9.6. Road and Traffics

9.6.1. Introduction

Roads are the most important means for traffic and transportation to support urban functions. Along roads, which extend linearly, various types of communication and supply and treatment facilities (such as those for tap and waste water, electricity, gas, etc.) are buried, providing roads with the functions of not only transporting people and goods but also transmitting information. Therefore, earthquake damages to roads pose not only the problem of resulting in physical damages to individual structures buried along roads, but also that of potential malfunction of the total systems resulting from the destruction of individual structures. Furthermore, roads play important roles in evacuation, information gathering, rescue, medical aid, etc., all of which are required immediately after earthquakes, and roads are also significantly important in the transportation of relief goods and restoration activities inevitably necessary after earthquakes. When considered from these points of views and in order to establish preventive measures against earthquake damages and establish plans for restoration, it is essential to first estimate the extent of the expected earthquake damages based on the result of the study and on an understanding of the current situation of roads and their functions. In addition, through evaluating theimportance of road networks, it becomes possible to clearly identify which routes and sections are important and to set up priorities among the preventive measures against earthquakes in advance, so that more reliable road systems can be constructed.

Based on the above viewpoints, the importance of road networks, the prioritisation evaluation of reinforcement of bridges against earthquakes, and the estimation of damage from road blockades caused by collapses of roadside buildings are described in this section.

9.6.2. Importance Evaluation on Road Network

On the roads in the Study Area surveyed, many bridges have been constructed because of road network characteristics and topographic reasons. Therefore, in evaluating the importance of the road network for the purpose of disaster prevention, it is necessary to study not only the relative importance of routes along sections of the entire network, but also the impact when bridges are damaged, as well as the potential impact to surrounding areas. Furthermore, it is effective to determine the importance of individual routes and prioritise these along with proposed measures to protect the bridges from earthquake disaster after comprehensively reviewing and evaluating the results from these studies. Figure 9.6.1 shows the flow of the evaluation study on the importance of road networks.

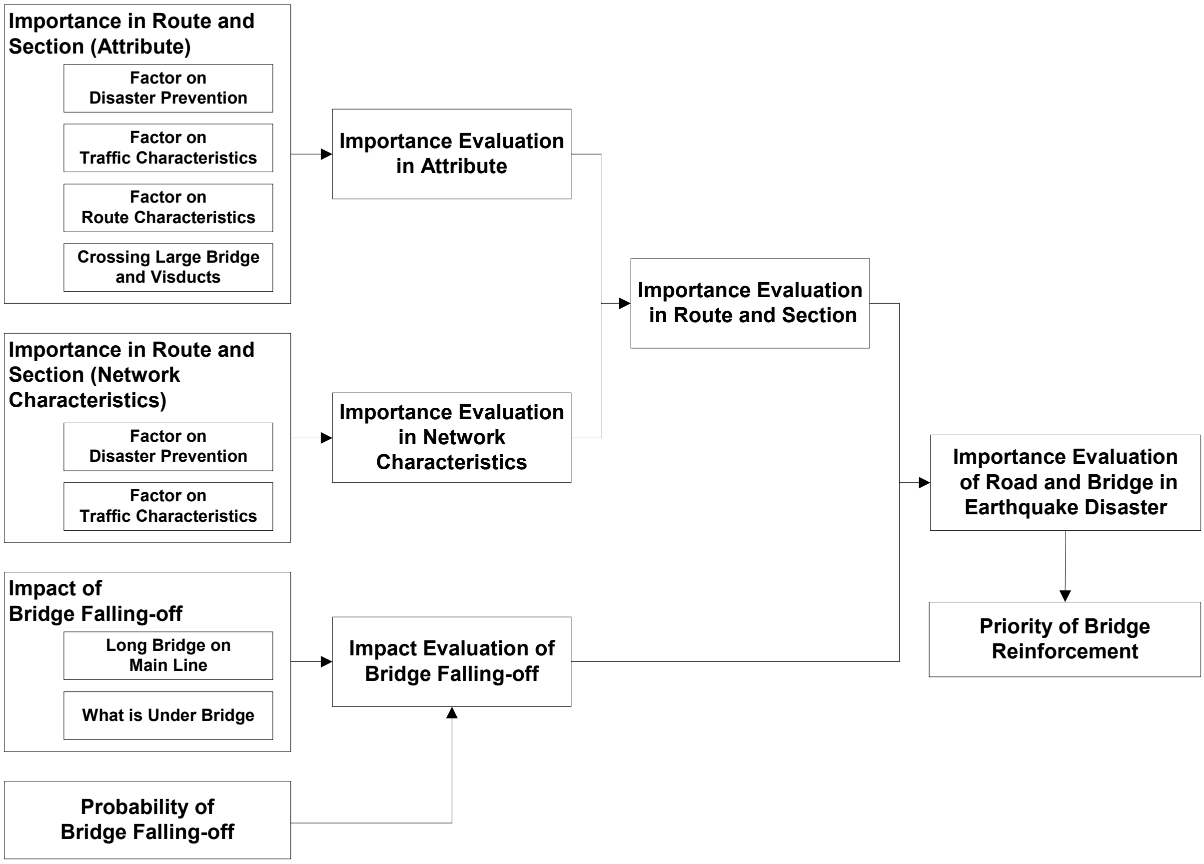

Figure 9.6.1 Flow of Importance Evaluation

As shown in Figure 9.6.2 to Figure 9.6.4, IMM classifies roads based on their functions. In evaluating the importance of road networks, the IMM's classification has been referenced.

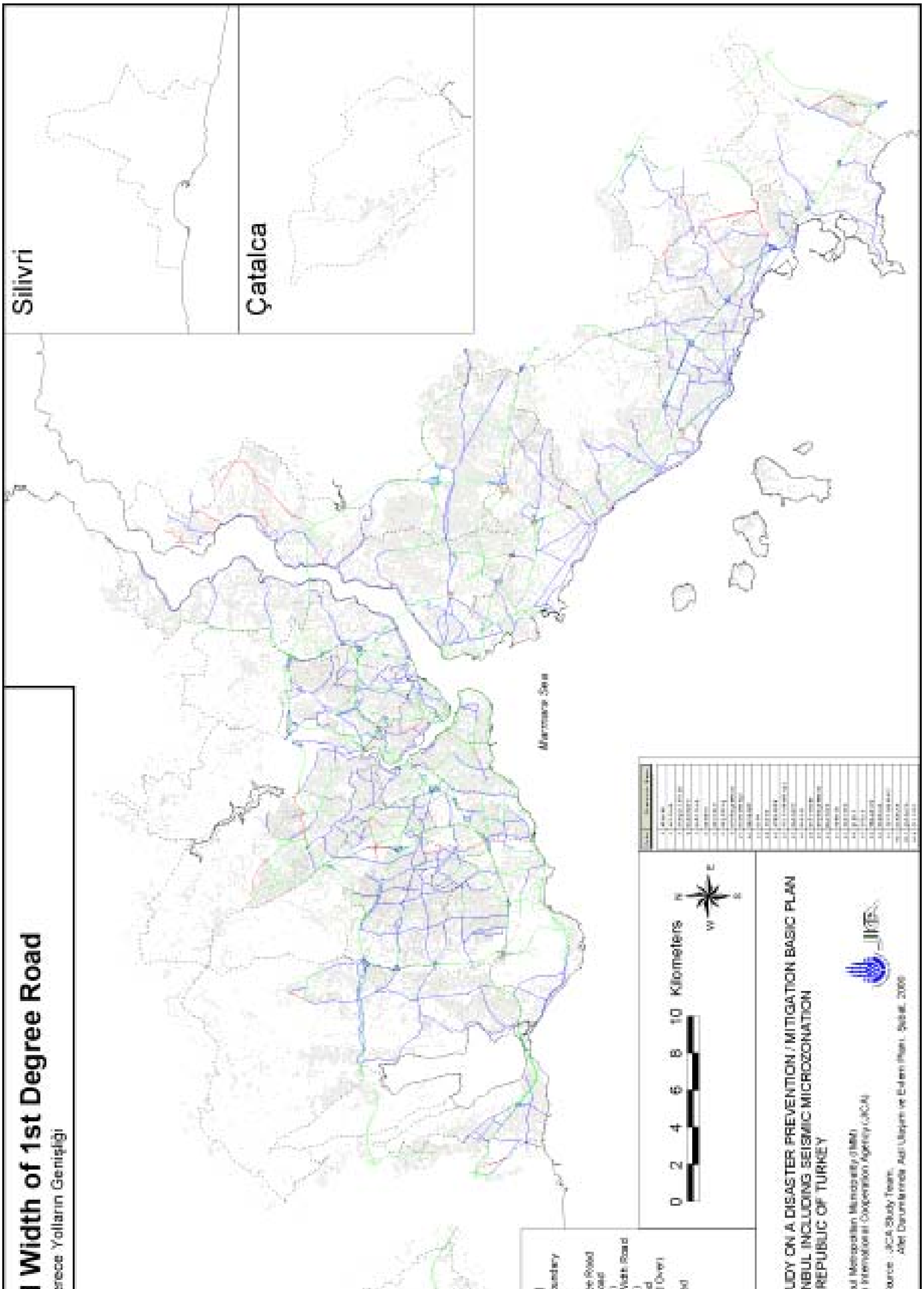

Figure 9.6.2 Road Width of 1st Degree Road

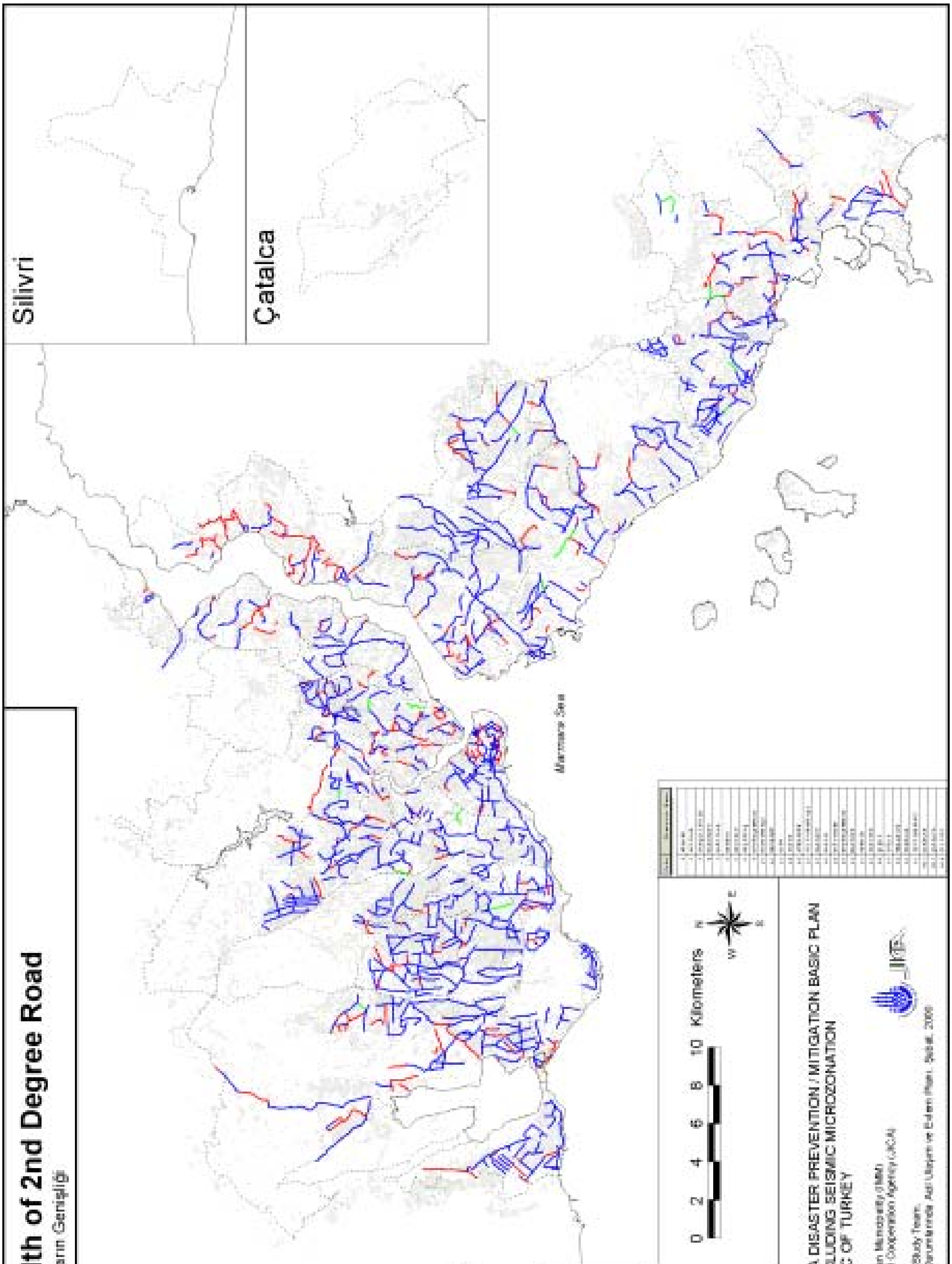

Figure 9.6.3 Road Width of 2nd Degree Road

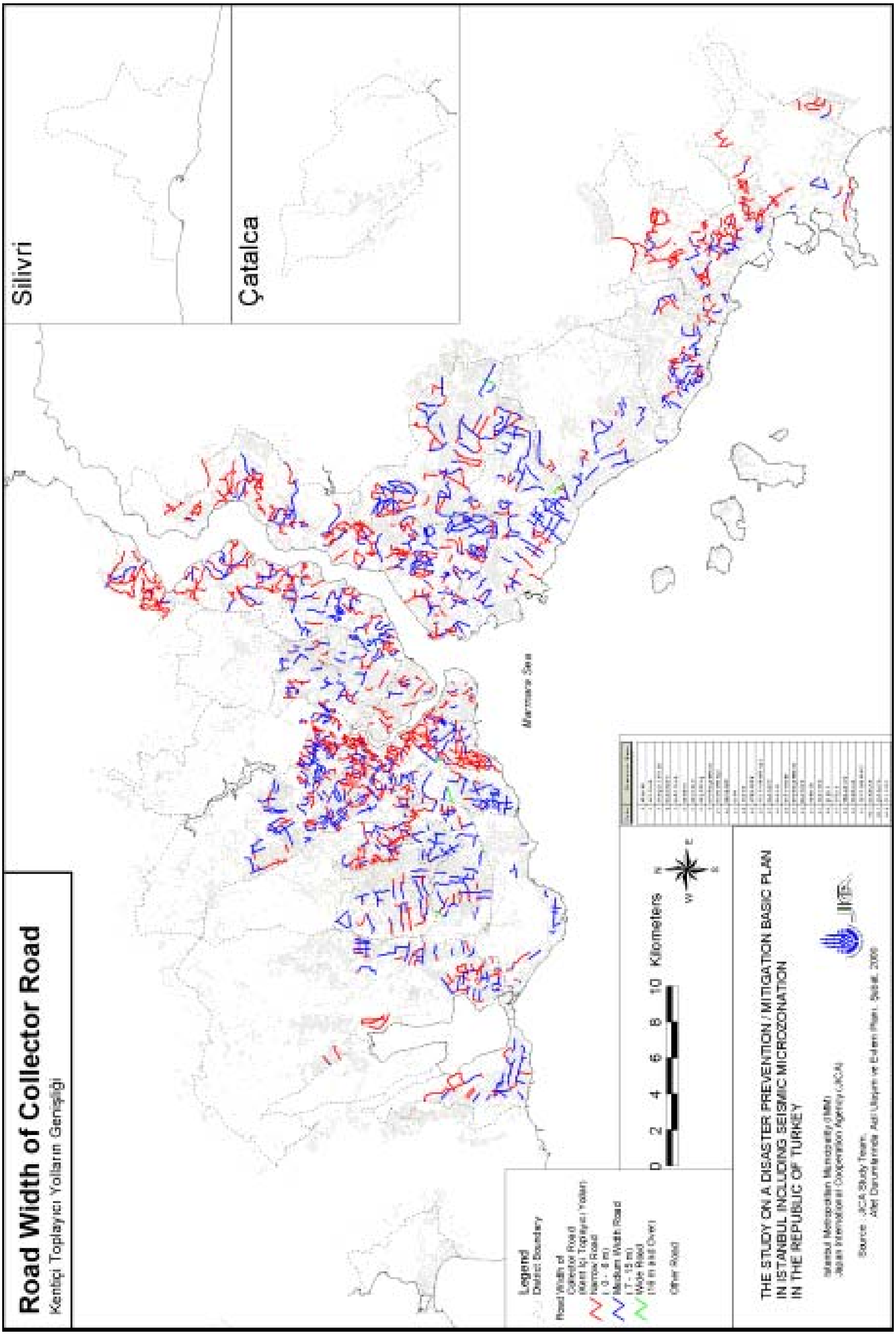

Figure 9.6.4 Road Width of Collector Road

(1) Importance Evaluation of Routes and Sections Along Network

a. Importance Evaluation of Route and Section Based on Attributes

Evaluation Method

As shown in Figure 9.6.5, the route to be studied is divided by 500 m grids to form sections, and factors capturing disaster prevention importance among routes and sections, traffic characteristics, route characteristic, and the status of each route's river crossing are assigned to each section as attributes. The "score" from the evaluation of an attribute j is expressed as Xj and is multiplied by Wj (weight coefficient of attribute j). The sum of the product "Xj x Wj" is calculated to determine the overall importance of a specific route and section. Namely, the evaluation score of a route and section, I_A, is expressed using the following formula:

$$I_A = \sum_{j=1}^{n} Wj \cdot Xj$$

I_A : Importance Score of Targeted Route and Section

Wj : Weight Coefficient of Attribute j

Xj : Points in Evaluation to Attribute j

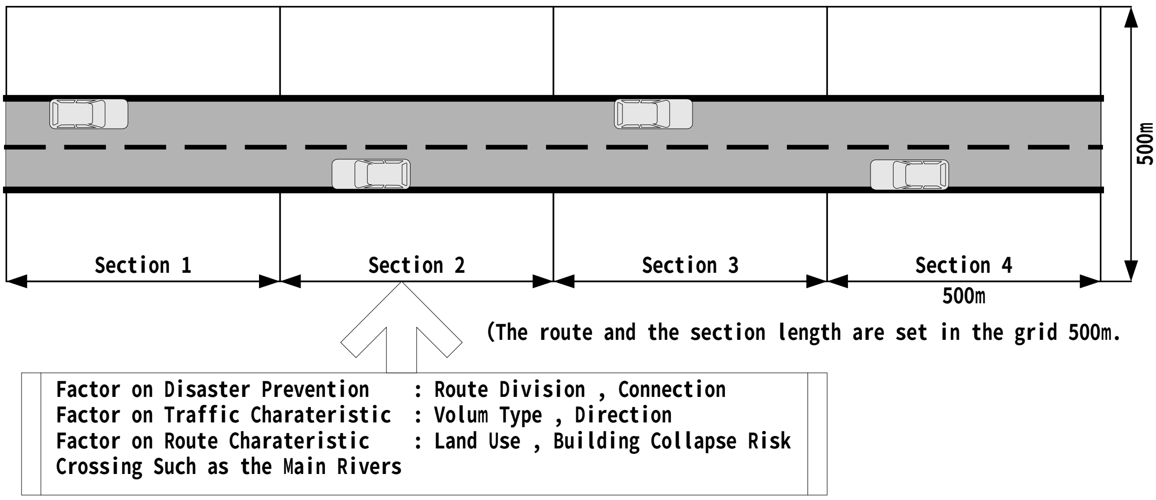

Figure 9.6.5 Evaluation and Attribute in Route

The larger the value of I_A, the higher the route's importance, and the relative importance of sections are classified as "primary," "secondary," or "other" as shown in the histogram of the score, or points, of evaluated sections. The following is an explanation of the 4 factors shown in Figure 9.6.5.

Factor on Disaster Prevention

Regarding the factor on disaster prevention, connecting status of the route division with other area, which is presumed by the road's function, etc., is considered.

Route Division (Figure 9.6.6)

Routes have been classified into Type 1 to Type 4, supposing there are 4 types of roads: 1) evacuation or escape roads, 2) emergency transportation roads, 3) roads urgently developed for emergency use, and 4) other roads. Type 1 roads are for escape of refugees and other passersby as well as for rescue operations, and are assigned the highest number of points. Types 2 and 3 are considered to be the next important.

Connection (Figure 9.6.7
Figure 9.6.7)

It is expected that wide routes and sections that serve as critical connections to other areas will perform important functions in rescue operations and the transportation of external relief supplies. Therefore, routes having such characteristics are assigned a high number of points.

Factor on Traffic Characteristic

As part of the traffic characteristic factor, traffic volume capacity and direction of roads are taken in consideration.

Volume Type (Figure 9.6.8)

This factor is added to the traffic volume in evaluation. Higher points are given to roads with broad width and most capable of securing speed service.

Direction (Figure 9.6.9)

In the area studied, there are two national traffic axes running east and west, other traffic axe(s) running north and south connecting the national axes, and routes which form an inner city traffic network. The two highways running east and west are the main "loop" roads in Istanbul, and the connecting roads running north and south as well asthe other roads directly connected to them can be regarded as "radial lines." In the road network, it is necessary to use the loop line to move between radial lines. Therefore, regarding road direction, loop lines are given higher points than radial lines. Main roads other than the radial lines are given lower points than the ones given to the radial lines, depending on their function.

Route Characteristic Factor

As part of the route characteristic factor, the status of land utilisation and degree of collapse risk of roadside buildings due to earthquakes are considered.

Land Use (Figure 9.6.10)

For land use determination, IMM's data (2000) was utilised. In regard to the roadside land utilisation, areas are classified as "residential," "industry," "public facility," "transportation facility," "park," and "other Areas," and the routes and sections passing through these areas are assigned different points according to this classification. Once an earthquake has caused damages, public and transportation facilities are required to reserve and fulfill their functions as primary rescue centres to cope with the disaster. Therefore, with regards to the land use factor, routes passing through public or transportation facilities, which can cause great impacts when damaged, are assigned the highest number of points.

Building Collapse Risk (Figure 9.6.11)

When roadside buildings collapse due to an earthquake, it is presumed that they lower the functionality of roads and greatly detering effective transportation and contributing to traffic congestion. Therefore, the number of collapsed houses due to the vibration in Model-C in each 500 m grid is counted to determine the house collapse risk of each section, and the sections with the highest collapse risk are given the highest points.

Crossing Large Bridges and Viaducts (Figure 9.6.12)

Roads crossing over rivers and straits, as well as disaster prevention routes, are some of the most important factors in earthquake disaster. In Istanbul, it is likely that the damage of bridges spanning main rivers and straits would cause a break in the connection among areas and significantly inhibit escape, rescue, and restoration activities. From this point of view, routes and sections having bridges of 50m or longer, and those crossing over rivers and straits, are considered to be very important and are assigned a high number of points accordingly.

Table 9.4.1 shows point and weight coefficients of individual attributes used in the evaluation of the importance of routes and sections.

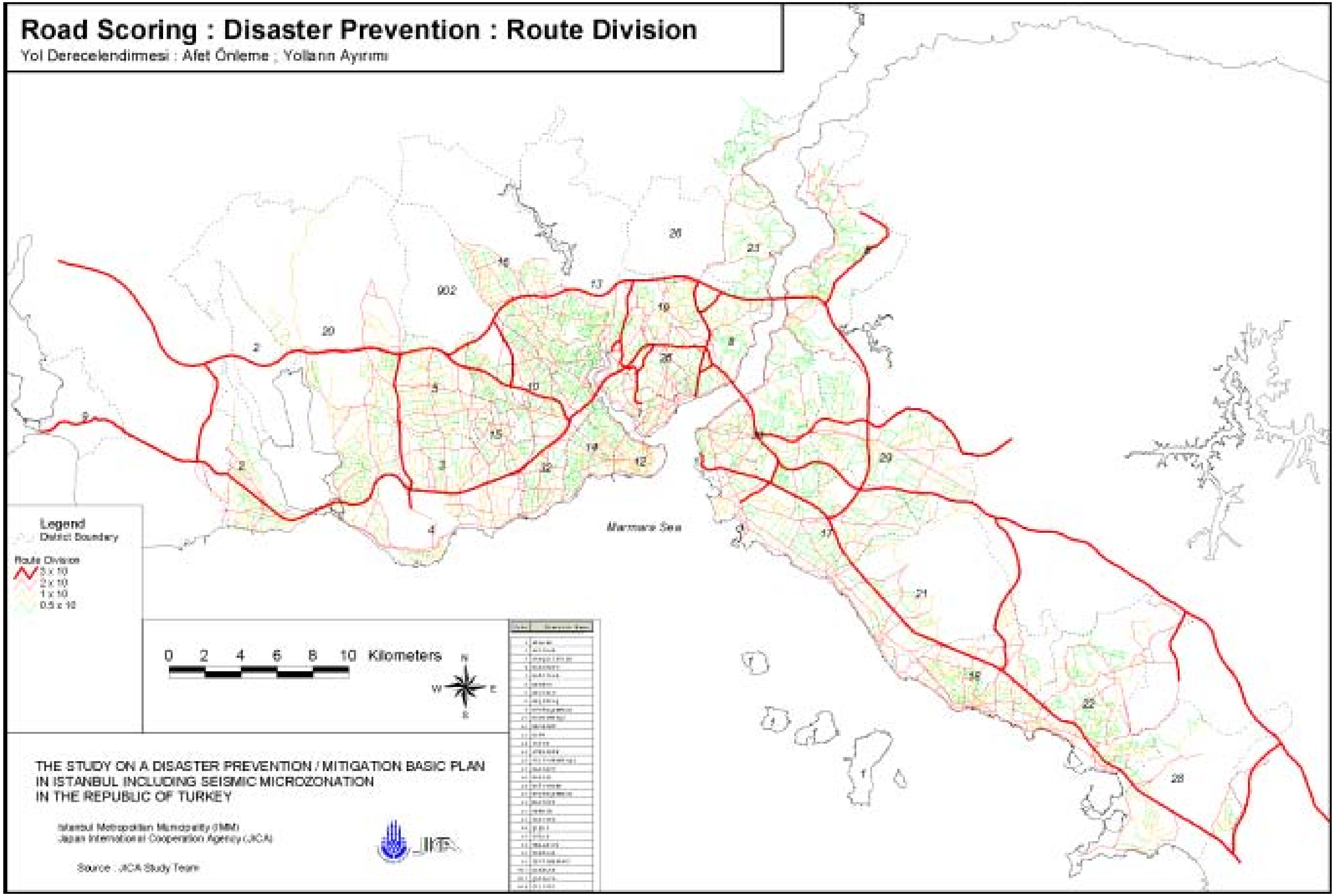

Figure 9.6.6 Road Scoring : Disaster Prevention : Route Division

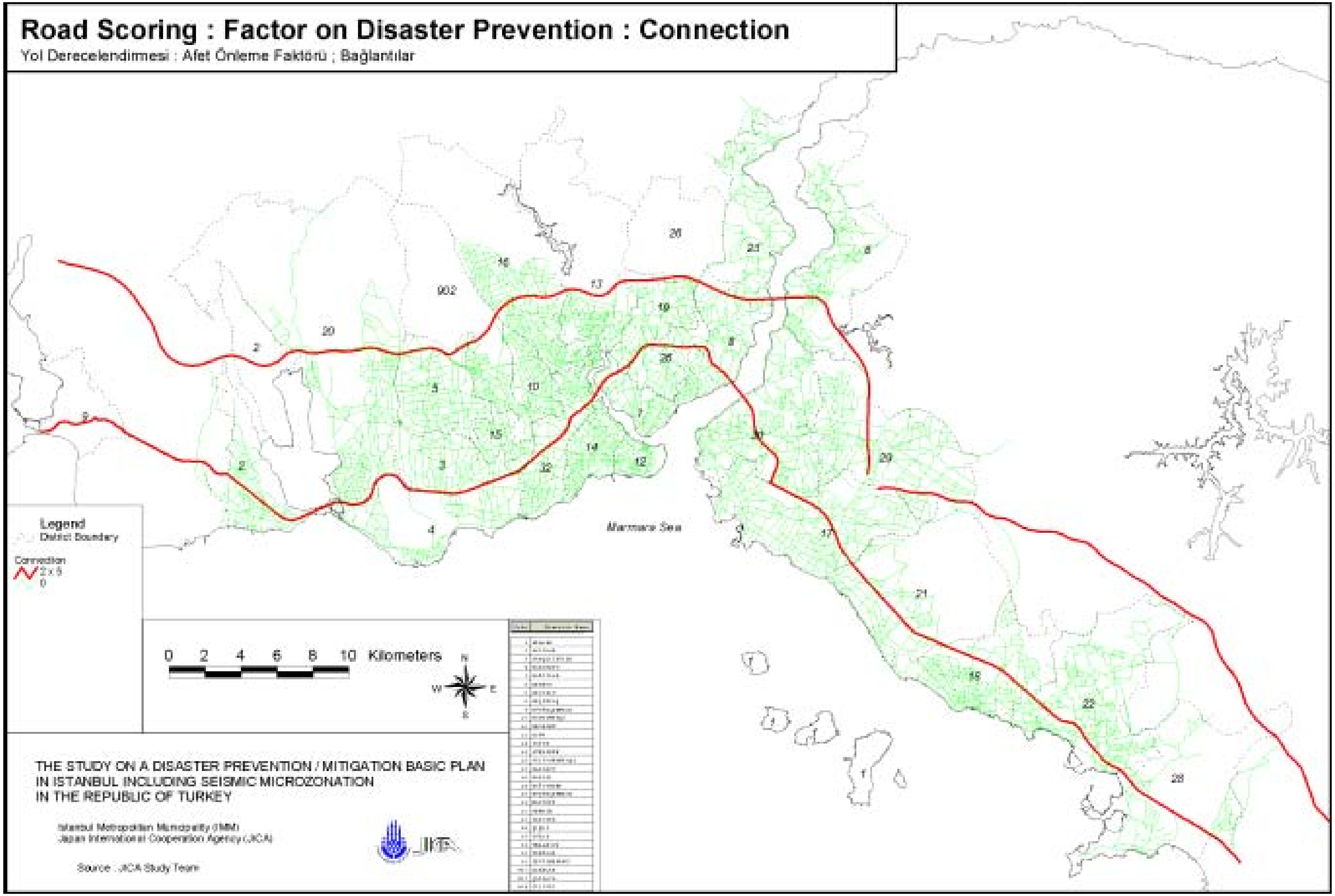

Figure 9.6.7 Road Scoring : Factor on Disaster Prevention : Connection

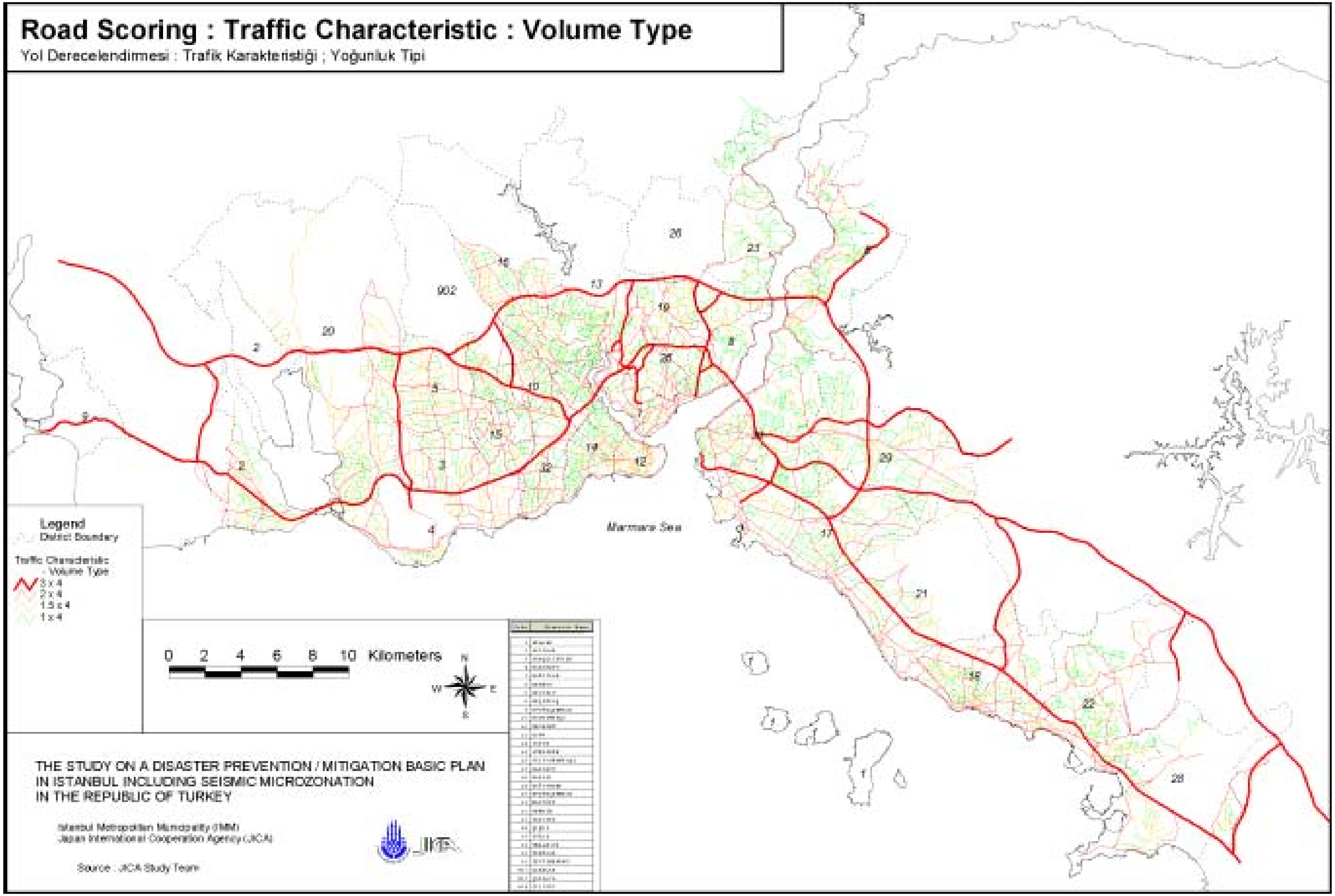

Figure 9.6.8 Road Scoring : Traffic Characteristic : Volume Type

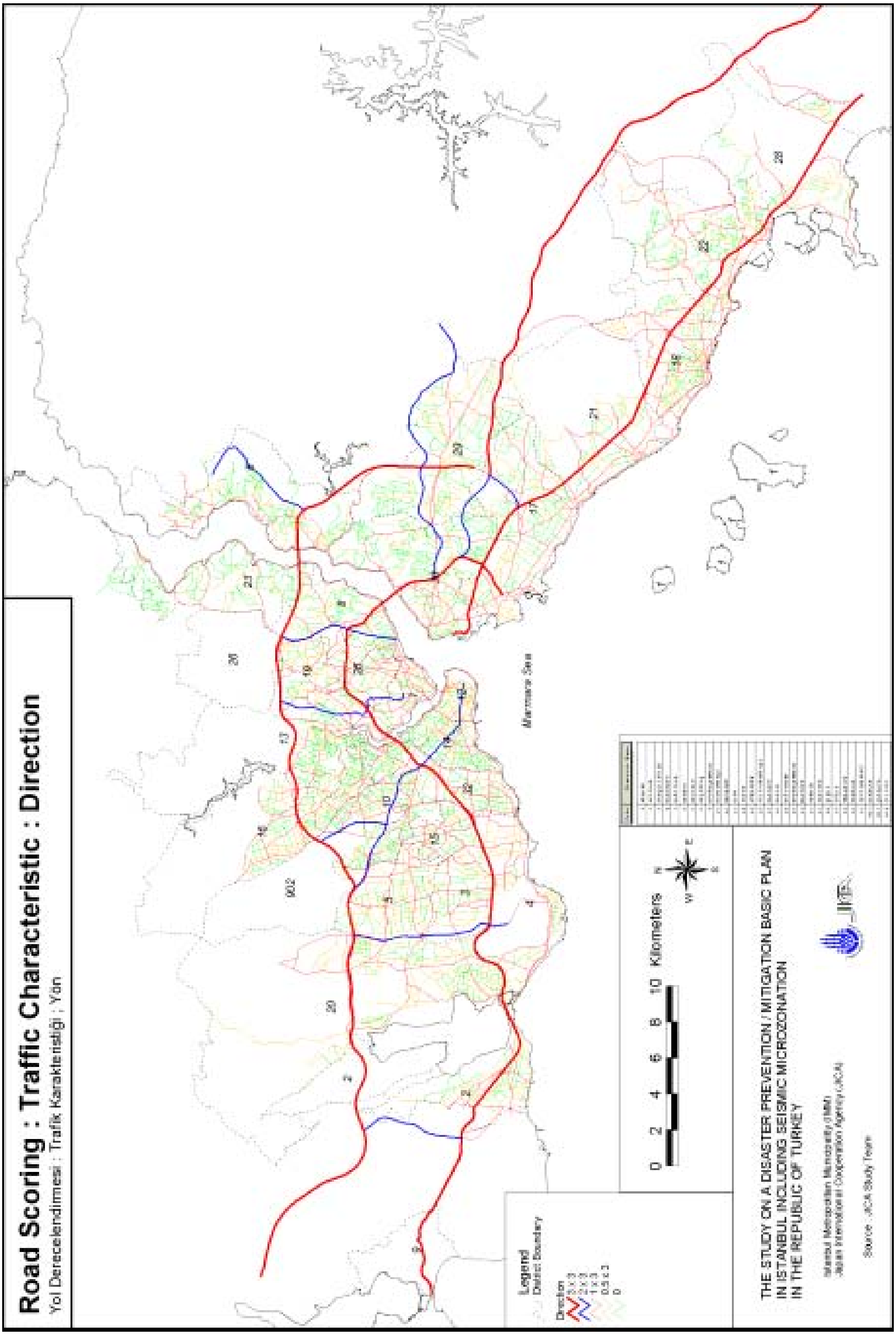

Figure 9.6.9 Road Scoring : Traffic Characteristic : Direction

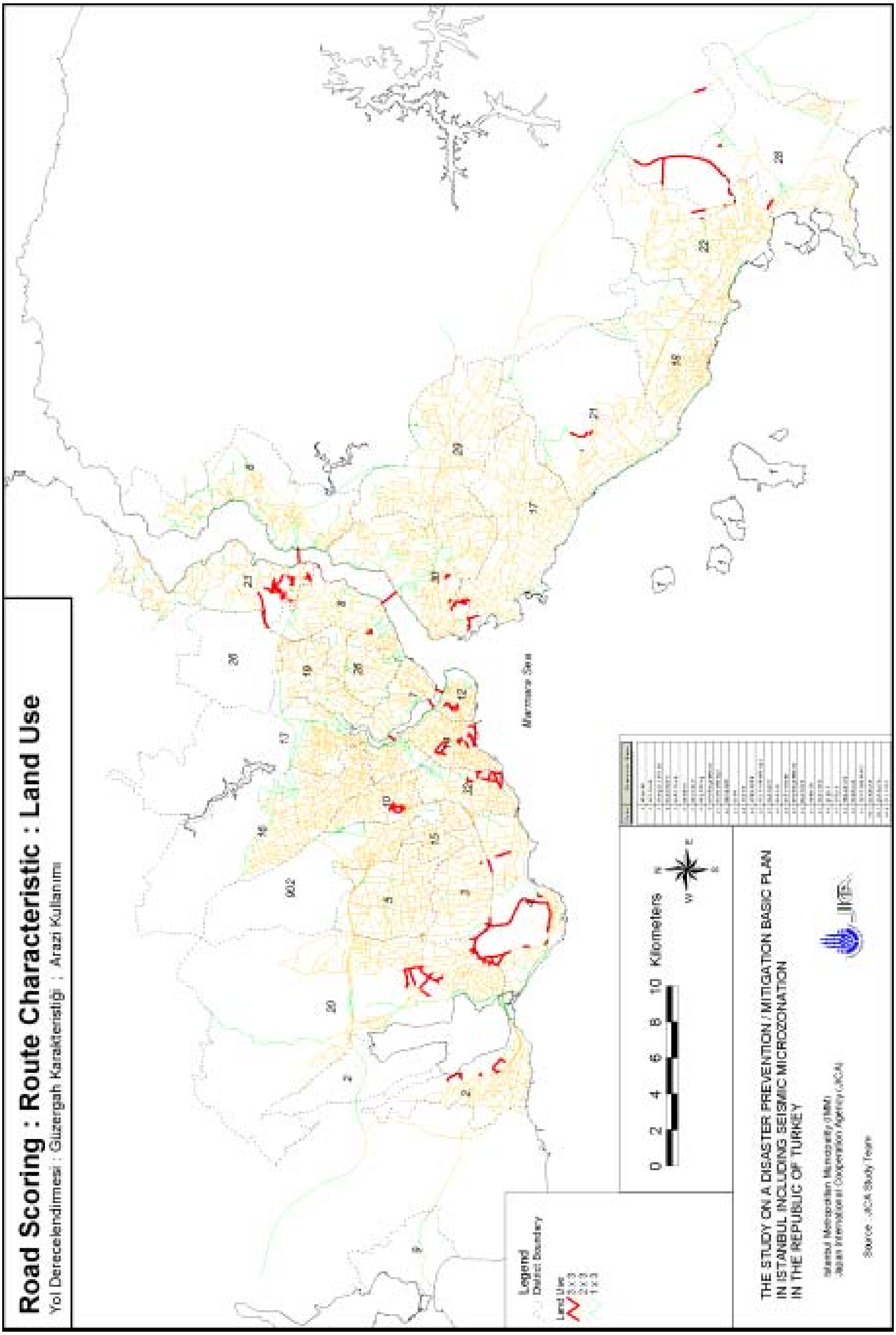

Figure 9.6.10 Road Scoring : Route Characteristic : Land Use

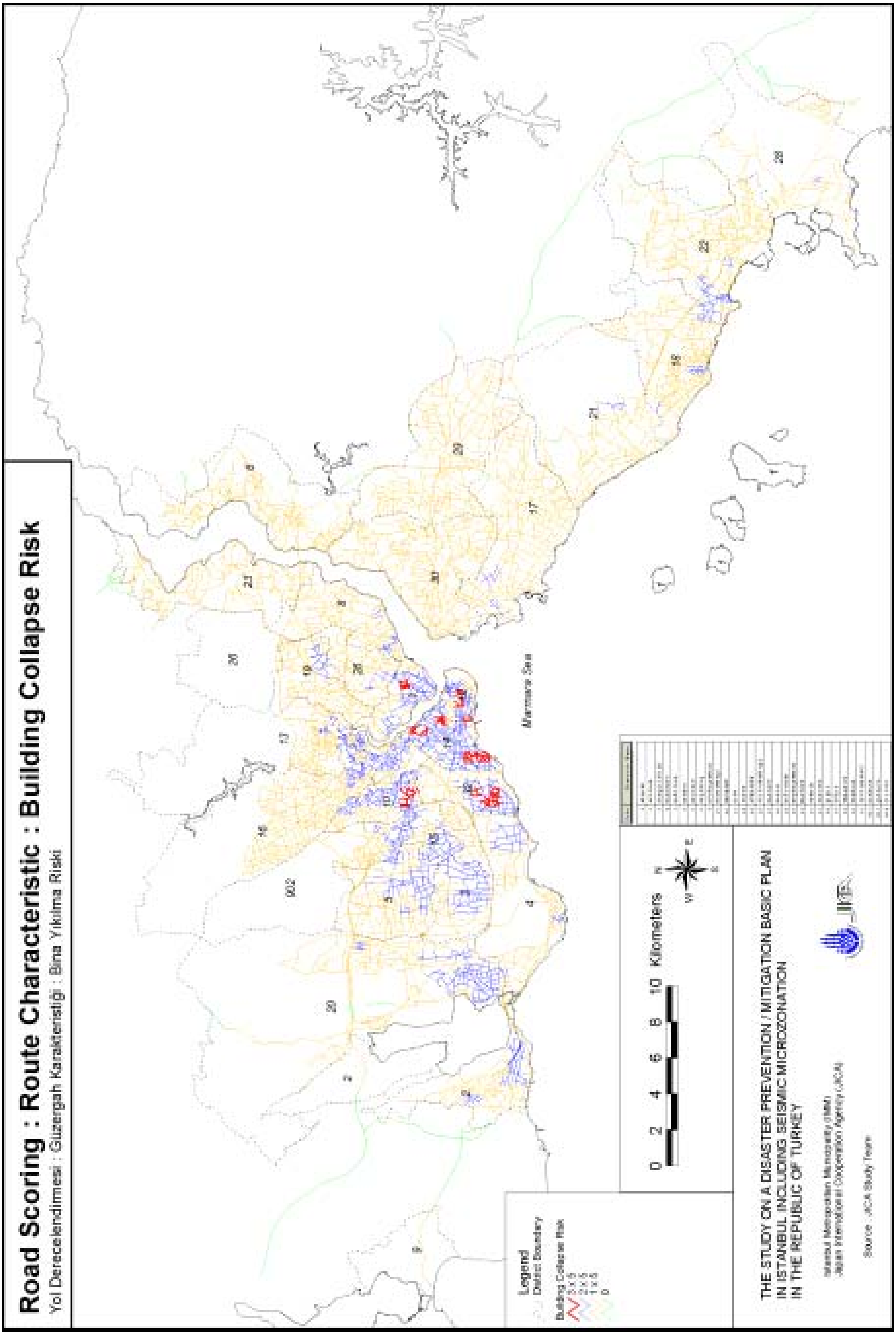

Figure 9.6.11 Road Scoring : Route Characteristic : Building Collapse Risk

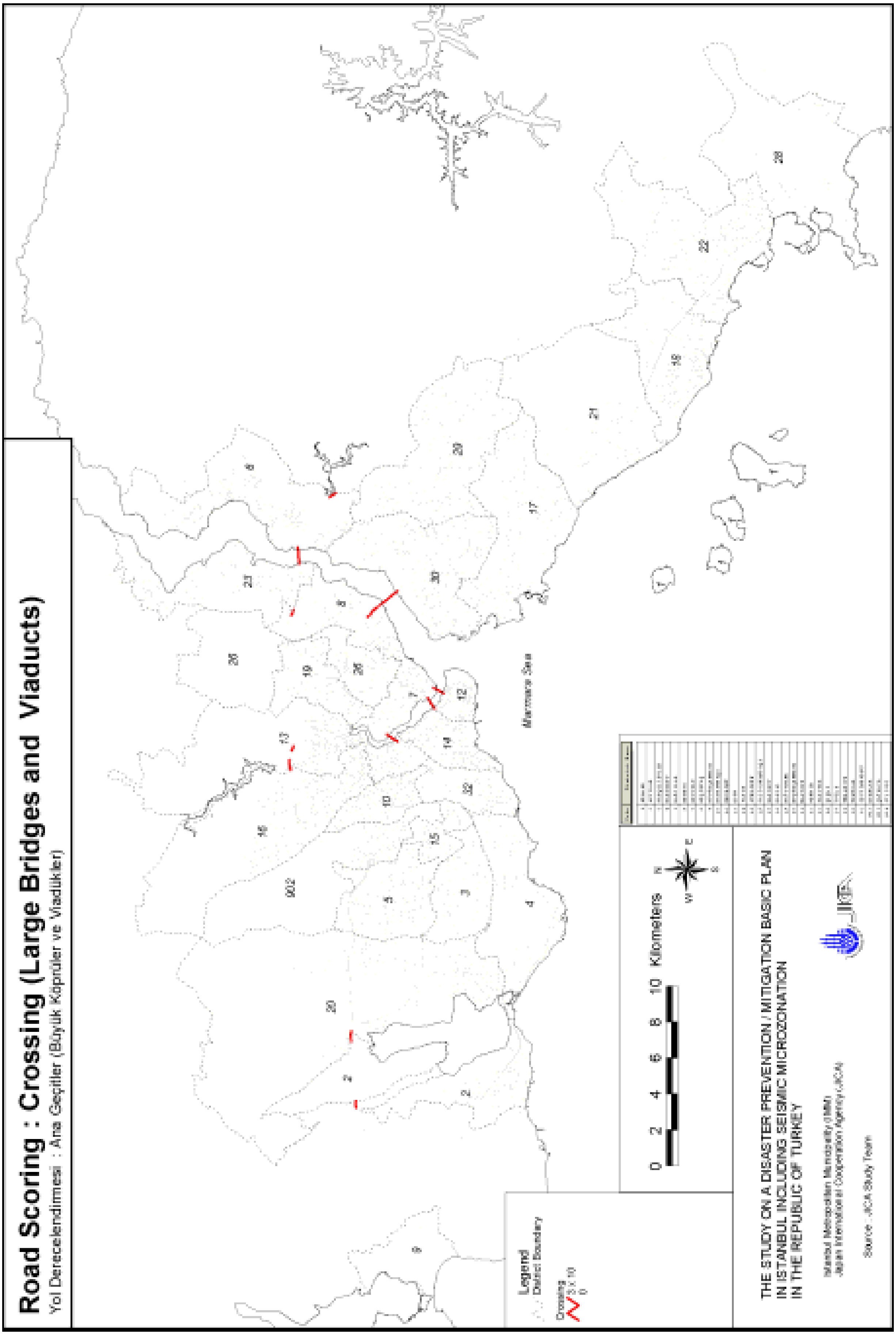

Figure 9.6.12 Road Scoring : Crossing (Large Bridges and Viaducts)

Table 9.6.1 Points in Evaluation and Coefficient Factor Weights

Factor			Points in Evaluation Xj	Weight Coefficient Wj
Factor on Disaster Prevention	Route Division	Type-1	3	10
		Type-2	2	
		Type-3	1	
		Type-4	0.5	
	Connection		2	5
Factor on Traffic Characteristic	Volume Type	Highway	3	4
		1st Degree Road (Highway is Excluded)	2	
		2nd Degree Road	1.5	
		Collector Road	1	
	Direction	Main Loop Road	3	3
		Main Radial Road	2	
		1st Degree Road Except the Above-Mentioned	1	
		2nd Degree Road	0.5	
		Others	0	
Factor on Route Characteristic	Land Use	Public Facility	3	3
		Transportation Facility		
		Residential Area	2	
		Industry		
		Park	1	
		Others		
	Building Collapse Risk	200 - 500	3	5
		100 - 200	2	
		50 - 100		
		20 - 50	1	
		1 - 20		
		0	0	
Crossing Such as the Main Rivers		Section where the Main River is Crossed	3	10
		Excluding the Above-Mentioned	0	
Total				40

Evaluation Result

Shown in Figure 9.6.13 and Figure 9.6.14 are the results of analyses carried out under the above conditions. A score for the importance of each route and section has been calculated using the previously introduced formula, and Figure 9.6.13 shows the road distances at 10~100 points and accumulation frequency of distance. The importance in routes and sections is as shown in Figure 9.6.14. The importance has been set up based on the score of importance, $I_{A,}$ of the main loop and radial lines and the distribution of I_A.

As a result of the evaluation of the importance of routes and sections based on their individual attributes, the main loop and main radial lines, both of which are highways, and the routes that connect with them have been extracted as the most important routes and sections. As secondarily important, the routes forming the rural traffic network have been extracted.

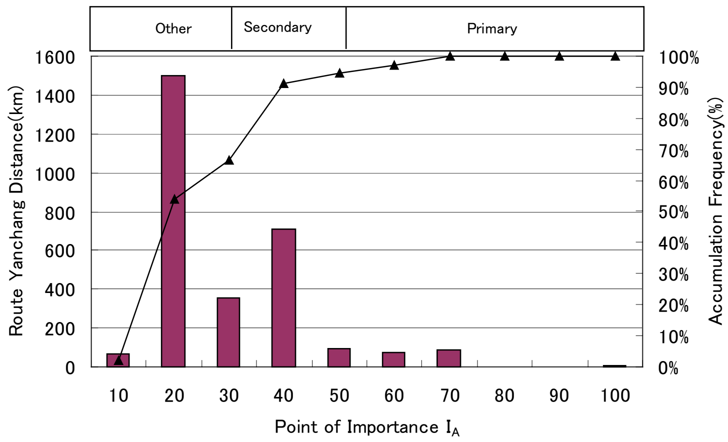

Figure 9.6.13 Point Distribution of Importance I_A in Route and Section Based on Attribute

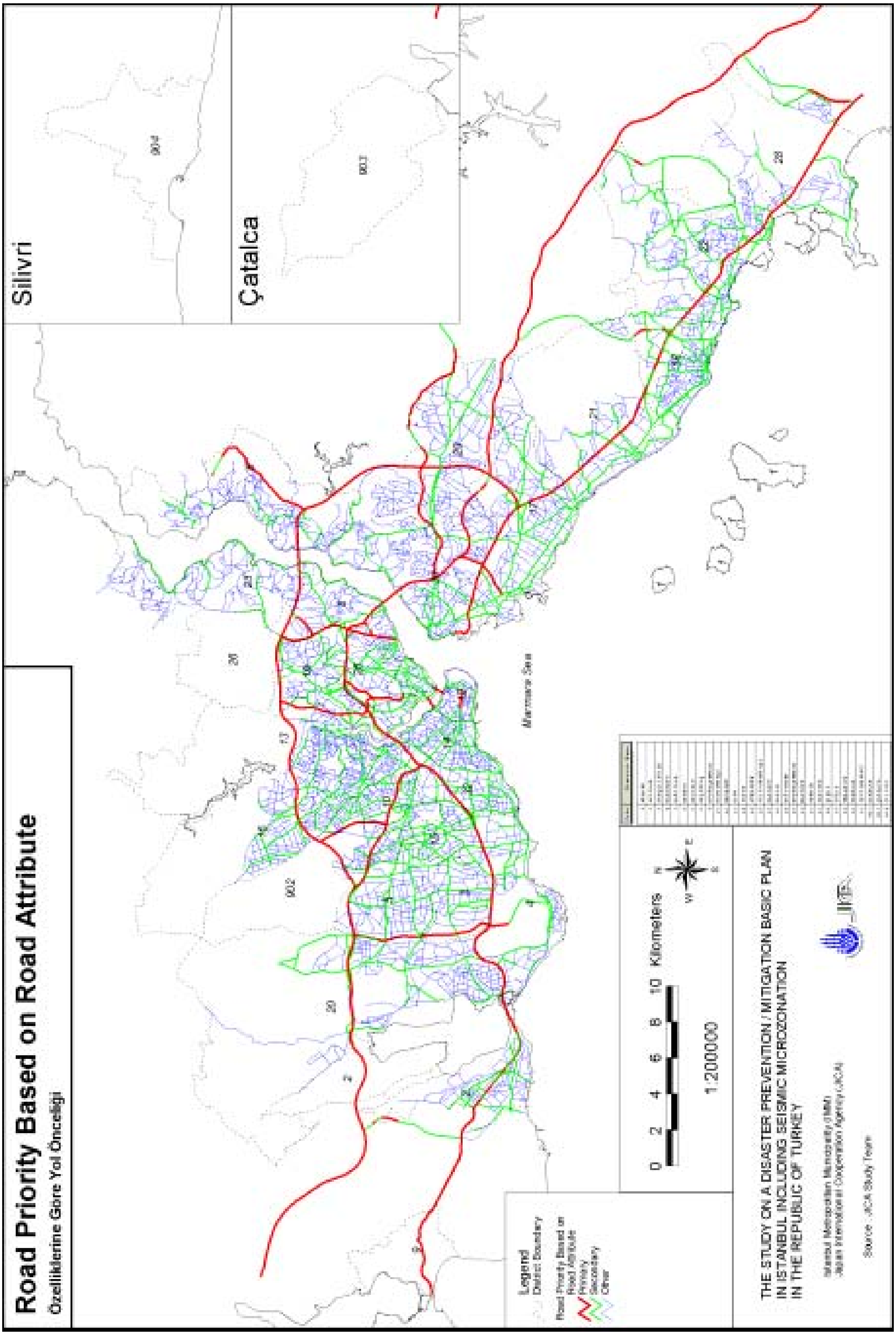

Figure 9.6.14 Road Priority Based on Road Attribute

b. Importance Evaluation Based on Road Network Characteristics

Importance based on road network characteristics should be evaluated at several stages including immediately after the earthquake, during the period of information gathering and rescue, and also during emergency restoration. To help see the road network from a broad perspective, factors to be taken into consideration in implementing the evaluation are current road utilisation, direction and volume of traffic, and characteristics of traffic and roadsides. Among the stages after an earthquake, the escape of refugees just after an earthquake is considered primarily as individuals' moving actions, and theirtrip lengths are generally short. Therefore, it is thought inappropriate to evaluate the function of road network immediately after an earthquake. From this point of view, the evaluation based on road network characteristics after an earthquake is implemented only for the stages of information gathering and rescue, as well as for the stage of emergency restoration.

Evaluation Method

The following evaluation method has been employed:

At any stage, certainty, meaning that traffic allows people to reach their desired destination within a prescribed time, is considered to be most important. In this respect, to begin with, the number of routes passed when one, taking the shortest possible route, moves between selected important facilities is counted, and frequency of utilisation of each route is evaluated. Then, the particularly noticeable routes and sections are extracted based on trends of utilisation frequency, and the same evaluation as above is carried out for cases when bridges on these routes cannot be used. From the results of these two evaluations, the comparative importance of the road networks are evaluated and classified as three grades.

I_N, the importance of the road network, is determined from the evaluation matrix shown in Table 9.6.2 which is prepared based on the results of the importance evaluation of each route and section during the stages of information gathering, rescue, and emergency restoration. The important facilities selected for use in the network analysis are listed in Table 9.6.3, Figure 9.6.15 and Figure 9.6.16. Among them, the facilities selected as the important ones during the periods of information gathering and rescue are shown in (1) in Table 9.6.3, and their locations in Figure 9.6.15. The important facilities selected for the evaluation at the stage of emergency restoration are shown in (1) and (2) of Table 9.6.3 and their locations in Figure 9.6.16.

Table 9.6.2 Evaluation Matrix of Importance Based on Road Network

		Emergency Restoration		
		Largeness	Inside	Smallness
Information Gathering - Rescue	Largeness	Primary		
	Inside		Secondary	
	Smallness			Other

Table 9.6.3 Facilities Targeted by Road Network Analysis

(1)Facilities of Rescue Period	Number of Point
Crisis Centers	4
IMM	1
District Municipality, Kaymakamılık	60
District Disaster Management Center	29
Airport	4
Ports	5
TOTAL	103
(2) Facilities of Emergency Restoration Period	Number of Point
Firebrigate	44
Health Facilities (Note: Including Hospital Emergency Health Service, Health Center)	95
Military	46
IMM Relief and Response Units	18
Main Gathering Centers for Machinery	2
1. Gathering Area for District Search-Rescue Teams	15
1. Gathering Area for District Machinery	9
1. Degree Heliport Areas : Existing and Planned	200
Piers	44
SUB_TOTAL	473
Logistic Support and Coordination Centers	2
Centers for Unloading and Loading : for Sea and Land Transport	6
Centers for Vehicle Unloading and Loading : Truck Terminal	9
Centers for Unloading and Loading Supply Materials	4
Centers for Unloading and Loading Vehicle Equipment	3
Loading Heavy Machinery	5
SUB_TOTAL	29

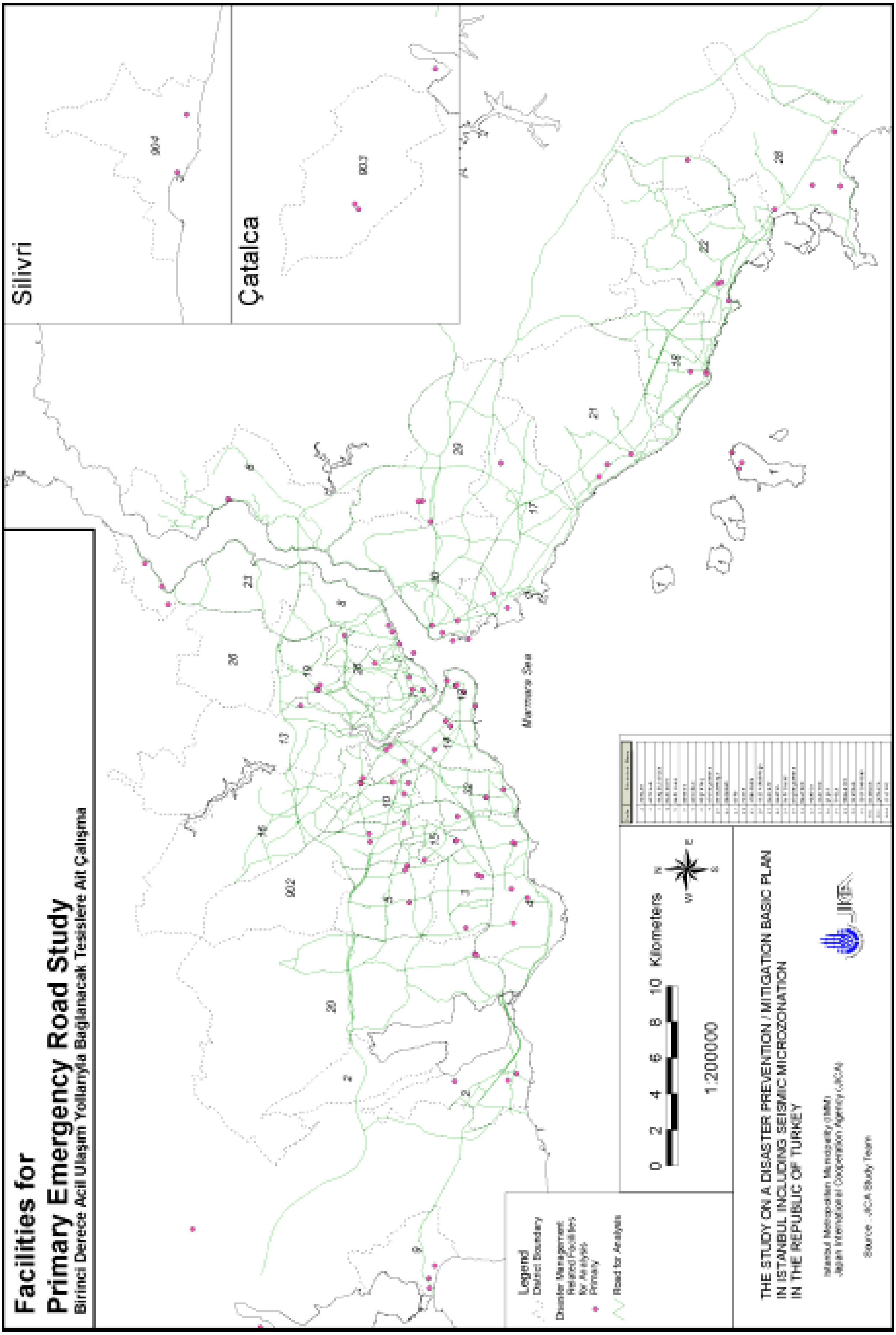

Figure 9.6.15 Facilities for Primary Emergency Road Study

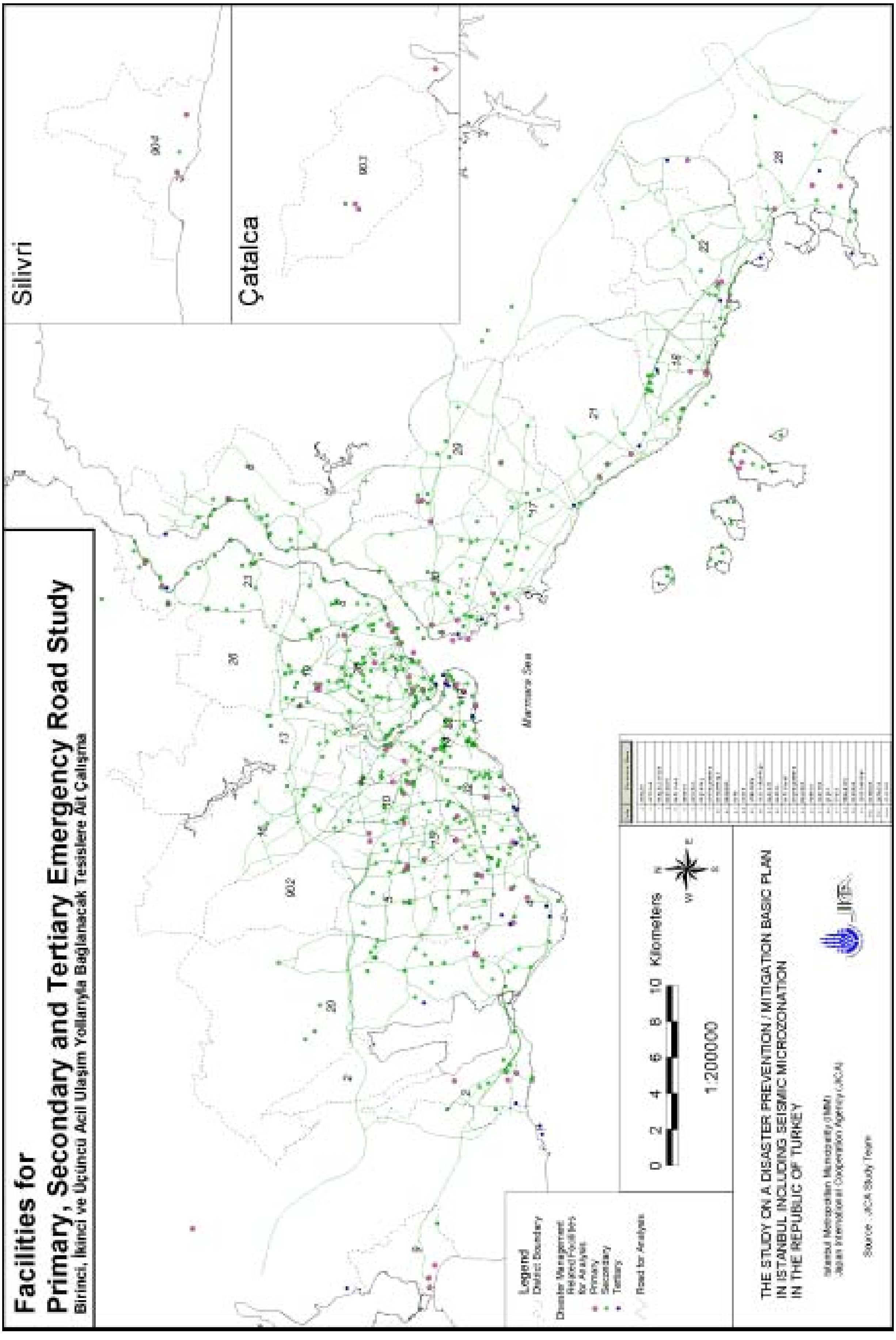

Figure 9.6.16 Facilities for Primary, Secondary and Tertiary Emergency Road Study

Evaluation Result

In the road network analysis, the same routes and sections as examined in the importance evaluation based on attributes were selected, and a network consisting of about 1,300 nodes was studied. Figure 9.6.17 shows the network used for the analysis. Among these nodes, the important facilities shown in Table 9.6.3, Figure 9.6.15 and Figure 9.6.16 were selected as the starting points and destinations of the traffics. Ttraffic volumes from all the facilities were presumed to be the same, and traffic speeds were set as shown below according to the road specifications and/or widths:

- Highway: 80km/h
- Width, 16m or wider: 40km/h
- Width, 7m to 15m: 30km/h
- Width other than the above: 20km/h

The analysis result is explained in the following:

Information gathering period – rescue period

Figure 9.6.18 shows the model of network analysis for the information gathering and rescue stages. The heaviest traffic resulted in southern areas of the main loop (E5 to O-1). Namely, it can be said that the routes and sections to be extensively studied were those from the Golden Horn Inlet area to the No.1 Bosporus Bridge area. Therefore, as a next step, a network analysis was carried out on assuming that the bridge spanning the Golden Horn Inlet and the bridge on the European side, which is connected with the No.1 Bosporus Bridge, could not be used. Figure 9.6.19 shows the network analysis model for the case when routes and sections are to be extensivelystudied, and the two bridges mentioned above cannot be traversed. According to the analysis result, in the case when the two bridges cannot be traversed, the traffic flow would move to the loop line to the north (O-2) and, at the same time, traffic on the radial lines connecting the southern and northern loop lines would increase. Figure 9.6.20 shows the result of superimposing Figure 9.6.18 and Figure 9.6.19.

Emergency restoration period

Figure 9.6.21 shows the network analysis model for the emergency restoration stage. When compared with the results of the above analysis, in general, higher passing counts and longer sections with high counts are seen because of the increased number of selected facilities spread out over a wider area. However, the routes and sections having the heaviest traffic in this analysis extend from the Golden Horn Inlet area to the No.1

Bosporus Bridge area on the loop line in the southern area (E5 to O-1), which is the same section as resulting in the above analysis. Then, a network analysis was implemented, in the same manner as applied to the above analysis; that is, assuming that the bridge spanning Golden Horn Inlet and the bridge on the European side connected to the No.1 Bosporus Bridge, could not be traversed. The analysis result shown in Figure 9.6.22 indicates the same trend of traffic flow as shown in the result of the above analysis; that is, because Route O-1, which spans the Golden Horn Inlet, cannot be traversed, the traffic passes onto the loop line in the north (O-2) via main radial lines before and after the bridge become main stream. Figure 9.6.23 is the result of superimposing of Figure 9.6.21 and Figure 9.6.22.

Figure 9.6.24 illustrates I_N, which expresses the importance based on the network characteristics and is obtained through the integrated evaluation of the results of the two analyses utilising the evaluation matrix shown in Table 9.6.2. This result indicates a tendency for the importance of main loop lines and main radial lines connected to them to become relatively high..