# Expression of Relation of Medical Institutions and the Simulation of the Relation Recovery for Disaster

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***Abstract*—The present medical institution cooperate each other, such as specialty skills or regional peculiarity. However, when disasters, such as an earthquake, an institution may not have function as a medical institution and the balance of the medical service at the time will usually unstable. Restoring medical service, each medical institution also becomes to be stable. In this research, we express relation of the medical institutions as a medical network. Moreover, we get the simulation of the degree of relation of a medical institution. By expressing a medical network, it becomes clear where it needs medical services. And it becomes possible where we should focus to advance restoration by medical network simulation.**

***Keywords-queue; simulation***

## I. INTRODUCTION

Currently, medical institutions collaborate with various specialties and areas to provide a range of medical services. However, some medical facilities have lost the ability to function properly following a disaster such as an earthquake; thus, the balance of normal medical services has collapsed. As recovery progresses, each medical institution restore its ability to provide services and return to normalcy. This research aims to describe the connection among medical institutions in normal conditions as a functional medical network and simulate the degree of their connections when restoring medical services following a disaster. This simulation makes possible the clarification of them edictal services that are insufficient in the medical network and the degree of connection during a disaster to facilitate the prioritization of restoration efforts.

## II. MODELING BY A CLOSED QUEUING NETWORK

In this study, we modeled a closed queuing network using hospital capacities and geographic locations, and we used the system to determine the frequency of hospital use by customers. With this model, the closed queuing network [1] [2] focused solely on the movement within the system to determine the overall hospital system equilibrium within a local area. The study considered:

i.The type of customer using the network services in the network,

ii.$K$ sites within the network, and

iii.that the system would have a finite number of total customers *(N)*, to satisfy the equation given below, as the number of customers at site $k$:

$$N=\sum_{k=1}^{K} n_k$$

Where $n_k$ is the number of customers at site $k$.

iv.At site $k$, the service time followed an exponential distribution of service rate $\mu_k$ .

v.The rate of completed arrivals of customers from the inner network at site $k$ is $\alpha_k$ .

vi.Customers who received service at site $i$ move to site $j$ with the probability as follows:

$$p_{ij} \qquad (1\le i, j\le K, p_{ij}\ge 0, \sum_{j=1}^{K} p_{ij}=1)$$

We defined the service rate at each site as users' utilization frequency. In addition, $\alpha_k$ must satisfy the equation as follows:

$$x_1=1, \; x_k=\sum_{j=1}^{k} x_j p_{jk} \;, (k=2,3,\ldots,K)$$

Moreover, $\rho_k=\alpha_k/\mu_k$ ,(k=1,2,…,K)

Therefore, the stationary distribution in which there are n1 people in facility 1, …, $n_k$ people in facility k is as follows:

$$\pi(n_1,n_2,\ldots,n_k)=1/G(N,K)\prod_{k=1}^{K}\rho_k^{n_k}$$

Where $G(N,K)=\sum_{n_1+\ldots n_k=N}\prod_{k=1}^{K}\rho_k^{n_k}$

We calculated transition probability $p_{ij}$ according to the gravity model as follows:

$f_{ij}$ : The amount of movement from region i to region j

$p_i$ : The total amount of movement from region i as the departure place

$q_j$ : The total amount of movement from region j as the arrival place

$d_{ij}$ : The distance between regions i and j

C: The gravity model normalization constant: 0.145722117443322

 

$$f_{ij} = C\frac{p_i^a q_j^b}{d_{ij}^c},\ i \in K, j \in K$$

In this study, we performed calculations with a = b = 1 and c = 0.5.

## III. SYSTEM FLOW

The proposed system flow for this study is shown in Figure 1 First, we selected sites for inclusion in this system. Then, based on population information and the distance between sites, we determined the transition probability using the gravity model. Subsequently, we calculated the average wait number, which is considered to be the time required for the hospital, at each site in the queuing network.

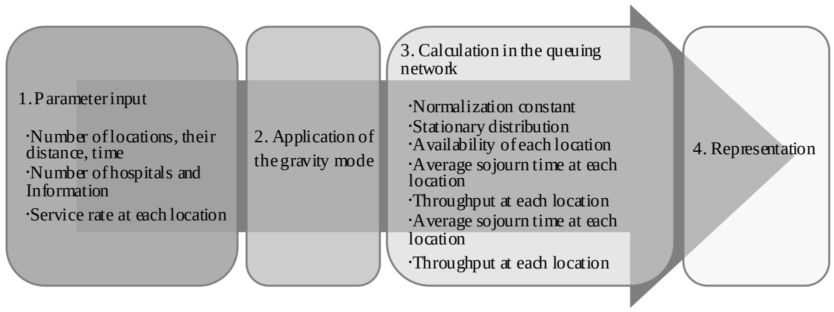


FIGURE I. SYSTEM FLOW.

## IV. EXAMPLE OF NUMERICAL CALCULATIONS

The numerical calculations for this study were performed as follows:

- Four disaster base hospitals and eight emergency response hospitals in Hamamatsu City were used, as shown in Table 1.
- The population distribution used in the gravity model define swards as units, as shown in Table2
- When multiple sites within the same ward were used, we divided the population by the number of used sites within the ward to determine the population at the sites.
- The service rate of each site was scored at a maximum of *10.0* for both disaster and emergency hospitals. The service rate was considered to be an indicator of hospital cooperation in this model. When the cooperation indicator is high in a disaster base hospital, for instance, its service rate is set as low.
- The frequency of hospital use was assumed to total *100* within the entire network to indicate that there were*100*customerswithin the network.

TABLE I. FOUR DISASTER BASE HOSPITALS AND EIGHT EMERGENCY RESPONSE HOSPITALS.

| id | name | address | Latitude longitude | Service rate |
|---|---|---|---|---|
| 308 | Seirei-Mikatahara Hospital | 328 Mikatahara-cho, Kita-ku, Hamamatsu City, Shizuoka Prefecture | 34.7918791 137.6927563 | 10 |
| 309 | Hamamtsu University Hospital | 1-20-1 Handayama, Higashi-ku, Hamamatsu City, Shizuoka Prefecture | 34.7706730 137.7432854 | 10 |
| 310 | Hamamatsu Medical Center | 328 Tomitsuka-cho, Naka-ku, Hamamatsu-City, Shizuoka Prefecture | 34.7161447 137.7014358 | 10 |
| 311 | Japanese Red Cross Hamamatsu Hospital | 1088-1 Kobayashi, Kita-ku, Hamamatsu-City, Shizuoka Prefecture | 34.8062210 137.7892746 | 10 |
| 312 | Seirei Hamamatsu General Hospital | 2-12-12, Sumiyoshi, Naka-ku, Hamaatsu-City, Shizuoka Prefecture | 34.7298132 137.7256608 | 10 |
| 313 | JA Shizuoka Kohseiren Enshu Hospital | 1-1-1, Chuou, Naka-ku, Hamamatsu-City, Shizuoka Prefecture | 34.7125678 137.7347363 | 10 |
| 314 | Hamamatsu-Kita-Hospital | 1568 Ose-cho, Higashi-ku, Hamamatsu-City, Shizuoka Prefecture | 34.7636607 137.7713422 | 10 |
| 315 | Hamamatsu Rosai (Laborers') Hospital | 25 Shougen-cho, Hgashi-ku, Hamamatsu-City, Shizuoka Prefecture | 34.7167150 137.7557101 | 10 |
| 316 | Suzukake Central Hospital | 120-1, Tajiri-cho, Mimami-ku, Hamamatsu-City, Shizuoka Prefecture | 34.6807885 137.7259073 | 10 |
| 317 | Juzen Memorial Hospital | 1700 Hitakuchi, Kita-ku, Hamamatsu-City, Shizuoka Prefecture | 34.8035260 137.7722651 | 10 |
| 318 | Tenryu Hospital | 4201-2, Oro, Kita-ku, Hamamatsu-City, Shizuoka Prefecture | 34.8543648 137.7987834 | 10 |
| 319 | Sakuma Hospital | 18-5, Nakabe, Sakuma-cho, Tenryu-ku, Hamamatsu-City, Shizuoka Prefecture | 35.0818964 137.8002208 | 10 |

TABLE II. POPULATION IN HAMAMATSU CITY FOR EACH WARD

| Ward | Population |
|---|---|
| Naka-ku, Hamamatsu City | 232,479 persons |
| Kita-ku, Hamamatsu City | 93,799 persons |
| Minami-ku, Hamatsu City | 98,428 persons |
| Tenryu-ku, Hamamatsu City | 33,490 persons |
| Higashi-ku, Hamamatsu City | 125,745 persons |
| Kita-ku, Hamamatsu City | 92,691 persons |
| Nishi-ku, Hamamatsu City | 107,677 persons |

### A. *A Case where Four Disaster Base Hospitals and Eight Emergency Response Hospitals are Used*

We considered a case in which four disaster base hospitals and eight emergency response hospitals were used in normal non-disaster conditions. Where there are several hospitals within the same ward, the allocated population is equal to the ward population divided by the number of hospitals within the ward. Table 3 shows a transition probability matrix obtained from the gravity model using the population assigned and the transport distance or the travel time between hospitals. The transport distance and the travel time between hospitals were automatically determined using Google Map API. The order of elements in the matrix corresponds to their IDs shown in Table 1. In addition, we calculated the transition probability matrix shown in Table 3 on the basis of the transport distance.

TABLE III. TRANSITION PROBABILITY MATRIX OBTAINED FROM THE GRAVITY MODEL.

| 308 | 308 | 309 | 314 | 315 | 310 | 312 | 313 | 311 | 317 | 318 | 316 | 319 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 308 | 0 | 0.2083 | 0.0878 | 0.0571 | 0.0908 | 0.207 | 0.1118 | 0.0465 | 0.0752 | 0.0284 | 0.0843 | 0.0027 |
| 309 | 0.1676 | 0 | 0.3508 | 0.0484 | 0.0606 | 0.1294 | 0.0934 | 0.0277 | 0.0526 | 0.0126 | 0.0561 | 0.0009 |
| 314 | 0.0746 | 0.3704 | 0 | 0.0785 | 0.0529 | 0.1117 | 0.1 | 0.0648 | 0.101 | 0.0185 | 0.0267 | 0.0009 |
| 315 | 0.0247 | 0.026 | 0.0399 | 0 | 0.0939 | 0.2361 | 0.461 | 0.0091 | 0.0103 | 0.0028 | 0.0959 | 0.0004 |
| 310 | 0.03 | 0.0249 | 0.0206 | 0.0718 | 0 | 0.3248 | 0.3828 | 0.006 | 0.0082 | 0.0038 | 0.1269 | 0.0004 |
| 312 | 0.048 | 0.0372 | 0.0305 | 0.1268 | 0.2279 | 0 | 0.4117 | 0.0059 | 0.0098 | 0.0037 | 0.0982 | 0.0003 |
| 313 | 0.0211 | 0.0219 | 0.0222 | 0.2016 | 0.2186 | 0.3351 | 0 | 0.0043 | 0.0062 | 0.0026 | 0.1661 | 0.0003 |
| 311 | 0.0672 | 0.0497 | 0.1101 | 0.0304 | 0.0263 | 0.0368 | 0.0332 | 0 | 0.5482 | 0.0754 | 0.021 | 0.0016 |
| 317 | 0.0909 | 0.079 | 0.1437 | 0.0288 | 0.0302 | 0.0509 | 0.0398 | 0.4589 | 0 | 0.0457 | 0.0308 | 0.0012 |
| 318 | 0.1332 | 0.0732 | 0.1021 | 0.0309 | 0.0538 | 0.0755 | 0.0645 | 0.2445 | 0.1769 | 0 | 0.039 | 0.0065 |
| 316 | 0.0393 | 0.0325 | 0.0146 | 0.1036 | 0.179 | 0.1975 | 0.4103 | 0.0068 | 0.0119 | 0.0039 | 0 | 0.0007 |
| 319 | 0.1874 | 0.0763 | 0.0721 | 0.0593 | 0.0749 | 0.0768 | 0.0995 | 0.0752 | 0.0717 | 0.0969 | 0.11 | 0 |

Table 4represents the degree of relationship among the hospitals when all 12 sites are used. We calculated the result using the distance between the population distribution and the hospital. Although there were many factors that could be considered, including the number of doctors and nurses and their skill levels at these hospitals, we considered that the distance and population distribution were the greater factors when anticipating a disaster. In this case, the value of Enshu Hospital is very high, indicating that this hospital is located in a geographically and demographically key location.

### B. *A Case in which only Four Disaster Base Hospitals Sites are in Operation*

Next, we considered a case in which emergency response hospitals are not available and only disaster base hospitals are operating.

In this case, the value of the Hamamatsu University Hospital located in the centre of the map is greater than the others, as shown in table 4. The degree of relationship among the disaster hospitals in this case is also greater than that in the 12sites case.

### C. *Degree of Relationship among Hospitals when Emergency Response Hospitals become Available*

We next considered the degree of relationship among hospitals when emergency response hospitals become sequentially available. For this case, we performed the calculations with the assumption that hospitals with lower values shown in Table 4 would become available earlier than those with higher values. The case in which 12 sites were used is assumed to be the normal situation. It shows hospitals serving as relationship centres when sites are added one-by-one, assuming that the number of sites is four for a condition under which only disaster base hospitals are available during an earthquake. In this case, we found that central sites interchange through the influence of the locations of hospitals and populations as hospitals are progressively added.

Table 4 show the changes in the degrees of relationship due to the recovery of sites. This result indicates that the degree of relationship is also changed by the added hospitals when medical institutions are in the process of recovery. We consider these data to be essential information for establishing a chain of command following a disaster.

TABLE IV. CHANGE IN THE DEGREES OF RELATIONSHIP DUE TO THE RECOVERY OF SITES.

| Name of base | 12 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|
| Seirei-Mikatahara Hospital | 0.232 | 1.802 | 1.806 | 1.952 | 1.744 | 0.927 | 0.758 | 0.481 | 0.296 |
| Hamamtsu University Hospital | 0.306 | 95.349 | 95.329 | 94.980 | 94.531 | 77.086 | 6.372 | 0.724 | 0.377 |
| Hamamatsu Medical Center | 1.332 | 2.235 | 2.240 | 2.446 | 2.089 | 1.414 | 85.790 | 94.989 | 3.529 |
| Japanese Red Cross Hamamatsu Hospital | 0.150 | 0.614 | 0.617 | 0.385 | 0.628 | 0.632 | 0.477 | 0.344 | 0.179 |
| Seirei Hamamatsu General Hospital | 4.375 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 93.862 |
| JA Shizuoka Kohseiren Enshu Hospital | 91.632 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Hamamatsu-Kita-Hospital | 0.285 | 0.000 | 0.000 | 0.000 | 0.000 | 18.924 | 3.975 | 0.655 | 0.341 |
| Hamamatsu Rosai Hospital | 0.777 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.748 | 0.560 |
| Suzukake Central Hospital | 0.680 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.862 | 1.537 | 0.581 |
| Juzen Memorial Hospital | 0.185 | 0.000 | 0.000 | 0.000 | 0.862 | 0.878 | 0.649 | 0.432 | 0.223 |
| Tenryu Hospital | 0.042 | 0.000 | 0.000 | 0.228 | 0.139 | 0.132 | 0.110 | 0.084 | 0.049 |
| Sakuma Hospital | 0.003 | 0.000 | 0.008 | 0.008 | 0.008 | 0.007 | 0.007 | 0.005 | 0.003 |

### D. *The Model that Added Hospital Information*

We consider the model that added hospital information. In this case, the information added is the number of beds and the number of medical departments of the hospital. We define following variables.

$T_i$ : The number of beds of the hospital i.

$S_i$ : The number of medical departments of the hospital i.

Thus, we modify the gravity model equation.

$$f_{ij} = C\frac{(p_i + T_i \times S_i \times w)^a \times (q_j + T_j \times S_j \times w)^b}{d_{ij}^c}$$

$$i \in K, j \in K$$

Where means that the weight variable of hospital information. We assume that number of medical examinees $T_i \times S_i \times w$. We use this modified model that included hospital information, we can get more precise information.

## V. CONCLUSION

In this study, we expressed the balance among hospitals as a stream of customers using a closed queuing network, and based on their own assessments and geographical locations, we expressed the degrees of relationship among hospitals. However, hospital values must be evaluated from various perspectives such as the number of doctors and nurses, number of beds, and quality of their medical services. In a future study, we will achieve higher quality simulation by establishing additional elements for evaluation from multiple perspectives.


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