STUDY OF GIS FOR GRASPING OF THE DYSFUNCTION OF STREET - A CASE OF HANSHIN-AWAJI EARTHQUAKE -

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ABSTRACT :

To maintain the traffic routes is an important issue at the time of earthquake disaster in order to rescue human life and transport the relief commodities. The earthquake which struck Kobe city and its outskirts on January 17th, 1995 caused the functional damage at the street by debris or the falling poles such as the electric light pole. The authors measured the blockade situation of the street using the air-photograph and grasped dysfunction at the street using GIS. Then, the authors analyzed the result of the measurement using the network analyses such as the pathfinding. As a result, it has become clear that the system which jointly uses air-photograph interpretation and GIS is useful in grasping the dysfunction of streets. Especially, GIS integrates and visually expresses the spatial data and attribute information and facilitates network analysis by the structurization of spatial data. In the future, it is necessary to reduce the time from the taking of air-photograph to the grasping of dysfunction and to establish a network analysis technique in order for the GIS to be able to support the various activities at the time of disaster such as refuge, rescue, relief and restoration.

1.Introduction

The earthquake which struck at Kobe city and the outskirts on January 17th, 1995 brought about the biggest damage since Kanto Earthquake which occurred in 1923 in Japan. The city function suffered enormous damage , which created an opportunity to reconsider the measures against earthquake in this country. The securing of traffic routes at the time of the earthquake disaster is given as one of these measures. The traffic congestion occurred at the street which is possible to pass immediately after the earthquake.

Based on reconsideration, the securing of transportation routes at the urgent time began to be examined by a lot of administrative organs in Japan. On the other hand, the examination began just now for the securing of traffic routes at the periphery of disaster area. To do the analysis, we must acquire data at the several-meter scale. Also, when examining, the situation of disaster must be reproduced in some form. As one of these methods, there are follow-up investigation made at the actual site and interpretation of air-photograph taken immediately after the disaster. The field investigation makes it possible to collect the sure information detail. However, the field investigation sometimes lacks the simultaneity and the objectivity which are necessary for the evaluation. Therefore, in this study, the authors grasped dysfunction at the street immediately after the earthquake disaster based on the measurement and the interpretation of the air-photograph. Then, authors attempted to reproduce in the traffic situation immediately after the earthquake disaster on GIS. Also, authors assumed the influence which the street blockade immediately after the earthquake disaster gave to the street traffic using a network analysis.

Also, the authors used GIS to integrate the information of the spatial data and the attribute and realized quick computation and simulation. Furthermore, we aimed at the system structure which can rapidly cope with the earthquake expected to take place in the future and provide useful information immediately after the occurrence of earthquake by constructing the flow of the process from taking air-photographs to the data processing on GIS.

2. Method

This study went on by procedure as shown in Figure 1.

2. 1. Analysis area

In this study, we didn't handle the whole area which attacked by the earthquake, but it selected and studied 7 areas with the different degree of damage and characteristic as case study. Description is made on the profile in each area together with the situation of disaster.

a. Nagata area

As for this area, the downtown, the habitation area, the industrial area are intermingled. The percentage

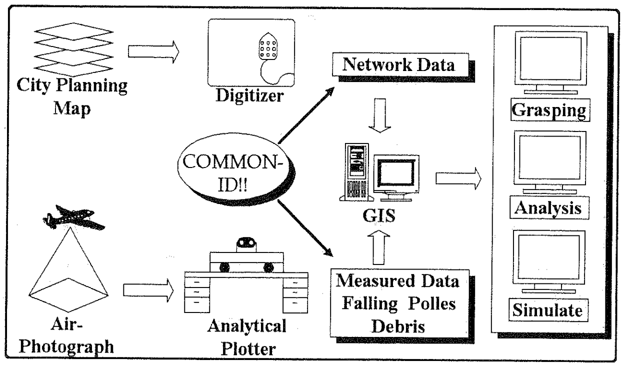

Figure 1.Flow Chart of This Study

of the wooden building is a middle degree. The degree of damage was very big. This area is apart from epicenter by 14 km.

b. Hyougo area

The town and the habitation area are contained in this area. The percentage of the wooden building is high. The degree of damage was very big. This area is apart from epicenter by 16 km.

c. Sannomiya area

This is area of commercial center. The percentage of the wooden building is low. The degree of damage was big. This area is apart from the epicenter by 20 km.

d. Kasuganomichi area

This area is a dwelling center. The wooden percentage of the building is high. The degree of damage was light. This area is apart from the epicenter by 22 km.

e. Rokkoumichi area

As for this area, the downtown and the habitation area are intermingled. The percentage of the wooden building is ordinary. The degree of being suffered was big. This area is apart from the epicenter by 25 km.

f. Uozaki area

It is an area of the habitation center. The percentage of the wooden building is high. The degree of being suffered was very big. This area is apart from the epicenter by 28 km.

g. Ashiya area

It is a habitation area. The percentage of the wooden building is high. The degree of being suffered was light. This area is apart from the epicenter by 32 km.

2. 2. Construction of a data base

The authors acquired the following data and built a data base.

1)Structure of street (width of street and walkway)
2)Debris and Falling poles (such as electric pole, signal, streetside tree etc.)
3)Street network

<Measurement of the structure of the street>

Width of street was measured from the air-photograph using the analytical plotter. The distance between the intersections was determined as one link. The narrowest portion in a link was employed as the width of the link. That is because, the passage possibility of the link is determined by the condition of the narrowest width part. Also, when examining dysfunction at the street, we need the width of the driveway. Therefore, the authors measured the width of the walkway together with the data of the street section.

<Measurement of the falling poles and debris>

Measurement was done using the air-photograph which was taken after the earthquake. The air-photograph was taken on next day of the earthquake, January 18th, 1995. The air-photograph used was vertical photographs at the scale of 1/5,000. Photograph was also taken immediately after the earthquake, on January 17th, but there was a possibility to lead to a fault in the air-photograph interpretation because of the smoke by fire etc., and we didn't use for the measurement. The falling of poles was measured in 3 dimensional coordinates at the root and the head of poles using the analytical plotters. The blockade percentage of the street was calculated from this measurement value and the width of street. We employed the debris which protruded over the road because of the collapse of houses, etc. for the objects of our study. The measurement was made to determine the percentage of debris blockade over the road. As for the measuring method, we used the interpretation by analytical plotter and visual interpretation of air-photograph enlarged by 5 times. The measurement was represented by the part having the highest blockade ratio among each link.

<Construction of a street network>

A street network was made from the city planning map (scale 1:2500) published by municipalities using the digitizer, and inputting a street centerline to it.

Incidentally, in the time used for data acquisition is as follows. The number of link is 400 on the average in one area.

A) Measurement of street width by analytical plotter : 1day for 1 area by one professional operator
B) Measurement of falling poles by analytical plotter : 1day for 1 area by one professional operator
C) Measurement of debris : 1day per 1 area by pair of operators
D) Construction of network data : half day per 1 area by one operator

2. 3. Integration of the data base

Acquired digital data was introduced to GIS. The structure of the street and the situation of the blockade were combined with the link of the network and used for the analysis. Before data acquisition, peculiar ID gave to the street link to provide the consistency among the data. ARC/INFO(ver7.03) was used on SparcStation(Sun-4/10) for GIS. Incidentally, in the time used for integration of data (the error checking and the correction etc. is contained) is half day per 1 areas by one operator.

2. 4. Grasping of the blockade situation of the street

Grasped an items shown below .

A) Street width before the earthquake disaster
B) Decrease of street width by pole falling
C) Decrease of street width by debris
D) Decrease of street width by debris and pole falling

Each item was classified by following standard.

i) equal to or less than 1.5-m width (Pedestrian passage possible)
ii) equal to or less than 3.0-m width (Bicycle passage possible)
iii) equal to or less than 6.5-m width (1 vehicle passage possible)
iv) more than 6.5-m width (2 vehicle passage possible)

We paid notice to the possibility of vehicle's passage to identify the situation of blockade. And then, the authors grasped identify the situation of blockade. And then, the authors grasped what passage condition the street equal to or more than 3-m width by the influence of the blockade. Also, the passage possibility of the vehicle was found out from the remaining width of the street as a result of the blockade. The standard is based on i)-iv) above-mentioned.

2. 5. Implementation and evaluation of the analysis

The passage situation of the street was simulated based on the structure of the street and the measurement data of the blockade and the pathfinding was implemented using network data on GIS. A pathfinding was implemented by following technique.

1) Choose one node which belongs to main street on analysis area borders(about 6 nodes in 1 area).
2) Implement pathfinding from chosen node to each node.
3) Total frequency of pathfinding for every link.

We can estimate the degree of the flow from the main street to the analysis area from above. The value of the load of each link was estimated from this result.
It causes the result to have disregarded the structure of the street if the pathfinding is performed only based on the distance. Therefore, the authors set the impedance of each link simply as follows from width.

Impedance = (Length of link) / (Width of link)

The result of the pathfinding is presented as the frequency that the link was chosen. Also, it is inevitable that the invisible area occurs as long as an air-photograph is used. We excluded the invisible area from this analysis.

3. Results

3. 1. Grasping of the blockade situation of the street

The authors totaled the amount of each link according to the following item using GIS.

3. 1. 1. Street width before the earthquake disaster: The number of the links by the width in the investigation area is shown in the Figure 2. The characteristic of the investigation area is as follows in general.

A) There are comparatively many streets with wide width in Sannomiya and Nagata area where commerce and industry are developing.
B) There are many street where the vehicle can not pass in the Hyogo area.
C) As for the other area, the rate of the distinction at the street by the width is approximately the same.

3. 1. 2. Decrease of the street width by the influence of falling poles: The situation of streetway blockade due to fallen poles is shown in Figure 3. for the streets with the width of 3 to less than 6.5m and in Figure 4. for the streets with the width of 6.5m or wider. There are few absolute numbers of the blockade part by the falling of poles. However, the possibility of the passage of the vehicle in the blockade occurrences is low.

3. 1. 3. Decrease of the street width by the influence of debris: The situation of streetway blockade due to debris is shown in Figure 5. for the streets with the width of 3 to less than 6.5m and in Figure 6. for the streets with the width of 6.5m or wider. Occurrence of debris is overwhelmingly higher comparing with the falling of poles. However, the hindrance to the vehicle passage due to the street blockade resulting from debris is less significant comparing with those resulting from pole falling. But the passage of vehicle is impossible at 60% or more of the streets on average in case where the street width is 3 - 6.5m while it is around 30% on average where the width is 6.5 m or more. Therefore, this result shows that the securing of width can be the basic factor of the securing of vehicle passage.

3. 1. 4. Decrease of the street width by the influence of falling of poles and debris: The situation of streetway blockade due to fallen poles and debris is shown in Figure 7. Here we roughly classified the streets into those where vehicles could pass and could not pass after the earthquake. And the streets where the vehicles could not pass were further divided into those with which non-passage was caused by the structure itself of street before the occurrence of earthquake and those with which hindrance to the passage was caused by the street blockade resulting from the earthquake. As a result, it was found that the damage of the street blockade was big in Rokkoumichi and Uozaki areas, and that the damage was small in Kasuganomichi and Hyougo area.

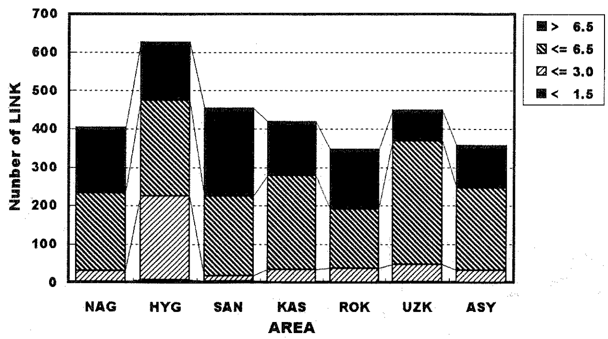

Figure 2. Width member of the street

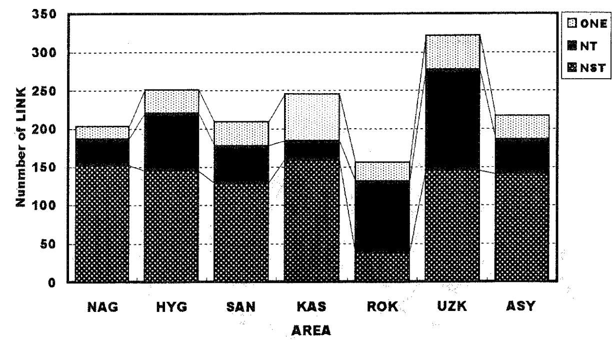

Figure 5. Blockade situation of street by debris (Width 3-6.5m)

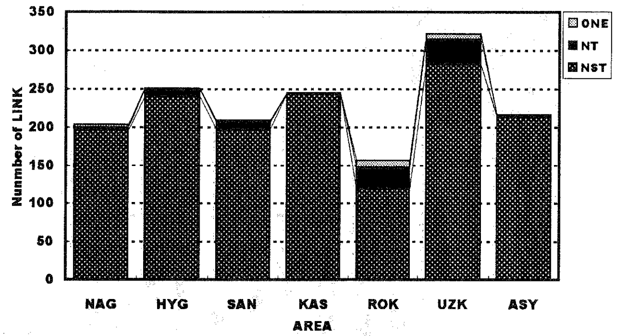

Figure 3. Blockade situation of street by falling poles (Width 3-6.5m)

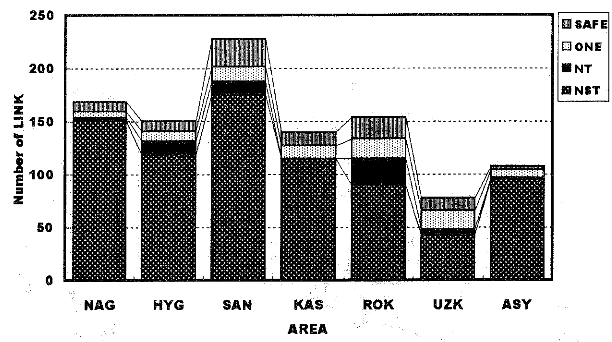

Figure 6. Blockade situation of street by debris (Width 6.5m-)

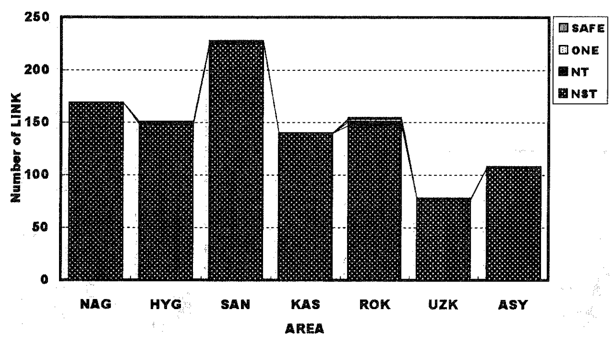

Figure 4. Blockade situation of street by falling poles (Width 6.5m-)

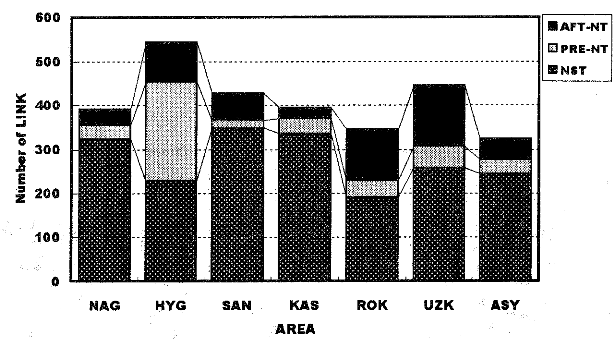

Figure 7. Passage situation of street

NAG:Nagata, **HYG**:Hyougo, **SAN**:Sannomiya, **KAS**:Kasuganomichi, **ROK**:Rokkoumichi, **UZK**:Uozaki, **ASY**:Ashiya

NST:No Blockade, **NT**:Passage impossible, **ONE**:1 Vehicle passage, **SAFE**: 2 Vehicle passage, **PRE-NT**:Passage impossible before earthquake, **AFT-NT**:Passage impossible after earthquake

3. 2. Implementation and evaluation of the analysis

Here, we examine Rokkoumichi area where the damage was large in comparison with Kasuganomichi area where the damage was relatively small.

3.2.1.Condition of the network before the earthquake disaster: An analysis results are shown in the Figure 8-1. and the Figure 9-1., respectively. Both of the areas show a pattern that main street with large width is chosen up to the vicinity of destination and then the path with small width is selected near at the destination. As a result, the street with large width has a high frequency of choice. There is not a difference in the tendency by the areas especially.

3. 2. 2. Condition of the network after the earthquake disaster

(1) Condition of the network: An analysis result in each area is shown in the Figure 8-2. and the Figure 9-2., respectively. Unless the blockade takes place, no big difference was observed from the normal pattern. On the other hand, there are some links where an isolated node is created by blockage and frequency of selection becomes lower because it is eliminated from the objects of selection. Especially, the big damage Rokkoumichi area has this

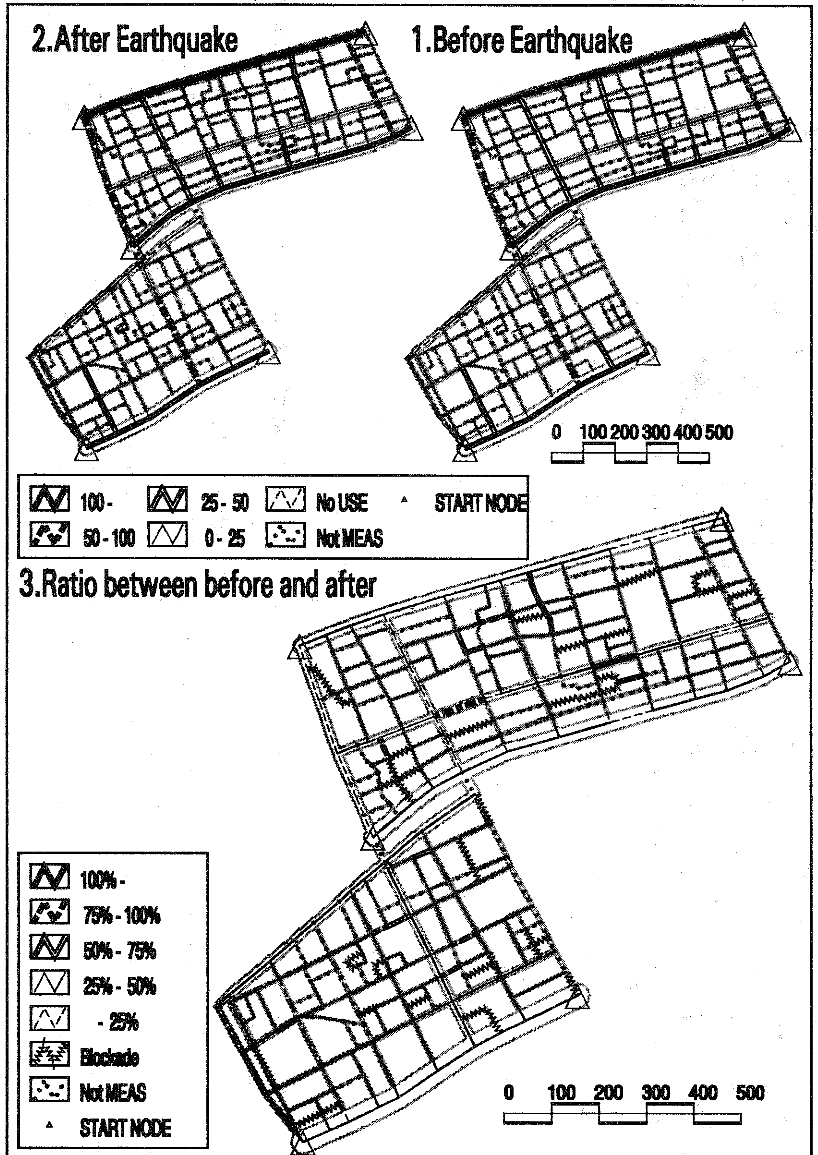

Figure 8. Result of Pathfinding Analysis (Kasuganomichi Area)

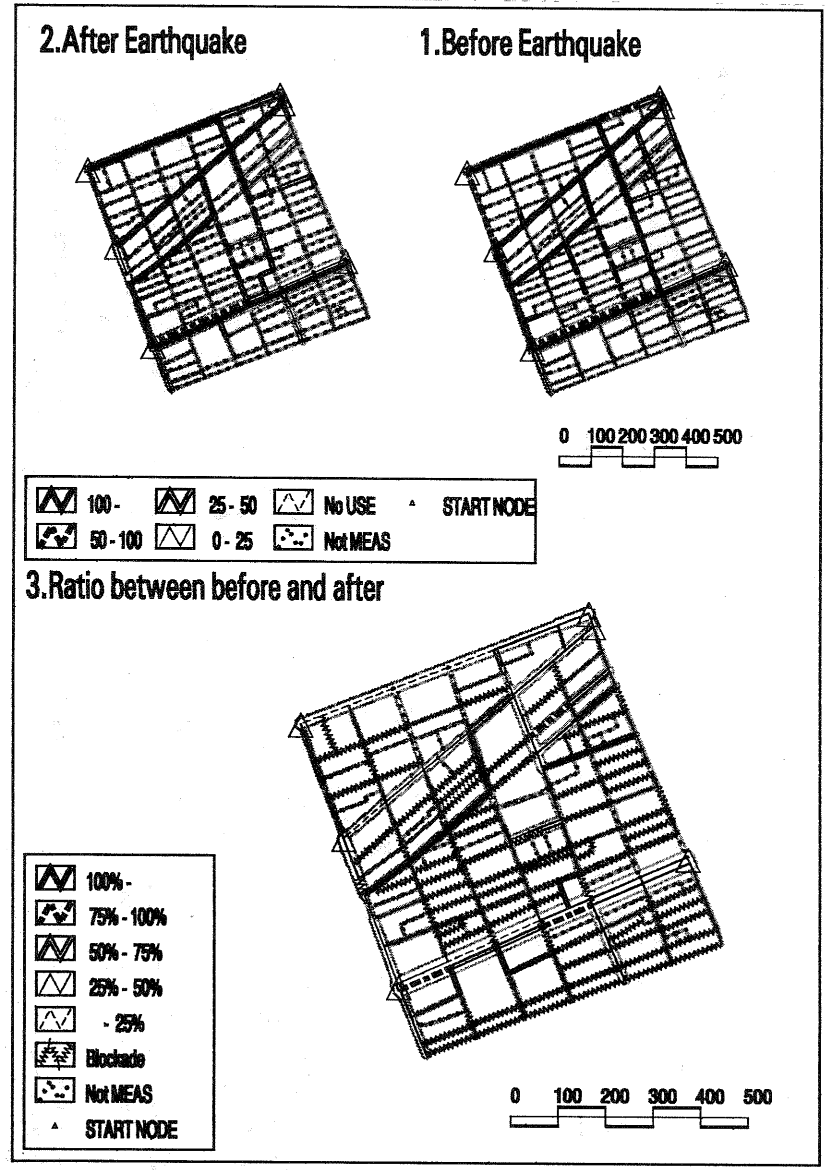

Figure 9. Result of Pathfinding Analysis (Rokkoumichi Area)

Top map of each Figure describes total frequency of pathfinding.(left: after earthquake ,right: before earthquake). Bottom map of each figure describes ratio of frequency between before and after earthquake. Blockade: Blockade occurred Link , No USE: No chosen Link by pathfinding. Not MEAS: Invisible Link (by smoke or arcade etc.)

tendency strongly.

(2)Comparison with the situation before the earthquake disaster: An analysis results in each area are shown in the Figure 8-3. and the Figure 9-3., respectively. In the Rokkoumichi area, the style that the traffic concentrates on the street which was left after suffered comes out clear. When the street with large width is blocked, the adjacent small streets are chosen at high frequency while other streets with large width are not chosen. We think that one pattern of the traffic congestion at the earthquake disaster occurred probably under such a situation. On the other hand, in Kasuganomichi area, because comparatively a lot of streets are left, pathfinding concentration is few. However, there is a street where the detour is chosen in large width street which has been blockaded and it is expected that the traffic concentration takes place there. The width of these streets is narrow for the most part. As for the possibility to become the situation which is the same in Rokkoumichi, the degree of the damage is different only and is this area.

4. Discussion

In this study, we processed from the acquisition of network data and integration of the data base to the analysis and the output using GIS. Now, we considers the advantage and the problem of GIS for the grasping of a street function.

4. 1. Role of GIS for the street function grasping

The role of GIS in this study is as follows. Street function grasping was effectively carried forward by these roles.

(1) Integration of the data base: In this study, the authors gave ID number to the link before acquiring data in an aim for the common use of data. As a result, the data were smoothly integrated. Also, the merit of the GIS utilization when examining dysfunction of the street is to grasp visually "to what degree and where has the fault took place", in addition grasping the degree of the fault quantitatively.

(2) Execution of the analysis by the topological data: Link data was structured, provided with a topology and was processed in the form with which it is possible to analyze a network. As a result, the simulation to reproduce a traffic situation in the earthquake disaster has become possible by using the technique of the pathfinding. The technique of the network analysis has the room for further improvement in the network analysis. However, the frame of the basic processing has been completed. It opens the way for the establishment of the analysis technique and the possibility of the practical use, too, in the future.

4. 2. Problem of GIS use

(1) Establishment of the analysis technique: In the pathfinding, we guessed passage time only from the width and the length of the link. Idealistically, we should have introduced a formula of the relation between the width and the speed based on the traffic engineering. Also, the analyzed result has not been verified by the spot investigation etc. The verification of the analysis result which was based on the hearing investigation is hoped for. Also, the more realistic analysis becomes possible by adding the data of the traffic regulation and obstacles in normal time.

(2) Speeding up of data base construction: About three day is necessary for one area to construct a data base. This is no problem, if the study and the plan etc. are its purpose. However, GIS will show real value only if it is used to support some kinds of decision making. The data of the network and the street structure can be prepared in normal time. Therefore, the key is how to take in the data of the blockade such as the pole falling and debris efficiently. By this study, we could establish this system. But we cannot deny that we had not a small confusion as to the difference in the recognition of data measurement and the definition of common use of data. Therefore, it is hoped to establish and speed up the system from data acquisition and analysis to the output.

5. Epilogue

By this study, the authors made GIS the saucer of the information and tried the integration and the analysis of the information on the dysfunction at the street. Generally, it is said that "the success or failure of the GIS project depends on how to build a data base smoothly first". The efficient data base building became possible by investing a analytical plotter into the flow of the data acquisition.

The air-photograph can record the information in concert with the change of the time when the phenomenon in the ground changes every moment like the time of the earthquake disaster. Also, the air-photograph will be valuable sources for analyzing because the condition in the past can be reproduced afterwards. It is possible to realize efficient processing process by adding GIS processing thereto, and it will be possible to handle the air-photograph information more effectively.

Finally, we point out the problem in grasping a function of street using GIS in the following.

- Integration and speeding up of the system from the data acquisition to the output.
- Establishment of processing process for the smooth data exchange.
- Realization of simple system which is available for an inexperienced person of GIS.
- Establishment of technique about street blockade and traffic route evaluation.

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