STUDY ON MINING HAUL TRUCK DRIVER TASKS, ALERTNESS AND COGNITIVE DECISION MAKING

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This paper is part of the course project for SYDE 642: Cognitive Engineering Methods and presents findings from the cognitive analysis of tasks performed by mining haul truck drivers. Results and Analysis that are relevant to the haul truck operator safety, efficiency and productivity are part of the paper. The limitations of the study has also been identified.

Mines are large deposits of natural resources like coal and other minerals spread over thousands of acres. Most mines work for at least 20 to 30 years before closing down and beginning an environmental restoration process. The basic activities that take place during mining are : An excavator mines the ore and drops it on to the Mining haul truck and the Haul truck transports the ore to the crusher. For the ore transportation, the mining industry typically uses huge mining haul trucks. Our focus is on the Mining part involving the mining haul trucks where it transports the ore from the mines to the crusher.

The study is conducted mostly based off on the driver/operator. The study focussed on 3 main aspects of the operation of a mining haul truck. First, how the operator in a haul truck functions in an environment that is monotonous. Second, how does the driver react to errors, blind spots and other vehicles present in the mine. Third, how does fatigue affect overall performance of haul truck operators in mines. The paper also conveys suggestions from participants to solve some of the problems affecting drivers of the haul truck.

INTRODUCTION

Mining is one of the most hazardous work environments in the world. There is always a threat of accidents that occur either due to negligence or due to the failure of equipment or due to the working environment. Workers can be at risk of serious injury or death due to hazards involving vehicles and mobile equipment at mines. Alertness during extended or undemanding tasks is essential for safety and productivity.

The study by the government of Western Australian mining industry during the period of July to December 2013 [1] indicates that 55% of the injuries happened during operations in mining and 28% during maintenance. The risk assessment for haul truck-related fatalities in mining [2] by Z.A. MD-NORET and et al. also demonstrates that human errors caused 49.5 % of fatalities during operation of mining haul trucks.

The main causes of accidents are identified as failure of the operator to identify blind spots, to mis-locate workers on the sides of the truck and failure to control the truck by loss of focus as a result of negligence and lack of vigilance while driving.

Long, undemanding and monotonous driving, such as during certain mining operations, facilitates sleepiness as does any other tedious work. A number of accidents, which would be attributed to the loss of control due to the sleepiness of drivers, have been reported at mines as well. [3]

The research cited above often provide recommendations, such as pre-operation inspections (e.g., ensuring use of seatbelts, and clean and non-slippery surfaces to move on) and means to heighten the safety of critical haul phases (e.g., use of cameras or proximity sensors for stationary dumping and backing up) (Turin, Wiehagen, Jaspal & Mayton, 2001). [4]

In contrast, this paper focuses on how to improve task efficiency, critical decision making and studies decrements to situation awareness caused by fatigue.

OBJECTIVES OF THE STUDY

The objective of this study was to identify how expert mining haul truck drivers performed their tasks in the truck, their mental model of making critical decision on accidents and fatigue causing factors potentially affecting the situation awareness during haul driving and mining operations.

The data collected and analyzed can be used:

1) To train the novice drivers on how to perform these tasks as efficiently as an expert driver.
2) To design truck systems with the operator in mind and the tasks he has to perform.
3) To provide better insights and solutions to minimize accident occurrences based on suggestions from participants.
4) To optimize how can automation aid the driver to achieve the goals above.

METHODS

1. COGNITIVE TASK ANALYSIS

Cognitive Task Analysis was conducted to know how the driver performed tasks in truck. It help to breakdown tasks into subtasks and understand each task in detail.

Participants

The Participants for cognitive task analysis consisted of 2 expert drivers. Both were 30 years old and had experience of over 4 years in driving the truck and has a background knowledge in mechanical design engineering. Both participants have spent significant amount of time in test driving new variants and models of trucks for a private mining company.

Apparatus

A semi structured interview was conducted through skype with a subset of questions on mining industry, tasks, operator environment, health, safety and issues affecting performance. Also used videos of other drivers performing tasks so that the participants could comment on the actions of the driver in video based on their experience. The interviews were recorded and manually transcribed later for in-depth analysis.

Procedure

First, we collected background preliminary knowledge in mining cycle and haul truck working. Based on the information collected, semi structured interviews with two experts in mining driving field were conducted to figure out the cognitive tasks of drivers with significant experience. The time length of the interviews were close to 50 minutes each.

Questions asked in the interview include:

1) *Please elaborate on the tasks that are performed in mining haul truck operation from a driver's perspective?*
2) *Which tasks are more significant compared to the other ones?*

The information acquired from the semi structured interview was used to decompose the operations performed by the driver into tasks and subtasks distributed throughout the mining cycle. A task analysis diagram was created using the information to identify how the driver performed during the mining cycle in various tasks from truck manipulation to communication and providing indicators and warning.

2. CRITICAL DECISION METHOD

Critical Decision Method was used to study accidents or occurrences that impacted employee and truck safety and provide solutions on the basis of the occurrence.

Participants

Two semi-structured interviews were conducted for the same participants of cognitive task analysis to study their recent accidents or critical occurrences and potential solutions to prevent the re-occurrence of these. Both experts had non-routine accident history.

Apparatus

A semi structured interview was conducted through skype with a subset of questions on accident occurrences and critical incidents. The interviews were recorded and manually transcribed later for in-depth analysis.

Procedure

The structured probes and unstructured follow-up questions in the interview were focused on the recent mining field incidents that our participants made decisions on (i.e. They were the operator of the truck involved in the incident).

Questions asked in the interview include:

1) *Do you have any experience on decisions in critical cases of operation? Can you elaborate on them?*
2) *Have you ever encountered dangerous situations? Has it resulted in accidents?*

The interview also followed up with questions of their feeling, suggestions and what-ifs on the selected incidents. The examples of the deeper probes include:

1) *Which steps that you told us previously needed more attention during this incident?*
2) *What can be done to mitigate this situation without causing accidents?*

Accordingly, a timeline of one incident that is identified to be critical and a repeated occurrence is constructed and verified by the participant. The decision making issues and suggestions from the participants was used to create a summary table.

3. SITUATION AWARENESS

Situation awareness survey was done to study decrements in performance on basis of fatigue which would compromise the alertness of the driver.

Participants

Participants for the situation awareness survey consisted of 6 expert drivers with an average age of 32. All the drivers who took the survey had an experience of 4-8 years with no engineering background.

Apparatus

A situation awareness questionnaire with 20 questions was created after going through literatures on fatigue and effects on mining haul truck drivers. The questions were self explanatory and had relevant explanations to make it easier for the operators to understand and answer the survey accurately.

Procedure

The survey was taken by 6 experienced drivers do as to study decrements in performance on basis of fatigue, sleepiness and other factors that may compromise the alertness during driving and operations. The results from the survey was analysed with respect to the factors and incidents caused.

Although SAGAT was planned for study on situation awareness of mining haul truck driving, due to the time and location constraints, it was decided to list this method as scope for further study in the future.

RESULTS AND ANALYSIS

1. COGNITIVE TASK ANALYSIS

Cognitive task analysis was helpful in creating a decomposition diagram (Figure 1) of the operations performed by the operator of the truck throughout the mining cycle.

The main problems identified from the decomposition diagram were:

1) The driver has to constantly keep the next attention item in mind, Drivers often missed steps to be performed while driving due to the huge number of attention items.
2) Drivers has to keep constantly checking the dispatch display for monitoring truck.
3) Productivity is negatively impacted as the driver has to figure out path constantly depending upon changing parameters like ore, number of trucks in path, etc.

4) Drivers constantly miss to check the load on the truck mainly due to the lack of a notification system and less attention during low arousal phases like loading of ore, this often leads to overloading of truck.

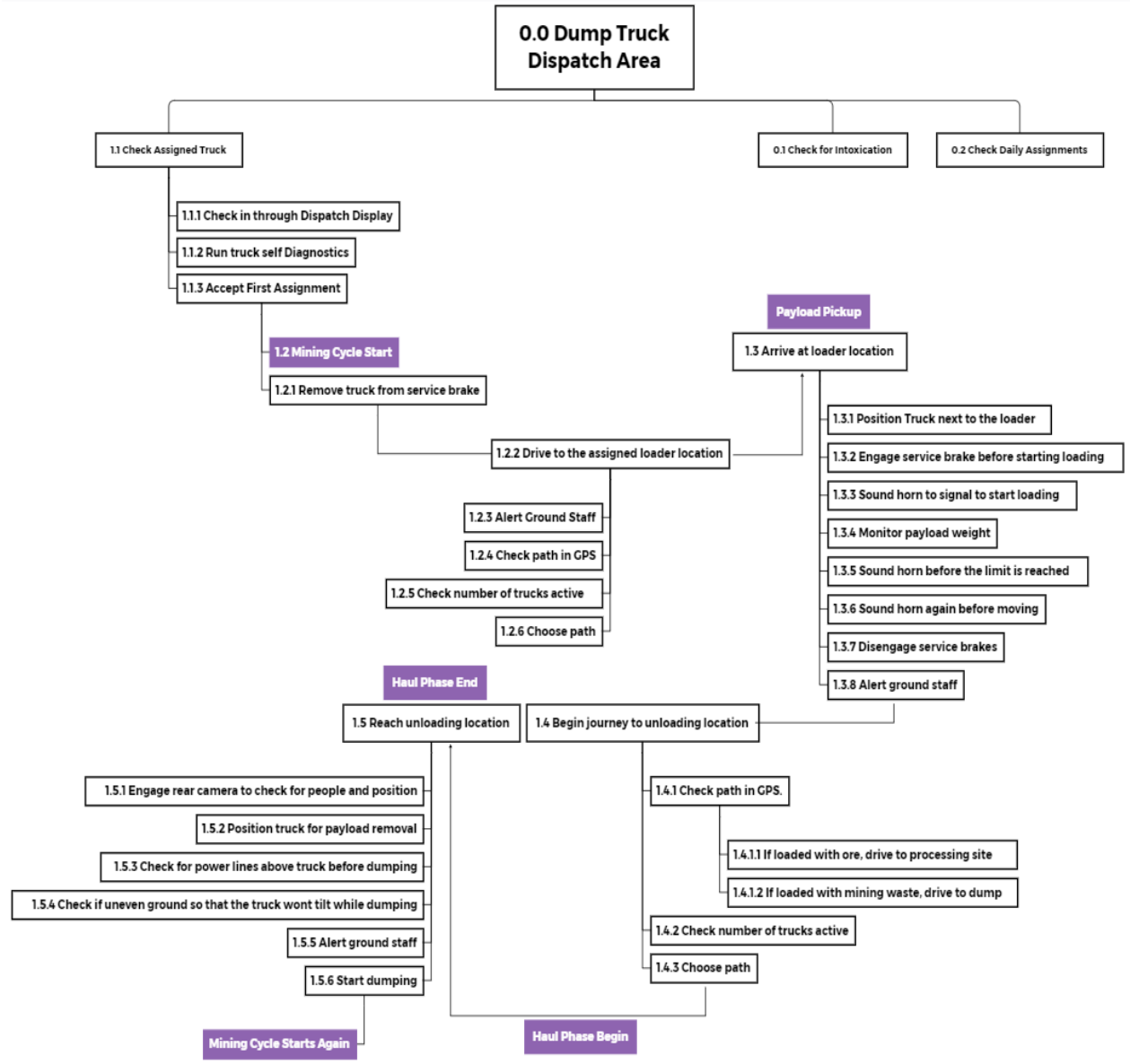

Figure 1: Cognitive Task Analysis Decomposition Diagram

Conclusions of Cognitive Task Analysis performed were:

1) A form of checklist for operators should be implemented to increase operator knowledge on action items to be done during each tasks of the mining cycle. This will benefit novice drivers and expert drivers alike.
2) The checklist can make it easier to take critical decisions as the driver is more informed and helps focus attention.

3) Cognitive Task Analysis also makes a case for implementation of automation in mining haul trucks. This allows the operator to assume a monitoring role than a control role. Ex: Auto Horning when payload limit is reached.
4) As drivers should be engaged during the low arousal phases of loading and unloading and the haul phase in the mining cycle, there should be appropriate tools provided to engage the driver.

2. CRITICAL DECISION METHOD

The two critical decision interviews conducted were used to create a timeline (Figure 2) of a non routine incident that is bound to happen if the operator is not aware and does not check the blind spots on the sides of the truck for other workers, ground staff or other vehicles. have been implemented, each lasting about 50 minutes.

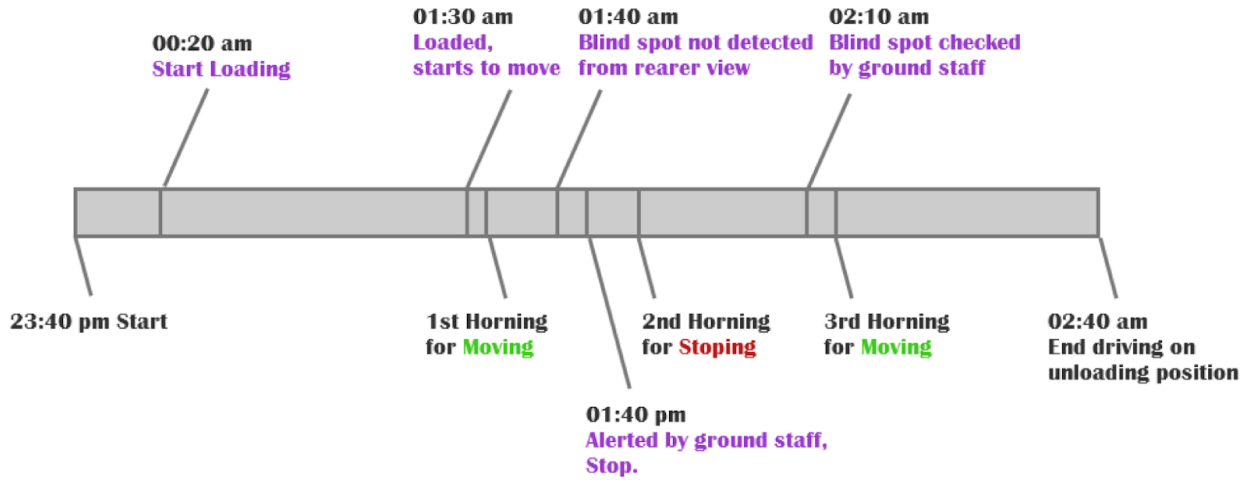

Figure 2: Constructed Timeline of mining haul truck incident of blind spot error

The timeline helps to understand the occurrence pattern of the incident and was verified by the expert. On the basis of the conducted interviews, a summary table of the issues raised by interviewers and their suggested solutions were analyzed and documented (Table 1).

The decision making issues identified by participants includes untrusty automated system for truck speed monitoring, inappropriate mental models such as missing to fasten seat belt, operation system User Interface inconsistency between different variants and models of trucks, the deepening learning curve when changing trucks and the likelihood of forgetting routine steps.

The issues with missing equipment on trucks without optional systems equipped were also raised. In particular, the trucks that lacked the equipment's were said to be difficult to operate. The participant suggested that driving aids should be consistent and standard across all trucks as the drivers who have considerable experience using these devices where less productive and efficient while driving trucks without the optional driving aids equipped.

Decision Making Issue Identified	Solutions Suggested by Participants
Trust - Although drivers do have speed monitoring system,they still override the automated speed to increase truck speed because for maintaining the truck more close to others or sometime by driver's visual information throughtrucks.	Max attainable speed should not be limited to the same value for empty load and loaded condition. Higher speeds at no load condition helps increase productivity.
Mental Model - Errors like forgetting to put on seat belts before driving or using service brakes above 10 km/hr speed are vital but easy to miss.	Warning lights go unnoticed due to the small size of the indicator on the dash. Audio warning is necessary. especially for service brakes engaged condition. But this may cause irritation as the driver is constantly alerted during loading when the brakes are engaged.
OS Consistency - With familair type of truck and monitory operationg system,drivers usually have a good idea of the side views , the front and the rear views of the truck. So at that point of the time, drivers may not face much of a blind spot situation, When it comes to a point where we have to change new type of truck or redesigned operation system, where drivers have to handle a different truck or a different brand of truck, that's when blind spot inccidents are likely to happen.	Train on the basis of truck model and controls. Give the driver appropriate time with an expert co driver who has knowledge of the truck controls. Implement camera systems on sides of the truck to minimize blind spots. As this are optional equipment, mining companies are required to pay extra for these which leads to no adoption. Making these standard across trucks will help. Also, the drivers who use driving aids are less productive when allotted to trucks without these.
Alert Technology - Before moving,or like after loading of trucks, there should be proper horning before drivers move so that everybody gets an alert that the truck is starting to move to avoid unattetioned inccidents. While missing this manual operation is not uncommon from driver's perspective.	A checklist system is good. But it would require extra effort from the driver. A system with visual checks implemented on dispatch display informing the driver to honk before moving when truck is idle is an easier way to alert.
Entertainment - Within trucks there is radio system, and drivers are allowed to use smartphone also. The communication to the people in the mining area would be through the radio system. And also a music system in our truck and most of the drivers spend a lot of time in the truck listening to music. Drivers usually treat this kind of entertainment during works as a complacent during idling process like waiting for loading or hauling phase.	As there is little to no engagement on haul cycle, automation may help transferring the driver to a monitoring role than control role.

Table 1: Summary Table of results from CDM

3. SITUATION AWARENESS

The online survey of six expert haul truck drivers who have 4-8 years experience was conducted on Survey Monkey. The survey was made of 50 questions that mainly focused on factors which consists of sub-optimally designed shift schedules, inadequate sleep, fatigue, extended driving times, monotonous nature of tasks and lifestyle which compromise the alertness of the haul truck drivers.

The survey provides a base for further deep studies on the subject of fatigue, its effects on mining haul truck drivers and decrements to situation awareness that happen. The outcome of the survey was that fatigue was a severe concern among operators and different drivers adopted different techniques to overcome fatigue. Although the sample size of the survey was low, the outcomes of the survey was as expected. For example, the working hours and load on the operator are directly co-related.

Figure 3 shows average hours per day that our participants were working and had off hours. Among the participant, 5 of 6 have worked over 8 hours per day and have around 2.73 hours off per day. It is no surprise that the workload is high but working time pattern is appropriate.

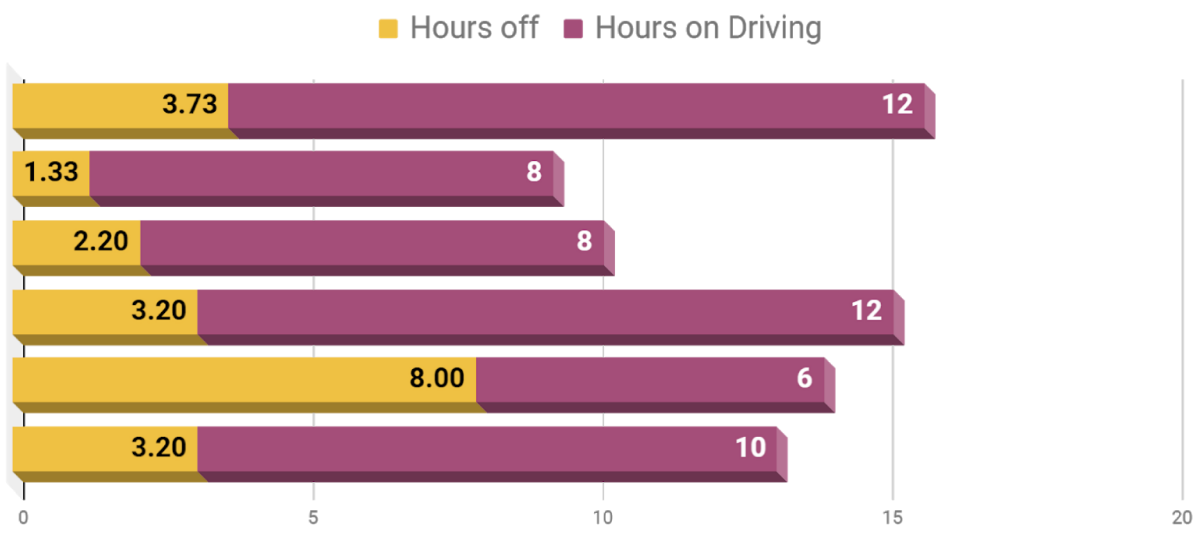

Figure 3: How many hours per day do you usually work and off?

Participants were also questioned about their subjective awareness rankings in day shift and night shift timings to optimize their designated shift schedules. The results are demonstrated in Figure 4. It indicates that between 7 AM in the morning and 11 PM during evening, drivers tend to have more awareness from their own perspective. Also, night shifts have fairly high subjective awareness but the lowest awareness as well. This can be interpreted as drivers who tend to sleep during night shifts due to fatigue, tiredness and lack of light. Low awareness is particularly noticed and critical in the middle to end part of the night shift.

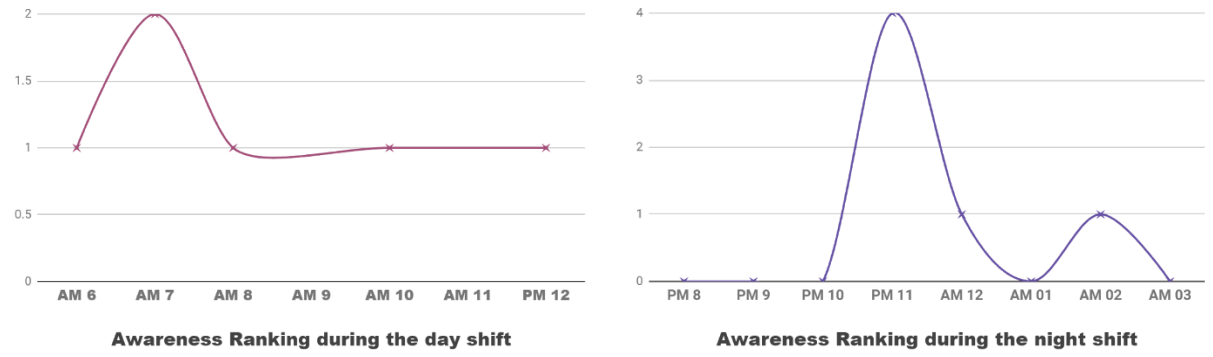

Figure 4: Subjective Awareness Ranking during day/night shift

Among all participants, 83.4% advocated that they have experienced falling asleep while driving, though only 16.7% claims they had no such experience ever. This can be attributed to lower levels of awareness while doing night shift and also decrements in situation awareness due to fatigue caused by sleepiness. The reasons for falling asleep behind the wheel includes Monotonous work/road (50.00%), Unscientific working hours (33.33%) and also being too many hours behind the wheel at a go (16.67%)

There is 16.67% drivers that declared they carried on driving although they were tired and sleepy, while 33.33% stated that they carried on driving while feeling sleepy by turning on music or making it

louder under the same circumstances. This is concerning as most of the accidents or critical incidents that endanger mine safety happen due to the lower attention to environment and decrements in awareness caused due to lack of communication with ground staff. When tracing back the possible reasons of tiredness and sleepiness, Stress/worries definitely is the most significant common factor among all participants in as represented in Figure 5.

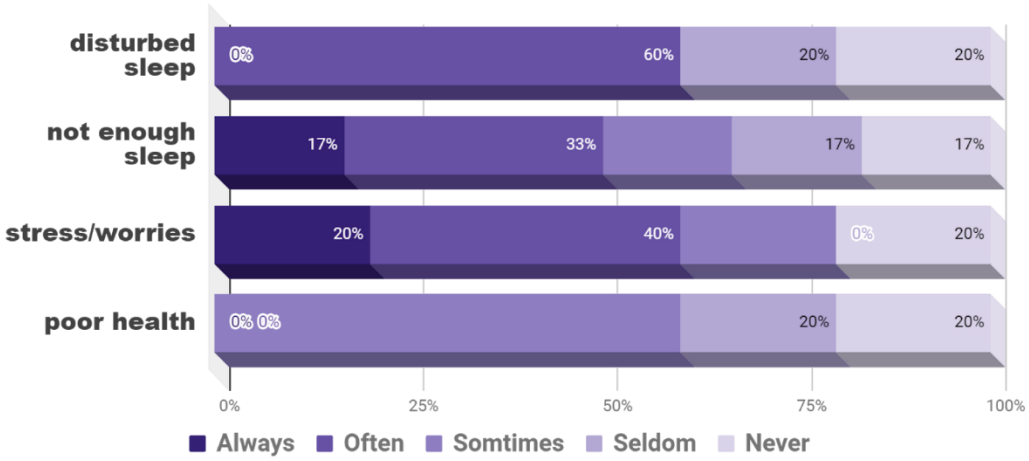

Figure 5: Reasons of tiredness or sleepiness

Among the survey content, there is no obvious correlations between awareness and lifestyle, like caffeine-abuse or physical exercise, from participants feedback.

CONCLUSIONS AND LIMITATIONS

The decomposition diagram of mining haul truck driving procedure has given us a great opportunity to have preliminary knowledge of mining haul truck and can be utilized as a form of checklist for novice drivers and expert drivers alike. It also emphasizes the importance of keeping the focus of the driver intact on the task in progress and the next action item. The decision making issues identified by expert drivers on machine monitoring system, improvements in more specific situations such as loading and unloading, the suggestions to help solve the issues, requirement of more in-depth training sessions on safety issues, changes to training process according to the truck variants used and maintaining operation system UI consistency to minimize learning curve are suggestions of the critical decision making study. This will help optimize safety and efficiency for mining haul truck driving.

Although, sub-optimally designed shift schedules, inadequate sleep, fatigue, extended driving times, monotonous nature of tasks show obvious correlation of decreasing alertness of the haul truck drivers subjectively, further field assessment and SAGAT probe is needed for more objective Situation Awareness study.

Another thought from the study is that long, undemanding and monotonous task such as the hauling phase is conducive to sleepiness and increases the risk of accidents, especially during night shift. Fully automated trucks could bring benefits in such specific situations from the perspectives of safety and efficiency.

REFERENCES

[1] Analysis of serious injury data in the western Australian mining industry, July to December 2013. Published by Government of Western Australia, Department of mines and petroleum.

[2] Risk assessment for haul truck-related fatalities in mining: Z.A. MD-NOR, V. KECOJEVIC, D. KOMLJENOVIC AND W. GROVES

[3] Factors affecting driver alertness during the operation of haul trucks in the South African mining industry, PC Schutte and CC Maldonado, June 2003

[4] A Field Study of Haul Truck Operations in Open Pit Mines- Patrick Stahl, Birsen Donmez, Greg Jamieson

APPENDIX

CDM- Critical Decision Method

CTA- Cognitive Task Analysis

Mines- Mines are large deposits of natural resources like coal and other minerals spread over thousands of acres. Most mines work for at least 20 to 30 years before closing down and beginning an environmental restoration process.

Mining Cycle- The basic activities that take place during mining are :

1) An excavator mines the ore and drops it on to the Mining haul truck – Loading Process
2) The Haul truck transports the ore to the crusher – Hauling Process
3) The truck unloads the ore to a crusher or a dumping zone- Unloading Process

Optional Equipment (OE)- Equipment that are not part of the standard kit of the truck. The buyer has to pay extra for OE's.

SA- Situation Awareness

UI- User Interface

INDIVIDUAL CONTRIBUTIONS

Fan He - SA Survey, CDM and SA Questionnaire, Results and Analysis of CDM and SA and Report.

Neuel Sam - CDM Questionnaire, CDM and CTA Interviews, Results and Analysis of CTA and Report.