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IMPACT ANALYSES ON IMPROVEMENT OF DISASTER PREVENTION FACILITIES --THROUGH THE DEGREE OF REFUGE DANGER IN CASE OF POST-EARTHQUAKE URBAN FIRES-

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SUMMARY

In Tokyo-ward-area, 42 refuge bases:RBs for big earthquake disasters were designated in 1968 by Tokyo Metropolitan Government:TMG, and there are 137 RBs at present. But the effect of the improvement of disaster prevention facilities:DPFs were not analyzed quantitatively. So the purpose of this paper is to analyze the effect of the improvement of DPFs, such as RBs and refuge roads:RRs, through the degree of refuge danger:RD in Tokyo-ward-area.
    One of the conclusions in this study is that the improvement of RBs is effective in the refuge area:RA larger than 700ha.

INTRODUCTION

In Japan, the urban disaster prevention planning is an indispensable element in the urban planning. Especially, for the last several decades, the earthquake disaster prevention plan is the most important in large cities of Japan. In case of Tokyo Metropolitan Government:TMG, projects for big earthquake disaster prevention are shown in Fig.-1.
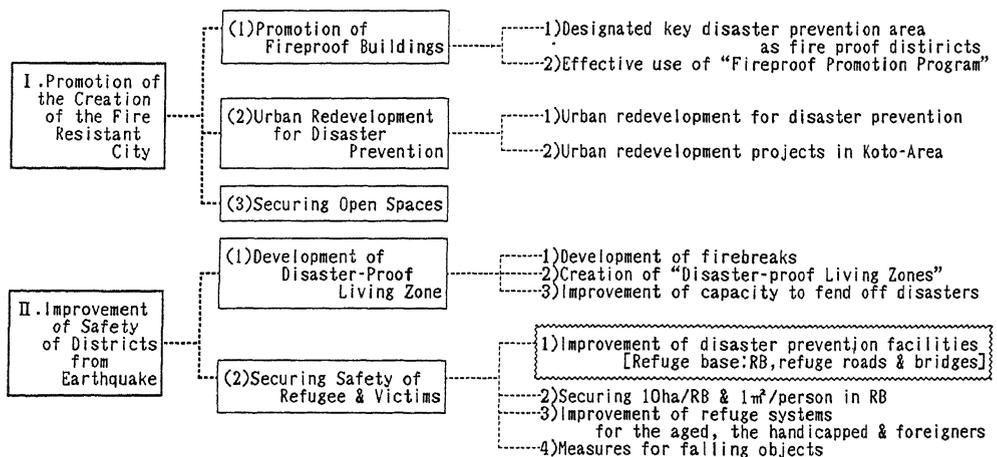

Fig.-1 Projects for big earthquake disaster prevention in TMG

According to "Ⅱ-(2)-1:Improvement of disaster prevention facilities" in Fig.-1, TMG designated 42 RBs in 1968 in cooperation with the ward offices and others in Tokyo -ward-area. After this designation, RBs are increased step by step as follows.

1968.5 : 42 RBs
1970.8 : 4 RBs additions, 46 RBs in total
1977.7 : 121 RBs were designated based on "Earthquake Disaster Prevention Ordinance".
1979.4 : 13 RBs additions, 134 RBs in total
206 refuge roads:RRs, extending 307km, of 56 routes, leading to 37 RBs.
1985.5 : 3 RBs additions, 137 RBs in total
195 refuge roads, totaling 285km, of 55 routes, leading to 37 RBs.
All of RBs, refuge area:RA of each RB and RRs are shown in Fig.-2.

But the impact of the improvement of disaster prevention facilities:DPFs has not been analyzed quantitatively yet. So the object of this paper is to analyze the impact of the improvement of DPFs, such as RBs and RRs, through the degree of refuge danger:RD.
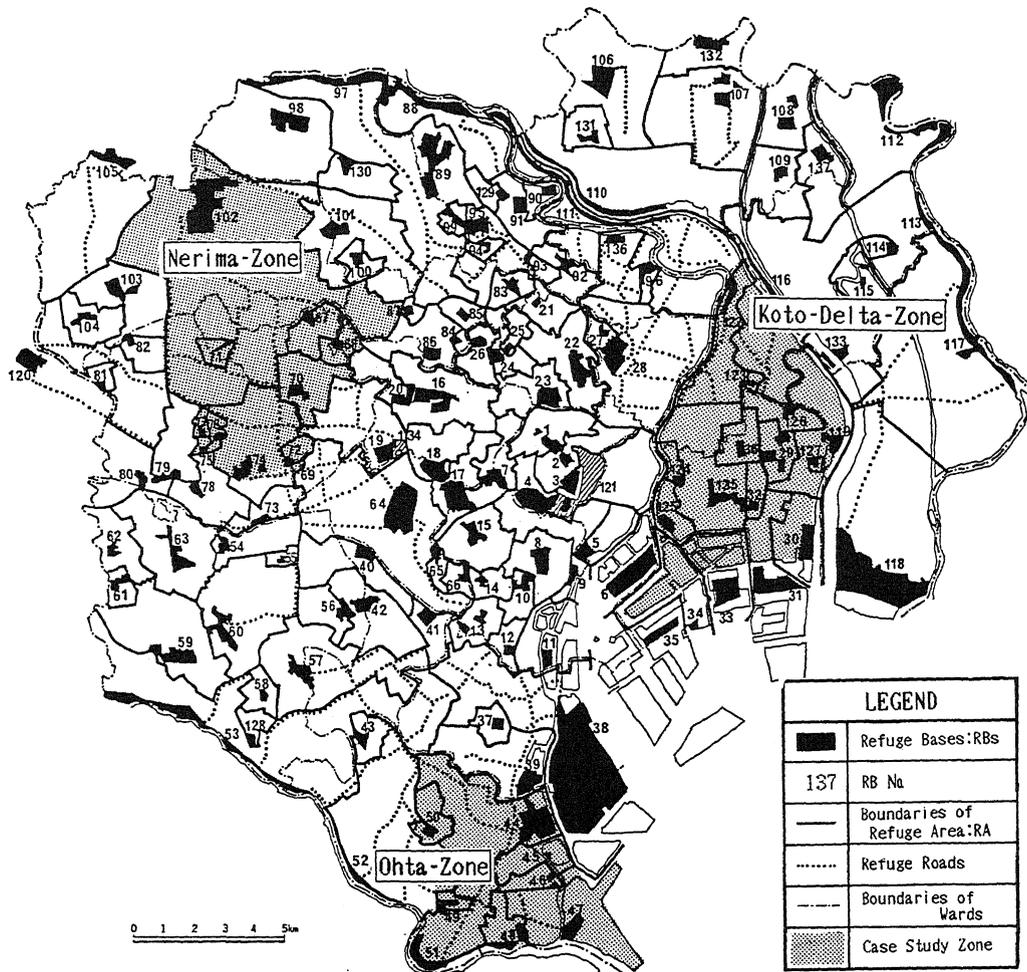

Fig.-2 Allocation of DPFs and 3 case study zones in Tokyo-ward-area

PREPARATIONS FOR IMPACT ANALYSES

The outline of this study based on Fig.-3 is as follows.
URBANIZATION AND IMPROVEMENT OF DPFs IN TOKYO-WARD-AREA   Data in relation to
urbanization and DPFs are population, open spaces, such as parks, housing complexes
and agricultural land, and roads wider than 15m. Data without population are arranged
by aerial photographs in 1961 and 1/10,000 maps in 1983. The transitions in Tokyo-ward
-area from 1961 to 1983 are as follows.

     1)Population : The increase of population from 1961 to 1983 is 170,000 in
        Tokyo-ward-area. Especially, in the outer ring of the ward-area, the
        increase of population is approximately 1,000,000.
     2)Agricultural land : In the zone of population increase, agricultural land
        changed to residential land.
     3)Refuge bases : In 1961, 26 RBs among 134 RBs designated in 1979 were not
        existent. In the waterfront area, 8 RBs had been reclaiming. In Koto-Delta
        -Area and the northwest zone of the ward-area, 13 RBs were factory sites.
     4)Roads : Construction of roads wider than 15m from 1961 to 1983 is
        approximately 550km. In the waterfront area and the outer ring of the
        ward-area, many roads were constructed.
Results of this data arrangement are as follows.
   • Koto-Delta-Area was a vulnerable zone from the point of view of refuge in
    1961. But the improvements of DPFs advanced.
   • The outer ring of the ward-area changed to a vulnerable zone in the process
    of urbanization.
SELECTION OF CASE STUDY ZONES   Based on the above investigations, 3 zones shown in
Fig.-3-② are selected. 16% of nighttime population in Tokyo-ward-area is living in
these zones, and the rate of the area in Tokyo-ward-area is approximately 21%.

① Data arrangement
about improvement of DPFs and
the urbanization in Tokyo-ward-area
(1961 and 1983)

• Refuge bases
• Road network
• Nighttime population and vacant sites
in each district used by statistic data,
aerial photographs in 1961 and others

② Selection of case study zones

Koto-Delta-Zone   : 17
Nerima~Suginami-Zone : 7
Ohta-Zone   : 8
Total of refuge area : 32 (Fig.-2)

③ Estimation of
time required
for refuge in
several cases

④ Investigation
on improvement
of DPFs
('61→'83)

Estimation cases
of degree of refuge danger

Case	RBs	Roads	Population
A	'83	'83	'83
B	'83	'61	'83
C	'61	'83	'83
D	'61	'61	'61

⑤ Impact analyses of
improvement and
these evaluations

Viewpoints of the impact analyses
  • Impact of DPFs '61→'83   : A⇔D
  • Impact of roads '61→'83   : A⇔B
  • Imapct of RBs '61→'83   : A⇔C
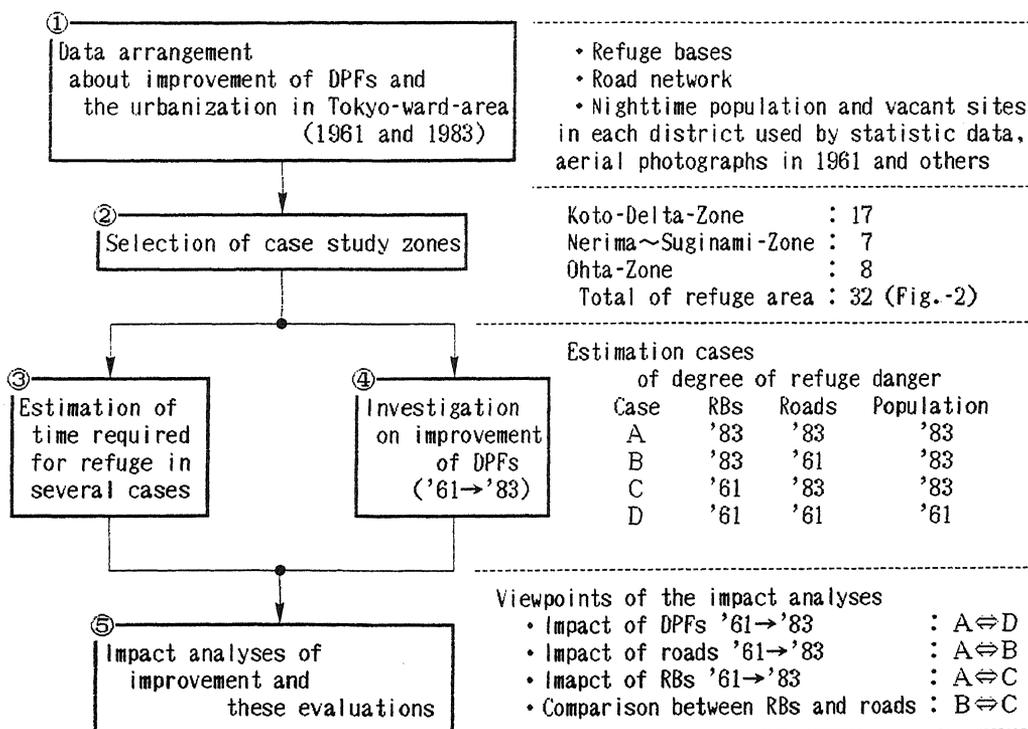 • Comparison between RBs and roads : B⇔C

Fig.-3 Outline of this study

ESTIMATION METHOD OF THE TIME REQUIRED FOR REFUGE

The estimation method of the time required for refuge in this paper is an application of the estimation model proposed in "Estimation of The Degree of Refuge Danger by Districts for Extensive Refuge Plan in Tokyo-ward-area". This model was developed by Prof. Kaji(U. of Tsukuba) and the auther of this paper, and applied to the estimation of danger degree at a time of a big earthquake in Tokyo Metropolis. The diagram of this model is shown in Fig.-4. Assumptions of this model are as follows.

1) The whole area for the estimation of the time required is divided into 500m×500m grid.
2) Refugee should move along the only normalized refuge route from an origin:i to the RB:I.

In this paper, only the inside of bold dotted line in Fig.-4 is applied to make clear the impact of the improvement of DPFs from 1961 to 1983.

Upon the above assumptions, the time required for refuge from an origin:i to the RB:I is formulated as follows.

1) Walking velocity:$S_k(t)$ in a grid:k at time:t is given by Equa.-1.

$$S_k(t) = S_O \times c\gamma_k(t) \text{ -- Equa.-1}$$
$$S_O : \text{The standard walking velocity;90m/min.}$$
$$c\gamma_k(t) = F\{E_k(t), C_k(t)\}$$

2) When the length of the refuge road in grid:k is d_k and the time required to pass grid:k is Δt_k, a relationship between $S_k(t)$, d_k and Δt_k is shown in Equa.-2.

$$d_k = \int_t^{t+\Delta t_k} S_k(t)\, dt \text{ -- Equa.-2}$$

3) The time required from i to I is estimated by Equa.-3.

$$T_i = \sum_{k=i}^{I} \Delta t_k \text{ -- Equa.-3}$$

THE IMPACTS ANALYSES ON THE DPFs IMPROVEMENTS

Averages of the time required for refuge in each case and RA are shown in Fig.-5. Based on Fig.-5, relations between change of refuge time and improvements of DPFs are shown in Fig.-6 and 7.

DPFs IMPROVEMENTS IMPACT ON AVERAGE REFUGE TIME   Comparing case:A and case:D, We can explain the effects of DPFs improvements as follows.
1) In Koto-Delta-zone, the improvement of DPFs brings marked decrease in average refuge time.
2) In Nerima-Zone, average refuge time is increased by urbanization and the lack of DPFs.

IMPACTS OF THE ROAD NETWORK IMPROVEMENT   Impacts of the road network improvement are summarized as follows(Comparing case:A and case:B).
3) The improvement of the road network has an effect in RAs where roads have been provided more than 150m per 500m×500m grid(See point "a" in Fig.-6).
4) In RA where the longest distance to RB is more than 2,500m, the improvement of the road network is effective(See point "b" in Fig.-7).
5) Characteristics of RA where the improvement of the road network is effective are that there is RB in the center of the RA and 1~2 refuge routes to RB in the RA.
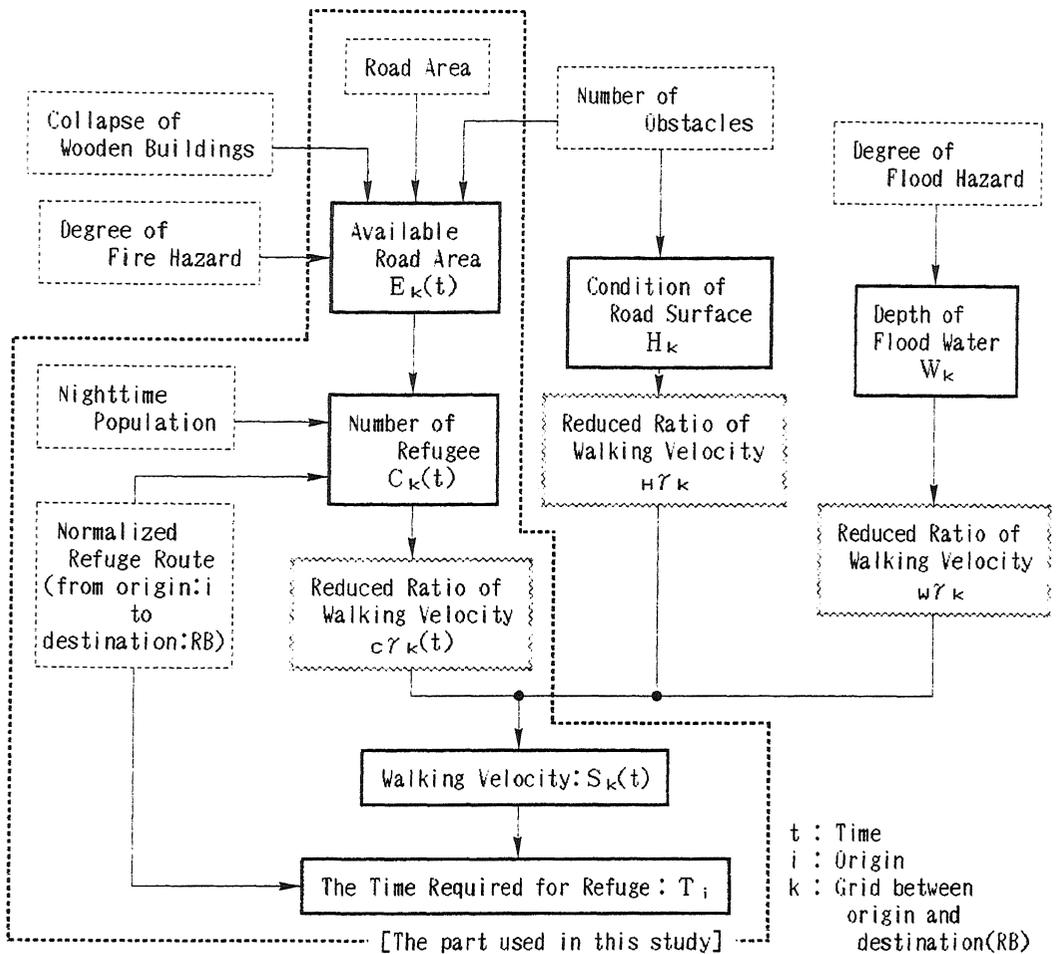
Fig.-4 Estimation Diagram of the Time Required for Refuge

Flow diagram elements:
- Road Area
- Collapse of Wooden Buildings
- Degree of Fire Hazard
- Number of Obstacles
- Degree of Flood Hazard
- Available Road Area $E_k(t)$
- Condition of Road Surface H_k
- Depth of Flood Water W_k
- Nighttime Population
- Number of Refugee $C_k(t)$
- Reduced Ratio of Walking Velocity $H\gamma_k$
- Reduced Ratio of Walking Velocity $W\gamma_k$
- Normalized Refuge Route (from origin:i to destination:RB)
- Reduced Ratio of Walking Velocity $c\gamma_k(t)$
- Walking Velocity: $S_k(t)$
- The Time Required for Refuge : T_i
- [The part used in this study]

Legend:
- t : Time
- i : Origin
- k : Grid between origin and destination(RB)

Zone	RA No.	0	10	20	30	40	50	60	70	80	90	100	110	120	140	160	180 min.
↑	29	AB											D				
↑	30					AB		D C									
↑	31			ABC			D										
Koto	32			AB		C D											
	36			AB											C	D	
	116					AB					C			D			
Delta	119					AB		C		D							
↑	122				AB			C		D							
↑	126			AB							DC						
↓	127	AB				D	C										
Ohta	45			AB				C	D								
Delta	33				CD	AB											
Nerima	102									CD				AB			
Nerima	74							D		AB							
Delta	123	A														C	D

Fig.-5 Average refuge time by refuge area:RA of 4 cases:A~D(See Fig.-3)

IMPACT OF REFUGE BASES IMPROVEMENT   According to the comparison between case:A and case:C, we can explain the impact of refuge bases improvements as follows.
　　　6) The improvement of RB is effective in a RA where is approximately
　　　　700~1,000ha.

COMPARISON BETWEEN REFUGE BASES AND THE ROAD NETWORK   We can compare the effect of the DPFs improvement between case:B and case:C and explain as follows.
　　　7) The improvement impact of the road network is better than the improvement
　　　　of RBs.

CONCLUSIONS

Conclusions of this impact analyses are as follows.

　　a) In the sprawling zone, it is very important to conserve agricultural land
　　　 to secure RBs.
　　b) The improvement of RBs is effective in RA larger than 700ha.
　　c) The improvement of the road network should be effective in congested RAs
　　　 which are 300~600ha, 1~2 approaches to RB, more than 2,500m to RB or high
　　　 population density.

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1. The Tokyo Metlopolitan Government, Planning of Tokyo 1988, (1988).
2. Kaji,H., Kumagai,Y. et al., "Estimation of The Degree of Refuge Danger by Districts
   for Extensive Refuge Plan in Tokyo-ward-area", City Planning No.17, Institute of
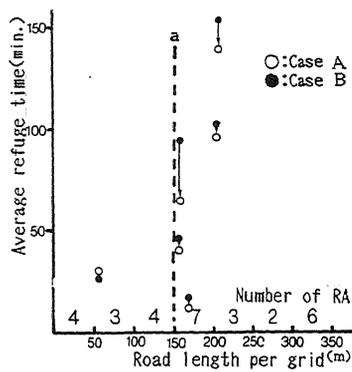   City Planning of Japan, 559−564, (1982)

Fig.-6 Change of average refuge time
　　　　owing to the improvement
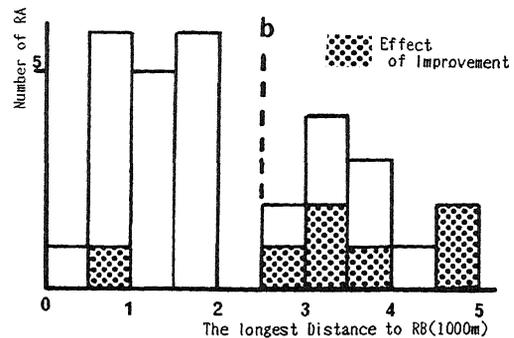　　　　　　of the road network

Fig.-7 Relation between
　　　　the longest refuge distance and
　　　　the improvement of the road network