URBAN UNDERGROUND SPACE DEVELOPMENT AND CIVIL DEFENCE CONSTRUCTION ——A SPECIAL PROBLEM'S S.D. MODEL

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ABSTRACT

Owing to the development of the cubic construction of modern cities and the protective functions of underground space against the disasters such as earthquake and air raids by modern weapons, the development of urban underground space and the construction of protective sheltering against disasters have become an important policy for many cities. Nevertheless, contradictions between investment and benefit as well as between protection and economy will often occur as a result of the very expensive cost of underground space development. As managers of system, they tend to need to understand these problems and adopt effective measures to find out solutions for them. The method of System Dynamics is no doubt a useful tool for the studies of such problems.

This paper has established a system dynamic model about urban underground space development and civil defence construction, including development fund raising, fund distribution, urban underground space construction, subway(i.e., underground railway) construction, urban population and the other auxiliary business dealings performed by the development departments. The model has successfully solved the problem of offering methods for the efficiency of protecting against disasters, the social and economic benefits of urban underground space development and civil defence construction. It reveals the feedback and circulation mechanism and tendency of urban underground space development and civil defence construction.

Part One System Analysis

1.1 System Environment

There exists a kind of interaction between underground space development system and environment. The quantity of urban population sets out a task upon the system. With the growth of population, the area of underground space in need also increases. The amount of fund to be raised from the society is one of environmental conditions as input of energy to the system; and variations of the external sources of fund exert influences upon the rate of system development. Urban subway construction will increase the total scale of underground space development. The presumed environment of disasters such as earthquakes and air raids by modern weapons is a kind of 'soft' dynamic power

for system development and construction; it applies constriction and guidance to the system in terms of conception, policy and technology.

1.2 System Elements

The system in question includes such elements as underground space development activities, commercial activities through the use of underground space. the protection offered by underground space, social benefits produced by undergrund space, auxiliary management activities performed by the development compnanies, etc., of which the main ones will be dealt with in the analysis of the causal relationship.

1.3 Targets Describing System Tendency

Underground space is to be divided into two categories: Type A represents the space with relatively good capability against disasters and with the commercial usage playing the secondary role; Type B denotes the space which is mainly devoted for commercial use and whose level of protection against disasters is comparatively low. The targets reflecting the level of protection against disasters are as follows:

(1) Total area; (2) Rate of admission, i.e., the ratio of the number of people who can be admitted into the underground space during the period of emergency to the total population; (3) D—value of area in comparison with the planned objective; (4) Protective effectiveness of underground space against disasters, the value of which is the ratio of the survivals due to the protection obtained during the occurrence of disasters to the number of casualties which will occur without protection under the similar conditions of disasters; (5) Rate of association with the space system, i.e., the proportion of space Type A in the total space. The three proceding targets reflect the level of protection against disasters in terms of quantity, while the last two items reflect the level of protection against disasters in terms of protection.

The targets reflecting the economic level are as follows:

(1) Rent collected from the letting of underground space, which is alternatively called income of usage fees; (2) Output value and economic benefit arising from the commercial dealings through the use of underground space; (3) Output value and economic benefit arising from the design and construction of the projects undertaken by the development companies under contract; (4) Total output value and total economic benefit of the system, which are the sum of the previous three items; (5) Output value and economic benefit per unit investment. In order to reflect the internal vitality of the system, some additional targets have been determined, for instance, the proportion of the internal income of the system in the total funds collected from the external sources, the proportion of the annual income through the use of underground space in the development investment for the said year.

1.4 Analysis of the Main Causal Relationship of the System

As shown in Fig. 1, area of Type B space→area of Type A space→total economic benefit→input of development funds→area of Type B exhibits positive feedbback loop, whish shows that Type B space will obtain relatively good economic benefit and will gain more development fund, thereby leading to the increase of investment for the development of Type B space; meanwhile, area of Type B space→total area available for development→rate of admission→protective effectiveness exhibits positive relationship, the

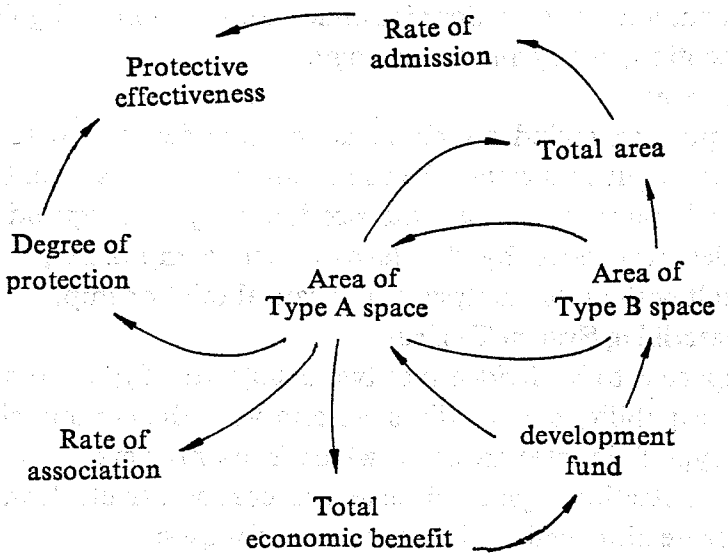

Fig. 1

increase of Type B space raises the protective effectiveness to a certain extent from the angle of enhancing the rate of admission, which is the positive side of the matter. However, area of Type B space→area of Type A space→degree of protection against disasters of the space system→protective effectiveness exhibits negative relationship; meanwhile, the increase of the quantity of Type B space reduces the rate of provision of the asssociated parts of the space system, which is the disadvantageous side of the matter. Similarly, the increase of the proportion of Type A space also exerts dual influence; that is to say, it enhances the rate of association and the protective effectiveness on one hand and reduces the protective effectiveness on the other. Then, what is the magnitude of the positive or negative influence? We can not make the answer immediately; the system possesses the anti–intuitiveness.

Fig. 2 is a diagram of causal relationship among the main factors of the system. The loop of total fund of the system→investment for public development→area of Type B space→total area for development→usable area→income of usage fees→internal income of the system→total funds of the system becomes the main loop, which determines the self–developing capability of the development system.

It can also be seen from Fig. 2 that urban population→growth of urban buildings above the ground→demand on the undergorund space→incidental investment for the construction work above the ground and group development investment→external fund raising→total fund of the system exhibits positive relationship; urban population→population to be sheltered according to the planning→ rate of admission→ protective effectiveness exhibits negative relationship; investment for the construction of subway→ area of subway→shelterable area→total area of underground space→rate of admission →protective effectiveness also exhibits positive relationship; and output value of the aux-

iliary business dealings→sum of profit and taxes to be delivered or paid→profit→investment for redevelopment→internal income of the system→total fund of the system also exhibits positive relationship. Besides, the increase of the construction cost of development and the decay of the growth rate of economic benefit act as constriction and limitation on the system. The causal relationship is omitted in the diagram.

In Fig. 2, the loop of investment for public development→non-developmental consumption→investment for public development, the loop of investment for public development→maintenance and repair cost for the developed space→investment for public development, the loop of area of Type A space→area of Type B space→area of Type A space and so on all exhibit the complementary relationship, in which any one item of the

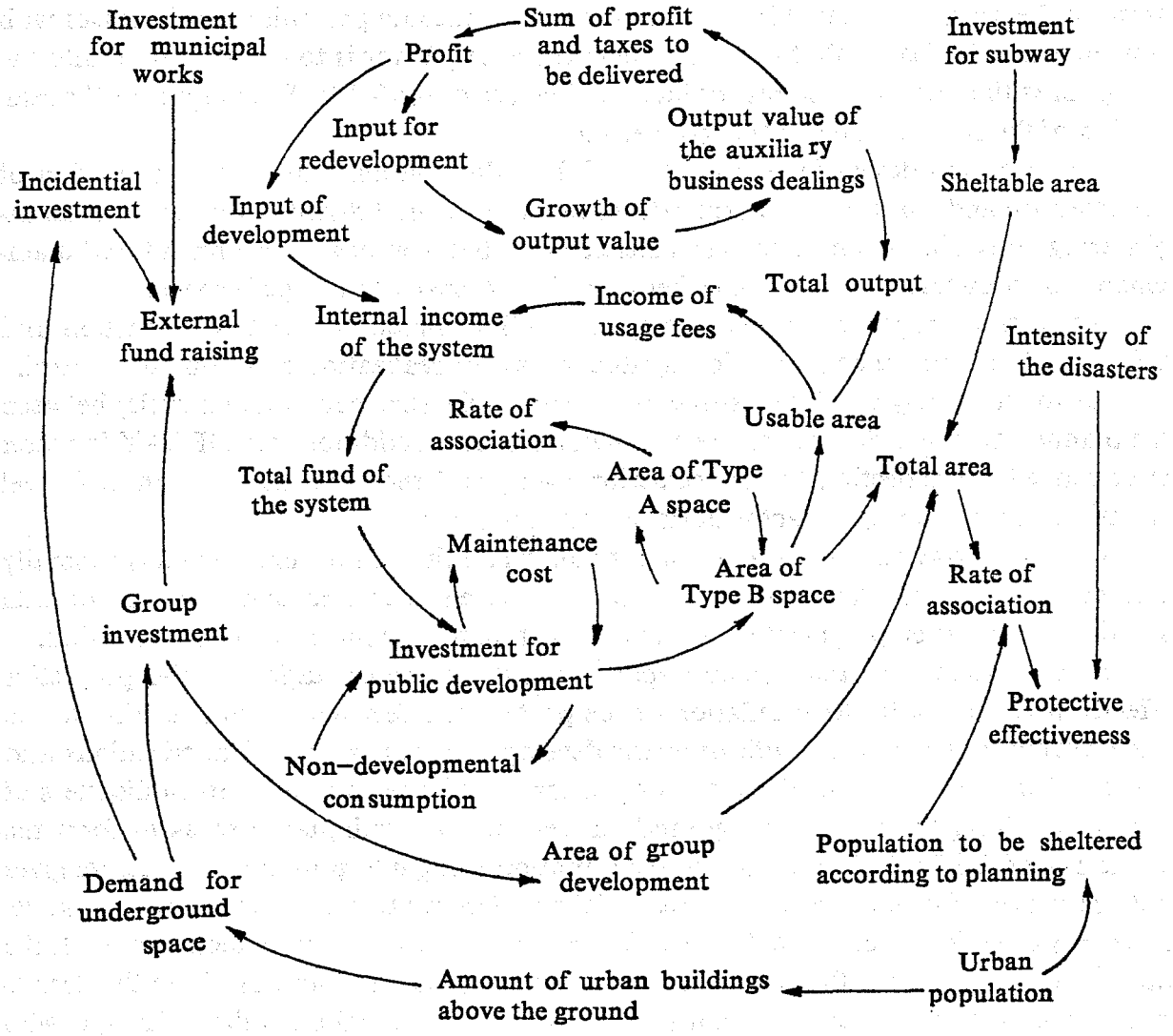

Fig. 2

factors rises, then another item will lower itself. The effect of the variations of these relations on the system will be listed as one of subjects for major studies of the model under consideration.

Part Two System Model

In the program design, four kinds of variations for the external fund are to be supposed, i.e., increase, reduction, maintenance of the present level without change and random variations within the range of the historical lower and upper limits. The Multiple SWITCH function, the CLIP function and NOISE function are employed for the program design.

As to the problem of the income of usage fees for underground space, it is necessary to take into account the general regulations of business dealings and other unforseeable factors; the scope of gradual increase of the rate of income per unit area decreases with time in a certain degree, that is to say, the linear decay factor is to be introduced into the program with relation to the rate of income. The use of the TABLE function for the realization of the said fuction is rather convenient.

The program design for the module of fund distribution aims at the realization of the selection and control of the proportions in terms of fund distribution between the engineering construction and auxiliary construction, between new development and maintenance or transformation as well as between Type A space and Type B space.

As to the foregoing various layers, the TABLE function, the CLIP function and SWITCH function are employed in a synthetic way for realization of automatic control.

As for the newly developed space, there exists delay(i.e., construction cycle) between the planned area and the area of the completed works. In addition, the DELAY function is employed for reflecting the construction cycle, and the TABLE function and level equations for reflecting the factor of rising construction cost.

Urban subway construction is not continuous on the axis of time, which is generally divided into the first–phase project, the second–phase project and so on; the appropriate solution lies in the employment of the STEP function for the purpose of superposition.

In the module of underground space benefit, the computation of the protective effectiveness rests with the simulation of the protective effectiveness with relation to the underground space systems with different development scales, spatial distributions and degree of protection against disasters inaccordance with the environments of disasters of each city arising from air raids by modern weapons or earthquakes so as to form the equations of the TABLE function for computation using interpolation. The model gives out the values of protective effectiveness of the underground space with three typical degrees of protection , i.e., Type A space, Type B space and subway, which vary with the rate of admission under the conditions of the given plane distributions. With the derivation of the protective effectiveness, it is still possible to derive the number of people who are rescued in the space system according to the rate of casualty without protection in the given disastrous environment of each city. The whole set of the disaster–modeling program can be used in conjunction with the S.D. program.

Part Three Modeling Computation of the System

Table of the modeling computation of the system is listed in following table:

Table of Computational Scheme

Regulations of variations of the external conditions	Variations of policy with relation to system development		Serial number of scheme
	First layer	Second and third layers	
Maintenance of status quo	Reduction of the proportion of the non– developmental fund from 10% to 5% and increase of the proportion of the developmental fund from 90% to 95%	a) Proportion of fund for maintenance, repair and transformation:13% b) Proportion of fund for new development: 87% c) Coefficient of proportionality for Type B space: 1.0 for years before 2000 and 0.8 for years after 2000	1
		a), b) ditto; c) Coefficient of proportionality for Type B space: 0.8 for years before 2000 and 0.6 for years after 2000	2
		a) b) ditto; c) Coefficient of proportionality for Type B space: 1.0 for years around 2000	3
		a), b) ditto; c) Coefficient of proportionality for Type B space: 1.0 for years before 2000 and 0.5 for years after 2000	4
		a), b) ditto; c) Coefficient of proportionality for Type B space: 1.0 for years before 2000 and 0 for years after 2000	5
	Reduction of the proportion of the non– developmental fund from 15% to 10% and increase of the proportion of the developmental fund from 85% to 90%	a), b) ditto; c) Coefficient of proportionality for Type B space: 1.0 for years before 2000 and 0.8 for years after 2000	6
Random variations	This layer is same as the 1st ~5th schemes.	a), b), c) Same as Scheme 1	7
Slow increase		a), b), c) Same as Scheme 1	8
Gradual reduction		a), b), c) Same as Scheme 1	9

Part Four Example of Computation for Representative City

4.1 Computation Result and Tendency Analysis Corresponding to the First Scheme

The length of the step for modeling computation lasts for one year, starting from 1991 and ending at 2010 with the total length of time period being 20 years. For the starting year of modeling computation, the total fund from the external sources approximates 20,000,000 units of currency, and the urban population amounts to 2,390,000 people.

The development tendency of the construction of the protective works against disasters specified in the first scheme is as follows:

The rate of association is expected to maintain the present level(i.e., less than 5 per cent), leaving a considerable gap in comparison with the planned rate of association. The present rate admission of underground space is 54 per cent and will rise to 65 per cent at the end of the precent century(with the urban population being 2,718,700), and will increase up to 77 per cent at 2010(with the urban population being 2,954,200). The protective effectiveness will reach 65 per cent at 2010.

The development tendency of economic benefit specified in the first scheme is as follows:

The usage fees of underground space to be counted up to the end of the present century will be equivalent to 3.4 times of the present ones; and they will be equivalent to 5.8 times of the present ones. The total output value of the usage will be equivalent to 2.2 times of the present figure; it will, up to the year 2010, be equivalent to 2.5 times of the present figure. The output value per unit investment will increase by 50 per cent at 2010 compared with the present value, and the economic benefit per unit investment will be doubled in comparison with the present one.

The additional targets of the first scheme are as follows:

The proportion of the internal income to the total fund from the external sources is less than 20 per cent at present, and will reach 60 per cent at the end of the present century, which still fails to strike a balance. It is only possible to strike a balance up to 2009; and at 2010, the internal income of the departments will slightly exceed the total fund from the external sources, which shows that a fundamental change has taken place within the system. The proportion of the income of usage fees to the investment for new development is to be computed from the year 1991, will make a slow increase up to 60 per cent, and will reach 70 per cent at 2010, which demonstrates the gradual enhancement of the capability of self strengthening of the system.

4.2 Effect of the Variations of the Second– and Third–Layer Conditions within the System on the Tendency

The result demonstrates that the target of economic benefit and the additional target in the third scheme are the highest; among the targets of protective benefits against disasters, the targets of spatial area and the rate of admission are the highest, and the peotective effectiveness resulting from the rate of admission is also considerably high, nevertheless, the rate of association is the lowest. The rate of association for the system specified in the fifth scheme is by far higher than the other schemes; but the target of

economic benefit and that of the total area are the lowest; and the amplitude of the increase of protective effectiveness derived from the enhancement of the degree of protection is lower than the one obtained from the raising of the admission rate. The remaining schemes fall between the two foregoing schemes with varying degrees.

4.3 Effect of the Variations of the First–Layer Conditions within the System on the Tendency

The developmental expenditures for the sixth scheme is somewhat reduced compared with the first scheme, and various targets are al lowered in varying degrees; but the targets of the economic benefit per unit investment and the ratio of the annual income resulting from the usage of space to the annual investment are increased instead, which shows that, on the whole, the absolute value of the benefitgained from underground projects is relatively low; the greater the input, the lower the rate of benefit per unit investment. This point also accords with the situation of underground space development itself. Anyhow, the balance of area for the planned target in the scheme has increased by 6 per cent.

4.4 Effect of the variations of the External Environmental Conditions on the System Tendency

Random variations within the range of 17,000,000 to 22,000,000 units of currency have been taken into account in the seventh scheme; but the general result exhibits no great difference in comparison with the first scheme. Based on the optimistic estimationas shown in the eighth scheme, if the external fund raising makes a slow increase in the proportion of 2 per cent, then the spatial area will increase by 5 per cent in comparison with the first scheme in 2010 with the other targets also making certain increases. Of course, the economic benefits per unit investment will make corresponding slight decrease. Based on the pessimistic estimation, when the external fund raising makes negative increase(i.e., decrease) in the same proportion, the spatial area will reduce by 4 per cent compared with the first scheme in 2010 with the other targets also making corresponding reductions. However, under the these conditions, the development speed of more than 10,000 units of area can be maintained every year and make slow increase at that. Up to 2010, the annual area of development may reach 11,300, despite the lowering by 19.8 per cent in comparison with the area of development obtained under the conditions of maintaining status quo. But it shows that, when the external fund raising makes gradual decrease, the main contribution to the maintenance of the above–mentioned speed in terms of development area comes from the internal part of the system. This is just the embodiment of the internal vitality.

Part Five Related Conclusion and Suggestions

5.1 Tendency of Underground Space Development under the Present Policies and Conditions

Just like the typical cities listed in this paper, up to the first ten years of the next century, the protective construction against disasters still cannot meet the planned targets. Nevertheless, if two measures are to be adopted, great improvement of the things will be made. One thing is to build subways. Considering the fact that part of the area will be

used as protection against the disasters, up to the year 2010, the total rate of admission will arrive at 92 per cent, the distance away from the planned rate of admission being greatly reduced. The other thing is to control the urban population. If effective control can be exercised over population, and its growth rate is kept at zero after 2000, then, up to 2010, the rate of admission of underground space will get to 92 per cent, the result being almost the same as building of subways. If the above–mentioned two measures are practised simultaneously, then, up to 2006, it is possible to meet the planned target of providing shelter to 100 per cent of the population. At that time, it can be said that the preset scale will have been fulfilled from the angle of the rate of admission.

By 2000, the income due to the usage of underground space will make considerable increase compared with the present one; and the economic benefit per unit investment can be doubled. By 2010, the income of usage fees and the internal income of the departments will be approximately as much as 5 times the present figure.

Up to 2000, the proportion of the internal income of the system will reach about 60 per cent of the total fund from the external sources; and up to 2009, a balance will be strikken between the internal and external funds; up to 2010, the internal fund will be in excess of the fund from the external sources. This demonstrates that, in the first ten years of the next century, a fundamental change will take place in the development of underground space and the protective construction against disasters; even if the fund from the external sources is reduced, the internal part of the system will still be able to maintain a certain rate of growth.

5.2 Tendency of Development Following the Adjustment of the Main Parameters of Planning within the System

If the proportion of the developmental fund is lowered, various targets will also be lowered likewise; if emphasis is laid on the construction of Type B space before 2000, the rate of admission and economic benefit will be markedly raised; but the rate of association can only be kept at the present level. If emphasis is laid on the construction of Type B space before 2000 and on the construction of Type A space after 2000, the rate of association will be raised by a big margin, which exerts no influence on the target of economic benefit for the end of the present century; but the long–term target of economic benefit will be loowered.

5.3 Tendency of Development with the Variation of the Main External Conditions

Considering the fact that the general tendency with the random variation within a certain interval is more or less the same as the scheme of maintaining the status quo, if the external fund raising can be increased in a certain degree, it is possible to get nearer to the planned target of construction up to 2010; even if the external fund will be gradually reduced, certain growth rate will be maintained with the support of the internal potentialities of the system. There is no doubt that the time period for the realization of the planned targets will be somewhat prolonged.

5.4 Related Suggestions

A multiple of policies and measures are to be adopted so as to strive for the realization of the target for the protective construction against disasters. Such policiies and measures include the strengthening of the internal vitality, the making of efforts for the

improvement of the external conditions, the control of the urban population, the construction of subways, the adjustment of policies towards sheltering, etc. As for the adoption of higher proportion of the developmental fund, for the present, the proportion can be fixed at 90 per cent and later on be gradually raised to 95 per cent. Before 2000, the investment for Type B space with high proportion shall be maintained so as to enable the departments to gain relatively solid financial basis and to shift the emphasis on the development of Type A space in a certain, suitably later period; it is also possible to consider the floating of the prices of usage fees for underground space in accordance with the actual conditions. Efforts shall be made to avoid the reduction of the available sources of external fund; and combination with municipal construction shall be insisted upon so as to absorb the investment for municipal construction. The urban population is to be controlled and urban subways to be developed. In addition, in combination with the actual conditions of various cities, an in–depth, all–round study shall be carried out with relation to the objects, scale and scope of sheltering for protection against disasters so as to set out different sheltering policies for different requirements.