

## “Technical Research and Development for Road Policy Quality Improvement” Study Summary

No.	Title	Principal Researcher
31-5	Planning and Evaluation Methodology for Functionally Hierarchical Road Networks According to Regional and Urban Structures	Prof. Hideki Nakamura Nagoya University

In order to evaluate the degree of hierarchy of road network in a region, road use characteristics that express the functional hierarchy of the road network, and the road network conditions and regional urban structure necessary for its evaluation are examined. This research proposes a method for evaluating the degree of hierarchy using these methods.

### 1. Background and Objectives

Although the road network is becoming more organized in Japan, the average travel speed provided by road use is largely divided into expressways and other roads, and there are few roads that provide intermediate travel speeds. This causes problems such as the long time required for traveling between important centers, and the concept of a functional hierarchical road network is one of the keys to solve these problems. However, there is no method to evaluate the extent to which the road network in a region can be used in a functional hierarchy.

In this study, we propose the degree of hierarchy as an index to evaluate the properties of a functionally hierarchical road network. Then, a method for planning a functionally hierarchical road network using the degree of hierarchy is established.

### 2. Activities in Research Period

- (1) Definition and representation of functional hierarchy of road network
- (2) Quantification of road network conditions and regional urban structures
- (3) Analysis of road use characteristics in functionally hierarchical road network
- (4) A method for evaluating the functionally hierarchical road network using the road use characteristic indices
- (5) Evaluation of road network using the degree of hierarchy

### 3. Study Results

- (1) The degree of hierarchy of the road network can be expressed by the road use characteristic, which is assumed to change depending on the road network conditions and regional urban structure.
- (2) In order to set indices for road network conditions used in evaluating the functional hierarchy of road network, we proposed a method for classifying road levels, a method for setting free speeds, and proposed indices for each level, such as free speeds. In addition, in order to set an index for the regional urban structure, we proposed a method of dividing the area to be analyzed into zones and setting up features and representative points related to multiple center facilities within the zones, and proposed indices for the distance from these representative points to roads in the upper levels.
- (3) Indices related to travel speed and road use differentiation were extracted as the road use characteristic that represents the functional hierarchy of road network. Then, sensitivity analysis was done in terms of road network conditions and regional urban structure, and the intersecting points of the hierarchical utilization curves ( $\theta$ ,  $f(\theta)$ ) according to trip length was selected as a representative index (Fig.1).
- (4) Based on the characteristics of the road network assumed from the

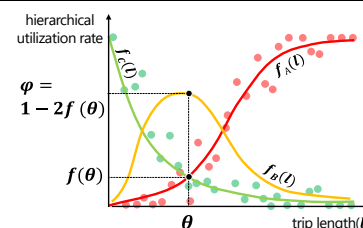


Fig.1 Intersecting points of hierarchical utilization curves

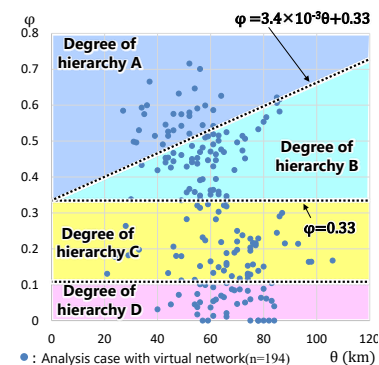


Fig.2 Classification of the degree of hierarchy

Table 1 Multiple liner regression analysis results

		independent variables	$\theta$	$f(\theta)$
road network conditions	Road Length Percentage	Level A $RL_A$ [%]	$-2.74 \times 10^{-3**}$	$4.57 \times 10^{-3**}$
		Level B $RL_B$ [%]	—	$-6.12 \times 10^{-3**}$
	Free Speed	Level A $V_A$ [km/h]	$-1.82 \times 10^{-3**}$	—
		Level B $V_B$ [km/h]	$-4.36 \times 10^{-4**}$	—
		Level C $V_C$ [km/h]	$2.16 \times 10^{-3**}$	—
	Free Speed Difference between 2 Levels	Level A and B $\Delta V_{AB}$ [km/h]	—	$5.14 \times 10^{-4**}$
Level B and C $\Delta V_{BC}$ [km/h]		—	$-2.36 \times 10^{-3**}$	
junction spacing (Level A) $s_{JA}$ [km]		—	$-1.43 \times 10^{-3**}$	
regional and urban structures	Inverse of the weighted average of the distances of level $h$ from the generation and attraction points	Level A $1/d_A$ [1/km]	$-1.29 \times 10^{-9**}$	$6.16 \times 10^{-1**}$
		Level B $1/d_B$ [1/km]	$-1.66 \times 10^{-1**}$	$-3.49 \times 10^{-1**}$
	Standard Deviation of the Distance of Level $h$ from the Generation and Attraction Points	Level A $S_A$ [km]	—	$1.02 \times 10^{-2**}$
		Level B $S_B$ [km]	—	—
	Constant		—	$5.78 \times 10^{-1**}$
Adjusted R Square		—	0.713	0.752
Number of Cases		—	194	

\*p < 0.05, \*\*p < 0.01  
 [ ]: Variables not selected due to low t-value  
 [X]: Variables excluded to avoid collinearity  
 [ ]: Variables excluded due to the free speeds at each level of the hierarchy

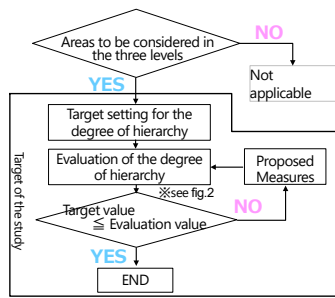


Fig.3 Flowchart for planning functionally hierarchical road networks

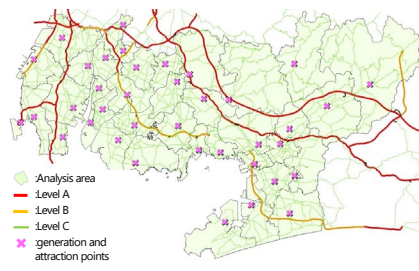


Fig.4 Current Conditions in East Aichi Region (case1-1)

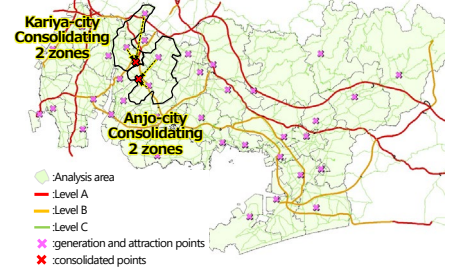


Fig.5 Proposed Measures for East Aichi Region (case1-3)

superimposed hierarchical utilization curves, we proposed a method to evaluate the degree of hierarchy of the road network using objective indicators ( $\theta$ ,  $\phi$ ) determined from the intersecting points of the hierarchical utilization curves (Fig.2). Paired Comparison Questionnaire Surveys were conducted on the functional hierarchy of road networks for experts involved in the study of functionally hierarchical road networks, and it was confirmed that the order of the obtained subjective evaluation and the order of the evaluation by objective indices were consistent at the evaluation category level of the degree of hierarchy.

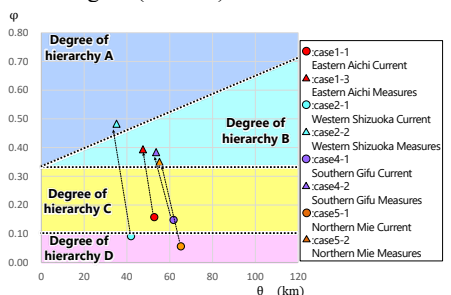


Fig.6 Change in the degree of hierarchy due to implementation of countermeasures

(5) In order to enable practitioners to easily use the evaluation method for the degree of hierarchy without having to conduct route searches, an estimation model for road use characteristic indices was developed (Table.1). Then, we proposed a method for planning a functionally hierarchical road network (Fig.3). Based on the results, the degree of hierarchy in the four Tokai regions was evaluated (Fig.4, 5, and 6).

#### 4. Papers for Presentation and Publication

- 1) Kakimoto, Y., Nakamura, H. and Ishiyama, R.: A Study on the Requirements for Forming a Functionally Hierarchical Road Network, Japan Society of Civil Engineers, No.60, 7 pages, 2019. (in Japanese)
- 2) Shimokawa, S.: Enhancement of Arterial Highway Network Functions in the Use Stage, Japan Society of Civil Engineers, IATSS Review, Vol.44, No.3, pp.34-42, 2020. (in Japanese)
- 3) Sekihara, T., Kakimoto, Y., Nakamura, H. and Iryo-Asano, M.: Analysis of Relationship between Road Use Characteristics Indicators and Functional Hierarchy of Road Network, Japan Society of Civil Engineers, No.62, 9 pages, 2020. (in Japanese)
- 4) Kakimoto, Y., Nakamura, H.: A Study on a Method for Determining Performance Target of Mobility Function for Forming a Functionally Hierarchical Road Network Journal of the Japan Society of Civil Engineers D3(Infrastructure Planning and Management), Vol.76, No.5, I\_1235-I\_1243, 2021. (in Japanese)
- 5) Sekihara, T., Kakimoto, Y., Nakamura, H. and Iryo-Asano, M.: Required Road and Traffic Operation Conditions for the Functionally Hierarchical Use of Road Networks, Journal of the Japan Society of Civil Engineers D3(Infrastructure Planning and Management), Vol.76, No.5, I\_1453-I\_1463, 2021. (in Japanese)
- 6) Saitoh, S., Shimokawa, S., Yoshioka, K. and Hanabusa, A Study on the Target Travel Time Between Cities Constituting Prefectures, Journal of the Japan Society of Civil Engineers D3(Infrastructure Planning and Management), Vol.76, No.5, I\_1287-I\_1295, 2021. (in Japanese)
- 7) Kakimoto, Y., Sekihara, T., Iryo-Asano, M., Nakamura, H. and Zhang, X.: Functional Hierarchy Evaluation of Road Networks Based on Paired Comparison Questionnaire Surveys, No.64, 7 pages, 2021. (in Japanese)
- 8) Sekihara, T., Kakimoto, Y., Nakamura, H., Iryo-Asano, M. and Zhang, X.: A Study on the Method for Setting the Location of Bases in the Functionally Hierarchical Road Network, Japan Society of Civil Engineers, No.64, 6 pages, 2021. (in Japanese)

#### 5. Study Development and Future Works

##### Applicability of the study results

- By organizing data on road network conditions and regional urban structure in any region, it is possible to evaluate the degree of hierarchy in the present situation and at the time of implementation of proposed measures.

##### Future works

- Further study on the explanatory variables that express the continuity of road network,
- A study of how to set regional features according to the type of center facility,
- A study of evaluation method of the degree of functional hierarchy for urban road network (e.g., consideration of access functions, consideration of users other than cars, etc).

#### 6. Contribution to the Quality Improvement of Road Policy

- Since the application to practice has been in mind from the beginning of the project, the proposed evaluation method is designed to be easily used by practitioners based on the information available to them,
- By this method, it becomes possible to make policy judgements on road networks from the viewpoint of functional hierarchy.

#### 7. References, Websites, etc.

N.A.