SATBAYEV UNIVERSITY

Engineering Journal of Satbayev University

Volume 145 (2023), Issue 4, 32-35

https://doi.org/10.51301/ejsu.2023.i4.05

Mining haul truck operation failure analysis

A. Shakenov*, D. Kramsakov, I. Stolpovskih

Satbayev University, Almaty, Kazakhstan

**Corresponding author: ashakenov@yahoo.com*

Abstract. Estimated 45% of all mining equipment worldwide is mining haul trucks. More than 44 thousand mining haul trucks are in operation worldwide as per 2017 Mine Safety and Health Administration of USA reports and over 20% of accidents with fatalities on mining equipment happens with participation of mining haul trucks. Mining haul trucks are critical equipment for mining industry of Kazakhstan where 80% of mines are operated by open cast mining. To better understand haul trucks operation failures statistical method was used during this study. 8 training instructors were interviews who trained 1048 truck operators over 3 years at 5 mine sites. The analyses explore the context of the accidents with focus on initiating reasons, outcomes of accidents and possible preventive and mitigative controls. Overall, most accidents take place due to haul road condition, read design and operation decision making. Bow-tie diagram as a constructive risk management tool used in this study for visual presentation of links between hazards, initiating controls, preventive and mitigative controls, and outcomes. The results of the study suggest improving organizational control over operator trainings and mine haul road design and maintenance.

Keywords: *mine haul trucks, safety on mine sites, failure analyses, accident preventive measures.*

1. Introduction

Mining haul trucks are most common peace of mining equipment of mining operations in Kazakhstan and the most related to safety accidents occurred in open cast mines. The same statistics we can observe in mining operations in USA. In fact, 6 out of 28 and 6 out of 27 mining fatal accidents that occurred in the USA in 2017 and 2018, respectively, were related to haul trucks [1].

Over last years, many researchers have studied and analyzed reasons of safety accidents keep taking place in mining industry. Mine Safety and Health Administration of USA has collected a lot of data on accidents related with mining haul trucks [2]. In general, safety accidents initiation events mostly the same with some alternations on proportions. An analyses of 31 safety accidents in 5 open cast mines on Kazakhstan from 2020 through 2023 found that 33% of the accidents involved in loose of control related to unacceptable road conditions, 20% related to operator qualification as abuse of service brakes and failures to follow policies and procedures, 35% related to operation of working areas as safety berms, dust control and illumination, 12% related to maintenance of equipment as misuse of tooling, fire safety and tire maintenance as shown in Figure 1.

Similarly, an earlier analysis of nonfatal accidents in USA found that operator failures and ground control hazards were two of the most frequent reported contributing factors to accidents [3]. Limited visibility due to poor illumination and dust control are common hazards that makes operating mining haul truck challenging to keep safe distance between vehicles and mine environment especially on night shifts. Mining haul truck drive over light vehicle as shown on figure 2 keep taking place in Kazakhstan so training the support and service personal away from blind sport are critical.

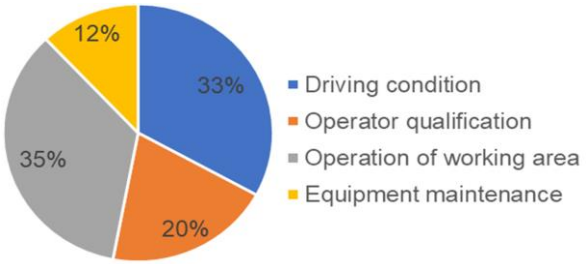

Figure 1. Safety accident initiation events with mining haul trucks in mines of Kazakhstan for 2020-2023

Figure 2. Mining haul truck drive over light vehicle in Kazakhstan

Operator fatigue due to monotonous driving brings to collisions with mine environment and other vehicles as shown in Figure 3. Haul road profile and condition is another major contributor to mine site hazards and cost of production. Use of proper tire handling tooling and maintenance of electrical parts of trucks as batteries can reduce contribution of number of accidents as well.

Engineering Journal of Satbayev University. eISSN 2959-2348. Published by Satbayev University

Figure 3. Two mining haul trucks collide due to operator fatigue in Kazakhstan

The aim of this work was to take analyze mining haul truck operation failures in make practical advice to mitigate the risks for long terms with help of modern technologies and best practices.

2. Materials and methods

Bowtie diagram method good practical tool for assembling information on hazards, initiating events, preventive and mitigative controls and comprehensive for understanding and training. Focus on health and safety controls and risk of bowtie can help mine managers to evaluate effectiveness of their current controls and further improve their risk management [4].

Using the accident information from 5 mine sites in Kazakhstan from 2020 to 2023 from training department of Borusan Makina Kazakhstan bowtie diagram was created and showed in Figure 4. Bowtie diagram includes following elements:

Initiating reasons: The events can lead to the loss of control such as driving conditions, driving condition, operator qualification, operation of working area, equipment maintenance.

Causes: Possible hazards that may contribute to the severity of the accidents.

Preventive controls: Possible controls that could prevent accident partially or completely.

Mitigative controls: Possible controls that can reduce the severity of the accidents.

Outcome: Event brings to safety accident or incident at mine site.

Generic definitions were selected to effectively group the results collected from mine sites. Causes, preventive and mitigative controls were developed based on modern trends and availability in mining industry in Kazakhstan. Missing or incomplete information was not taking to study. Fatal and nonfatal accidents were used all in total statistics. Name of mines not disclosed due to ethical reasons. Drugs and alcohol causes was not identified during data collection as all operators taking toxicology tests before shift. Collision avoidance system advised through internal expertise and previous research [5]. Corrective actions to include changes to policies and procedures as well as communication plan intend to support existing preventive measures. Operator and health and safety trainings for operators in Kazakh language will be beneficial as well as use of immersive training simulators for newcomer operators. Proper tooling and periodical inspection for maintenance of equipment can help to reduce possible equipment maintenance hazards.

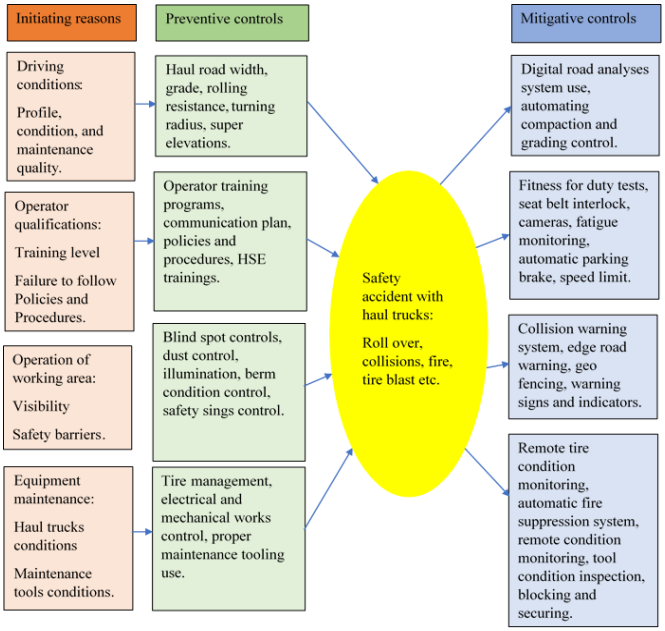

Figure 4. Bowtie diagram of mining haul truck operation failures analyzes of mines in Kazakhstan

3. Results and discussion

Typical failure of mining truck operation failures includes safety accidents connected with road condition, operator qualification, operation of work areas and equipment maintenance as shown in Table 1 bellow.

Table 1. Result of data collection from 5 mine sites in Kazakhstan from 2020 to 2023

N	Type of causes	Description of reasons brought to safety accidents	Quantity of occurrence
1	Road condition	Excessive grade and narrow haul roads, sharp turns, obstacles on haul roads bring to loss of control	10
2	Operator qualification	Abuse of service brakes, drive over service vehicles, misuse of parking brakes, not using while chocks	6
3	Operation of work area	Not enough berms, mine wall sliding, poor illumination of haul roads and workshop, poor dust suppression, not enough safety signs	11
4	Equipment maintenance	Use of unproper tooling for tire maintenance, wrong battery maintenance,	4
Total:			**31**

Driving conditions must be improved by proper design of haul road profile and road maintenance practice in order to improve haul road condition to safe operation level in terms of width, grade, turning radius and rolling resistance. Haul road condition can be proactively monitored with digital technologies [6].

Design of haul roads is critical factor to improve mining haul truck operation safety [7]. Better designed roads are safe to operate and cost effective.

Operator qualifications should be organized on systematic approach and regular fitness tests should be conducted on

regular bases. Communication plan about updates of policies and procedures as well as HSE updates should be on Kazakh language for understanding of all new coming operators. There are 7500 schools in Kazakhstan, 3700 of them in Kazakh language, 1200 schools are in Russian language and 2000 schools are in both Kazakh and Russian languages. 70% of new students entered in Kazakh schools in 2022 [8]. As per reported incidents data from Queensland, NSW and WA around 2.5% of notable incidents includes operator fatigue as a factor. More incident occurs on last new hours of shift and two third of them takes place in night shifts [9]. A number of fatigue detection equipment is available on market now that can contribute to improve fatigue risk management in mining industry [10]. New technologies such as fatigue monitoring, seat belt interlock, cameras, automatic parking brake, speed limit gradually entering to mining operations in Kazakhstan.

Operation of work areas can be improved by better control of safety berms, proper dust suppression and haul road illumination, use of more modern safety signs and markings. There are many ways to haul road dust control. Water spray is the most obvious, but there are many other ways which include:

- Salts – as calcium chloride, magnesium chloride, sodium silicates etc. Salts extracts moisture from atmosphere and increase surface moisture of haul road.

- Surfactants – as soaps and detergents. They decrease the surface tension of water, which allows the available moisture to wet haul road.

- Soil cement – cement mixed with native soil forms new surface compound.

- Bitumen – compounds delivered from coal and petroleum such as asphalt, oil etc.

- Films – polymers that form discrete tissues and layers such as vinyl and fabrics, etc.

These kinds of solutions form coherent surface layers that seal the haul road surface and reduce generation of dust [11]. Technologies for collision avoidance [12], road edge warning and geo fencing can significantly contribute to mitigate the risks as well.

Equipment management should be managed based on preventive maintenance principles. Tire maintenance and electrical components servicing are the special concern from safety point of view. Proper maintenance tools for mechanical and lifting works should be inspected on timely manner. Remote tire condition monitoring [13], automatic fire suppression system can contribute to mitigate the risks on equipment maintenance area.

4. Conclusions

Results of this study highlight necessary focus areas to mine manager's attention on effective preventive and mitigating measures to improve safety on mining truck operations in Kazakhstan. Haul road and mine operation improvements can avert most of the accidents in this study. Overall systematic view on operator trainings, health and safety policies and procedures as well as proper communication plan will provide a strong base for future improvement of mineworker's safety.

In the meantime, mine operation may consider additional investment to new technologies to proactively manage possible risks by remote condition monitoring of operators, haul roads and mining haul trucks.

Continues near-miss and safety accident studying should go on and could put more light on initiating reasons, preventing, and mitigating controls. Armed with this knowledge, safety experts should be able to further improve the safety of mining haul truck operators and their co-workers.

Acknowledgements

The authors gratitude the training department management of Borusan Makina Kazakhstan for provided data and cooperation during the study.

References

[1] Department of Labor. (2018). Mine Safety and Health Administration (MSHA). Fatality Reports, Washington. R*etrieved from:* https://www.msha.gov/data-reports/fatality-reports/2018/fatality-11-december-29-2018/final-report

[2] Randolph, R.F., Boldt, C.M.K. (1996). Safety analysis of surface haulage accidents. *Proceedings of 27th Annual Institute on Mining Health, Safety and Research, USA, Blacksburg*

[3] Santos, B.R., Porter, W.L. & Mayton, A.G. (2010). An Analysis of Injuries to Haul Truck Operators in the U.S. Mining Industry. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 54(21), 1875–1873*

[4] Bellanca, J.L., Ryan, M.E., Orr, T.J. & Burgess-Limerick, R.J. (2021). Why Do Haul Truck Fatal Accidents Keep Occurring? *Mining, Metallurgy and Exploration, 38(2), 1019–1029.* https://doi.org/10.1007/s42461-021-00410-1

[5] Burgess-Limerick, R. (2016). Bowtie analysis of mining fatalities to identify priority control technologies. *National Institute for Occupational Safety and Health, Pittsburgh, PA*

[6] Shakenov, A., Yegemberdiev, R., Kolga, A. & Stolpovskih, I. (2023). Monitoring the condition of mine haul roads using digital systems. *News of the academy of sciences of the Republic of Kazakhstan, 4(460), 236-248.* https://doi.org/10.32014/2023.2518-170X.332

[7] Yarmuch, J.L., Brazil, M., Rubinstcinc, H. & Doreen, A.T. (2021). Optimal design of profile of technological roads in quarries. *University of Melbourne, Victoria, Australia*

[8] Report of Ministry of Education of the Republic of Kazakhstan. *Retrieved from:* https://www.gov.kz/memleket/entities/edu

[9] Horberry, T., Harris, J., Way, K., Hill, A., Lim, N. & Dodshon, P. (2022). Fatigue Management in the Queensland Mining Industry and its relationship with Mental Health. *Final Report to Office of the Commissioner Resources Safety and Health, School of Psychology, The University of Queensland*

[10] Humphries, J., Koh, A., Thomas, I. & Latum, L. (2011). Monitoring haul truck operator fatigue using gyroscope data. *Proceedings of 35th APCOM Symposium*

[11] Fred, N. Kissell. (2003). Handbook for Dust Control in Mining. *Retrieved from:* https://www.cdc.gov/niosh/mining/userfiles/works/pdfs/2003-147.pdf

[12] Glynn, P.J. (2023). Collision Avoidance Systems for Mine Haul Trucks and Unambiguous Dynamic Real Time Single Object Detection. *Department of Management, Griffith University*

[13] Szczucka-Lasota, B., Węgrzyn, T., Łazarz, B. & Kamińska, J.A. (2021). Tire pressure remote monitoring system reducing the rubber waste. *Transportation Research Part D: Transport and Environment, (98), 102987.* https://doi.org/10.1016/j.trd.2021.102987

Тау-кен тасымаларының жұмысындағы абалдықтарды талдау

А. Шакенов*, Д. Крамсаков, И. Столповских
Satbayev University, Алматы, Қазақстан
**Корреспонденция үшін автор: ashakenov@yahoo.com*

Аңдатпа. Дүние жүзіндегі барлық тау-кен жабдықтарының 45%-ы тау-кен жүк көліктері болып табылады. 2017 жылғы АҚШ кендерінің қауіпсіздік және денсаулық басқармасы есептері бойынша дүние жүзінде 44 мыңнан астам тау-кен жүк көлігі жұмыс істейді және тау-кен жабдықтарында қаза болған апаттардың 20%-дан астамы тау-кен жүк көліктерінің қатысуымен болады. Тау-кен жүк көліктері Қазақстанның тау-кен өнеркәсібі үшін маңызды жабдық болып табылады, мұнда кеніштердің 80% ашық әдіспен жұмыс істейді. Жүк көліктерінің жұмысындағы ақауларды жақсы түсіну үшін осы зерттеу барысында статистикалық әдіс қолданылды. 8 оқыту нұсқаушысы әңгімелесуден өтті, олар 5 кен орнында 3 жыл ішінде 1048 жүк көлігі операторын оқытты. Талдаулар жазатайым оқиғалардың мәнмәтінін зерттейді, олардың себептерін, нәтижелерін және ықтимал алдын алу мен салдарын жоюды бақылауды бастауға назар аударады. Жалпы, апаттардың көпшілігі жол жағдайына, дизайнды оқуға және пайдалану туралы шешім қабылдауға байланысты орын алады. Bow-tie диаграммасы қауіп-қатер, бастапқы бақылау, алдын алу және жұмсарту бақылаулары мен нәтижелер арасындағы байланысты көрнекі көрсету үшін осы зерттеуде пайдаланылатын тәуекелдерді басқарудың сындарлы құралы ретінде. Зерттеу нәтижелері операторларды оқытуға және шахталық көлік жолдарын жобалау мен күтіп ұстауға ұйымдастырушылық бақылауды жақсартуды ұсынады.

Негізгі сөздер: *шахталық жүк көліктері, шахта учаскелеріндегі қауіпсіздік, ақауларды талдау, апаттың алдын алу шаралары.*

Анализ аварийности в работе карьерных автосамосвалов

А. Шакенов*, Д. Крамсаков, И. Столповских
Satbayev University, Алматы, Казахстан
**Автор для корреспонденции: ashakenov@yahoo.com*

Аннотация. По оценкам, 45% всего горнодобывающего оборудования в мире составляют карьерные самосвалы. По данным управление по безопасности и здоровью в шахтах США за 2017 год, в мире эксплуатируется более 44 тысяч карьерных самосвалов, и более 20% аварий со смертельным исходом на горнодобывающем оборудовании происходит с участием карьерных самосвалов. Карьерные самосвалы являются критически важным оборудованием для горнодобывающей промышленности Казахстана, где 80% горных разработок эксплуатируются открытым способом. Для лучшего понимания отказов в работе самосвалов в ходе исследования был использован статистический метод. Были опрошены 8 инструкторов по обучению, которые в течение 3 лет обучили 1048 водителей автосамосвалов на 5 рудниках. В ходе анализа изучается контекст происшествий с упором на инициирующие причины, последствия происшествий и возможные профилактические и смягчающие меры контроля. В целом, большинство аварий происходит из-за состояния дорог, проектирования и принятия эксплуатационных решений. Диаграмма Bow-tie как конструктивный инструмент управления рисками, использован в этом исследовании для визуального представления связей между опасностями, инициирующими мерами контроля, профилактическими и смягчающими мерами контроля, а также результатами. Результаты исследования позволяют предлагать улучшение организационного контроля за обучением операторов, проектированием и содержанием технологических дорог.

Ключевые слова: *карьерные самосвалы, безопасность на рудниках, анализ отказов, меры по предотвращению аварий.*

Received: 14 May 2023
Accepted: 15 August 2023
Available online: 31 August 2023