INDIRECT LOSS ESTIMATION USING ELECTRICITY CONSUMPTION INDEX

Masasuke TAKASHIMA[1] And Haruo HAYASHI[2]

SUMMARY

In this paper, how far the affected area due to Hanshin Awaji earthquake spread out and how different the convergence process from the disaster is by areas inside and around Hyogo pref. were investigated. To grasp the boundary of the affected area, 13 zones were set inside and around Hyogo pref. and "IoD (Impact of Disaster)" and "Opportunity losses" of each zone were estimated on the basis of the method to estimate these indices using electricity consumption of each zone proposed by Takashima and Hayashi [1998a],[1998b],[1999]. As a result, the spatial structure of affected area was clarified, and the zones were classified into four groups according to the reaction of the IoD. Then, the opportunity losses of the area determined on the basis of the spatial structure of affected area was also clarified. Opportunity losses of the zones classified into severely impacted group achieved 2.70 trillion yen from Jan. 1995 to Sep. 1998.

INTRODUCTION

In case of large earthquake disasters, it is expected that various aversive influences on the socio-economic activities in the affected area last over the long term after the event. We name them as "indirect losses"[App.1]. One of the most important problems in the recovery process is how to shorten the duration of such influences and to minimize their size. The enormousness of direct losses caused by Hanshin-Awaji earthquake disaster (1995.1.17) remind us the importance of minimizing indirect losses after the disaster. However, there is no method to quantify the indirect losses. There have been several attempts to estimate the size of indirect losses due to Hanshin-Awaji earthquake disaster. Six months after the earthquake, The Industrial Reconstruction Plan [1995] was presented by Industrial Reconstruction Conference. In that plan, indirect losses were estimated as 2.6 trillion yen based on the distribution of damaged buildings, the mesh data of Establishment Census and sales per capita in impacted area. In this estimation, however, the duration of shutdown of operation was assumed by the degree of damaged building. Toyoda and Kochi [1997] estimated the size of business losses as 7.2 trillion yen based on the survey to the member of Kobe Chamber of Commerce at just only one point in time after the disaster. It is impossible to monitor the reconstruction process over time with these two approaches.

In the Geneva appeal adopted at IDNDR, Program Forum in July 1997, it is emphasized the importance of estimating socio-economic losses in term of the GRP(Gross Regional Products; summation of value added in a certain region during a certain period. representative index indicating economic activity level of a region. The summation of the GRP of all regions comprizing a certain nation coincides the GDP of the nation.). In line with this appeal, Takashima and Hayashi [1998a],[1998b] provided the indices based on the GRP to monitor recovery/reconstruction processes. The actual data of the GRP, however, is released as annual total with a two-year delay in Japan. This means that estimation of indices will lag behind the times and that we can not recognize more detail movement of the GRP during the year. To solve this problem, they focused their attention on strong correlation between the GRP and the electricity consumption of the region and built the method to derive the monthly indices indicating recovery condition from the electricity consumption. Takashima and Hayashi [1999] applied this method to estimate the recovery condition of Hyogo pref. after Hanshin-Awaji earthquake disaster. In their estimation, the differences in recovery condition among different social sectors were also estimated from the electricity consumption of respective contract type. As a result, it was suggested that recovery of Hyogo pref. had not completed by Nov. 1998 and that the delay was due to the stagnation of large secondary industries. Indirect losses generated in Hyogo pref. were estimated to be 1.85 trillion yen.

[1] *Graduate School of Infomatics, Kyoto University, Kyoto, Japan E-mail: takashim@drs.dpri.kyoto-u.ac.jp*
[2] *Disaster Prevention Research Institute, Kyoto University, Uji, Japan E-mail:hayashi@drs.dpri.kyoto-u.ac.jp*

One of the challenges addressed in Takashima and Hayashi [1999] is how to read the recovery condition from the data available in public domain. Therefore, they analyzed the prefecture level as of a minimum unit because of the availability of electricity consumption data. There remains, however, some problems as follows, 1) Is only Hyogo pref. impacted area of Hanshin-Awaji earthquake disaster?, 2)Is there any differences of the recovery process from the disaster by the zones in Hyogo pref.? In this paper, we set 13 zones around Hyogo pref. and investigated how far the impact of the disaster propagated and how different the convergence process is by the zones. Then, we estimated the indirect losses of these areas determined on the basis of the spatial structure of affected area.

2. DEFINITION OF INDEX AND OUTLINE OF THE METHOD TO ESTIMATE

In this paper, we propose two indices, "impact of disaster (IoD)" and opportunity losses. IoD is an extention of "recovery rate" proposed by Takashima and Hayashi [1999]. These indices were defined based on the conceptual model of recovery process from the disaster illustrated on the basis of GRP in Fig.1. In Fig.1, line $GRP_{0,x\ t}$ shows the movement of hypothetical GRP which would have been achieved in case there is no disaster. In case of earthquake disaster, various patterns of the GRP generated in area x can be expected. Line $GRP'_{1,x,t}$, $GRP''_{1,x,t}$ and $GRP'''_{1,x,t}$ show the examples of the pattern in case there is earthquake disaster. The GRP generated in the area where most of buildings and infrastructure are severely damaged may be described as line $GRP'_{1,x,t}$ in Fig.1. Some areas neighbouring severely impacted areas may profit by the demand for recovery rising in the neighbour. Line $GRP''_{1,x,t}$ may show the pattern of the GRP generated in such area. Other areas neighbouring severely impacted areas may be influenced by the neighbour although there are slight damages of buildings in the areas themselves. The pattern of the GRP generated in such area may be described as line $GRP'''_{1,x,t}$. Anyway, we can assume two kinds of GRP, hypothetical GRP which would have been achieved in case there is no disaster ($GRP_{0,x\ t}$), and actual GRP after disaster ($GRP_{1,x,t}$). With these assumed GRP, following two kinds of indices indicating the condition of an area on convergence process from disaster, 1) impact of disaster, 2) opportunity losses, can be defined.

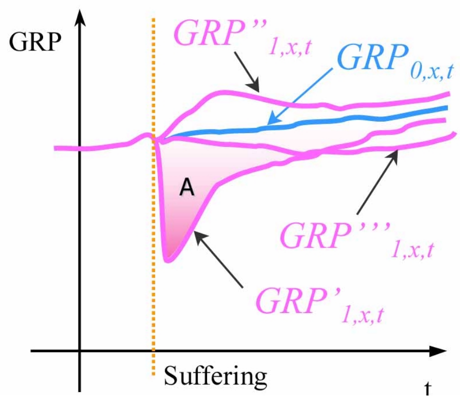


Figure 1: The conceptual model of convergence process after the disaster

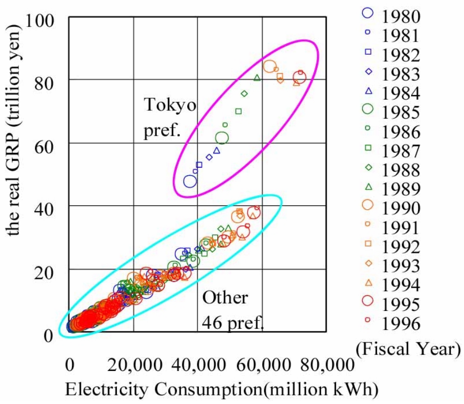


Figure 2: The relationship between the GRP and the electricity consumption of each prefecture in Japan

2.1. Impact of Disaster (IoD)

If there is no disaster, the area concerned must have achieved the economic activity level shown by line $GRP_{0,x\ t}$. Because of disaster, the economic activity of some areas would be exposed to downward or upward pressure. Larger the impact is, more distant actual GRP will be from hypothetical GRP. Therefore, we can define the impact of disaster as how much actual line $GRP_{1,x,t}$ is distant from hypothetical line $GRP_{0,x,t}$, more specifically, the ratio of $GRP_{1,x,t}$ to $GRP_{0,x,t}$ shown as Eq.1.

$$r_{x,t} = \frac{GRP_{1,x,t}}{GRP_{0,x,t}} \times 100(\%) \quad (1)$$

$r_{x,t}$: impact of disaster on area x, in phase t after earthquake

IoD smaller than 100% means that the activity level of the area concerned is worse compared with the case there is no disaster. On the contrary, IoD larger than 100% means the activity level is better.

2.2. Opportunity Losses

Without disaster, the area concerned must have obtained value added shown by line $GRP_{0,x,t}$. In disaster situation, however, some areas would be forced to obtain less value added as shown by line $GRP'_{1,x,t}$. Therefore, opportunity losses can be defined as cumulative differences between $GRP_{0,x,t}$ and $GRP_{1,x,t}$. In other word, area "A" enclosed with line $GRP_{0,x,t}$ and line $GRP_{1,x,t}$ indicates the size of actual opportunity losses. Consequently, opportunity losses are defined as Eq.2. The difference between opportunity losses in this paper and in Takashima and Hayashi [1999] is whether social discount rate is considered in opportunity losses.

$$L_{GRP,x,t} = \sum_{t=1}^{t} \frac{GRP_{0,x,t} - GRP_{1,x,t}}{(1+r)^{t-1}} \tag{2}$$

$L_{GRP,x,t}$: opportunity losses of area x, until phase t after earthquake; r: social discount rate

2.3. Relationship between electricity consumption and GRP

To derive IoD and opportunity losses from Eq.1 and Eq.2, we need to gain the actual data of $GRP_{1,x,t}$ and to estimate $GRP_{0,x,t}$. The actual data of the GRP is released as annual total after a two-year delay in Japan. Therefore, we will estimate out-of-date indices, if we wait the official release of the GRP. Then, in a series of studies by Takashima and Hayashi, they focused on the correlation between the electricity consumption and The GRP. Fig.2 provides relationship between electricity consumption and the real GRP of each prefecture in Japan from 1980 to 1996. It can be seen that there exists strong linear relationship between the electricity consumption and the GRP, and that there are two groups; that is Tokyo Pref. and the other 46 prefectures. Thus, they performed simple linear regression analysis on each group. As a result, it was clarified that the relationship between the electricity consumption and the GRP by prefectural unit in Japan is described as Eq.3.

$$GRP_x = a \cdot W_x \tag{3}$$

GRP_x: the GRP of prefecture x; W_x:electricity consumption of prefecture x; a: parameter

"a" indicates how much GRP can be achieved with unit electricity consumption, in other word, productivity of the region. After this, we call "a" GRP productivity. As a result of estimation based on Eq.3, GRP conductivity of Tokyo was estimated at 1246 yen/kWh and that of other 46 prefectures was estimated at 607 yen/kWh. The GRP-based definition of IoD and opportunity losses can be transformed by Eq.3 into electricity-consumption-based definition as Eq.4 and Eq.5. With these definitions, we can estimate the indices after 1-2 month delay.
Impact of Disaster (IoD)

$$r_{x,t} = \frac{W_{1,x,t}}{W_{0,x,t}} \times 100(\%) \tag{4}$$

Opportunity Losses

$$L_{W,x,t} = a \cdot \sum_{t=1}^{t} \frac{W_{0,x,t} - W_{1,x,t}}{(1+r)^{t-1}} \tag{5}$$

$W_{0,x,t}$: hypothetical electricity consumption which would have been achieved in case there is no disaster of area x, in phase t after earthquake; $W_{0,x,t}$: actual electricity consumption of area x, in phase t after earthquake.

3. ESTIMATION OF HYPOTHETICAL ELECTRICITY CONSUMPTION

To derive IoD and opportunity losses from Eq.4 and Eq.5, we need 1) to gain the actual data of $W_{2,x,t}$ (performance figure of electricity consumption after event), 2) to estimate $W_{0,x,t}$ (hypothetical figure of electricity consumption in case there is no disaster). As the data of $W_{2,x,t}$, we can use the monthly performance figure of electricity consumption in area x. The data of $W_{0,x,t}$, was estimated with the process shown in Fig.3. In the estimation process, we assumed "the reference area" in which the influence of concerning disaster was too small to be considered. Furthermore, we supposed that the pattern of the electricity consumption in area x is in synchronization with that in the reference area in case there is no disaster. On the basis of this assumption, we estimated $W_{0,x,t}$ through following process.

Step1): We formulated the relationship between the electricity consumption of the reference area,$W_{0,0,t}$, and that of area x, $W_{0,x,t}$,as Eq.6. $W_{0,x,t-1}$ can be estimated from $W_{0,0,t-1}$ based on Eq.6.

$$W_{0,x,t} = \alpha_x \cdot W_{0,0,t} + \sum_{i=1}^{12} \beta_{x,i} \cdot \delta_i \tag{6}$$

$W_{0,0,t}$: actual electricity consumption of the reference area in phase t; $W_{0,x,t}$: estimated electricity consumption of area x in phase t; α_x: parameter for $W_{0,0,t}$; δ_i: dummy parameter for seasonal adjustment (if phase t falls on month i:=1/ not:=0); $\beta_{x,i}$: parameter for δ_i

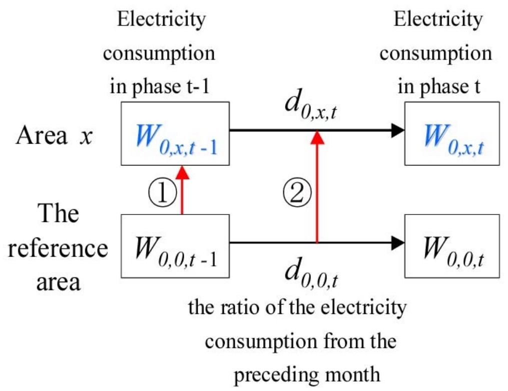


Figure 3: The process to estimate $W_{0,x,t}$

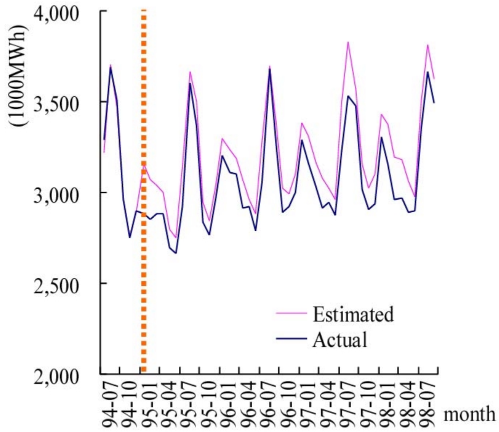


Figure 4:Actual electricity consumption and estimated electricity consumption of Hyogo pref.

Step2): We also formulated the relationship between the ratio of the electricity consumption from the preceding month of the reference area, $d_{0,0,t}$, and that of area x, $d_{0,x,t}$, as Eq.7. $d_{0,x,t}$ can be estimated from $d_{0,0,t}$ based on Eq.7.

$$d_{0,x,t} = \gamma_x \cdot d_{0,0,t} + \sum_{i=1}^{12} \eta_{x,i} \cdot \delta_i \tag{7}$$

$$d_{0,0,t} = \frac{W_{0,0,t}}{W_{0,0,t-1}} - 1.0 \tag{8}$$

$$d_{0,x,t} = \frac{W_{0,x,t}}{W_{0,x,t-1}} - 1.0 \tag{9}$$

$d_{0,0,t}$: the ratio of the electricity consumption from the preceding month of the reference area in phase t; $d_{0,x,t}$: the ratio of the electricity consumption from the preceding month of area x in phase t; γ_x: parameter for $d_{0,0,t}$; $\eta_{x,i}$: parameter for δ_i

Dummy parameter was adopted to consider the difference of seasonal electricity consumption pattern between the reference and area x.

Step3): Eq.10 can be derived from Eq.9. Then, $W_{0,x,t}$ was derived from Eq.10 by substitution of $W_{0,x,t-1}$ estimated on Step1) and $d_{0,x,t}$ estimated on Step2)

$$W_{0,x,t} = (d_{0,x,t} + 1.0) \cdot W_{0,x,t-1} \tag{10}$$

This method to estimate hypothetical electricity consumption, $W_{0,x,t}$, from the actual electricity consumption of the reference area can consider the change of socio-economic circumstances in the larger area including area x and the reference area. For instance, in case the economic activity of the country including area x and the reference area slump after a certain disaster owing to anything but the disaster, the electricity consumption of area x will decline owing to the disaster and the stagnation of national economic. In this case, we must estimate hypothetical electricity consumption in case there is no disaster, $W_{0,x,t}$, lower taking into the stagnation of national economic account to avoid estimating IoD and opportunity losses worse than necessary. Such a change of socio-economic circumstances in the larger area including area x and the reference area is reflected on the actual electricity consumption of the reference area. Therefore, we can estimate IoD and opportunity losses taking the change of socio-economic circumstances in the larger area including area x into account with this method.

4. RESULT OF ESTIMATION

4.1. Data used for Estimation

Based on the method stated already, we estimated spacio-temporal patterns of IoD and opportunity losses around Hyogo pref. In this estimation, we set 13 zones around Hyogo pref. and estimated the indices by the zones. Three zones, Osaka, Okayama and Kyoto pref., were set for zoning outside of Hyogo pref.. The data of actual monthly electricity consumption, $W_{1,x,t}$ (1992.4 – 1998.9), for each zones came from the statistical data book of each prefectures. As the zones inside of Hyogo pref., we adopted the sales office areas in Hyogo pref. of Kansai Electric Company (KEC), because the areas are the unit of the actual electricity consumption data provided from KEC. KEC has two branches in Hyogo pref., Kobe branch and Himeji branch. Kobe branch has 7 sales offices in his area, Sannomiya, Hyogo, Nishinomiya, Amagasaki, Akashi, Awaji and Kaibara (The service area of Akashi sales office was enlarged at Oct. 1996. In this paper, the service area before Oct. 1996 is adopted as Akashi zone.). The provided data is the actual monthly electricity consumption (1992.4 – 1998.9) by the 7 sales offices. Thus, we set 8 zones, the 7 sales-office areas under Kobe branch and Himeji branch area, for zoning inside of Hyogo pref. The actual electricity consumption in Himeji branch area could be determined as the difference between the actual electricity consumption in Hyogo pref. and that in Kobe branch area. The actual data of monthly electricity consumption in Hyogo pref. came from the statistical data book of Hyogo pref.. We regarded the whole of Japan except Hyogo, Osaka, Okayama and Kyoto pref. as the reference area in this estimation. Therefore, as the data of the reference area, we used the difference between the actual monthly electricity consumption of Japan and that of Hyogo, Osaka, Okayama and Kyoto pref. The data source of the actual monthly electricity consumption of Japan is "statistical information of electricity" in the WWW site of Federation of Electric Power Companies (http://www.fepc.or.jp/). As the social rate of discount, we use long-term prime lending rate at 1995.1 of 0.049. To estimate hypothetical electricity consumption of each zones, $W_{0,x,t}$, we must determine the parameters, α_x, $\beta_{x,i}$, γ_x, $\eta_{x,i}$, in Eq.6,7 empirically. The parameter, α_x, $\beta_{x,i}$, of each zones were estimated using the respective actual electricity consumption, $W_{0,x,t}$, and that of the reference area, $W_{0,0,t}$. The parameter, γ_x, $\eta_{x,i}$, of each zones were estimated using the respective ratio of the electricity consumption from the preceding month, $d_{0,x,t}$, and that of the reference area, $d_{0,0,t}$. Each parameter estimation shown high adjusted R^2. The estimated monthly electricity consumption of Hyogo pref. in case there is no disaster and the actual electricity consumption of Hyogo pref. after Hanshin-Awaji earthquake disaster are shown in Fig.4. Fig. 4 suggests that the actual electricity consumption falls short of the hypothetical electricity consumption.

4.2. Impact of Disaster (IoD)

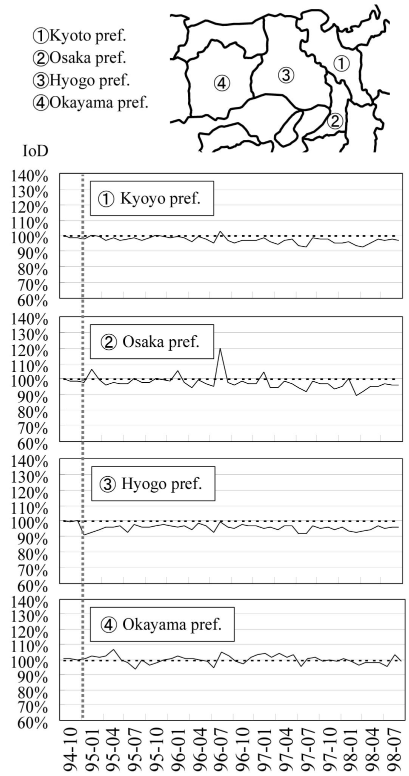
The estimation of IoD by each zones enabled to observe the convergence process of Hanshin-Awaji earthquake disaster from three different levels of viewpoint, 1)prefectural level, 2)branch level and 3)sales office level.

4.2.1. Prefectural Level

Estimated IoDs of Hyogo, Osaka, Okayama and Kyoto pref. from Jan. 1995 to Sep. 1998 are shown in Fig.5. In Hyogo pref., the IoD declined to 91.5% immediately after the earthquake of 1995.1. Then it stayed around 95.8%. In Osaka and Kyoto pref., the IoD did not show large movement initially, then gradually fell short of 100%. In Okayama pref., the IoD levelled off around 100% consistently after the event. From the viewpoint of prefectural level, it can be seen that Hyogo pref. was most impacted and could not fully recovered 45 months after the disaster and that the influence of the disaster reached to neighbouring Osaka and Kyoto pref..

4.2.2. Branch Level

Estimated IoDs of Kobe and Himeji branch zone in Hyogo pref. impacted most severely are shown in Fig.6. In Kobe branch area, the IoD fell to 85.8%, then gradually recovered to 100%. On the other hand, the IoD of Himeji



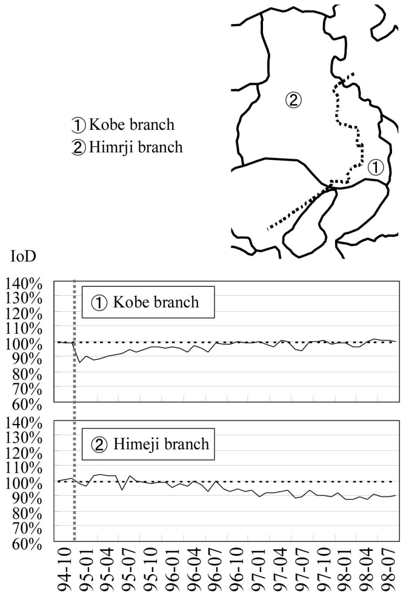


Figure 5:Estimated IoD of each prefectural level zone **Figure 6: Estimated IoD of each branch level zone**

branch area achieved 103.6% from Mar. 1995 to Jun. 1995, but gradually fell down after that and stayed around 89.5% in 1998. From these results, the reason the recovery of Hyogo pref. stagnated seems to be that the economic activity level of Himeji branch zone fell down although that of Kobe branch area progressed consistently.

4.2.3. Sales Office Level

Fig.7 shows the estimated IoDs of the 7 sales office zones under Kobe branch. It can be seen that the patterns of IoD varied from zone to zone. The 7 zones may be classified under two groups. One is the zones the IoD run under 100% (Sannomiya, Hyogo, Nishinomiya, Amagasaki, Awaji), Another is the zones the IoD run above 100%(Akashi, Kaibara). Sannomiya zone seems to be the most impacted due to the disaster in the former group. In Sannomiya zone, the IoD declined steeply to 60-70% and stayed there 7 months by Jul. 1995. It recovered to the 80^{th} % by Aug. 1995, then run with a slight upward trend. Hyogo zone also seems to be impacted severely. The IoD
declined to 77.8% by Mar. 1995 after the disaster. Though it inclined by Dec. 1995, then it levelled around 90.5%. After Jun. 1998, it resumed an upward trend. Compared with these two zones, the IoD of Nishinomiya and Amagasaki zones bottomed out earlier at Jan. 1995. Then, they levelled around 93.1% and 97.6 %, respectively. In Awaji zone, IoD did not react steeply compared with the former four zones. It levelled around 97.3% consistently after the disaster. As opposed to the former group, the IoD of the later group exceeded 100% after the disaster. The shift of economic activity from Sannomiya and Hyogo zones impacted severely due to the disaster to the later group may explain the exceeding 100% of the IoDs in the later group.

4.3. Structure of affected Area

The medians adopted as typical value for the IoDs of each zones after the disaster are shown in Fig.8. From the result shown in Fig.8, inside and around Hyogo pref. after the earthquake can be divided into 4 areas. 1)Impacted area :the area that the economic activity declined immediately after the earthquake such as Sannomiya, Hyogo, Nishinomiya, Amagasaki and Awaji zones, 2)Supporting area: the area that the economic activity swelled surrounding Impacted area such as Kaibara and Akashi zones, 3)Influenced area: the area that the economic activity declined gradually after the earthquake such as Himeji branch, Kyoto and Osaka pref. 4)Independent area: the area independent of the disaster such as Okayama pref.. This result can be modelled as shown in Fig.9. In

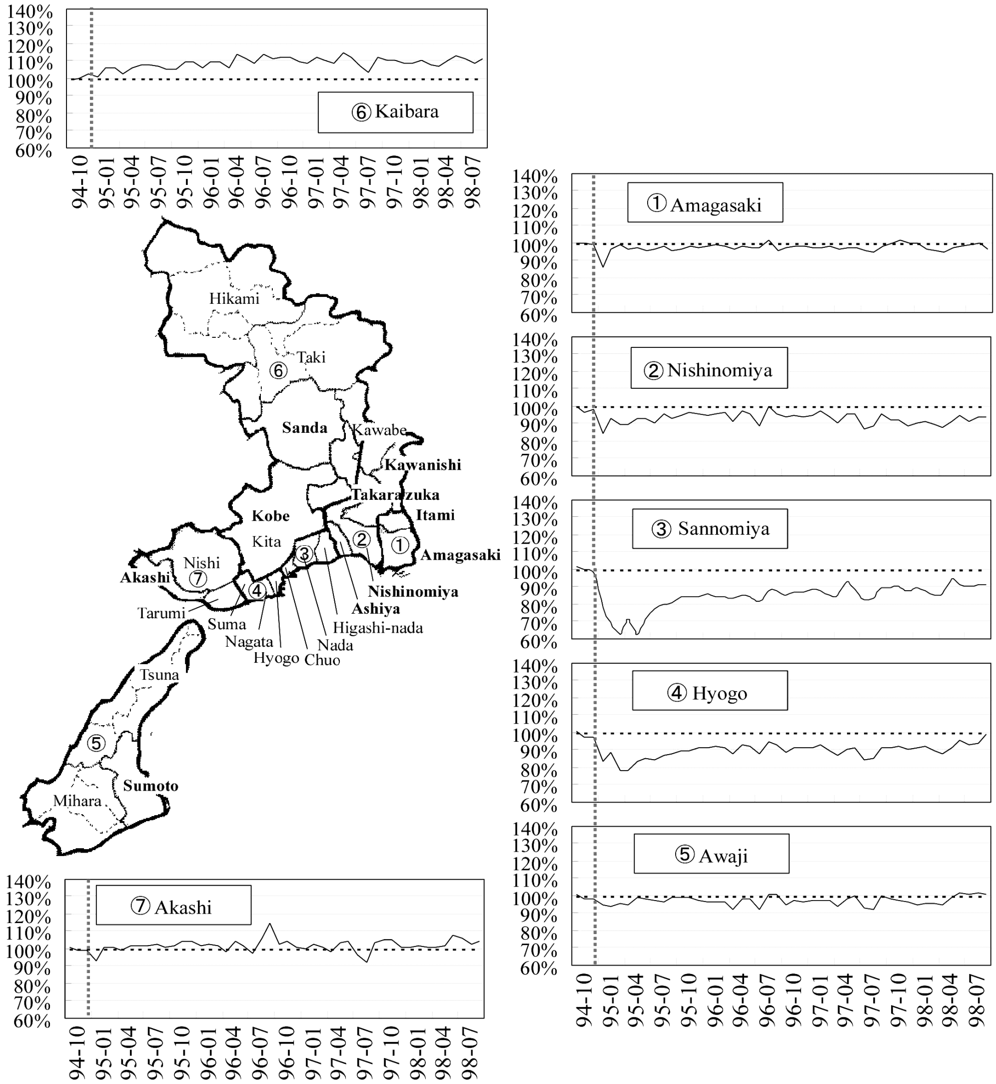


Figure 7: Estimated IoD of each sales office level zone

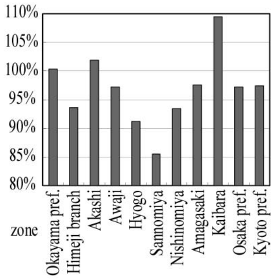


Figure 8: The median of IoD of the affected area

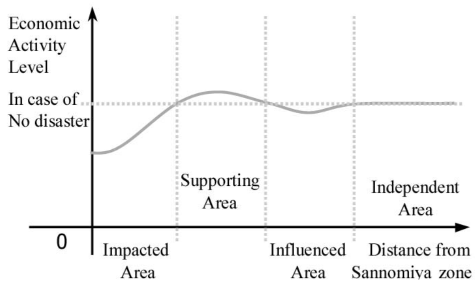


Figure 9: Spatial structure of each zone

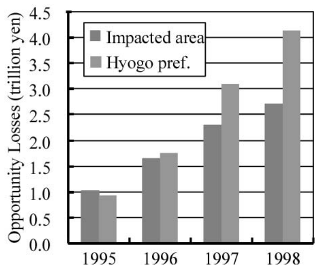


Figure 10: Estimated opportunity losses of Impacted area

Fig.9, lateral axis means the distance from Sannomiya zone impacted most severely due to the disaster, and vertical axis means the economic activity level. The spatial structure of economic activity level inside and outside of Hyogo pref. can be seen from this model.

4.4. Opportunity Losses of affected area

From the result as shown in Fig.9, three different ranges of affected area can be considered, which are 1) Impacted area, 2) the area including Impacted area and Supporting area, 3) the area including Impacted area, Supporting area and Influenced area. Fig.10 shows the estimated opportunity losses of Impacted area, affected area in the most narrow sense, and Hyogo pref.. The opportunity losses of Impacted area and Hyogo pref. achieved 2.70 trillion yen and 4.13 trillion yen by the Sep. 1999, respectively. It can be seen that the opportunity losses generated in Hyogo pref. for two years after the event concentrated on the Impacted area.

5. CONCLUSION

In this paper, we set 13 zones inside and around Hyogo pref. and estimated the IoD (Impact of Disaster) of each zone after Hanshin-Awaji earthquake. Furthermore, we built the spatial model of the affected area. From this model, the structure of so-called “affected area” suffering Hanshi-Awaji earthquake was clarified. There remains some problems requiring further study as follows. 1) why the economic activity of the area surrounding most impacted area swelled. 2) why the economic activity of the area distant from the most impacted areas stagnated. Further study to investigate the relationship between areas in the recovery process can solve these problems. Then, the opportunity losses of Impacted area determined on the basis of the spatial structure of affected area was estimated at 2.70 trillion yen from Jan. 1995 to Sep. 1998. This result suggests that measures to minimize opportunity losses after the earthquake should be also improved as in the case of mitigation against direct damages.

APPENDIX

Appendix 1

In a series of studies by Takashima and Hayashi, they classified losses due to natural disaster into two groups, direct losses and indirect losses. Direct losses mean the physical destruction caused by unusual natural hazard such as the collapse of buildings and infrastructures. Indirect losses mean the socio-economic influences resulting from direct damages such as stagnation of production activities and financial pressure on regional government owing to extra expense for recovery measures.

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