Simulation for a Deadly Blow to Tokyo by the Coming Next Large Earthquake*

by

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* This is a revised version of my paper which was presented at the 1990 European Conference of System Dynamics, at Universita L. Bocconi, Milan, Italy, October 1990.

1. Introduction

(1)Introduction of Japan and Tokyo

After the Second World War , Japan has achieved a rapid economic growth. GNP of Japan becomes the second in the developed industrialized countries after the USA. Per capita GNP will be the first in the world pararelled with Switzerland. Following to the high economic growth , Tokyo , capital of Japan has become a big monster concentrating many functions.

At present, Japan has 120,000,000 of population. And in the Tokyo metropolitan area , there are 30,000,000 of the population , in truth , 25 % of the total population of Japan.

Tokyo is one of the most softy city in the world in the field of crime. Homer Tokyo is one of the most dangerous cities in the field of the earthquake like ITALY.

(2)The purpose of this study

If a large earthquake were to attack Tokyo in these days, what would happen?

Perhaps Tokyo will be destroyed by big fires and by big floods. In Japan , on September 1 , 1923, there was a large earthquake , so called "Kanto Dai Shinsai" (in Japanese) , that is ," The large Tokyo disaster ".This disaster meant the collapse of Tokyo , the capital of Japan .

According to a recent theory set forth by the ‹ Institute of Geophysical Sciences , a large earthquake similar to the " Kanto Dai Shinsai " will likely occur within about sixty nine years of the former large earthquake.

Why , then , has there not an appropriate policy been accepted for the next coming big Tokyo disaster ? The major reason is that the scientific prediction and the evaluation of policy's effectiveness have not been carried out.

The main purpose of this study is to build a system dynamics model for simulating impacts on the Tokyo Metropolitan area by the coming next large earthquake.

Tokyo may well suffur a deadly blow , and the Japanese economy could be destroyed by the consequences of such a disaster.

As a result , international conflict between Japan and USA will disappear.

2. A System Dynamics Model of the Disaster and Recovery Process of the Coming Tokyo Earthquake

2.1 The purpose of the model

The components of disaster brought on by the large earthquake are destruction of buildings and roads by the direct impact of the earthquake , houses and offices burned down by big fires , and subsequent damage to the social system : for example confusion of economic activities. We would like to make a comprehensive system simulation model of the damage and recovery process of Tokyo. The area of study for this model is the Tokyo Metropolitan area. This area consists of four prefectures : Tokyo , Kanagawa , Saitama , and Chiba. We calculated 60 days for a simulation period with one day as a unit interval. We chose a System Dynamics method for system simulation because we cannot use past data for these situations.

2.2 The Basic Structure of the Model

Our model consists of four subsectors : that is population, regional economy , transportation , and material sectors. The interrelationship of four sectors is shown in figure 1. The causal feedback loop which indicates the basic structure of the model is shown in figure 2. We note that transportation capacity plays an important role in the process of recovery from the disaster.

3. Results of Simulation Experiment

3.1 Simulation Case

The scale of damage brought on by the large earthquake is quite dependent on the size of the earthquake. In this model we set up several simulation cases given the occurrence of a large earthquake whose characteristics are the same as those of Kanto Daishinsai (the former Tokyo disaster). We build up four simulation cases which are shown in table 1 according to the season ,time , and weather , and also recovery policy after the earthquake.

A. Case I (Pessimistic Case)

For this pessimistic case we assume the earthquake takes place at dinner time under strong wind conditions in the winter season.

There will be many deaths since the earthquake occurs during the commuting hours.

Thirty percent of the wooden buildings are burnt down. We assume there is one road obstacle per 1 km distance. The road damage is network type destruction.

In the economic sector we assume that the petrochemistry combinate belt suffers deadly destruction , and thus does not recover during the sixty day period. None of the petroleum tanks can be employed because of the destruction and fires in the belt.

The main parts of steam power generationg stations are damaged, and as a result the supply of electric power is curtailed.

B. Case II (Optimistic Case)

For this optimistic case we suppose that the large earthquake ocurrs at midnight at a time of weak winds , during the summer season.

We assume both of mortality of the refuges and loss of buildings due to fire at the low level. The occurrence of road obstacles are few , and road damage is single-type destruction.

C. Case III (Intermediate Case)

For this intermediate case we assume the middle level between case I and II. Hence , each parameter is set up at an intermediate level of the two cases.

D. Case Ⅳ (Standard Case)

For this standard case we suppose that each parameter is chosen as the most feasible situation to be encountered in reality. This case is the most probable case in our model.

3.2 Results of Simulation Experiments

For each case we carried out a computer simulation , and obtained certain interesting results. We want to explain the simulation results comparing the several cases.

First , simulated regional population levels are shown in figure 3. The minimum of the population occurrs with standard case Ⅳ , and the passage of time when the minimum takes place is earlier than in the pessimistic case Ⅰ. In the pessimistic case Ⅰ , the transportation multiplier becomes very small , hence the population who can not find refuge elsewhere stay in the region.

The changing levels of food stocks are shown in figure 4. For the pessimistic case Ⅰ and the standard case Ⅳ , the food stocks are exhausted 10 and 40 days after the earthquake , respectively. This is because of population staying in the region , very low transportation capacity.

The number of roads interruped is shown in figure 5. For the optimistic case Ⅱ and the intermediate case , over 50% recovery is projected within 20 days. However for the pessimistic case Ⅰ and the standard case Ⅳ , the recovery pace is slightly slower. This reason is the shortness of the behavior according to the decrease of the population.

Changes in fuel stocks are shown in figure 6. For the standard case Ⅳ , the exhaustion of stocks appears earlier time than in the pessimistic case Ⅰ.

Transportation capacity changes are shown in figure 7. For the pessimistic case Ⅰ and the standard case Ⅳ , share declines in transportation capacity appear 50 and 30 days after the earthquake , respectively ,brought on by lack of fuel.

4. Concluding Remarks and Discuussion

We succeeded in formulating the simulation model for a deadly blow to Tokyo by the next large earthquake. System Dynamics method is useful rather than Econometric method , because this problem is future oriented and complex.

We had an interesting result using simulation experiments by System Dynamics Model. A complex relationship among subsystems of the socio-economic system , has been analyzed by the feedback loop of the System Dynamics Model.

We found out that in this complex model the bottle neck element plays an important role in the behavior of the socio-economic system. In this case , transportation capacity is a bottle neck factor and behavior of each subsystem is influenced by the transportation capacity.

Moreover , we have to develop our model including other sectors such as a communication system , land use and environmental systems.

References

1. Forester, J.W.,1969, Urban Dynamics MIT Press

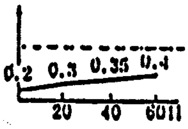
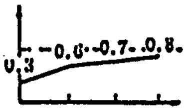
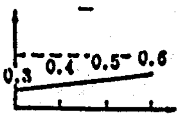
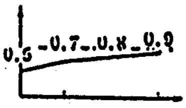
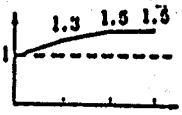
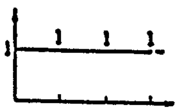
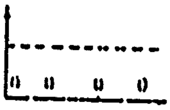
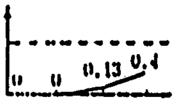
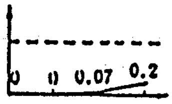
2. Goodman,M.R., 1974, Study Notes in System Dynamics Wright-Allen Press

3. Yasuda,Y. and M.Hijikata, 1982, "A Gaming Simulation of the Human Behavior of Taking Refuge in an Emergency —A Case Study of the Coming Big Earthquake in the Tokyo Metropolitan Area—," Modeling and Simulation, Vol.13, pp.1147-1154

4. Yasuda,Y. (ed), 1979, A Study of the Protective Systems for Large Disasters, The Foundation of Advanced International Sciences, Japan (in Japanese)

5. Yasuda,Y. and M.Hijikata, 1979, "Simulation of a Disaster Caused by the Coming Large Earthquake in Tokyo Using a System Dynamics Approach", Communications of Operations Research, September 1979, pp.549-555 (in Japanese)

Table-1 Simulation Case

Case		I Pessimistic Case	II Optimistic Case	III Intermediate Case	IV Standard Case
Sector	Index	(Age)			
Population	Death Population during the Refuge	0~14:40thou. 15~64:200 〃 65~ : 20 〃	15thou. 150 〃 10 〃	30thou. 200 〃 15 〃	Same as II
Facilities	Rate of Burnt Down Wooden Buildings	30%	10%	20%	〃 III
	Occurrence Rate of Road Obstacles	1(part)/km	0.4/km	0.7/km	〃 I
Transportation	Pattern of the Damaged Road	Network Destroying Type	One Part Destroying Type	Intermediate Type	〃 III
Economy	Electric Power Supply Multiplier				〃 III
	Multiplier of Materials Carried to the District				〃 II
	Rate of Burnt Down Stocks of Producers' Fuel	100%	30%	50%	〃 I
	Level of Fuel Production				〃 I

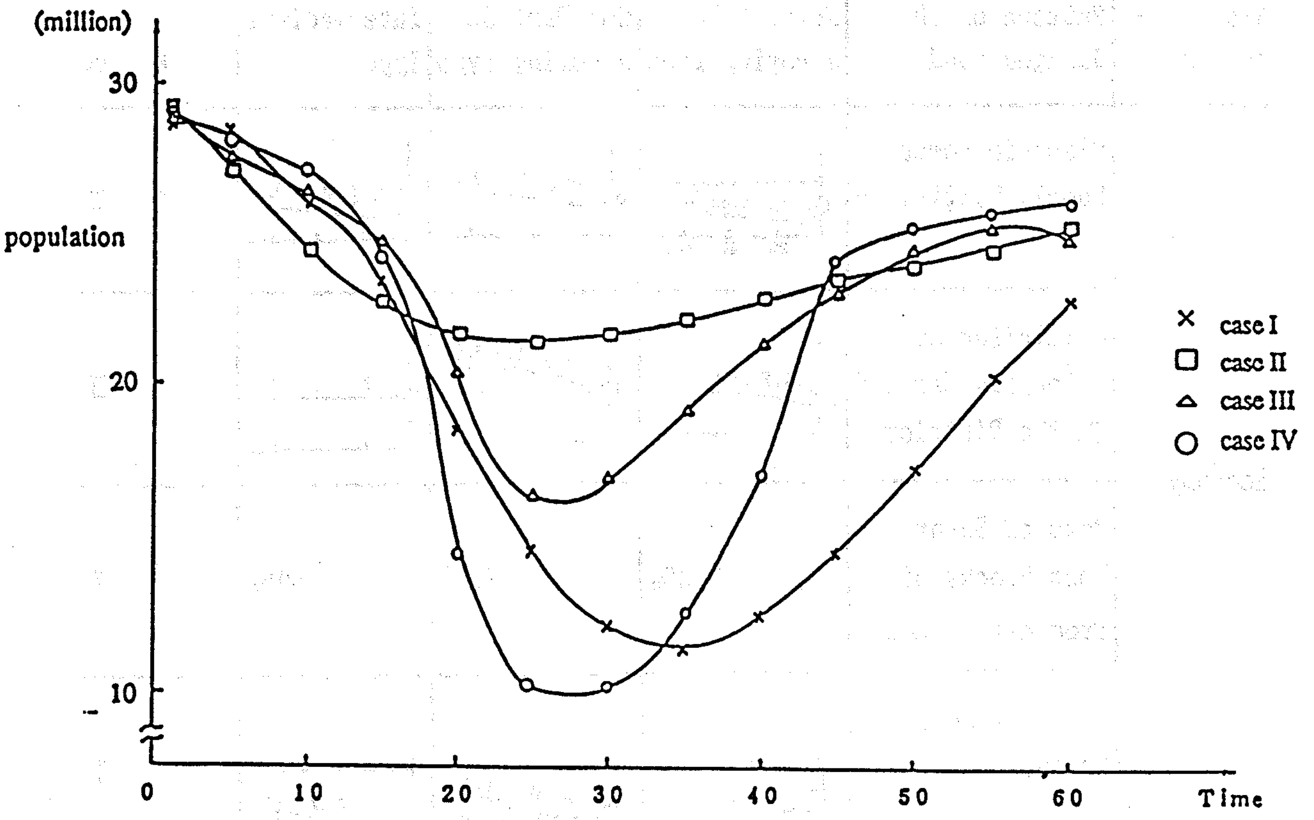


Figure 3 Total population in the Region

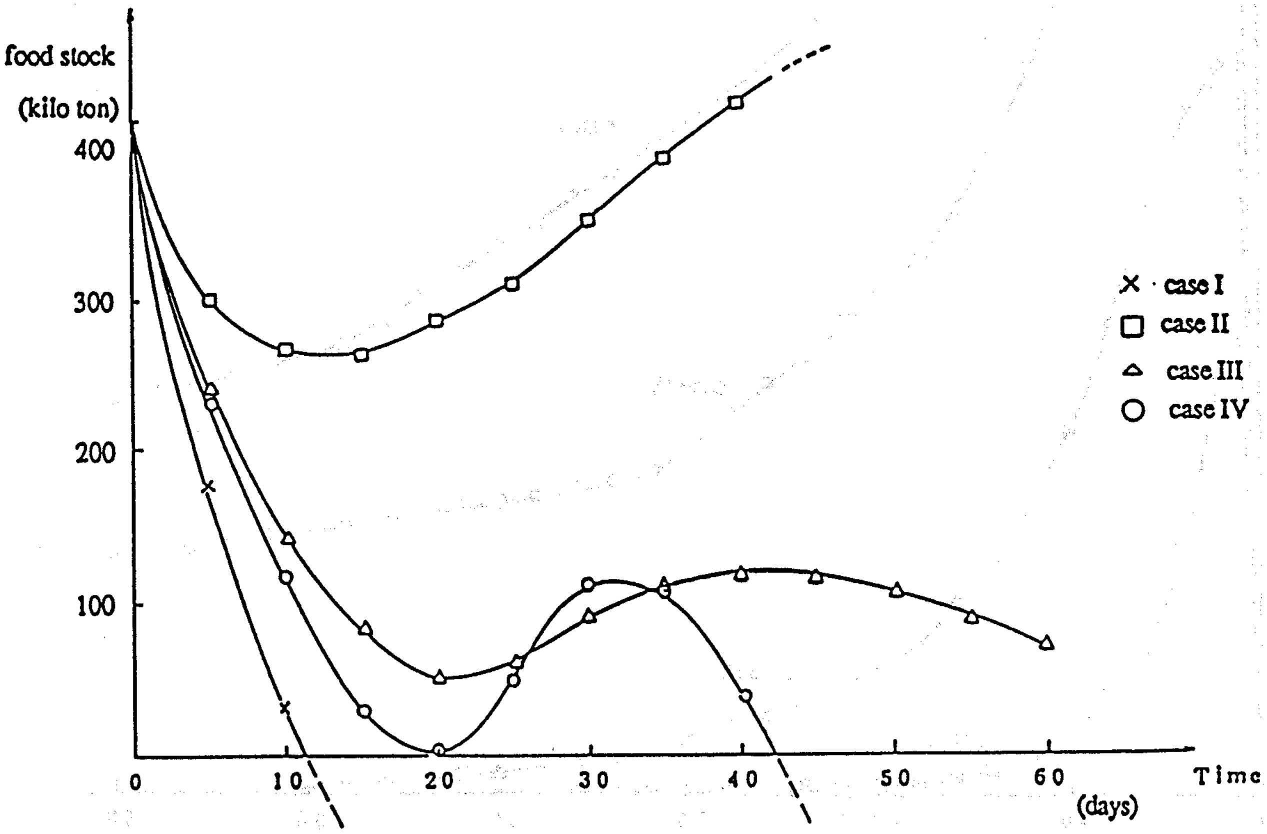


Figure 4 Food stock

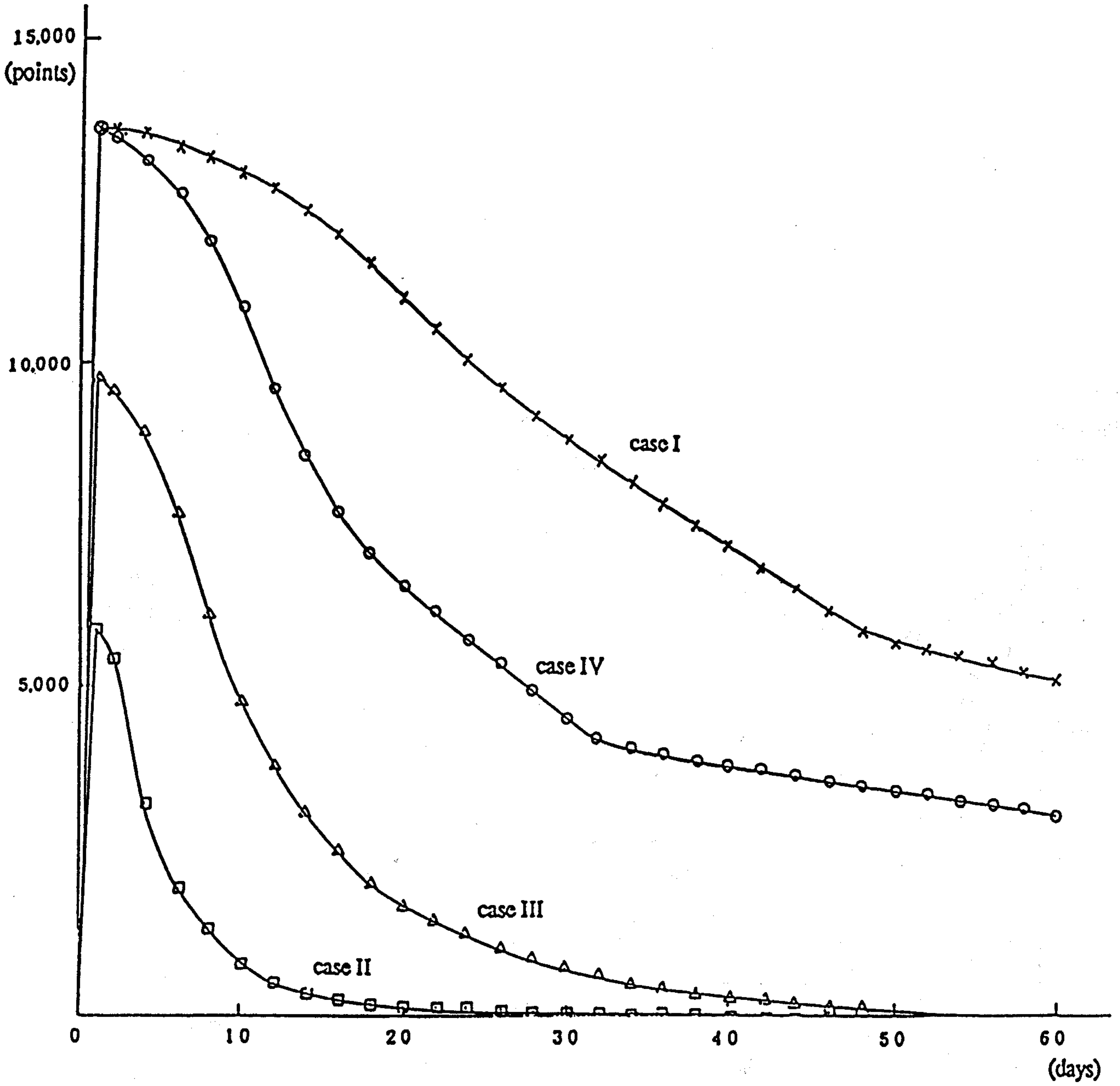


Figure 5 Roads Interrupted

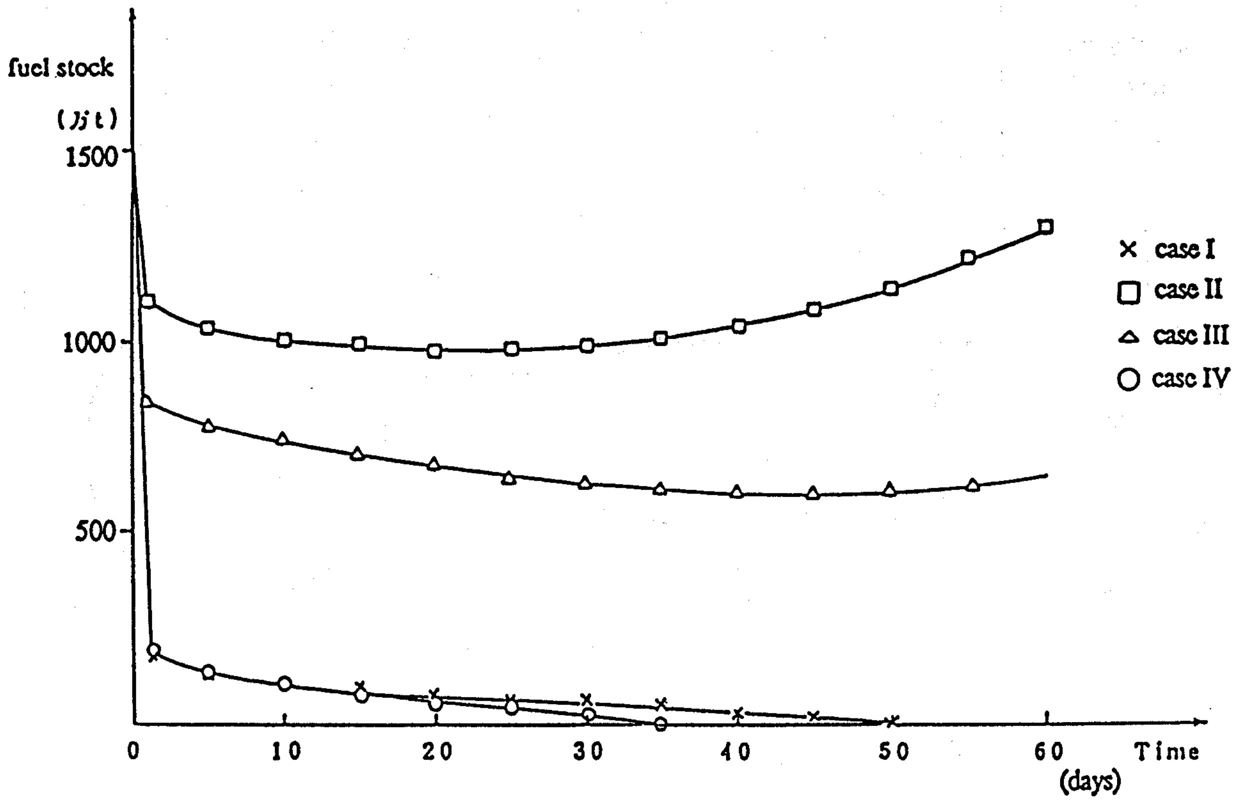


Figure 6 Fuel stock

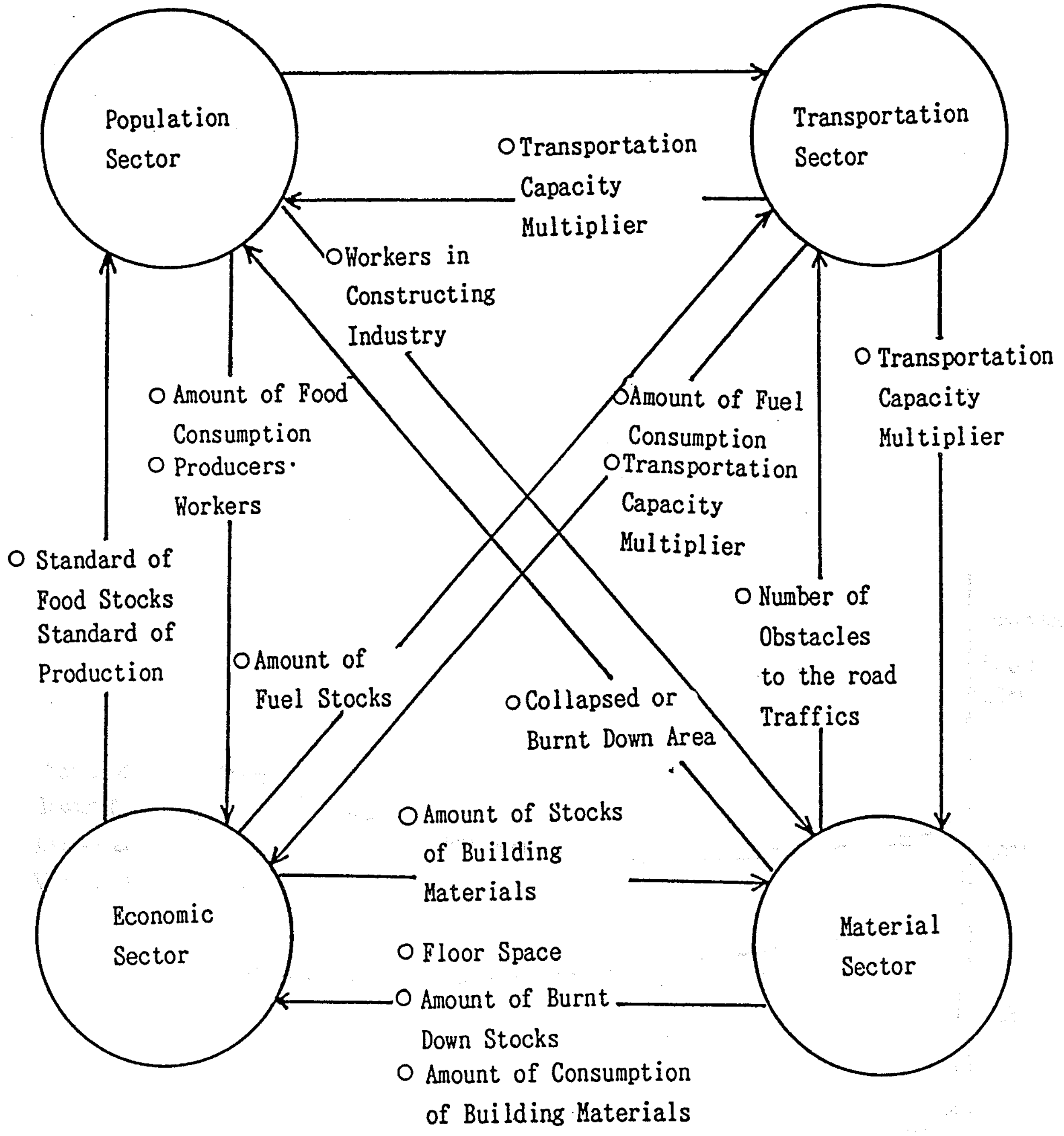


Figure 1 Relationship between Each Sector

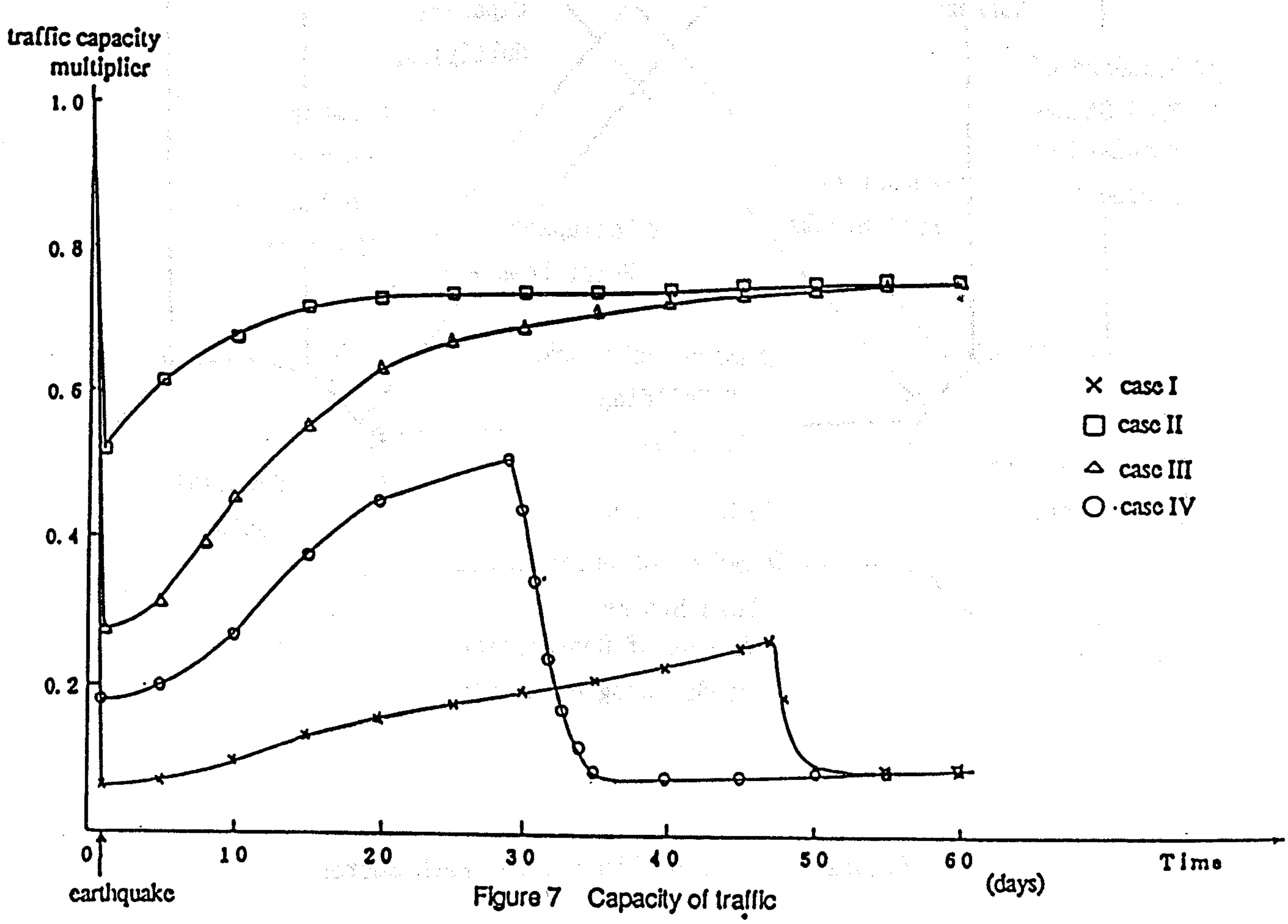
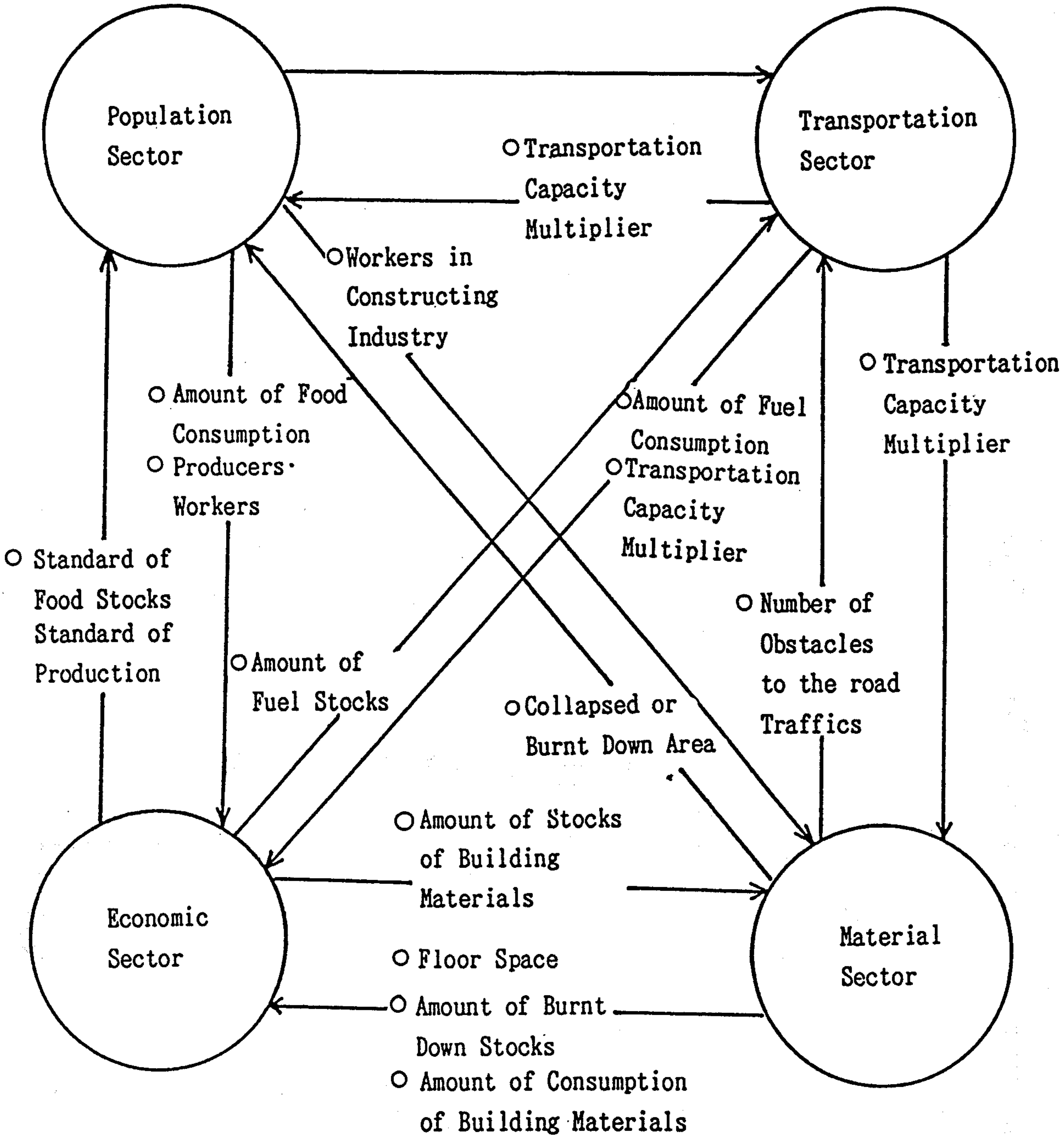


Figure 7 Capacity of traffic



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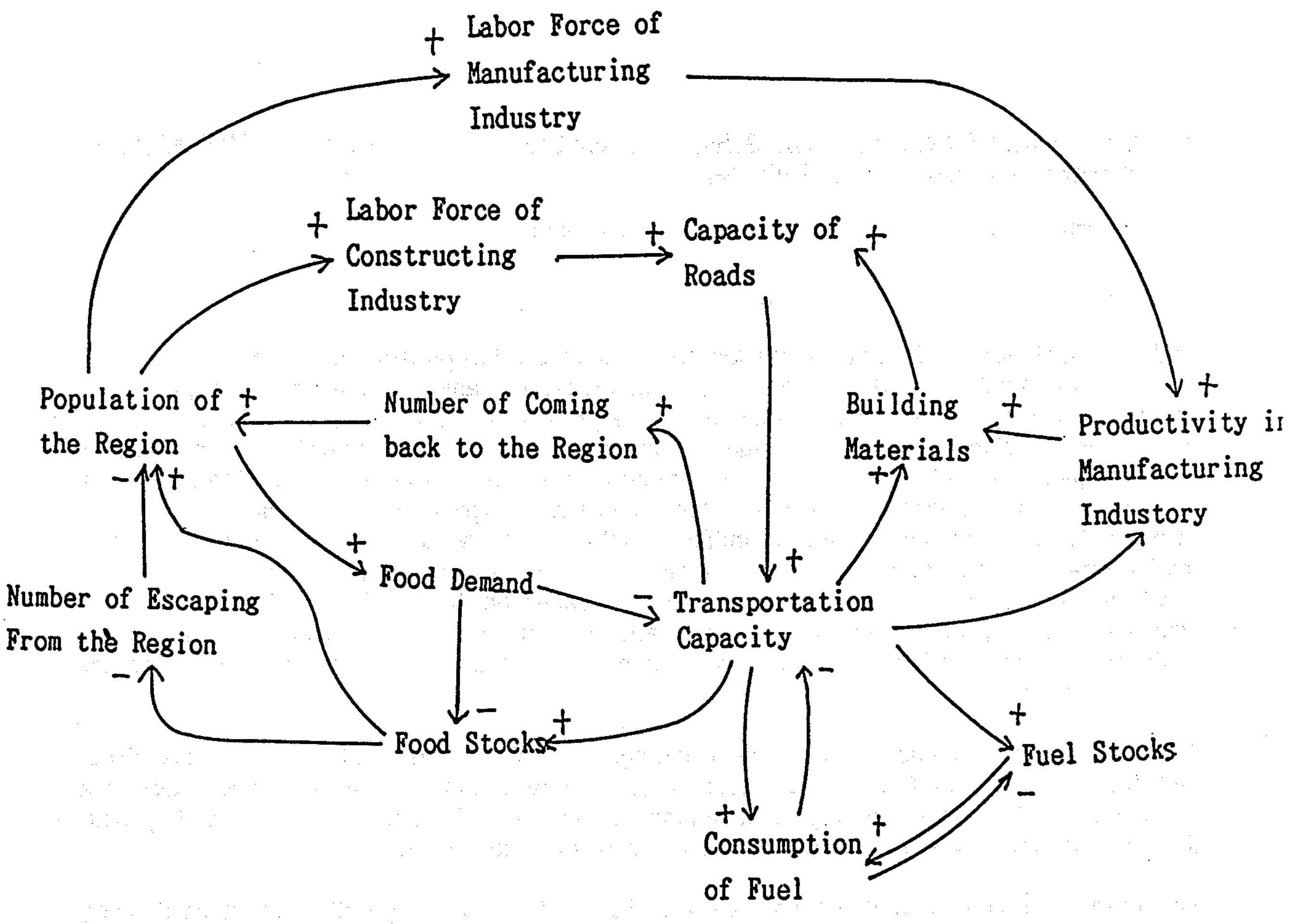

Figure 2 Loop diagram