THE AUTOMATIC LAYOUT MODEL IN THE SEQUENCING OF CONSTRUCTION ACTIVITIES OF MULTI-OBJECTIVE DIAPHRAGM WALL UNIT BY USING SELF-LEARNING NEURAL NETWORK

Ping-Tsang Yang

Instructor, Department of Civil Engineering, Cheng Shiu Institute of Technology
President, Construction Science & Technology Center

Shu-Ling Lu

Master, Department of Construction Engineering National Taiwan University of Science and Technology
Engineer, Taiwan Real-Estate Management Group.

Abstract: Foundation construction process has been an important key point in a successful construction engineering. The frequency of using diaphragm wall construction method among many deep excavation construction methods in Taiwan is the highest in the world. The traditional view of managing diaphragm wall unit in the sequencing of construction activities is to establish each phase of the sequencing of construction activities by heuristics. However, it conflicts final phase of engineering construction with unit construction and effects planning construction time. In order to avoid this kind of situation, we use management of science in the study of diaphragm wall unit construction to formulate multi-objective combinational optimization problem. Because the characteristic (belong to NP-Complete problem) of problem mathematic model is multi-objective and combining explosive, it is advised that using the 2-type Self-Learning Neural Network (SLNN) to solve the N=12, 24, 36 of diaphragm wall unit in the sequencing of construction activities program problem. In order to compare the liability of the results, this study will use random researching method in comparison with the SLNN. It is found that the testing result of SLNN is superior to random researching method in whether solution-quality or solving-efficiency.

Keywords: Diaphragm wall, Layout problem, Optimal combination, Artificial Neural Network, Self-Learning Neural Network

1.INTRODUCTION

In 1954, European Countries started to implement the diaphragm wall method in surrounding wall of the basement of the mansions. This is the beginning of using diaphragm wall method in the foundation engineering. In 1960, America and Canada also followed the way to use this method in the building. During 1950 to 1960, the development of diaphragm wall advanced fast and outstanding. Moreover, University of Galawa in Germany and ICOS Company in Italy cooperated to establish a first experimental diaphragm wall and this is a milestone in the research of engineering philosophy. In Taiwan, RSEA Engineering Corporation firstly uses this method in the building construction, harbor construction, defiled water filtered plant construction and etc. After that, importantly domestic building construction and high building mostly implemented this method in their building block. Until now, the frequency of using diaphragm wall construction method among many deep excavation construction methods in Taiwan is the highest in the world. The application of diaphragm wall construction method is particular relevant to Taiwan's fundamental construction engineering.

The diaphragm wall construction, only the guide wall is one time construction and the others are element construction of diaphragm wall construction unit. Element construction of diaphragm wall construction unit is a continual recycled work that includes caged reinforcement construction, element unit digging, caged reinforcement hanging and concrete placement. This is regarded as a repeated scheduling problem. The traditional plan of managing diaphragm wall unit in sequential construction activities is to establish each phase of construction activities by heuristics. Poor arrangement may lead the sequential construction unit inter-conflict in the final phase of the construction and delay the construction time. This kind of situation mostly happens in some delayed projects and multi-machinery construction projects. The other main reason for conflicting construction sequence is that the machinery for the diaphragm wall construction may out of work or leaking cement and then makes construction sequence of diaphragm wall unit distorted. The latter is much harder to deal than former. Because of the limited resources, it has to rearrange resources into the construction that cannot follow by the common experience and standard procedures. Million-worthy construction may delay or necessitate much more input to continue the construction because of the poor sequential construction arrangement and unexpected factors that delay the construction time. It is why that establishing computer assisted system to properly arrange sequential diaphragm wall construction unit to proceed the construction is inevitable. Recently, the papers about construction scheduling of diaphragm wall unit are as follows: Handa[1] used Selinger's[2] scheduling theory and integer programming to discuss the two-dimensional problem of buffering time between units in 1986; Rusell[3] applied dynamic programming to discuss delayed time of proceeding unit and next unit in 1988; Moselhi[4] combined Rusell's dynamic planning model and cost concept to discuss the influence of construction cost in 1993; Kao[5] assumed that the relationship of units are sequential and took the relationship of cost and construction period into consideration to offer a new sequential assigned scheduling method in 1994; Ting[6] followed Law and Kelton's procedure, considered Next-event Algorithm, Backward Pass Algorithm, and combined Statistic rate technique to develop simulated scheduling technique of Discrete-event diaphragm wall.

The related problem of diaphragm wall only takes the relationship of constructing unit and neighboring unit into consideration. In practical situation, the practical application is limited in the practical constructing and machinery (quantity and size). It makes the relationship of construction unit and next one more complicated, i.e. limited assumptions include machine tool quantity, constraint of machinery, sequential diaphragm unit construction, construction scope of machine tool in implemented limit in entrance and exit and etc. That's why Yang[7] proposed Sequential assignment problem of Construction Activities of Diaphragm Wall Unit by single machinery. This study will formulate the combinatorial optimization mathematical model in aspect of scientific management. The objective of this model not only concerns normal fundamental construction time but also transfers soft penalty time from construction conflict of inappropriate arrangement to make the shortest construction of diaphragm wall; the problematic constrains is the relationship between unit and equipment is one to one. The characteristic is combining explosive and it is not suitable for using traditional mathematical analysis to solve (for example: if n=36, combining ration is 36!). This study will use self-learning neural network to solve the optimal sequential diaphragm wall unit construction. The results prove that using this method to solve the problem works pretty well. Although the procedures that mentioned above make the assigned problem of diaphragm wall unit construction more closely matches practical situation, Yang transfers some restricted terms into soft penalty and proves the legal resolution. However, the decisive process of single-objective sometimes cannot respond the decision-maker's requirement. That's why multi-objective problem of diaphragm wall unit is worthy discussed. I will divide the paper into 4 parts. Firstly, I will clarify the multi-objective assigned problem of diaphragm wall unit. Secondly, I will introduce self-learning neural network method. Thirdly, I will use Artificial Neural Network method in application. Finally, I will compare the testing results with other method and give a conclusion and summary.

2. MUTTI-OBJECTIVE DIAPHRAGM WALL UNIT LAYOUT PROBLEM

The importance of Layout Problem of Multi-Objective Diaphragm Wall Unit and establishment of Problematic Mathematical Model are described as follows:

2.1 Layout Problem of Multi-Objective Diaphragm Wall Unit

In general, the practical decisive process is a serial of objective requirements. If it is dealt by a single-objective way, it is not convincing. For an individual, he always picks a decision among many practical ways to satisfy some specific objective. However, among these single-object decisions, it implied that it includes not only a desired decisive goal and these goals would conflict each other. The traditional decision-maker would concerns these weighted objectives by a general-objective concept or pick one to represent all. The generalization and single-objective would influence decision-maker's key information. Understanding multi-objective and taking many decisions into consideration is a way to help a decision-maker to find a one or some good substituted resolution. That's why multi-objective is better than single-objective.

The application of multi-objective, there are three advantages of using multi-objective planning as follows:

1. Participant plays an aggressive role during decisive process.
2. The scope of substituted case is large and substituted one is the same.
3. In order to accurately solve the problem while many objectives are concerned, it provides more complete analysis.

Two purposes of multi-objective assigned problem of diaphragm wall unit is searching the shortest construction time (basic constructing time of unit, delayed time of concrete unsetting, delayed time of caged reinforcement construction, violated time of exit and entry conflict) and the lowest conflicted index of all units (female and male unit conflicted index and machinery conflicted index); constraints concern single-machinery operation and the relationship of unit and machinery operation is one to one.

2.2 Establishment of Problematic Mathematical Model

The constraints and objectives of diaphragm wall mentioned below that clarify assigned establishment of problematic mathematical model.

Related symbols represent:

Z1 ： objective function. Seeking for the shortest sequential construction unit time of diaphragm wall （unit：hour）.

Z2：objective function. Search for the lowest conflicted index of unit construction (unit: index).

T1：basic construction time of unit.

T2~T4：penalty time of construction unit.

I1~I2：penalty time of construction unit.

$X_{i,j}$ ： decision variable, $X_{i,j} \in \{0,1\}$. If the sequence of unit *i* is *j*, then $X_{ij}=1$; else $X_{ij}=0$.

T_i： construction time of unit *i*. female construction unit is f_1 （unit ： hour）, male construction unit is f_2（unit：hour）.

Q： if male construction unit continuously implements over 3 units（include $X_{ij}=1$）, it would give f_3 penalty each unit.

R： the penalty time for neighboring unit implementing before concrete final set (It is necessary for 10 hours).

G_{in} ： construction unit position of exit and entry of construction-site.

G_{out} ： construction unit position of exit and entry of construction-site.

f_3： delayed time of male unit continuously implements 3 caged reinforcements（unit：hour）.

f_4： the penalty time for inter-conflict between exit and entry during construction（unit：hour）.

g_1：conflicted index of available scope of machinery's operation.

g_2 ： violating conflicted index for male and female unit's sequential operation.

n：unit number.

i：unit index. The odd number is male unit（*fi*）; the even number is female unit（*f2*）.

J,k2：the index of construction sequence.

k1：cycle index（1~n）.

2.2.1 Constraints

In the condition of normal diaphragm wall construction, the relationship between machinery and construction unit is one to one only. It is represented by the equation to express the relationship between construction unit and construction sequence (process of machinery operation). Because the relationship of machinery and unit is one to one only, the equation (1) and (2) is tough constraint.

$$\sum_{i=1}^{n} X_{ij} = 1 \quad , j=1\sim n \qquad (1)$$

$$\sum_{j=1}^{n} X_{ij} = 1 \quad , i=1\sim n \qquad (2)$$

2.2.2 Objective Foundation 1

$$Min \quad Z1 = T1+T2+T3+T4 \qquad (3)$$

Objective Z1's components are 4 time-related factors that described as below:

Factor1: if there is no conflicted construction occurred during the process of diaphragm wall construction, the fundamental time is the construction time of female and male operation time (construction time of female unit is longer than male unit). The equation can be given as follows:

$$T1 = T_i \cdot X_{i,j} \qquad (4)$$

Factor2: because digging time of general female unit is longer than caged reinforcement construction, it won't affect construction time of female unit; digging time of male unit is shorter than caged reinforcement construction, so continual constructing male unit would delay caged reinforcement construction. Therefore, the penalty time equation of soft constraint can be given as follows:

$$T2 = f_3 \cdot X_{i,j} \cdot Q \ , \ i \ mod \ 2=0 \qquad (5)$$

Factor3: before concrete setting, it cannot disturb neighboring unit or it would cause cement leaking or influence hardness. It is represented by time equation of soft limited penalty.

$$T3 = X_{i,j} \cdot R \qquad (6)$$

Factor4: in general condition, there are exit and entry of construction site. There is only single-machinery layout concerned. In practical, the single machinery concerns two aspects (digging and placing); the sequential constructions cannot be operating at the same time. It is represented by time equation of soft limited penalty.

$$T4 = f_4 \left(X_{Gin\ ,j} \cdot X_{Gout\ j+1} + X_{Gout\ ,j} \cdot X_{Gin\ ,j+1} \right) \quad (7)$$

2.2.3 Objective Foundation 2

$$Min \quad Z2 = I1 + I2 \quad (8)$$

Objective Z2 is combined by related two conflicted factors that are described separately as follows:

Factor1: because a of digger and a agitator truck occupy a large space during the process of diaphragm wall construction, the neighboring unit of operating unit cannot be a next operating unit to prevent inter-conflict among machinery operation. If it is represented by penalty time, it is sometimes hard to get an accurate time. Here, it is represented by the equation of soft-conflict index.

$$I1 = g_1 \cdot \left(X_{i,j} \cdot \sum_{k1=-2}^{2} X_{i+k1,j+1} \right) \quad , k1 \neq 0 \quad (9)$$

Factor2: the sequential principle of diaphragm wall is female unit is prior to male unit or it would lead an appropriate layout. It is not proper to represent by penalty time. Here, it is represented by the soft conflicted index formulation.

$$I2 = g_2 \cdot \left(2 - \sum_{k1=-1}^{1} \sum_{k2=1}^{j-1} X_{i+k1,k2} \right) \quad ,k1 \neq 0, i \ mod\ 2=0 \quad (10)$$

The problem that mentioned above limits the relationship of machinery and unit is one to one. That's increases the possibility of combining explosion according the scope of problem. In addition, problematic objective is multi-objective; the efficiency of calculated tool would seriously effect the solution-quality. It is advised that using 2-type self-learning neural network to solve multi-objective assigned problem of diaphragm wall construction.

3.THE APPLICATION OF ARTIFICIAL NEURAL NETWORK MODEL

Self-Learning Neural Network is a method that combining many simple neural units into complicated calculated network. It is the calculated method that simulating thinking process of human. At present, the application of Artificial Neural Network could divided into 4 types: Supervised learning network, Unsupervised learning network, Associate learning network, and optimization application network. Among those, optimization application network mostly used to solve combinatorial optimization problem [8]. Hopfield and Tank[9] are the first on to use Artificial Neural Network to solve combinatorial optimization problem. They proposed Hopfield-Tank neural network to efficiently solve TSP problem. That is a beginning of application of solving combinatorial optimization problem by using Artificial Neural Network.

P. T. Yang proposes Self Learning Neural Network in 1997 and it is extend by modified YT-network algorithm [10] that is a 2-phase optimal network model and mostly used to solve the optimal problem with constraint satisfaction. The network will be identified into 3 types that is 2-byte type, integral type or mixed type according to the type of problem [10~15]. Because decisive variable of assigned problematic mathematics model in multi-objective diaphragm wall construction is binary (0,1), currently relevant researches prove that 2-type self-learning neural network would solve the single and multi-objective problem [10]. This multi-objective problem in this paper would apply to -type self-learning neural network. Conditioned variable of neural unit is represented by 2-dimension matrix. Each decisive variable of matrix represents a neural unit. Each neural unit has its conditioned variable and energy quantity (While the energy of neural unit is bigger than 0, neural unit is in active condition; otherwise, it is in inactive condition). The next will introduce the establishment of energy active equation and algorithmic procedure of using self-learning neural network in solving the problem.

3.1 The establishment of energy active equation

The two requirements for establishing the energy active equation for the sequential arrangement problem of diaphragm wall construction unit by using self-learning neural network are as follows:

(1)Objective function: seeking for the shortest construction time of each unit.

(2)Constraint: individually search for the shortest operation time and the lowest conflicted-unit index.

Energy active equation of problem：

$$E1_{i,j} = \square \quad [(1 - \sum_{x=1}^{n} V_{ix}) + (1 - \sum_{x=1}^{n} V_{xj})] \quad (11)$$

$$E2_{i,j} = \square \quad (1 - T_i^*) \quad (12)$$

$$E3_{i,j} = \begin{cases} -\gamma & \text{if } V_{i,j}=1 \text{ and } S2=1 \text{ and } i \ mod\ 2=0 \\ 0 & \text{if } V_{i,j}=1 \text{ and } S2=0 \text{ and } i \ mod\ 2=0 \end{cases} \quad (13)$$

$$E4_{i,j} = \begin{cases} -\lambda & \text{if } S4=1 \\ 0 & \text{if } S4=0 \end{cases} \quad (14)$$

$$E5_{i,j} = \square \quad (V_{Gin\ ,j} V_{Gout\ j+1} + V_{Gout\ ,j} V_{Gin\ ,j+1}) \quad (15)$$

$$\begin{cases} -\varphi , & \text{if } V_{i,j}=1 \text{ and } S3=1 \end{cases}$$

$E6_{i,j} =$ (16)

0 , if $V_{i,j}=1$ and $S3=0$

$$E7_{i,j} = \begin{cases} -\Psi, & \text{if } V_{i,j}=1 \text{ and } S1=1 \text{ and } i \bmod 2=0 \\ 0, & \text{if } V_{i,j}=1 \text{ and } S1=0 \text{ and } i \bmod 2=0 \end{cases} \quad (17)$$

α : Parameter. Learning process α_L, Recalling process α_R.

β : Parameter. Learning process β_L, Recalling process β_R.

γ : Parameter. Learning process γ_L, Recalling process γ_R.

λ : Parameter. Learning process λ_L, Recalling process λ_R.

δ : Parameter. Learning process δ_L, Recalling process δ_R.

φ : Parameter. Learning process φ_L, Recalling process φ_R.

Ψ : Parameter. Learning process Ψ_L, Recalling process Ψ_R.

S1 : if male construction unit implements before neighboring female construction unit, then $S1=1$; else $S1=0$.

S2 : if male construction unit continuously implements over 3 units, then $S2=1$; elseS2=0.

S3 : if next construction unit appears in the scope of each 2 neighboring construction units of constructing unit, then S3=1; else S3=0.

S4 : if implementing construction unit is before concrete final setting, then S4=1;else S4=0.

$V_{i,j}$: Neuron state variable.

T_i^* : T of Normalization (0.0~1.0) .

The energy active equation E is the sum of above E1, E2, E3, E4, E5, E6 and E7. Energy active equation E1 is referenced to the equation (1) (2); E2 is referenced to the equation (4); E3 is referenced to the equation (5); E4 is referenced to the equation (6), E5 is referenced to the equation (7); E6 is referenced to the equation (9) and E7 is referenced to the equation (10).

3.2 Network algorithm process

step 1.0 : Establish fundamental data

step 1.1 : Set *V*(neuron state variable matrix), *U*(neuron energy matrix)

step 1.2 : Set parameter G_{in} 、G_{out} 、f_1 、f_2 、f_3 、f_4 、g_1 、g_2

step 1.3 : Normalize *T to T**

step 2.0 : Learning process

step 2.1 : Set learning process parameter

Set parameter α_L, β_L, γ_L, δ_L, φ_L, Ψ_L, T_L(learning iteration number), U_{Lmax}(learning process neuron energy upper bound), U_{Lmin}(learning process neuron energy lower bound), U_{bound}(neuron energy bound)

step 2.2 : Calculate neuron energy

Set *V*, *U* for zero matrix, *t=0*

do until $t=T_L$

$t=t+1$ ($i=1\sim n, j=1\sim n$)

if $U_{xi}(t-1)\neq U_{bound}$ *then* $U_{ij}(t)=U_{ij}(t-1)+E_{ij}$

if $U_{ij}(t)>0$ *then* $V_{ij}(t)=1$ *else* $V_{ij}(t)=0$

if $U_{ij}(t)>U_{Lmax}$ *then* $U_{ij}(t)=U_{Lmax}$

if $U_{ij}(t)<U_{Lmin}$ *then* $U_{ji}(t)=U_{bound}$

loop

step 3.0 : Recalling process

step 3.1 : Set recalling process parameter

Set parameter α_R, β_R, γ_R, δ_R, φ_R, Ψ_R, T_R(recalling iteration number), U_{Rmax}(recalling process neuron energy upper bound), U_{Rmin}(recalling process neuron energy lower bound)

step 3.2 : Compression neuron energy

if $U_{ij}(t)\neq U_{bound}$ *then* ($i=1\sim n, j=1\sim n$)

if $U_{ij}(t)>0$ *then* $U_{ij}(t)=U_{ij}(t)\cdot(U_{Rmax}/U_{Lmax})$

if $U_{ij}(t)<0$ *then* $U_{ij}(t)=U_{ij}(t)\cdot(U_{Rmin}/U_{Lmin})$

end if

step 3.3 : Run recalling process

t=0

do until $t=T_R$

$t=t+1$ ($i=1\sim n, j=1\sim n$)

if $U_{ij}(t-1)\neq U_{bound}$ *then* $U_{ij}(t)=U_{ij}(t-1)+E_{ij}$

if $U_{ij}(t)>0$ *then* $V_{ij}(t)=1$ *else* $V_{ij}(t)=0$

if $U_{ij}(t)>U_{Rmax}$ *then* $U_{ij}(t)=U_{Rmax}$

if $U_{ij}(t)<U_{Rmin}$ *then* $U_{ij}(t)=U_{Rmin}$

It is judged as a legal solution.

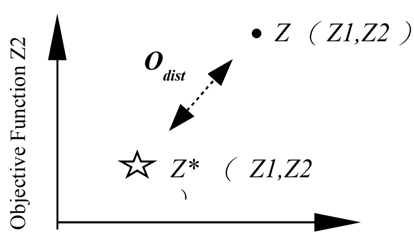
Save solving

loop

step 4.0 : End. Output optimal solving.

4. TESTED RESULTS AND COMPARE WITH OTHER METHOD

Because the problematic mathematics model is an optimal the optimal problem and the characteristic are combining explosive, the extent of the problem may influence the solution-quality. This study will discuss the sequential arrangement of multi-objective diaphragm wall construction of 12, 24, and 36 unit problem and using SLNN to solve the problem. In order to understand its superiority, this study will compare three-type problem with 10,000 random-searching solution to test the reliability of solution-quality and time-efficiency. The test results are displayed in table 1 and that is tested on the basis of Pentium 350MHz processor. In the aspect of evaluating multi-objective solution. It is represented by Eucliding Metric Distance (Eucliding Metric Distance : O_{dist}) . It is given as Figure 1 and equation (18) .



Objective Function Z1

Fig. 1 Eucliding Metric Distance

$$O_{dist} = \sqrt{(Z1^{*}-Z1)^{2}+(Z2^{*}-Z2)^{2}} \qquad (18)$$

Meanwhile：

*Z1*and Z2* are the optimal solution of each objective theory. Z1and Z2 are the optimal solution of theory.* ; more small of O_{dist} , more closer optimal solution is. Because the practice is limited in the inter-objective conflict, the O_{dis} could not be a 0.

Fundamental data of related problem define G_{in}=2, G_{out}=7, f_1=3, f_2=2, f_3=2, f_4=5, g_1=10 and g_2 =10. Followed the terms that mentioned above, the smallest theory of O_{dist} of 12,24 and 36 is 0. (It is assumed T1= $(f_1+f_2)*n/2$, *T2, T3 and T4 penalty time is 0; index of I1 and I2 is 0).*

Basic parameter set of SLNN:
Basic parameter set of 12 units:
T_L = 100, T_R = 300, α_L = 1.0, α_R = 1.0, β_L = 0.5, β_R = 0.02, γ_L = 0.2, γ_R = 0.01, λ_L = 0.5, λ_R = 0.01, φ_L = 1.0, φ_R = 0.02, δ_L = 0.5, δ_R = 0.01, Ψ_L = 1.0, Ψ_R = 0.2, U_{Lmax} = 10, U_{Lmin} = -10, U_{Rmax} = 10, U_{Rmin}=-10, U_{bound}=-100

Basic parameter set of 24 units:
T_L = 150, T_R = 300, α_L = 1.0, α_R = 1.0, β_L = 0.5, β_R = 0.02, γ_L = 0.2, γ_R = 0.01, λ_L = 0.5, λ_R = 0.01, φ_L = 1.0, φ_R = 0.02, δ_L = 0.5, δ_R = 0.01, Ψ_L = 1.0, Ψ_R = 0.2, U_{Lmax} = 10, U_{Lmin} = -10, U_{Rmax} = 10, U_{Rmin}=-10, U_{bound}=-100

Basic parameter set of 36 units:
T_L = 200, T_R = 300, α_L = 1.0, α_R = 1.0, β_L = 0.5, β_R = 0.02, γ_L = 0.2, γ_R = 0.01, λ_L = 0.5, λ_R = 0.01, φ_L = 1.0, φ_R = 0.02, δ_L = 0.5, δ_R = 0.01, Ψ_L = 1.0, Ψ_R = 0.2, U_{Lmax} = 10, U_{Lmin} = -10, U_{Rmax} = 10, U_{Rmin}=-10, U_{bound}=-100

Different five-parameter combination is tested to proceed problematic simulation by self-learning neural network under basic parameter (only adjusted parameter. $T_{L)}$). The results show that the absorptive percentage of self-learning neural network is 100%. From the figure 1, O_{dist} and standard deviation of random search's solution increases according to the problematic scope. If the solution of random searching and SLNN are 0 and comparison the solution in 3 degree are made, it is found that their error would decrease to 36.6%, 72.2% and 91.3%. There is a tendency to largely increase by the problematic scope; the miss of standard deviation improves 36.6%, 72.2% and 91.3%. The two indexes that mentioned above prove that SLNN is more efficient in the multi-objective assigned problem of diaphragm wall construction.

Tab 1 Case simulation result and balance

Unit	Solving Balance	Ran. Sol. Z1 (hr)	Ran. Sol. Z2 (Index)	Ran. Sol. *Odist*	SLNN Z1 (hr)	SLNN Z2 (Index)	SLNN *Odist*
12	Sol. No.	10,000			494		
	Max	123	190	205.0	71	80	89.9
	Mean	77.4	100.4	111.9	56.8	33.2	44.2
	Min	38	10	25.1	47	0	19.0
	s. d.	12.4	28.2	27.3	6.4	19.7	17.3
	Time	215 seconds			174 seconds		
24	Sol. No.	10,000			388		
	Max	174	300	305.0	83	50	51.0
	Mean	110.6	159.9	168.5	75.5	22.7	29.2
	Min	62	30	35.5	70	0	15.6
	s. d.	15.8	36.7	36.3	4.0	13.6	10.1
	Time	483 seconds			600 seconds		
36	Sol. No.	10,000			191		
	Max	214	410	414.4	129	80	84.4
	Mean	142.9	219.7	226.7	113.6	32.6	40.8
	Min	91	70	81.1	110	20	29.7
	s. d.	16.9	43.7	143.4	4.3	13.7	12.5
	Time	893 seconds			1674 seconds		

Because multi-objective assigned problem is limited by the effect of inter-conflicts between objectives, an ideal solution does not exist. General evaluation of each objective uses Eucliding Metric Distance. Because Eucliding Metric Distance is non unit-value, scope of objective is a key pint to the results in appraising best compromising solution. For example the area index of objective Z2 is larger, the solution-quality is seriously influenced by the Z2. It is showed form Figure 2 to 4.

CONCLUSIONS

1. This paper would formulate the assigned problem of multi-objective diaphragm wall construction into the combinatorial optimization problem. It proves that scientific management could apply in this field under efficiently established related problematic requirements. However, it is necessary for further practical application.
2. It is proved that self-learning neural network could solve assigned problem of multi-objective diaphragm wall construction just like solve sequential assigned problem of multi-objective diaphragm wall

construction unit activities.
3. In order to simplify the complexity of problem, it only takes a set of machinery into consideration. However, the practical application is limited by construction period and the multi-machinery assigned problem is worthy to be discussed due to higher problematic complexity.
4. Although the solution-quality of using SLNN performs well, the disadvantage is longer calculated time. In the future, it is advised to use SLNN and neighboring searching algorithm to decrease the number of recalling references' definition and shorten processing time of network.

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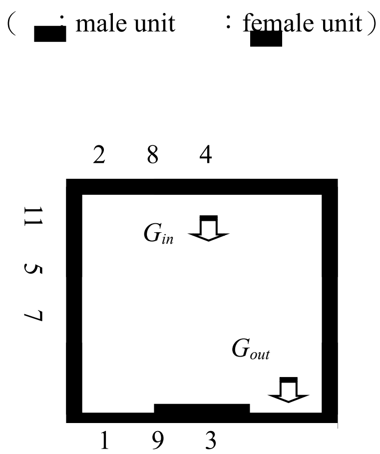
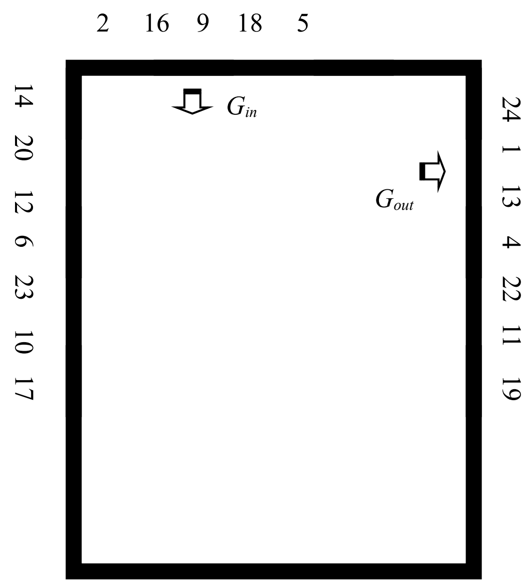


Fig. 2 One of 12 Unit of scheduling solving
(O_{dist} : 19.0)



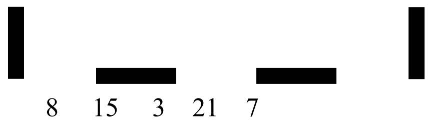


Fig. 3 One of 24 Unit of scheduling solving
（O_{dist}：15.6）

10 6 12

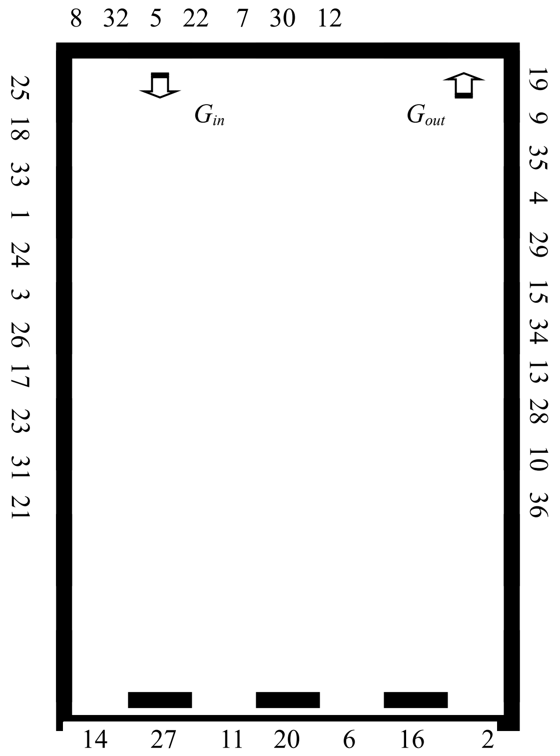


Fig. 4 One of 36 Unit of scheduling solving
（O_{dist}：29.7）