply chains. The commodity flows are mapped on Fig. [1]. The red dots represent the delivery origin, and the yellow dots are the destination. The destination is concentrated in certain locations, where Toyota Motor Corporation's final assembly factory is located.

Then the commodity flows are placed onto the real road network, using GIS's route search feature and the road network data. The result is mapped as Fig. [2]. All of the business relationships, the results are superimposed, and the color of the route shows the number of overlaps. Some of the major roads have more than 20 overlaps (red), these are estimated to be the highly important roads for automobile industry. Then, this study validates the exposure of these important roads to seismic intensity, liquefaction and tsunami of the Nankai Trough Earthquake and checks its correspondence to the current recovery plan of the designated roads. In the next step, the validation will be expanded to a wider range of industries, which will better reflect economic activities and lead to realistic road network recovery plan.

Keywords: Road Identification; Local Industry; Exposure; OD; Recovery Plan;

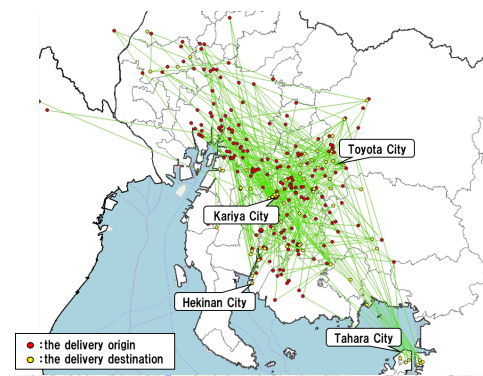


Fig. [1] Business relationships in Nishimikawa

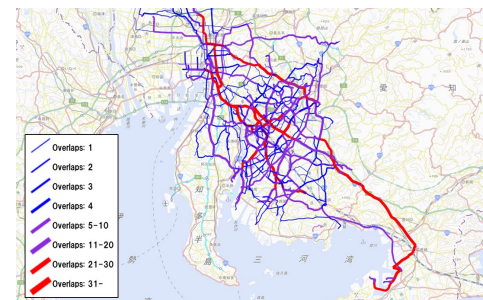


Fig. [2] Highly important roads for automobile industry in Nishimikawa



1. Introduction

Nankai Trough Earthquake, expected to occur sometime in the future, is estimated to render a massive damage on most of Japan, and the economic damage for the subsequent 20 years is estimated to reach 1.24 quadrillion yen in total. To avoid such a severe impact, measures to ensure early restoration of industries to maintain business operations are essential. While industrial operation requires various social infrastructures, such as electricity, water and communication, it is known to be particularly difficult to establish a uniform disaster prevention policy for the road network due to multiple stakeholders (administrators) within the same area. As explained later in this paper, various restoration plans and traffic control rules designed to “save life” at the earliest stage of disaster response are already in place, but there have so far been extremely insufficient number of examinations concerning disaster prevention measures from the viewpoint of “the early restoration of industrial activities”.

This paper extracts roads in Aichi Prefecture, which are identified to be particularly important in restoring industrial operations at an early stage, through inter-company logistic data based on our original survey and GIS. By doing so, it aims to establish a foundational resource, based on which the road restoration plan for Nankai trough Earthquake should be examined.

2. Disaster Prevention Measures for Roads at Nankai Trough Earthquake

This chapter overviews disaster prevention measures for roads in countering Nankai Trough Earthquake.

2.1 “Comb Teeth Routes” for Chubu Region Mission Comb Teeth

[Entity in Charge] Chubu Regional Bureau, Ministry of Land, Infrastructure, Transport and tourism (MLIT) (decided at the Committee for Disaster Prevention and Counter-Earthquake Measures in Road Management, a subcommittee of Chubu region Highway Council consisting of road administrators under the jurisdiction of Chubu Regional Bureau)

[Purpose of the Measure] To swiftly conduct rescue and relief activities and transport emergency goods in and around the Pacific Coast, where a devastating damage is expected to be inflicted by a massive earthquake centered in Nankai Trough.

[Details] The measure designates routes to be open prior to other routes within three days, if possible, after the Nankai Trough Earthquake. Routes are classified into STEP1 (broad area support routes), STEP2 (access routes to affected areas), and STEP3 (coastline routes). At the same time, the measure selects facilities, such as important disaster prevention hubs in the broad area support operation, main offices to be used as the headquarters for road opening operations, facilities in charge of securing energy in the immediate aftermath, and other locations designated by the prefecture’s and municipalities’ disaster prevention plans, to be made accessible within three days. The measure incorporates “Hub Access Routes” connecting these facilities with the Comb Teeth Routes.

[Discussions] In the detailed plan of Comb Teeth Routes in Aichi Prefecture, the national, prefectural, and city (Nagoya) governments are supposed to open roads through mutual collaboration. Also, the Comb Teeth Routes are expected to be temporarily restored within three days after the Nankai Trough Earthquake. The feasibility of the plan (the balance between the scale of the total damage and the governments’ responsive capacity) may separately require a thorough examination, but this paper will not endeavor to discuss it because, taking external factors like the restoration of other infrastructures and workers’ availability, companies would need at least a week or longer to resume operation, therefore it is reasonable to assume that the temporary restoration of the Comb Teeth Routes would be more or less completed by the time the industrial logistic activities resume.

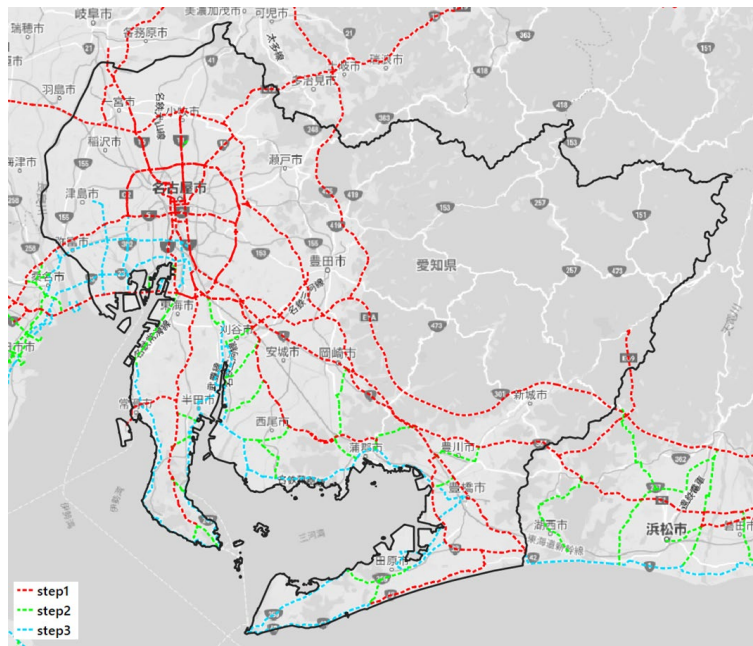


Fig. 1 –Comb teeth routes in Aichi prefecture

2.2 Emergency Transport Roads in Aichi Prefecture

[Entity in Charge] Aichi Prefecture

[Purpose] Emergency Transport Roads are indispensable routes in ensuring passage of emergency vehicles engaging in relief activities, such as evacuation, rescue, and relief goods delivery, from immediately after the disaster.

[Details] The network consists of “Primary Emergency Transport Road Network” interconnecting prefectural capitals, central cities in the regions, important harbors, airports, etc., “Secondary Emergency Transport Road Network” connecting municipal government offices and disaster prevention hubs (public facilities, major stations, heliports, medical facilities, and Self-Defense Force bases), and “Tertiary Emergency Transport Road Network” comprised of other roads.

[Discussions] According to the regional disaster prevention plan of Aichi Prefecture, the Comb Teeth Routes within Aichi Prefecture are selected from the Primary and Secondary Emergency Transport Road Networks. Emergency Transport Roads will be given priority over other roads in the post-disaster restoration works, but the plan explicitly states that the Comb Teeth Routes will be given the highest priority at the occurrence of tsunami. In other words, Emergency Transport Roads would likely be open, at least in some part, in addition to the Comb Teeth Routes by the time the industrial restoration activities start to take place in the aftermath of Nankai Trough Earthquake.

Furthermore, the Emergency Transport Roads are also designated as “Emergency Traffic Routes”, and according to the website of Aichi Prefectural Police Department, the police shall control the traffic of the roads in time of disasters. The website also explains that expressways and limited highways would be immediately under the police control at the occurrence of Nankai Trough Earthquake and, if it deems necessary in view of the extent of damage, major National Routes would also be subject to the police control. Among these roads, the locations of “the first roads to be subject to traffic control” on the map shows that many of them are designated as the Primary Emergency Transport Roads. The period of traffic control is not clearly defined, as the control would be gradually reduced in accordance with the progress of road restoration and the traffic demand.

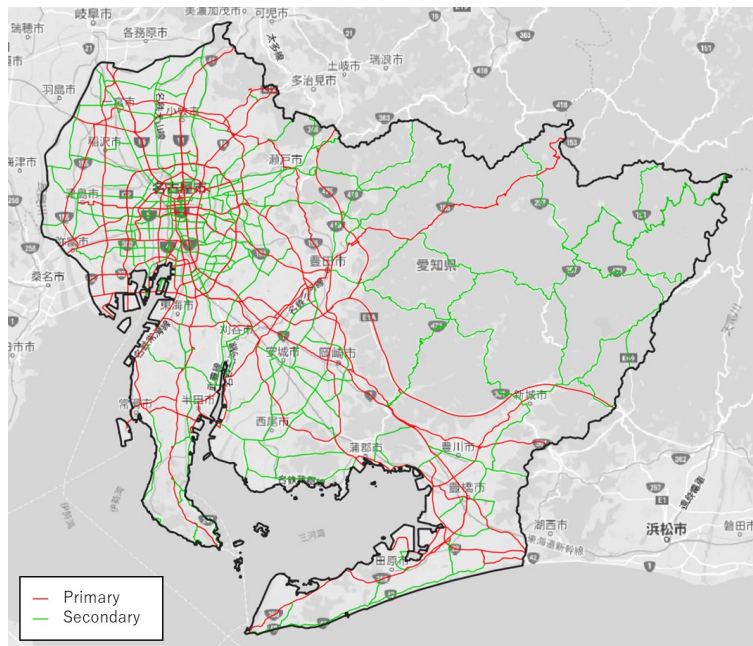


Fig. 2 – Emergency transport roads in Aichi prefecture

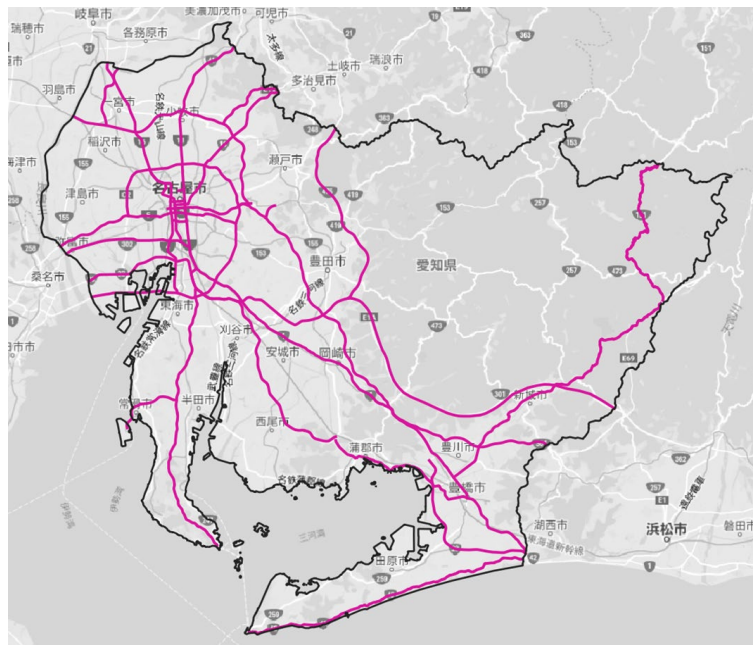


Fig. 3 – Top priority roads for traffic control in emergency traffic routes

2.3 Important Logistic Roads

[Entity in Charge] Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

[Purpose of the Measure] In accordance with the revised Road Act, the national government shall be authorized to designate logistically important road transportation network and reinforce their functionality to ensure stable logistic activities both in normal times and during disasters. Also, municipal governments may



request the national government to take over the road restoration work during disasters if they are incapacitated.

[Details] The “stable goods transport during a disaster” refers to the transport of emergency goods and excludes private passenger vehicles and delivery vehicles for industrial logistic activities. One of the reasons behind the revision of the Road Act was the 2016 Kumamoto Earthquakes, in which multiple damages wrought on the Emergency Transport Roads hindered the delivery of relief goods to the affected areas. The amendment enables the national government to restore roads in place of incapacitated municipal governments.

[Discussions] In Aichi Prefecture, almost all the Important Logistic Roads are included in the Primary Emergency Transport Roads. Surmising from the above three plans, the situation in the industrial restoration phase at least a week after the Nankai Trough Earthquake would be as follows: (1) the Comb Teeth Routes are temporarily restored; (2) prioritized routes among the Emergency Transport Roads are under traffic control and off limits to private passenger vehicles and industrial logistic vehicles; and (3) even the Important Logistic Roads will be subject to the first two principles. This assumption, however, is quite optimistic, as a much heavier traffic control might be in place if the actual situation requires so.

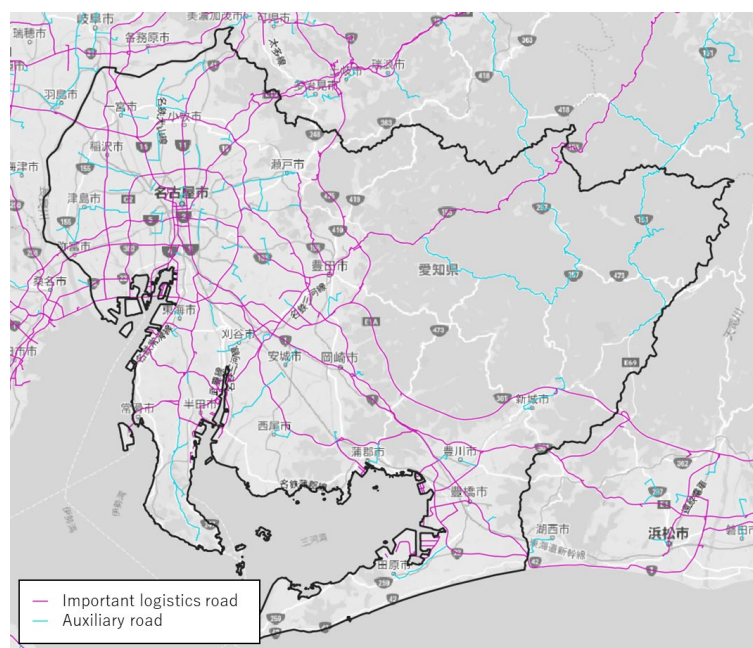


Fig. 4 – Important logistics roads in Aichi prefecture



3. Original Survey and Discussions on Inter-company Logistics

3.1 Visualization of Industrial Logistic Activities in the Automobile Industry

This section examines the disaster prevention measures for roads, as laid out above, from the viewpoint of the early restoration of industrial activities. To do so, identification of roads that are frequently utilized by industrial logistic activities in normal times should be necessary. Therefore, this study collects actual industrial transaction data and extracts roads frequented by industrial logistic vehicles. As the initial phase of the data collection, this paper uses the logistic activity information of the automobile industry in Aichi Prefecture. Aichi Prefecture's annual total product shipment value at approximately 47 trillion yen (2017) was the highest in Japan, and the majority of the shipment was automobile-related.

To be precise, the study targeted Toyota Group's 1,842 primary and secondary subcontracting companies, which have their headquarters in Aichi Prefecture (see Table 1). The survey was conducted by telephone calls, in which the names of the shipping origins (factories) of major business transactions, delivery destinations (client names and their city/town/village names), transaction volumes (shipment volumes), transaction frequencies, etc. were asked. The survey commenced in the end of February 2019 and lasted for about a month, during which a total of 543 valid responses (approx. 29%) were obtained.

Table 1 – Object of investigation (Toyota Group)

AISIN AW CO., LTD.	AISIN SEIKI Co.,Ltd.
Aichi Steel Corporation	JTEKT Corporation
Daihatsu Motor Co., Ltd.	TOYOTA AUTO BODY CO.,LTD.
Toyota Motor Corporation	Toyota Motor Kyushu, Inc.
TOYOTA MOTOR EAST JAPAN, INC.	TOYOTA MOTOR HOKKAIDO, INC.
Toyota Industries Corporation	TOYOTA BOSHOKU CORPORATION
DENSO Corporation	Hino Motors, Ltd.
Daihatsu Motor Kyushu Co., Ltd.	

From the obtained data, the study used the 338 links in which the shipping origins and the destinations were precisely located to estimate their transport routes, using GIS. Dijkstra's algorithm was used to estimate the route, with the search condition prioritizing the shortest traveling time. The search also limited the results to only include roads with at least 5.5m in width and exclude expressways and toll roads (see Figure 5 and Figure 6 for the result).

Although there have been previous surveys concerning the inter-company transactions, their data only focus on the amount of transactions made between the companies. This survey, in which the data of logistic activities between specific business (factory) locations are collected and visualized, is completely unprecedented.

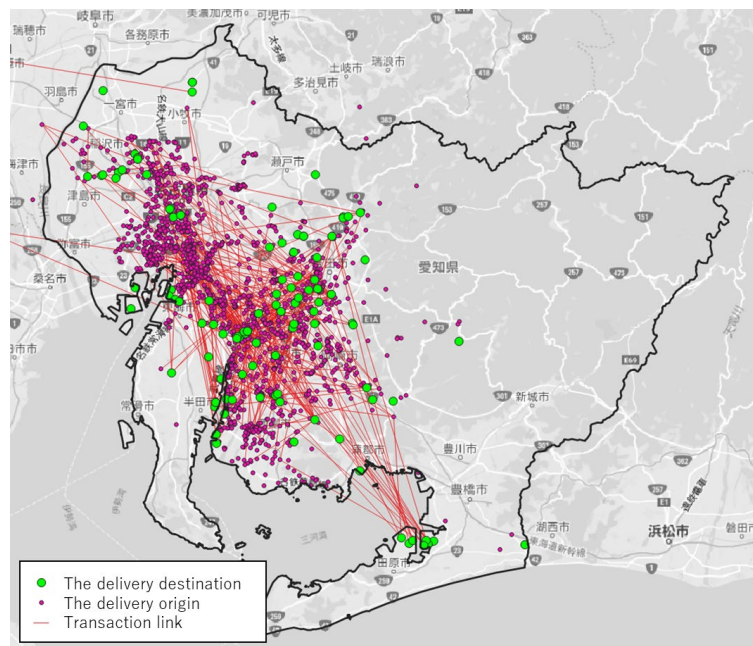


Fig. 5 – Inter-company transactions by automobile industries in Aichi prefecture

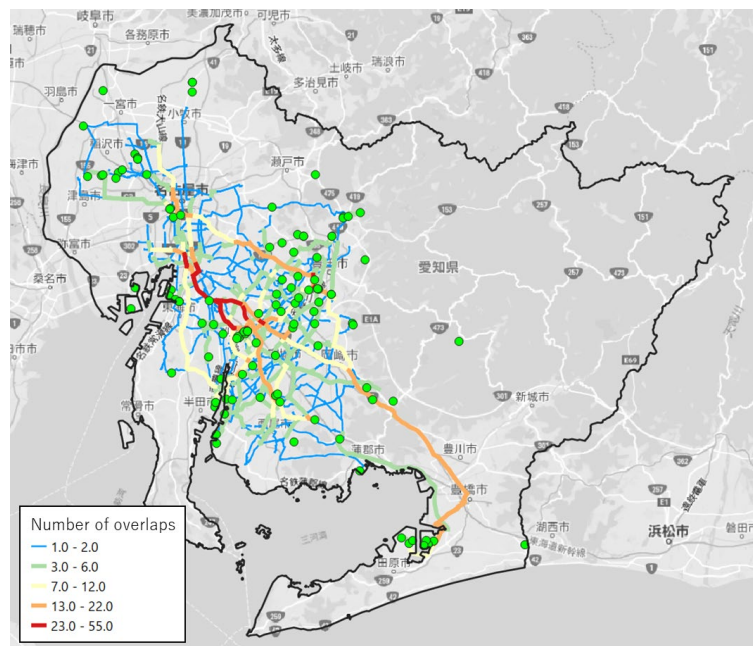


Fig.6 Roads used in automobile industrial logistics (estimated)

3.2 Extraction of Most Popular Routes in Each Region

(1) Route 1 (to Tahara): The route leads to Toyota Motor Corporation Tahara Plant, Toyota Boshoku Toyohashi Plant, Aisin AW Tahara Plant, etc. The shipping origins corresponding to these destinations are located in the northwest of the destination, namely the inland of Mikawa Area (Miyoshi City: 1, Anjo City: 3, Okazaki City: 3, Toyota City: 5), Owari Area (Inazawa City: 1, Nagoya City: 2, Toyoake City: 1), and others (Nishio City: 1, Obu City: 2) Their routes join Route 1 via secondary roads.



(2) Route 23 (to Nishio City): The route leads to Denso Nishio Plant, Aisin Seiki Nishio Die-casting Plant, Aisin Seiki Ogawa Plant (Nishio City), Aisin AW Office Plant (Anjo City), Aisin AW Shiroyama Plant (Nishio City), etc. The shipping origins corresponding to these destinations are the inland of Mikawa Area (Miyoshi City: 1, Anjo City: 3, Okazaki City: 4, Kariya City: 5, Takahama City: 4), Owari Area (Obu City: 4, Chiryu City: 1, Nisshin City: 1, Toyoake City: 1, Nagoya City: 8), and others (Nishio City: 6). They are located in the north of the destination. Through various roads, their routes go through the area specified in (3) below and finally join Route 23.

(3) Routes 1, 23, and 366 in Kariya City: The routes lead to a number of major plants, including Aisin Seiki Shintoyo Plant (Toyota City), Toyota Motor Corporation Takaoka Plant (Toyota City), Denso Anjo Plant, Toyota Auto Body Headquarters Fujimatsu Plant (Kariya City), Aisin Seiki Headquarters (Kariya City), JTEKT Kariya Plant, Toyota Auto Body Kariya Plant, Denso Headquarters (Kariya City), Toyota Industries Headquarters Kariya Plant, etc. A total of 115 transactions use the routes. Compared to (1) and (2) above, the routes have multiple shipping origins in the vicinity and beyond, probably making the logistic activities in this area highly complicated and voluminous. Furthermore, with routes (1) and (2) above going through this area, it serves as a logistic key point for the automobile industry but also a bottleneck at the same time.

(4) Route 153 (to Toyota City): The route leads to Toyota Motor Corporation Headquarters Plant, Motomachi Plant (Toyota City), and so on. The corresponding shipping origins are West Mikawa Area (Miyoshi City: 2, Kariya City: 2, Nishio City: 1, Chiryu City: 2, Hekinan City: 1, Toyota City: 4), and Owari Area (Nagoya City: 10, Inazawa City: 3). The great majority of the shipping origins are located in the west, with logistics from Owari Area heavily accounting for the use of Route 153. On the other hand, logistics from Chita and West Mikawa Area pass through the area specified in (3) above.

(5) Logistics Bound for the Industrial Zone in Port of Kinuura: The industrial zone surrounding the Port of Kinuura includes Toyota Motor Corporation Kinuura Plant (Hekinan City), Toyota Industries Hekinan Plant, Toyota Industries East Chita Plant (Handa City), Aisin Seiki Handa Plant, Aisin Seiki Shinkawa Plant (Hekinan City), etc. The corresponding shipping origins are Mikawa Area (Miyoshi City: 3, Anjo City: 1, Okazaki City: 1, Kariya City: 1, Nishio City: 1, Hekinan City: 2, Toyota City: 3), and Owari Area (Obu City: 1, Kitanagoya City: 2, Nagoya City: 9). Logistics from Owari Area to the Port of Kinuura use Prefectural Highway 55, while origins in West Mikawa Area use Route 419 and then Route 247.

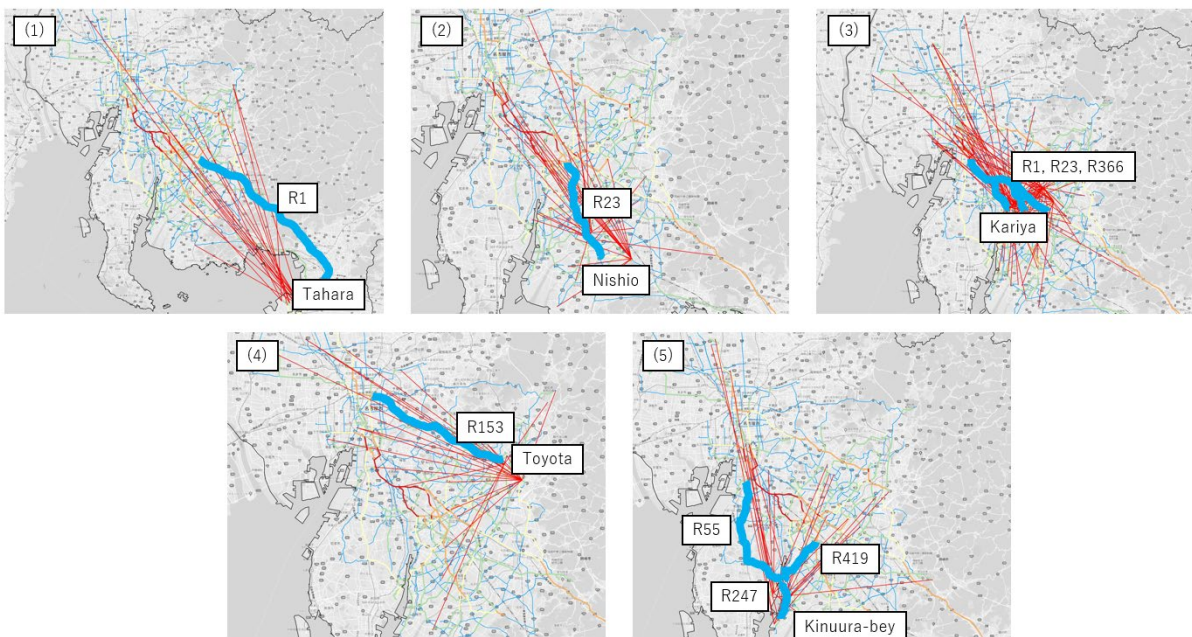


Fig.7 Most popular routes in each region ((1)Tahara, (2)Nishio, (3)Kariya, (4)Toyota, (5)Kinuura-bey)



3.3 Discussions on Each Routes from the Viewpoint of Early Restoration of Industrial Activities

In the following discussions, the roads designated either as the Comb Teeth Routes or the Emergency Transport Roads but not the primary target of traffic control are called the Potential Roads for Industrial Restoration. These roads may be given priority in the restoration activities and at the same time might allow the passage of private passenger vehicles and industrial logistic vehicles.

(1) Route 1 (to Tahara): The route is designated as the Comb Teeth Route and receives a preferential treatment in restoration activities, but it is also a highest prioritized Emergency Traffic Route subject to traffic control, restricting the industrial use for some length of time in the aftermath of a disaster. Industrial logistics therefore need to find detours. Good detours may be found on the southern side of Route 1, as the area is covered by multiple roads with the road width of 5.5m or wider, suitable for 10-ton trucks to pass. Because the south side has more than one Potential Roads for Industrial Restoration, these routes should be taken into account as primary detour options. At the same time, the route must avoid Gamagori City and the downtown of Toyohashi City, as these areas are likely to be inundated by tsunami.

(2) Route 23 (ot Nishio City): The route is part of the Comb Teeth Route and to be restored preferentially, but it is also subject to traffic control as the highest prioritized Emergency Traffic Route, shutting out industrial vehicles in the aftermath. Detours are therefore required for industrial logistics. There are two points of consideration in examining practical detours in this area; one is Yahagifurukawa River, running from north to south across the middle of Nishio City. There are many bridges over the river within the area, and the detours would be determined by which bridges remain passable during the disaster. Another point of concern is the possible massive damage wrought by the earthquake along the coast and Yahagifurukawa river basin. The area, which is expected to suffer relatively minor damage compared to other places in Nishio City, may have to accommodate evacuees from inundated areas and other people from the affected areas. Therefore, the Emergency Transport Roads within the area are expected to be basically closed for private passenger vehicles and industrial logistic vehicles for a substantial length of time. Certain measures must be examined, such as systematically opening part of these routes to passenger and industrial vehicles.

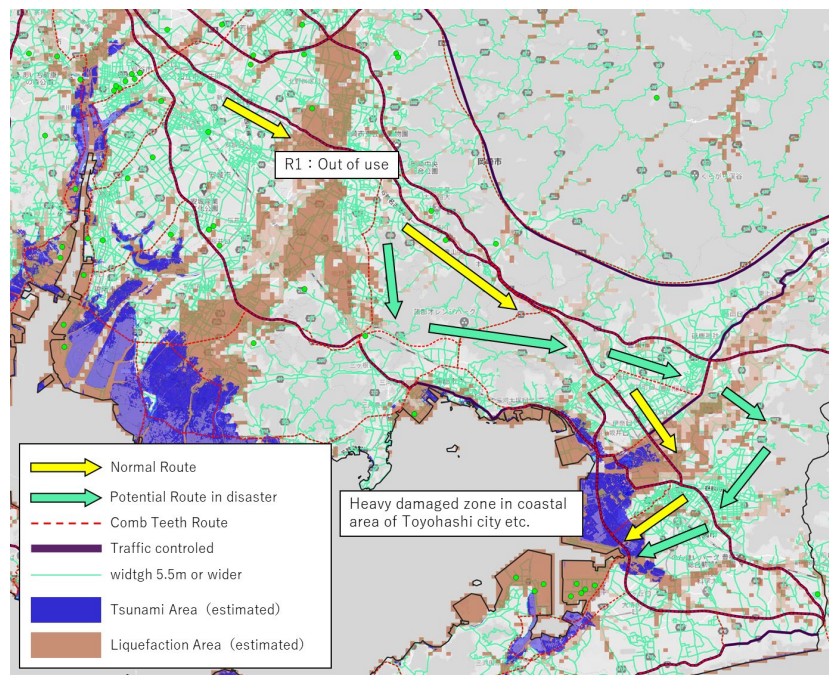


Fig.8 Potential roads for industrial restoration (CASE1: Tahara)

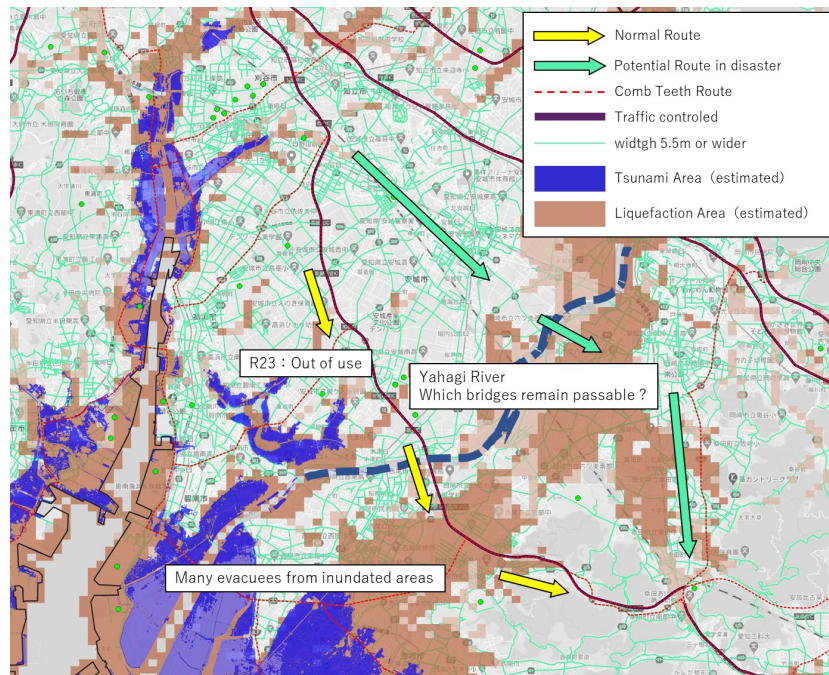


Fig.9 Potential roads for industrial restoration (CASE2: Nishio)

(3) Routes 1, 23, and 366 in Kariya City: Routes 1 and 23 are designated as the Comb Teeth Routes and to be restored preferentially, but it is also subject to traffic control as the highest prioritized Emergency Traffic Route and inaccessible by industrial vehicles for some time. Because the area is populated by a number of automobile-related large plants and provides routes for industrial logistics as described in (1), (2) and (5), the traffic in the area is very heavy even in normal times. In this area, Route 155 from the north would be an important Potential Roads for Industrial Restoration. As it may be impossible for detours to fully cater to the traffic demands concentrated in this area, group companies may be required to consider postponing the reopening of the plants in this area.

(4) Route 153 (to Toyota City): This route is not part of the Comb Teeth Routes and is not subject to primary traffic control, while it is designated as the Emergency Transport Road. Therefore, it is a Candidate Road for Industrial Restoration. Because the damage from earthquakes in this area is expected to be relatively limited, private and industrial vehicles may regain access at an early stage. Together with Route 155, as explained above, the route may become a crucial road connecting Owari Area in the west of Aichi and Mikawa Area in the east from an early stage. Group companies may need to establish a restoration strategy incorporating this area as the starting point.

(5) Logistics Bound for the Industrial Zone in Port of Kinuura: The area surrounding Port of Kinuura would suffer massive damage due to tsunami and tremors and, compared to other areas, likely to require longer time in resuming operation. Furthermore, major plants are located at the far end of the highways, making accesses extremely difficult. On the other hand, there are many designated Comb Teeth Routes in the area, which are not subject to highest prioritized traffic control. Therefore, some of these routes can be considered as Potential Roads for Industrial Restoration. A preparatory measure to classify roads into priority routes for emergency vehicles and other routes, and share such understanding among all stakeholders in the society, would be necessary.

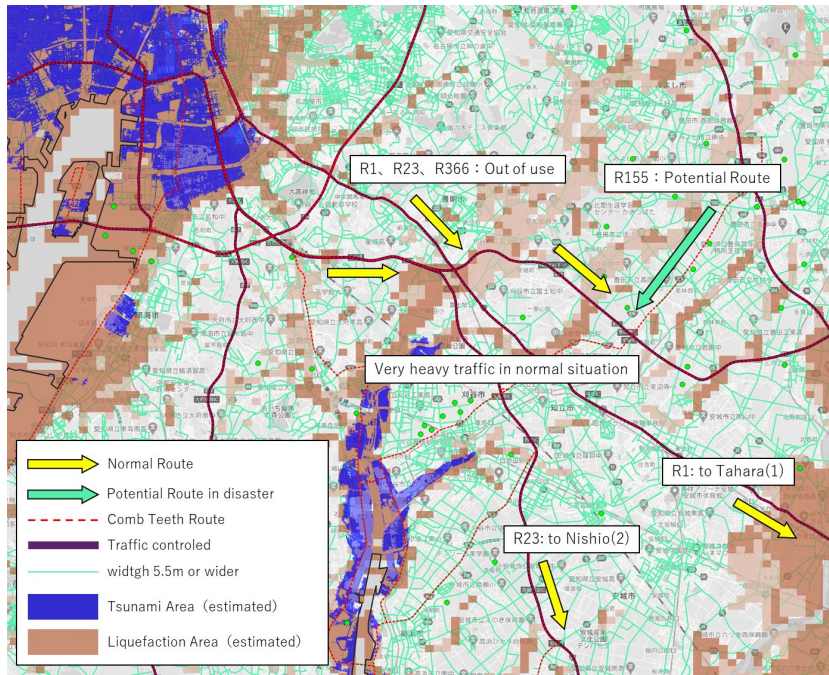


Fig.10 Potential roads for industrial restoration (CASE3: Kariya)

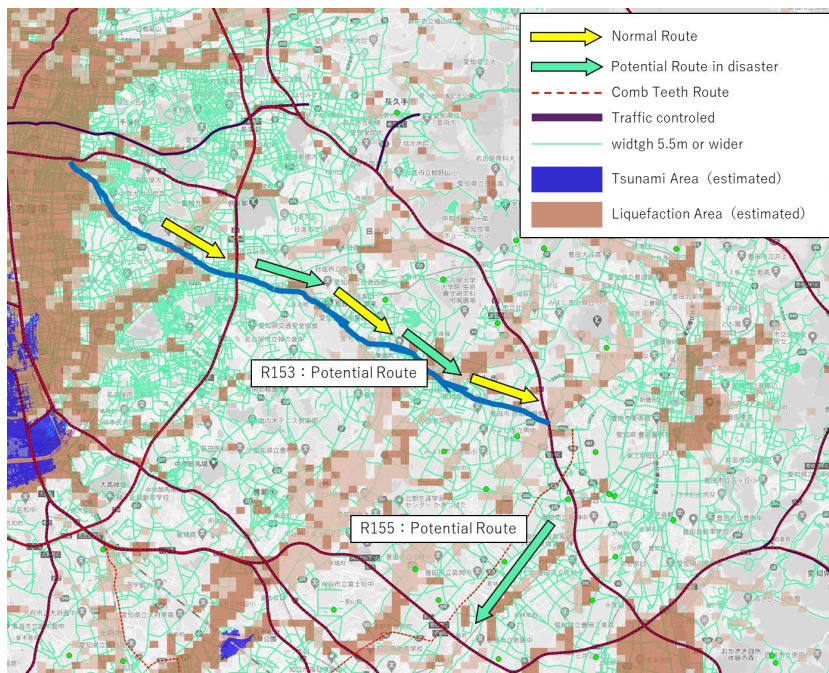


Fig.11 Potential roads for industrial restoration (CASE4: Toyota)

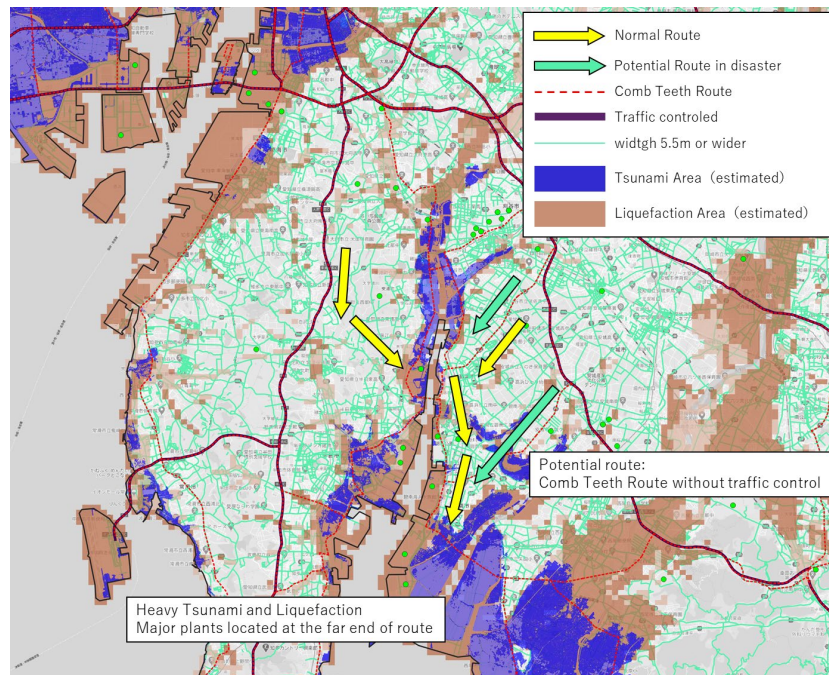


Fig.12 Potential roads for industrial restoration (CASE5: Kinuura-Bay)

4. Conclusion

This study extracted what it believes to be “relatively important roads in terms of the early restoration of industrial activities” under the conditions specified herein. It estimated the possible conditions of the extracted roads during a disaster and discussed them from the viewpoint of the early restoration of industrial activities. This study exclusively examined the automobile industry in Aichi Prefecture, but there are other roads that are also obviously important, such as roads connecting different medical institutes.

This study does not delineate the one and absolute strategy for the early restoration of industrial activities. Restoration strategies require various viewpoints, and this study focused on demonstrating how to collect and use sources for such examinations.

5. Acknowledgements

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