Computer-Aided Planning in Construction
Survey and Analysis of Group Planning Procedures

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Abstract

This paper discusses a survey on construction planning conducted in an attempt to establish a computer-aided support system and identify the newly established system's structure and method for construction planning and scheduling. After videotaping four engineers developing a given construction plan through group discussion, the minutes of the discussions was prepared for analysis. Based on the results of the analysis, the authors discussed the contents and methods of computer-aided support for the development of a construction plan by a group.

1.Introduction

This paper discusses a survey on construction planning conducted in an attempt to establish a computer-aided support system and identify the newly established system's structure and method.

In the previous paper[1)], which described the survey and analysis of a planning procedure carried out by one engineer, the authors identified the procedure, method, and characteristics of the planning.

In this paper, the authors present a survey and analysis of a planning procedure carried out by more than one engineer in order to identify the characteristics of the procedure and method for group planning. After videotaping four engineers developing a given construction plan through group discussion, the detail minutes of the discussions was prepared for analysis. Based on the results of the analysis, the authors discussed the contents and methods of computer-aided support for the development of a construction plan by a group.

2. Development of a construction plan by a group

2.1. Use of information and human resources in a group

Construction planning depends largely on the individual knowledge and experience of the engineers involved in the planning. For the following reasons, the information and human resources possessed by a company are usually not fully utilized in planning:

(1) Due to the great variance in building specifications and sites and environments for construction, it is difficult to establish a universal planning procedure and manuals.

(2)The methodology for making a plan in a group has not been established.

(3)The methodology for fully utilizing the information possessed by a company in the group planning

Although it is essential to effectively utilize the information and human resources belonging to an organization in order to make the optimum construction plan efficiently, practical construction planning depends more on the individual skills of the engineers than on the skills of the group. Therefore, even if a company has obtained from construction records useful information on the advantages and disadvantages of construction methods and details on the construction defects, etc., such information cannot be utilized fully at the construction planning phase. As a result, confusion and defects repeatedly occur in construction phase.

2.2. Highly advanced technology and specialization

As construction technology becomes highly-advanced and more complicated, specialized knowledge and information is required in construction planning. Particularly, in the case of rapid technological advancement, even an experienced engineer is unable to set aside enough time to assimilate all of the new development. Thus, in spite of his/her accumulated experience, it becomes more and more difficult for him or her to acquire a thorough knowledge in all phases. Since this makes it considerably difficult for one engineer to make a plan for all construction phases, specialists are required for the planning of each phase.

Although specialization in construction planning has the merit that each plan is made by the most appropriately specialized engineer, the following demerits can prevent a plan from turning out satisfactorily: firstly, a plan is likely to lack unity and consistency, and secondly, it becomes difficult to train engineers to make a well-balanced construction plan as specialization produces engineers whose knowledge are narrowed down into specific domain of construction phases.

Moreover, as an engineer who has not made a plan by himself or herself is in charge of construction management at the construction phase, the planner's intention cannot be reflected in the actual construction work. To deal with developments and complications in construction technology expected in the future, there is a need to establish a methodology for making a construction plan by engineers in a group rather than by an individual specialist. Moreover, there is a need to establish a methodology for supporting construction planning by a group.

2.3. Specialist-type and generalist-type group activities

There are two systems for group planning. In the first system, the "specialist-type", a construction plan is divided into specialized fields, and an individual specialized engineer is in charge of each aspect of planning. In the second system, the "generalist-type", engineers who are not rigidly specialized make a whole construction plan through group discussions.

In the first system, each part can be planned with advanced knowledge as the plan is made in accordance with each specialized field, but the interrelated parts are unlikely to be discussed comprehensively. In the second system, the overlapping of specialized fields makes it difficult to efficiently allocate human resources and to pass advanced judgment based on technical knowledge. Fig. 2.1 shows a general framework of specialized fields and skills of engineers involved in construction planning.

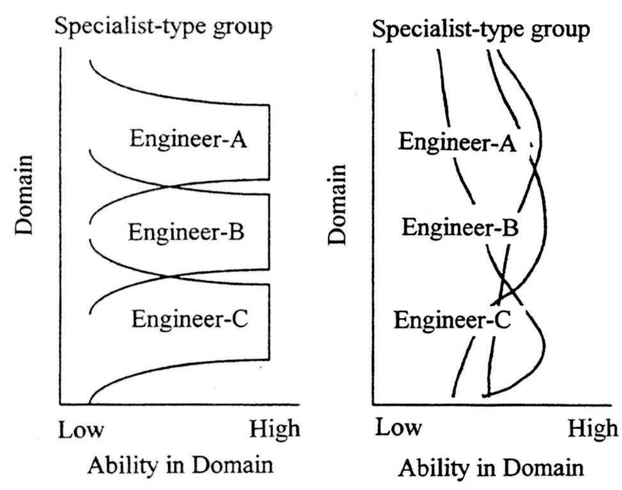


Fig. 2.1. Group Activity in construction planning

From this figure, the advantages and disadvantages can be identified as follows:

<Specialist-type group activities>

Advantages:

(1) Highly advanced, specialized decisions can be made.

(2)Specialized engineers can accumulate practical experiences in planning.

(3) Engineers can be utilized effectively, as specialized fields do not overlap each other.

Disadvantages:

(1) It is difficult to coordinate each specialized field.

(2) It is difficult to identify and point out problems and inappropriateness in the judgments of other specialized engineers.

(3) Comprehensive discussion is unlikely to be carried out as group discussion on planning is based on only the results of decision of each specialized field.

(4) A separate engineer is required to take charge of the arrangement of the whole construction plan.

<Generalist-type group activities>

Advantages:

(1) It is relatively easy to remark on plans made by other engineers.

(2) As all engineers participate in the discussion, the whole construction plan can be discussed from various viewpoints.

(3) Participants can promote creative activities by stimulating each other intellectually.

(4) An opportunity for educating young engineers is provided through planning (thus, OJT is expected to exert large effects).

Disadvantages:

(1) As participants' specialized fields overlap, allocation of human resources becomes inefficient.

(2) Each participant finds it difficult to make remarks reflecting specialized knowledge.

(3) Contents and levels of participants' remarks tend to have uniformity, and in some cases, group activities do not bring about any effect.

3. Survey and analysis on a plan made by a group

3.1. Objectives and methods of the survey

This survey sought to identify the process of construction planning and information exchange by recording and analyzing a group-planning process.

The remarks and activities were videotaped at each planning phase throughout the group-planning process, and a book of minutes, showing the contents of remarks and

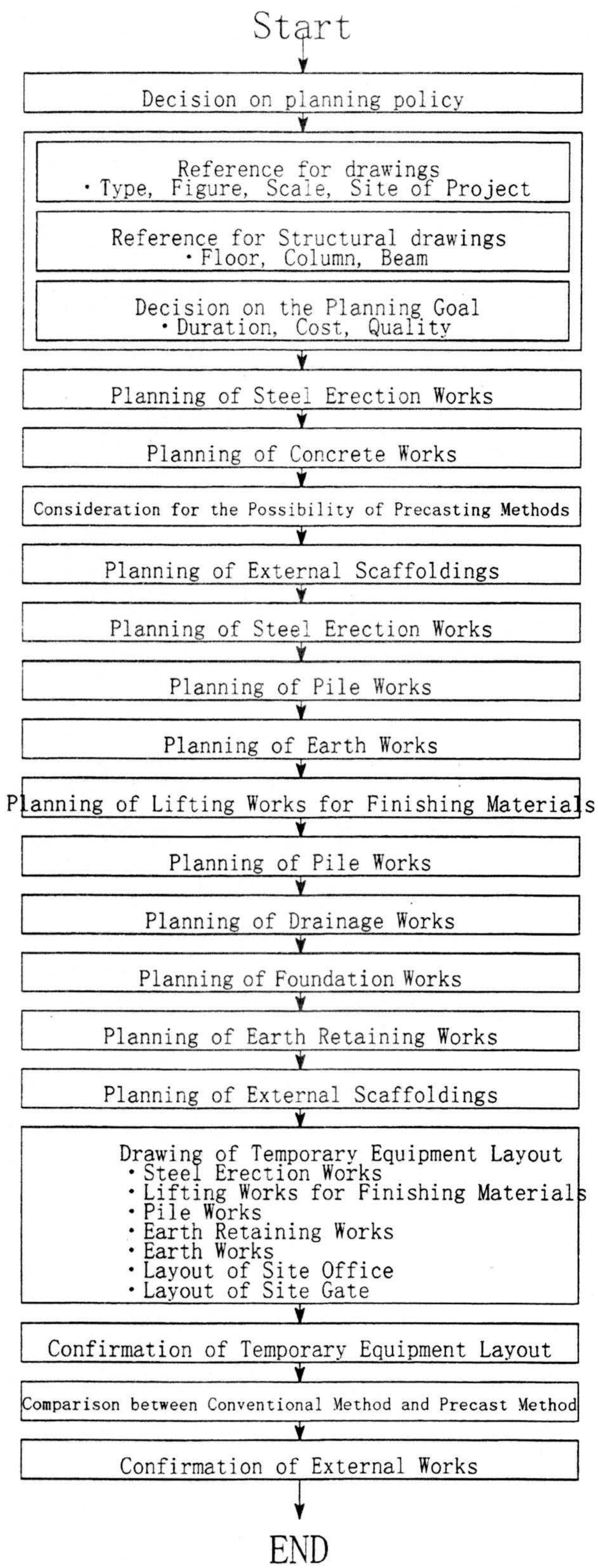


Fig. 3.1 General procedure of construction planning

start and finish times of the discussions was made based on the videotape. This survey did not include the minutes of one-day site investigation tour . This book was used as basic data for the analysis.

3.2. Construction Project and planners

3.2.1. Construction Project

In the present survey, the authors investigated the construction work for a four-story fumigation warehouse with a total floor area of about 10,000 m^2. The authors covered the construction planning and decision making for the preparation of the master schedule before the start of the construction phase, and observed and recorded the meetings held over two days from the start to finish of planning.

3.2.2. Engineers in charge of planning

Four engineers participated in this construction planning. Years of experience (on-site experience + office experience) for the respective engineers were 35 years(A), 27 years(B), 12 years(C), and 3 years(D). The engineer with 35 years of experience was designated as the construction chief manager at the site. The other engineers belonged to the engineering division of a branch office.

3.3. Results of the survey

3.3.1. Planning procedure

Fig. 3.1. shows the planning procedure observed in this construction planning. As shown in the figure, the planning process starts from detailed examination and consultation of the drawings by all participants. One of the engineers (the construction chief manager at the site) presented information to explain the planning and inform the other engineers on the scope of the construction project. Then, critical activities throughout the whole construction work were picked out, and a master plan for these activities was made. A plan for each sectional construction was made in accordance with the sequence of activities in the construction work. After the master schedule of construction was grasped, the contents of the proposed plan were discussed in further detail by adding more detailed contents and/or making corrections. Based on these results, drawings of temporary equipment and scaffoldings were prepared for the further discussion.

In planning by a group, a plan is made through discussion among engineers. Therefore, when one of the engineers points out the necessity of discussing a planning item which is likely to affect other planning items, the topic of discussion is often changed to one of the other planning items. Characteristically, the engineers engaged in group planning exchange information and stimulate each other while developing their own ideas. In the survey, the planning process and contents were changed dynamically and treated back and forth.

The observation clarified that the development of a detailed plan was rarely a direct process. In most cases, after deciding the contents of a plan schematically, contents of other related planning items were designed, and then the initial planning item was taken up again and designed in further detail. This shows that it is easier for engineers involved in the planning to share information when they decide the details of a plan.

3.3.2. Frequency of remarks made by engineers

Fig. 3.2 shows the frequency of remarks made by each engineer. On the first day of the survey, the frequency of remarks made by Engineer A was the highest, followed in sequence by Engineer B, Engineer C, and Engineer D. On the second day, when Engineer B did not attend the meeting, the frequency of remarks by Engineer A was again the highest, followed by Engineer C and Engineer D.

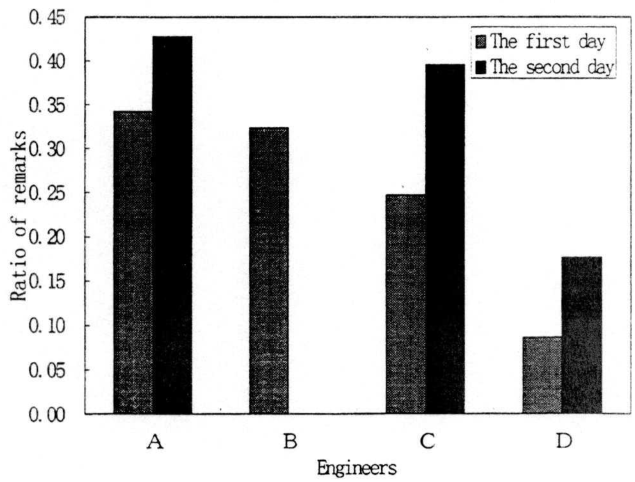


Fig. 3.2 Frequency of remarks made by each engineer

When comparing the first day and second day, the role of Engineer B on the first day was passed on to the other engineers during his absence on the second day. The frequency of remarks made by Engineer A on the second day was about 1.3 times higher than that on the first day, and the frequencies of remarks by C and D on the second day showed approximate increases of 1.6 and 1.9, respectively. Thus, the frequency of remarks made by these three engineers increased. Engineer B, who belonged to a branch office, was in charge of deciding the course of the meeting and leading it. On the second day, that role was passed on to Engineer C. The significant increase in the frequency of Engineer D's remarks on the second day was attributable to the effects of Engineers A and C to get the information on the planning results from the CAD drawings which Engineer E had prepared based on the meeting of the first day. In other words, the important role of Engineer A on the first day, that is, "to present required information," was passed on to Engineer D, who had worked based on that information.

Therefore, for group planning, in addition to an engineer to lead the whole meeting, there should be a requirement for an engineer who offers useful information by carrying out activities based on the results of earlier meetings.

3.4. Analysis of results of the survey

3.4.1. Analysis of items communicated by engineers at planning

The contents of remarks made by engineers at planning included the following three items: C (request for information) 23%, F (evaluation of information) 23%, and D (presentation of information) 21%. These three items accounted for 67% of all contents. This shows that in planning by a group, it is important to repeat the process of "request-presentation-evaluation" in order to work out a thorough plan based on the information possessed by the engineers. The time spent on creating the contents of a plan is relatively short. In group planning, rather than merely making a plan as a group, it is more productive to share useful information and improve a plan.

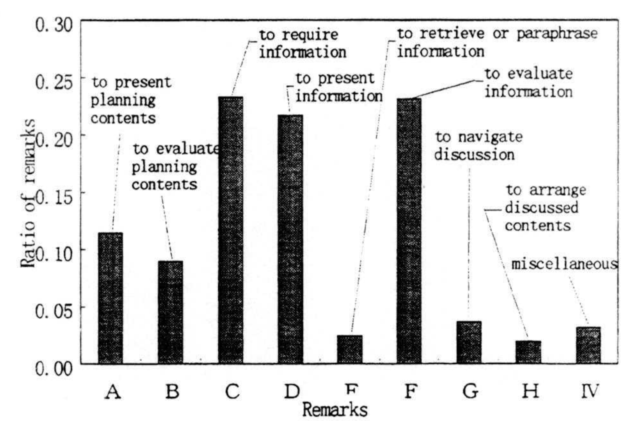


Fig. 3.3 Frequency of items communicated by engineers at planning

3.4.2. Analysis on items communicated by each engineer

a. Remarks made by Engineer A

The items remarked by each engineer are shown in Figs. 3.4.a, b, c, and d, respectively, in the order of frequency. The bars in the figures show the frequency of items communicated, while lines in the figures show cumulative values of the frequency of the items.

Fig. 3.4.a shows the frequency of items communicated by Engineer A. Compared to the other engineers, Engineer A more frequently remarked on item D1 (to present required information). Engineer A, as mentioned above, was a construction chief manager at the site. Therefore, he filled the role of presenting detailed information on the site which the other engineers did not have, as well as knowledge of construction acquired through his long experience as a chief manager at the site. Among the items communicated by engineer A, item F1 (to approve or adopt information) showed the highest frequency; however, the other engineers showed the highest frequency in this item as well. Information that is once sent out from an engineer is not left as it is; it becomes an item such as approval, denial, or confirmation. In this survey, items on approval/adoption were communicated more frequently than those on denial. Presumably, this was because the sender of information knew better than the receivers, so, in most cases, the others followed the opinion of the well-informed person. In addition, item A2 (to present a plan) showed high frequency for the following three reasons: (1) Engineers B, C, and D paid more attention to the opinions and policies of Engineer A, the construction chief manager at the site; (2) Engineer A was most familiar with the situation of the site; and, (3) Engineer A had a great stock of knowledge acquired from the past experiences. The figure shows that Engineer A has a superior ability in planning.

b. Remarks made by Engineer B

Fig. 3.4.b shows the frequency of items communicated by Engineer B. He communicated item C3 (to confirm the information acquired as it is or by paraphrasing) the most frequently. This shows that Engineer B confirmed information one by one, and presented appropriate problems in planning. In addition, the communications on item A1 (to present planning items and problems) and item A2 (to present a plan) also showed high frequency. This means that Engineer B effectively utilized acquired information, and appropriately pointed out problems in planning contents or planning items to be discussed. Compared to the other engineers in the branch office, Engineer B had a great deal of knowledge and experience as well as high planning ability. The figure shows that he made objective judgment or evaluation on a plan.

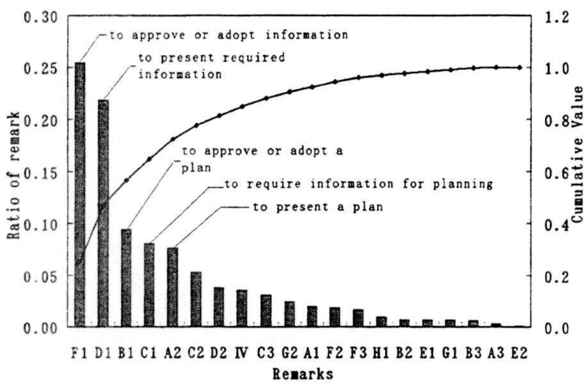


Fig. 3.4.a. Frequency and cumulative values of items remarked by Engineer A

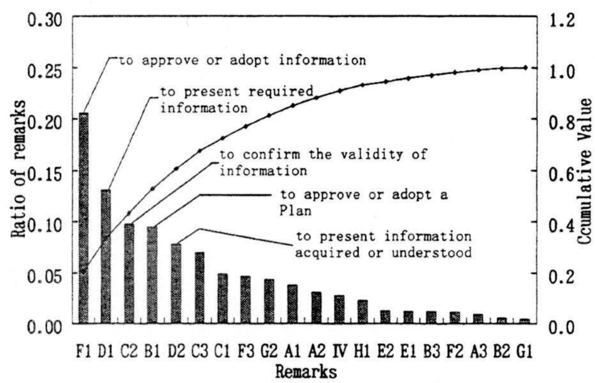


Fig. 3.4.c. Frequency and cumulative values of items remarked by Engineer C

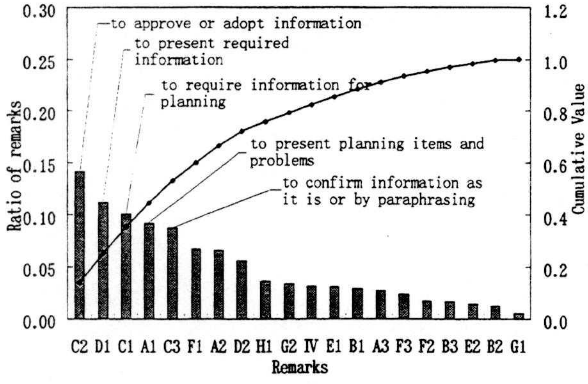


Fig. 3.4.b. Frequency and cumulative values of items remarked by Engineer B

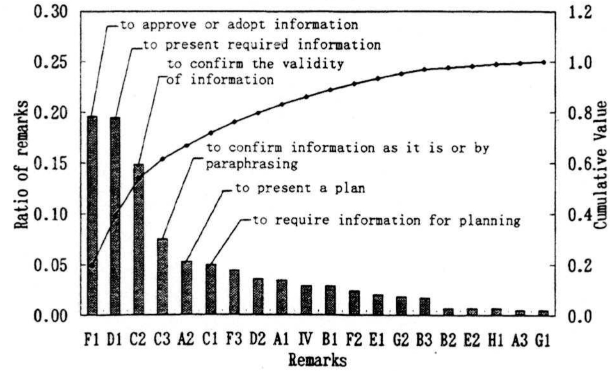


Fig. 3.4.d. Frequency and cumulative values of items remarked by Engineer D

Table.3.1 Matrix of chain in items communicated

(%)

Remarks (Before)	A1	A2	A3	B1	B2	B3	C1	C2	C3	D1	D2	E1	E2	F1	F2	F3	G1	G2	H1	IV
A1	7	9		38				6		9										
A2		9		46				6	10											
A3	8			48			8	8												
B1	17	15		19			5	8		7										
B2		9		15	15	9	11		7							7				
B3				27		10	12	9	9	12										
C1							17	8		50				7						
C2								6		13				51		6				
C3								7	9	13				42						
D1							10	11	8	17	17			17						
D2		5					8	10		31	8			12						
E1		8						7		15		5		41						
E2								20	24	7			11	16		7				
F1	7	7					7	16	9	15				15				5		
F2							9	11	5	20	7			18	13					
F3				8			8	10		13	8			22		8		5		
G1	13						6	10		10				16			19	10	6	
G2								8		12				37				18		
H1	8							10						49					11	
IV		8						8		19				6						32

Items G2 (to present a planning policy) and H1 (to arrange the discussed contents) were communicated by Engineer B with a relatively high frequency. This suggests that he was in a position to navigate the meeting.

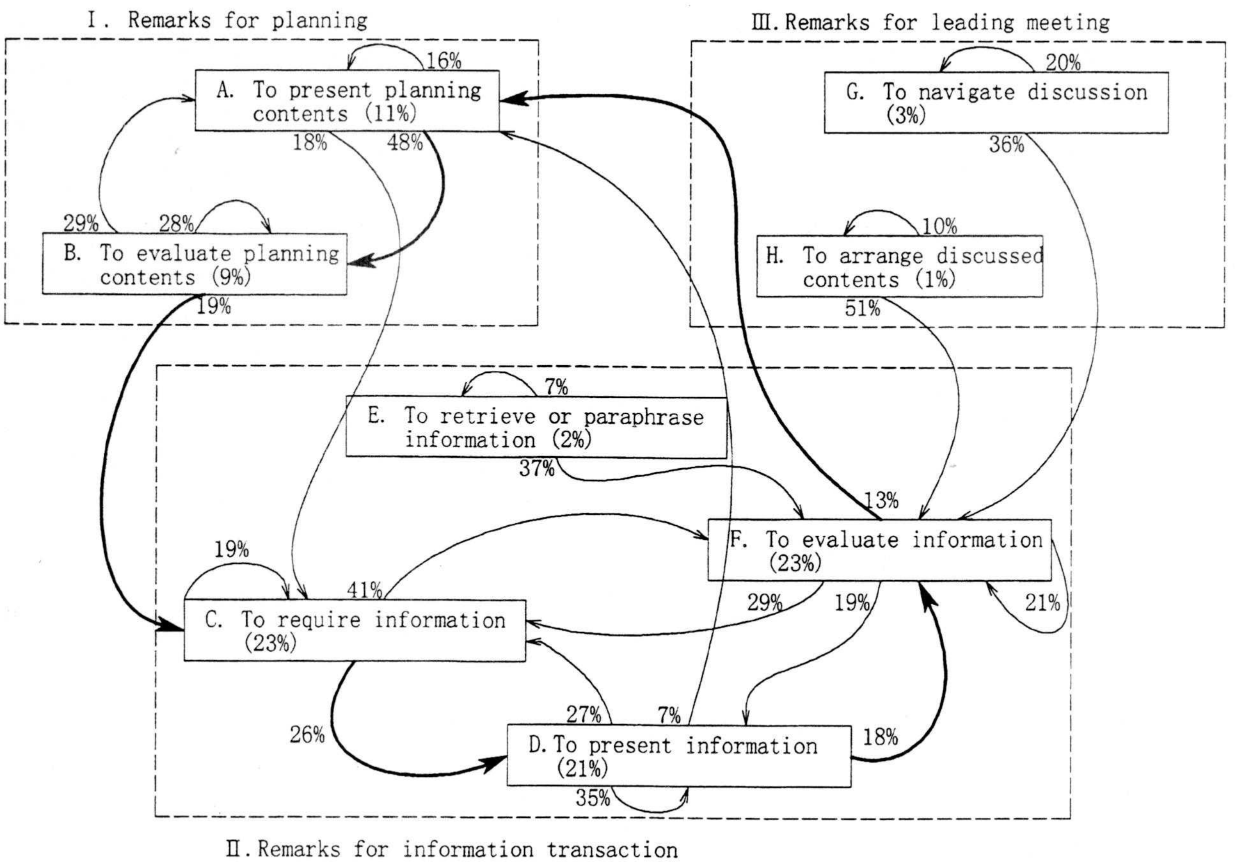
c. Remarks made by Engineer C

Fig. 3.4.c shows the frequency of items communicated by Engineer C. Item A2 (to present a plan) showed low frequency, while item B1 (to approve or adopt planning items and contents) showed high frequency. This means that the major role of Engineer C was to objectively evaluate the plans made by the other engineers, rather than making plans by himself. Remarks on item G1 (to present a planning policy) and item H1 (to arrange the discussed contents) showed relatively high frequencies, as Engineer C assumed the role of navigating the meeting on the second day due to Engineer B's absence.

d. Remarks made by Engineer D

Fig. 3.4.d shows the frequency of items communicated by Engineer D. Remarks on item D1 (to present required information) and item A2 (to present an plan) showed high frequency. Those communications were related to the CAD

drawings of temporary equipment and scaffoldings, the contents of which had been already decided and confirmed at the meeting. As Engineer D was somewhat less experienced than the others, he filled the role of examining the suggested contents using CAD. The figure shows that he presented the information that was obtained



note:Arrow(➡)depicts the main discussion route.

in the process of making the drawings.

3.4.3. Analysis of sequential relation in items communicated

In planning by a group, one remark induces another remarks, and those remark, in turn, induces others. In order to enhance efficiency in planning by a group, this chain must be carried out meaningfully and effectively. Table.3.1 shows the matrix of the chain of communications in planning, indicating the types of items that were communicated subsequent to specific types of communications. Strong sequences were observed in the relations between the following items: item C2 (to confirm the validity of information), as well as item H1 (to arrange the discussed contents) and item F1 (to approve or adopt the information); item C1 (to require information) and item D1 (to present the information); items A2 (to present a plan) and A3 (to present a plan and contents to be affected), and item B1 (to approve or adopt a plan).

Fig. 3.5 shows the analysis of chain flow of items communicated using the medium-level classification in Appendix. An arrow in the figure connecting each item shows the relation of items with strong sequence. A numerical value in a node shows the percentage of a particular item among all items communicated; while a numerical value beside an arrow shows the percentage of occurrence of other items after a particular item is communicated.

Each item is remarked through communication among engineers according to the chain flow of items shown in Fig. 3.5. The flow of items connected by an arrow in bold face shows a major flow chain cycled in planning, i.e., A (to suggest a planning content) -> B (to evaluate the planning content) -> C (to request information) -> D (to present the information) -> E (to evaluate the information) - A (to suggest a planning content) -> and so on.

4. Construction planning by a group

4.1. Structure of construction planning by a group

When making a construction plan as a group, all the participants should be allowed to suggest, point out, and evaluate the problems freely. It is also necessary to clearly identify which parts should be made through "specialist-type" activities and which parts should be made through "generalist-type" activities.

The participants in group planning must pay attention to the following points:

(1) Information sharing must be achieved effectively.
(2) Participants must make remarks in correspondence with their ability.
(3) Each participant must make remarks to induce intellectual ideas in the others.
(4) Each participant must make remarks that are different from the remarks of the others.
(5) Participants must make remarks to decide the course of discussion.

4.2. Roles of engineers in group activities

When making a construction plan as a group, it is necessary for each engineer to take a different role in order to establish an effective group in which the comprehensive abilities of the group will be achieved and ideas will be developed. If some of the engineers in a group engage in planning without any role, the quality of planning will not be improved even if many of the other engineers in the group play their roles. Therefore, in order to implement construction planning effectively, each participant must make every endeavor to play one of the following roles. Also, when making a group, suitable persons must be selected to fill these roles effectively.

(1) Suggesting the initial plan
(2) Offering related information
(3) Pointing out advantages and disadvantages of the suggestion
(4) Pointing out unclear points
(5) Suggesting different opinions if need be
(6) Agreeing or disagreeing
(7) Concluding the discussion
(8) Evaluating objectively
(9) Deciding whether the suggestion will be adopted or rejected
(10) Carrying out activities (e.g. drawing a plan) based on the discussion
(11) Recording the process of the discussion

5. Structural information on support system at planning by a group

Although various beneficial effects such as introduction of wide domain knowledge and activation of creativity are expected when making a plan as a group, there are many problems as well. The engineers involved in the group planning must spend a great deal of time sharing information and knowledge related to the plan. In cases where the necessary information is not available, the engineers cannot carry the discussion forward, and end up wasting time. Efficiency and promptness are required in the following parts of group activities:

(1) Sharing information among engineers
(2) Coordinating opinions among engineers
(3) Offering appropriate information
(4) Non-creative tasks based on the discussion

Computer-aided support for the above activities requires the establishment of the following three support systems:

(1) Group work support

Each type of information will be arranged and expressed in order to record the process of planning through discussion and to share appropriate information among engineers. In addition, an information communications method using computers will be established to enable engineers in distant places to participate in the discussion efficiently.

(2) Information retrieval support

Based on the database and knowledge-base, information that is required for discussion will be offered to engineers appropriately and promptly.

(3) Planning support

By carrying out simulation and what-if analysis on a plan suggested in the discussion, the plan will be evaluated and alternatives will be selected. In addition, based on the planning principle suggested in the discussion, the details will be arranged as feedback to the planners.

6. Conclusion

In this paper, the authors pointed out advantages in group planning and identified the methods and contents of support systems necessary for efficient planning based on the results of the survey. Computer-aided support, however, will have a tremendous impact on traditional structures and procedures of planning. The introduction of a computer-aided support system to construction planning phase entails not only replacing the handwork of the engineers with computers in the planning process, but also drastic changing the planning procedure itself. To conclude, in order to utilize information in a company effectively, support systems are required at the planning phase to facilitate the restructuring of planning organizations, establishment of an advanced planning procedures, and education of engineers on a Computer-Aided Planning procedure.

<Reference>

1)Naruo kano, et al: "Computer Aided Planning in Construction, Survey and Analysis of Construction Planning Procedures," Proc. of ISARC, 1995.06, pp365-374, IAARC

Appendix:

Table Classification of Remarks/Actions in planning

Ⅰ. Remarks /Actions for planning

A. Presentation of planning contents

1. to present planning items and problems
2. to present a plan
3. to present the items affected by a plan

B. Evaluation of planning contents

1. to approve or adopt a plan
2. to deny or reject a plan
3. to present an alternative plan

Ⅱ.Remarks /Actions for information transaction

C. Request for information

1. to require information for planning
2. to confirm the validity of information on hand
3.to confirm information as it is or by paraphrasing

D. Presentation of information

1. to present required information
2. to present information acquired or understood

E. Retrieval of information

1. to present the contents affected by information
2. to retrieve data and process the data

F. Evaluation of information

1.to approve or adopt information
2.to deny or reject information
3.to modify and supplement information

Ⅲ.Remarks /Actions for leading meeting

G. Navigation for discussion

1. to proceed with discussion
2. to present planning policy

H. Arrangement for discussion

1.to arrange discussed contents

Ⅳ. Miscellaneous