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Information Sharing and Decision Making in the Quality Control of a Tunnel Concrete Lining

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Abstract. Quality control is always required to meet the specified criteria of a tunnel project, such as in terms of safety and durability. However, practices in tunneling have indicated that underground construction projects are notorious quality controls, often as a result of inaccurate interpretation of related information and therefore incorrect predictions. The process of quality controls in tunneling can be improved, provided that the related conflicts can be easily identified and settled or prevented, with transparent information sharing on a project status and its boundary conditions. A case history of the cracking control of a loess tunnel concrete lining is presented, with special reference to the information sharing in the decision making under a specified contractual frame in China.

Introduction

It is well accepted that modern infrastructure projects are vital to a sustainable society. In the recent years, various large and complex underground infrastructures, such as tunnels in railway and road system, metro systems in urban areas, have been built in the world. To meet the requirements of safety and durability criteria, quality control is always necessary in a tunnel project. However, numerous practices in tunneling have indicated that tunnel and underground construction projects are notorious quality controls, often as a result of inaccurate interpretation of information and therefore incorrect predictions. This is mainly because that the practical situation of a tunnel project is often complicated in terms of project management and decision making.

In general, modern tunneling is a dynamic process [1]. During the tunneling of complicated tunnel project, the monitored behaviors of the surrounding rocks and supports, as well as their interactions, should be evaluated and compared with the predicted values, such as in terms of quality control. To meet the requirements of quality control, decision making should be timely and effective. In the decision making process, a few groups, including owner or its representatives, contractor, designer or its representative, consultants, are involved during the construction of a tunnel project. There are not only common interests but also conflicts among the groups. And therefore, the effective quality control in tunneling depends on the decision making of involved groups, provided that the related conflicts can be identified and settled or prevented, with transparent information on a project status and its boundary conditions [2]. In this contribution, the general features of group decision making in tunneling is briefly discussed and then, a case history of the cracking control of a loess tunnel concrete lining is the presented, with special reference to the information sharing in the decision making under a specified contractual frame in China.

General Features of Group Decision Making in Tunneling

During the construction of a tunnel, which is designed and to be built in a dynamic procedure, the real time data of tunneling operations is required for understanding the interaction between the supporting system, the ground and the tunnel structure in a specified procedure. As the volume of measurement

data is huge, useful information can only be obtained from monitoring data with proper filtering and a threshold-based alarming system, in which information sharing, a judgment and decision making is always necessary. For example, the filtered data for relevance and summarized the information can be considered easily accessible for the decision-makers of the project. And therefore, an effective quality control in tunneling depends on the decision making of involved groups under a specified working frame, in which a proper representation and treatment of related information is vital in support to decision making [3].

Group Decision Making in General

The involved groups in tunneling are from different organizations [4], which have their own organizational culture background. The beliefs of the staff of organization and values for their work will influence their attitudes and behaviors. In tunneling, the personal need to make decision with related uncertainties under consideration. The decision making in this situation is often of the features of heuristics, i.e., making decisions based on unjustified or routine thinking. Although the efficiency of heuristic thinking may be fitting to the dynamic features of tunneling, the outcomes are more likely to experience fallacies or inaccuracies [5]. The decision making situation is generally in the field of Kahneman's System 1 [6], which is fast, instinctive and emotional and imperfect. Decision maker's behavior is readily influenced by the environment of the moment and also by irrelevant numbers. A personal limited to heuristic thinking would only be able to think of similar historical cases when presented with a new dispute, rather than seeing the unique aspects of the practical tunnel case. Under this situation, optimistic bias is most likely the decision maker's illusion of control. As a result, the information, which is familiar to the decision maker, will have a good chance of being over-evaluated or specially underlined in drawing a conclusion, as Kahneman stated that people have a tendency of avoiding feeling regret. This means that it is generally difficult to adjust the precedent point of view.

On the other hand, there is interaction of decision makers during tunneling. This often means it is difficult for a group to make a decision while taking into account how other groups in the situation will respond to the decision that is taken. In practice, an actual decision outcome for a critical situation involving a potential for large consequences typically needs a thorough process which combines (1) an analytic evaluation of the situation by rigorous, replicable methods, and (2) a deliberative group exercise in which all involved stakeholders and decision makers collectively consider the decision issues, with full information under consideration [7].

In tunneling, personal works for or as a representative of an organization. The background culture in the organization is generally of characteristics, in terms of beliefs and values. The beliefs of the staff and values for their work will influence their attitudes and behaviors in task implementation [8]. In terms of interests, there is often conflict among the involved groups, or the groups are, to some extent, competitors. There need an effective management frame to regulate the behaviors of the groups in their decision making. The leaders of the decision makers should often adjust the procedure of decision making to accomplish the common mission of the groups in a cooperation mode (Fig. 1).

The leadership behavior of the project will influence the involved groups' job satisfaction. One of ways to cope with this situation is to clearly define the terms of reference for decision making. For example, the owner or the project management group set up the terms of reference and show them clearly to the involved groups what their function and responsibilities are. It is practical that the terms should be short, simple and articulate, with the primary function of the groups being clearly presented.

Importance of Information Sharing

The information, on which the decision makers based and working procedure, which is followed in the tunneling project management, will have a strong influence in the decision making in the process of tunneling quality control. As Daniel Kahneman stated that a decision maker may draw final conclusions very quickly but based on limited and partly false information just because they are available [6]. People have a tendency of making an overrepresentation of some insignificant details that are easy to recognize over actually more important facts that are more difficult to perceive. Also,

biased thinking of the human mind is always related to the situation of information available being limited. This implies that the quality of decisions can be improved considerably by facilitating the perception of significant information and presenting decision-makers a more complete picture of the project in an easily interpreted and transparent manner, while diminishing false bias, such as through the meeting and discussing of the involved groups.

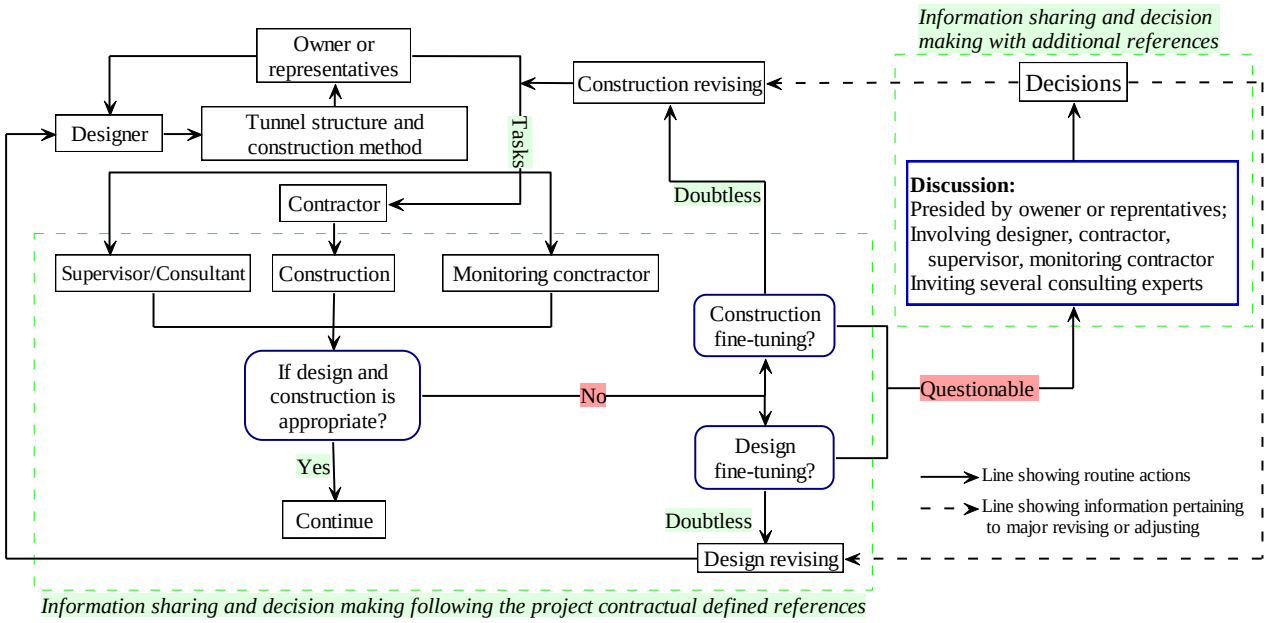

Figure 1. Information sharing and decision making of the involved groups in a tunneling procedure in China.

On the other hand, reporting and document management plan is vital to the success of quality control in tunneling. Large projects produce large amounts of documentation and reports. This puts important information at risk of being overlooked and the importance of a piece of information may only become apparent in hindsight. Since restricting the amount of documentation is not feasible, proper document management will play the crucial role of pre-evaluating and filtering available data for relevance. In practice, if information, such as the various monitoring data, should not be isolated products. It is only with integration into a common reference framework that information management can unfold its full potential.

The relationships between the involved groups, to some extent, are of competitive, such as in terms of interest between owner and contractors in a tunnel project. Among organizations, knowledge and information sharing is a catalyst to improve decision making to help finding better, more practical and well-founded solutions [9]. For example, information sharing relationships between groups in building activities are crucial to effectively make a decision, and therefore, the process of quality controls in tunneling can be improved, provided that the related conflicts can be identified and settled or prevented, with transparent information on a project status and its boundary conditions [2].

It is noted that effective group decisions are necessary to assure a tunnel project to be executed in a planned mode, such as in terms of quality control. Of effective decision making in a large project, intra-organizational and inter-organizational information sharing is always important [2] to successful projects. Although there is no single type of information sharing that can satisfy all the needs and concerns and the strategy of information sharing should be adoptive according to the situation of the project, a centralized mode is generally a way to facilitate interagency information sharing [9]. A balance between centralized and decentralized types of information sharing should be achieved to obtain advantages and diminish disadvantages.

Decision Making in the Quality Control of a Tunnel Concrete Lining

A case of the cracking control of a loess tunnel concrete lining is presented, with special reference to the information sharing in the decision making under a specified contractual frame in China.

Project Situation in General

A loess tunnel, with composite lining system, is 1022.7 m long and is constructed with conventional method, with special reference to the principles of New Austrian Tunneling Method (NATM). The composite lining system of the tunnel is composed of 30-cm-thick shotcrete primary lining (including steel sets or girders, steel meshes) and 55cm-thick cast-in-place reinforced concrete lining (final lining). Both of the lining layers are with invert to make them a closed supporting.

During the construction of the tunnel, the excavation face is generally "dry", i.e., there is no seepage water from the surrounding loess. It seems that the conventional function of the water-proof membrane useless in terms of building a dry tunnel. And therefore, there is a preliminary reorganization of canceling the designed water-proof membrane and geotextile sheet in the designed composite lining. A composite lining system without the interlayer is much favorable to the construction in terms of time schedule, cost and avoiding voids behind the final at the lining crown. Unfortunately, cracks appear in the adjusted concrete lining panels.

In general, the longitudinal cracks are much significant. The core boring tests of a few longitudinal cracks indicates that the cracks cut through the thickness of the final lining and the width of the tested cracks is almost same in the thickness. The surfaces of the sidewalls of the cracks also appear much rough and in a wavy pattern. These features imply their developments under tensile stresses.

Decision Making in the Cracking Control of the Tunnel Concrete Lining

The size magnitude and the features of the cracks in the above-mentioned several panels are beyond the allowable values in terms of the quality control of the project. There needs adjusting in the construction parameters related to the quality control of the tunnel cast-in-place concrete final lining.

In practice, the real time data that monitor tunneling operations is required for understanding the situations of quality control in the specified procedures, such as the size and round length of tunneling, excavation speed, timing of supporting system installation and lining building under the construction environment and conditions. Various factors or information can have strong influence on the tunneling quality control. The key information related to: (1) the environment of the tunnel, including ground model and neighbor structures, (2) the features of the tunnel structure, (3) the tunneling method and planned execution procedure, is important to obtain a full, transparent picture of the tunnel project and, must be presented in a common framework, which renders data easily accessible and indicates relevance to decision makers. Following the procedure (Fig. 1), a cracking control plan is developed among the involved groups, including owner representatives, contractor, site supervisor and designer representatives, as shown in Figure 2.

Based on testing and the monitoring data, including the preliminary results from site investigation, features of cracks, the monitoring results of the deformations of ground, shotcrete lining and the invert of the final lining, as well as the features of the potential thermal stresses in the final lining, it is generally accepted by the involved groups that the building situation of the final lining would have a strong influence on the cracking of the built panels. A relatively smooth surface and soft contacting conditions between the shotcrete lining and final lining are favorable to the concrete quality control. And therefore, the building situation is readjusted and the structures of the composite lining system are back to original situation, with water-proof membrane and geotextile sheet between the dual linings. The results of following building present the readjusting is reasonable, since the cracking of the concrete lining is under control.

Summary

Tunneling, with dynamic features in terms of design and construction, requires effective decision making by the involved groups to meet the specified criteria for quality control in a tunnel project. It is shown that the process of quality controls in tunneling can be improved, with transparent information sharing on a project status and its boundary conditions under a well planned and managed decision making frame, such as by the case of the cracking control of a loess tunnel concrete lining.

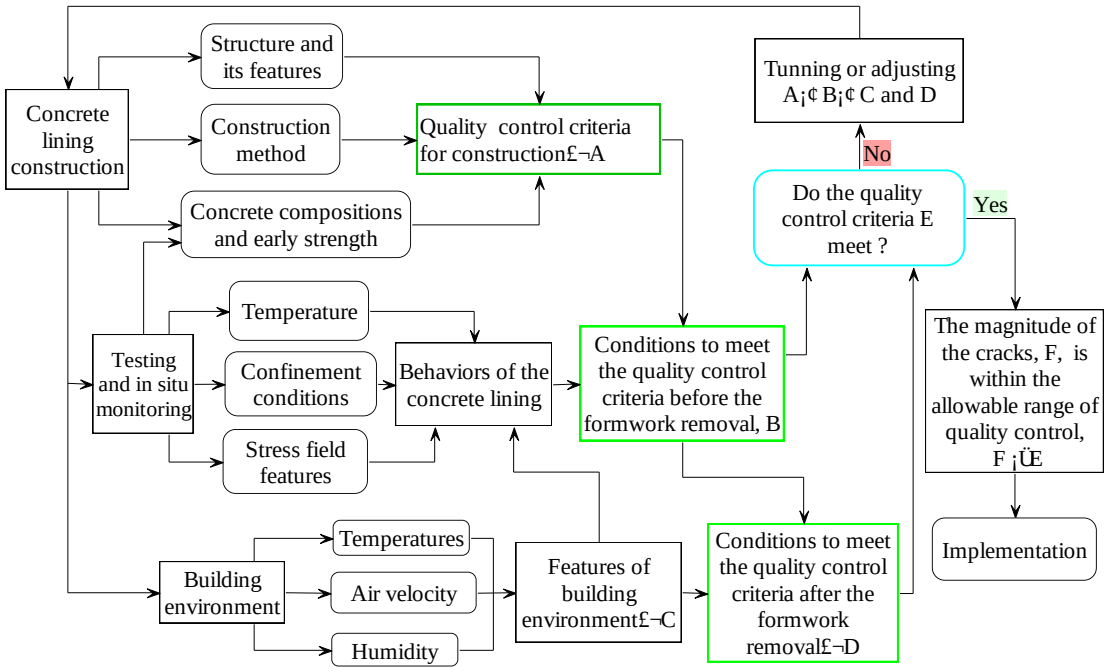

Figure 2. Key Information related to the cracking control of the tunnel concrete lining and sharing in procedure.

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