BEHAVIOR-BASED SAFETY (BBS) AS A NOVEL ASPECT OF THE SAFETY RISK ASSESSMENT AT A TUNNEL CONSTRUCTION SITE

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ABSTRACT

According to recent list of Statistical Surveys conducted by Ministry of Health, Labour and Welfare, the number of industrial accidents at tunnel construction sites has been decreased because of development of construction technology and/or promotion of machinery construction. However, accidents are not eradicated because safety of work circumstances under many tunnel construction sites is still depending on worker's attentiveness. Workers working at cutting face of tunnel are especially exposed to severe dangers and rarely equipped effective safety measure except attentiveness. For solving such problem, we have established a novel safety management system named the Safeguarding Supportive System, which monitors worker's working condition, identifies location of workers, and operates machines using ICT devices. On the other hand, some problems, the fact that some areas of tunnel construction site are not available to introduce ICT devices because of usage of dynamites and/or iron materials surrounding tunnel, are still left. We continuously keep groping effective and useful safety devices for protect tunnel workers from machinery safety aspect, some optimal management method of workers' behavior should be proposed from Behavior-Based Safety (BBS) aspect. BBS is one group of Behavior Analysis school which is one of Psychology. BBS is a quantitative, objective and direct method for measurement of behavior of workers and machinery system. BBS focuses on behavior of workers and tries to modify behavior by change of environment using some procedures. Goals of BBS are 1) prediction and control, 2) analysis and quantitative measurement, and 3) problem solving of behavior. Here, we show results of an experiment using a procedure of behavior analysis which was about risk assessment at a tunnel construction site, as an example of fusion of machinery safety and BBS.

Key words: Behavior Analysis, Behavior-Based Safety (BBS), machinery the Safeguarding Supportive System (SSS), residual risk, UWB, worker, location detection

INTRODUCTION

According to recent list of Statistical Surveys conducted by Ministry of Health, Labour and Welfare in Japan, accidents at tunnel construction site rapidly decreased because of development of construction technology and/or promotion of machinery construction. In the past, the fatalities in tunnel construction industry as well as all construction industry were more than 50 until the NATM was applied in Japan in 1978. After the NATM was applied, the number of fatalities was reduced to around 10–20 (Kikkawa et al., 2015). However, accidents are not eradicated because safety of work circumstances under many tunnel construction sites is still depending on worker's attentivenessIn Japan, However, the tunnel accident elicits fatal result if once accident occurs because safety at many tunnel work-sites in Japan are still dependent on workers attentiveness. Though it has been said that Japanese tunneling method induced by tunnel workers was highly organized and works of tunneling were precisely divided by the workers, the tunneling methods have never been quantitatively actually analyzed. It might be important to analyze behavioral pattern of workers and to apply some intervention procedure for increasing safety behavior and decreasing unsafe behavior.

In the present study, for detection of dangerous points in tunnel construction site, we analyzed the tunnel construction work in a tunnel in Japan using a procedure of Behavior-based safety (BBS). BBS involves the application of behaviour-analytic intervention strategies for workplace safety. Initially, a BBS measurement takes place in a setting allowing for observation of safe behaviour in an active, observable, measurable and reliable manner. Where dequate steps are taken, reliable data concerning the behaviour of workers can be used as the basis for scientifically sound interventions. We videotaped the behaviors of tunnel workers and heavy machines around tunneling face. The final goal of us is to identify dangerous points in tunnel construction sites and to induce safety measures using IoT or ICT devices. The experiment in the present study is a pilot study for the final goal.

MATERIALS AND METHODS

We used a video camera (HDM360MS, Panasonic, Japan) and recorded a work site at a face of tunnel in a tunnel construction site of Japan. The work at that moment in the tunnel construction site was excavated tunnel face. The date and time of the record was from 9:36:17 to 17:14:00 on 31 July 2019. There were 6 tunnel workers in the site. We counted number of workers and duration time existing at the face of tunnel. In addition, heavy machines used around the face of tunnel including dump truck and fuel feed vehicle was counted and recorded. We calculated the ratio of the most dangerous work which was tunnel In the present study, for detection of dangerous points in tunnel construction site, we analyzed the tunnel construction work in a tunnel in Japan. We videotaped the behaviors of tunnel workers and heavy machines around tunneling face. The final goal of us is to identify dangerous points in tunnel construction sites and to induce safety measures using IoT or ICT devices. The experiment in the present study is a pilot study for the final goal.

excavation within the whole work time.

At the face of the tunnel, 6 workers were working. Also, a drill machine, 2 tank trucks, 2 backhoes, 3 dump tracks, a fuel feed vehicle, and a tanker were existed at the same site.

RESULTS

As shown in Figures1 A-E, we measured the number of workers and heavy machines at the face of the tunnel. The data of the workers and machines was counted by 2-minute pitches. We found that work near the face of the tunnel was clearly divided into 4 kinds, which were preparation (Fig1A), transportation of the sand muck (Fig. 1B and D), the face excavation of the tunnel (Fig.1C), and clearance of the day (Fig. 1E). Among these four works, the most dangerous one was the face excavation because workers often stood very close to heavy machines in the work.

A

Time	Number of workers	Drill	Tank truck 1	Tank truck2	Backhoe 1	Dump truck1	Dump truck2	Oli feed vehcle	Dump truck3	Tanker	Backhoe2
09:36:17	1										
09:38:02	0										
09:40:17	3										
09:41:17	4										
09:44:17	3										
09:46:00	4										
09:52:45	5										
09:52:55	4										
09:56:40	3										
09:58:02	4										
10:00:57	5										
10:01:27	4										
10:02:05	5										
10:09:58	3										
10:12:25	4										
10:28:51	3										
10:46:04	4										
10:47:04	5										
10:54:24	6										
11:04:32	5										
11:08:35	4										
11:09:01	3										
11:10:30	1										
11:15:25	0										
11:16:36	1										
11:20:36	2										
11:21:06	3										
11:21:13	1										
11:22:13	2										
11:24:23	1										

B

Time	Number of workers	Drill	Tank truck 1	Tank truck2	Backhoe 1	Dump truck1	Dump truck2	Oli feed vehcle	Dump truck3	Tanker	Backhoe2
11:24:33	0										
11:25:36	0				1						
11:27:06	0				1	1					
11:30:06	0				1						
11:30:36	1				1		1				
11:32:58	1				1						
11:34:14	1				1	1					
11:37:38	1				1						
11:38:14	1				1		1				
11:40:48	1				1						
11:42:37	1				1	1					
11:46:20	2				1	1					
11:53:30	1				1	1					
11:57:42	1				1						
11:58:42	2				1						
11:59:02					1						
12：01~13：04	Lunch										
13:04:15					1						
13:05:10	1				1						
13:05:52	1				1		1				
13:07:56	1				1		1				
13:11:31	1				1						
13:13:25	1				1	1					
13:17:45	1				1						
13:18:30	1				1		1				
13:24:00	1				1						
13:25:15	1				1	1					
13:33:23	2				1						

C

Time	Number of workers	Drill	Tank truck 1	Tank truck2	Backhoe 1	Dump truck1	Dump truck2	Oli feed vehcle	Dump truck3	Tanker	Backhoe2
14:34:55	2										
14:35:20											
14:36:10	3										
13:37:50	2										
13:37:55	1										
13:41:26		1									
13:42:10	2	1									
13:44:35		1									
13:45:50	1	1									
13:55:26	1	1									
13:56:36	3	1									
14:00:10		1									
14:01:54	3	1									
14:27:59	3	1									
14:31:55	2	1									
14:34:15	3	1									
14:37:05	3	1									
14:41:21	3	1									
14:44:35	2	1									
14:45:25	1	1									
14:46:30	1										
14:47:40	0										
14:53:47	2										
14:57:10	3										
14:57:35	4										

D

Time	Number of workers	Drill	Tank truck 1	Tank truck2	Backhoe 1	Dump truck1	Dump truck2	Oli feed vehcle	Dump truck3	Tanker	Backhoe2
15:37:00					1						
15:40:10					1	1					
15:40:50					1						
15:43:10					1		1				
15:43:55					1						
15:53:22					1						
16:01:12					1						
16:02:47					1	1					
16:03:25					1						
16:05:58					1		1				
16:06:35					1						
16:09:58					1						
16:12:00					1	1					
16:12:40					1						
16:13:15					1		1				
16:15:20					1						
16:16:05					1	1					
16:18:27					1						
16:18:27					1		1				
16:21:55					1		1				
16:22:30					1						
16:25:25					1	1					
16:25:55					1						
16:28:12					1		1				
16:28:52					1						
16:31:42					1	1					
16:32:16					1						
16:33:53					1				1		
16:34:43					1						
16:35:43					1		1				
16:36:24					1						
16:37:34					1	1					
16:38:08											
16:40:25					1				1		
16:41:14					1						
16:41:14					1						
16:41:14					1						
16:42:20					1		1				
16:42:55					1						
16:46:35					1						
16:49:40					1						
16:59:25					1						
17:06:55											
17:08:55											
17:14:00											

E

Time	Number of workers	Drill	Tank truck 1	Tank truck2	Backhoe 1	Dump truck1	Dump truck2	Oli feed vehcle	Dump truck3	Tanker	Backhoe2
15:00:35	0										
15:03:10					1						
15:09:50	1				1						
15:11:27	1				1	1					
15:12:00	1				1						
15:13:40	1				1						
15:17:27	1				1						
15:19:27	1				1	1					
15:22:20	1				1		1				
15:22:56	1				1						
15:26:12	1				1	1					
15:26:45	1				1						
15:29:03	1				1		1				
15:30:03	1				1						
15:32:53	1				1	1					
15:33:30	1				1						
15:36:25	1				1		1				
15:36:35	1										

Fig.1: Tunnel construction work at the face of the tunnel. Preparation work (A), transportation of the sand muck (B and D), excavation work of the face of the tunnel (C) and clearance of the day (E).

We concluded that the most dangerous work was 13% of the whole daily job of the tunneling work. The results suggested that risk reduction would be possible by making precise operational standard for each process. In further research, dangerous point detection would be made by ICT or IoT devices (Fig. 2).

Dangerous point (tunneling at the face of the tunnel)

Place	Time	Number of worker	Drill car	Tank Truck
Around face of tunnel	13:55:26	1	1	
	13:56:36	3	1	
	14:01:54	3	1	
	14:27:59	3	1	Withdrawal
	14:31:55	2	1	
	14:34:15	3	1	
	14:37:05	3	1	

Fig.2: Dangerous time and point analysis using BBS at a construction work at the face of the tunnel.