



Road Transport Accident Analysis from A System-Based Accident Analysis Approach Using Swiss Cheese Model

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Abstract- Road safety has become a major concern to both developed and developing countries due to its negative economic impacts. Although, numerous approaches of accident analysis have been conducted, there seem to be an increase in road crashes every year. The main aim of this study is to analyse a driving school accident using a system-based accident analysis approach. The data for the study was collected using an interview. A Swiss Cheese Accident Causation Model was used to identify the factors that contributed to the accident. The study identified four weaknesses in the system defences of the driving school that created a possible accident trajectory. It is concluded that adopting system-based accident analysis approach in analysing road transport accidents, could lead to a greater understanding of latent conditions and road user error, which in turn could inform the development of intervention strategies within a road transport domain as suggested by other studies. Finally, the short falls of using only person approach of accident analysis in road transport domain are also highlighted.

Keywords – Accident analysis; Accra-Ghana; Driving School; System- based; Swiss-Cheese Model.

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1. Introduction

As the world advances in technology, transportation has become more comfortable and readily available, but with the passage of time, transportation faces many issues like high accident rate, traffic congestion, traffic & carbon emissions air pollution [21]. The incidence of deaths and injury as a result of road accidents is now a global phenomenon. As a result, authorities in virtually all countries of the world are now concerned about the growth in the number of people killed and injured on their roads including Ghana [13]. The main goal of traffic safety engineers is to reduce these negative effects to the minimum level to improve traffic safety. All over the world, road safety has become a major concern and priority for governments, policy makers and even to individuals because of its negative economic impacts. A study conducted by [11], revealed that road traffic accidents affect economic growth negatively and the degree of the negative effect is 0.209588%, implying that, increase in

road traffic accidents in Ghana, is a greater cost to the nation. For instance, road accidents in Ghana have been identified as one of the major causes of death in the country [18]. Thus, mobility, which is an important factor in the life of working people, and an essential ingredient in the economic and social development of Ghana, comes at a high cost which continues to be paid via traffic-related fatalities and life-altering injuries and economic costs [14]. [2]; concluded that transport-related injuries have longer disability times than injuries that are not traffic related in Ghana. They also purported that transport related injuries are associated with high medical costs and have a significant economic impact on the affected families and the national economy.

Many researchers in Ghana [3,6,7,18,17]; have tried to analyse the causes of road accident and proposed some measures in order to help reduce this road menace to the minimum level but there seems to be an increase in road accidents in the country every year. According to Ghana

National Road Safety Commission annual report [12], compared to the previous year (2015), there was a general annual increase in fatal crashes by 7.6% in 2016. [23], indicates that two approaches to the problem of human fallibility exist which include the person and the system approaches. The researcher explains that, the person approach focuses on the errors of individuals, blaming them for forgetfulness, inattention, or moral weakness whilst the system approach concentrates on the conditions under which individuals work and tries to build defences to avert errors or mitigate their effects.

The system-based accident analysis approach has not or received little adoption in analysing road accident in Ghana. A previous research state that it is notable the approach to accident analysis and investigation remains, on the whole, individual road user oriented [26]. The researchers after undertaking two research programs to investigate the utility of systems-based accident analysis within road transport, indicate that there are various reasons for which the person approach of accident analysis has dominated the road transport domain. This is because, there are quality of data available, its collection, coding and storage, the training and experience of the personnel available to analyze road traffic accidents. Since the early 1990s, the Swiss Cheese Model (SCM) of the English psychologist James Reason has established itself as a reference model in the aetiology, investigation or prevention of organizational accidents in many production systems (transportation, energy, healthcare). Based on the observation that, it's still today widely used [15]. It is now broadly recognized that accidents in complex systems occur through the concatenation of multiple factors, where each may be necessary, but where they are only jointly enough to produce the accident. All complex systems contain such potentially multi-causal conditions, but only rarely do they arise thereby creating a possible trajectory for an accident. Often these vulnerabilities are "latent", i.e., Present in the organization long before a specific incident is triggered. Furthermore, most of them are a product of the organization itself, as a result of its design or as a result of managerial decisions [22]. [4]; after studying several past accidents in process industries, concluded that usually an accident is caused by number of active and latent errors, although sometimes it is difficult to analyse the latent errors. Mainly latent errors are associated with the organizational characteristics; therefore, organizational characteristics have an influence on the outcome of operator's action. [8] indicate that, World Health Organization (WHO) and the World Bank launched a Decade of Action for Road Safety in 2011 with the goal of halving the number of injuries and deaths on the roads. However, no progress has been reported in Low and Middle-Income Countries (LMICs) and the number of deaths remains very high. To reach the target set, there is a need for interventions in several areas.

We, therefore, believe that one of such areas of intervention is to start paying attention to the system

approach of accident analysis in the road transport domain with the focus of analysing road accident individually especially the fatal ones. This will help in providing detail causal factors which in turn could inform the development of intervention strategies. The main aim of this study, therefore, is to adopt a system-based accident analysis approach by using a Swiss Cheese Model to identify the causes of an accident that occurred in a driving school in Ghana. of mobile technologies. Thanks to MALL, students are able to access foreign language learning materials and communicate at any time with their teachers and colleagues. The analysis of the studies[3] on courses in foreign language learning on mobile devices brings out the tendency to focus on grammar and vocabulary followed by pronunciation and reading.

2. Literature Review

2.1 Role of Driving Schools in Ghana

Driving, as a critical safety skill, depends on the integration between the road and the traffic environment, the vehicle being driven and most importantly, the driver's knowledge and competence. Research over the last couple of decades consistently show that many road traffic incidents are caused by human error: driver attitude and behaviour are cited in 80 per cent to 90 per cent of such traffic incidents [14]. Driving schools are set up by most countries to help learner drivers and older drivers acquire the necessary skills, knowledge on road safety as far as driving is concerned in order to reduce road accidents. Ghana has not been able to fully establish any legal legislation, backing driving schools as a compulsory medium through which driver training should be provided until road accident has become the second killer on the road. About a decade ago, it has become necessary for the government to follow the rest of the country that has seen and benefited from the implementation of legal backing for driving schools and to help do this properly, the Driver Vehicle and Licensing Authority (DVLA) of Ghana in 2008 closed down more than 31 driving schools that have failed to meet the set standard because the affected schools were using unroadworthy vehicles and untrained staff as driver instructors. The then Chief Technical Officer of the DVLA indicates that the move was in line with the Road Traffic Act of 2004, Act 683 (4) and meant to deal with unscrupulous activities of some driving schools and explained that the exercise was also intended to restore sanity in the system, as well as ensure that people did not set up schools to provide sub-standard service to clients. Additionally, this initiative was taken because the DVLA observed that the standards set for the operation of driving schools had drastically declined even after persistent education and advice. Furthermore, the use of unroadworthy vehicles to teach students posed a serious risk to the life of not only the students but the instructor as well [19]. Driving schools in the country have become the only medium through which driver training must be

provided before a driver license can be issued to new driver by the DVLA.

2.2 Road safety problems in Ghana.

Ghana has considerable problems with road safety, which manifest in the numerous incidences of road accidents [1]. In the past, road safety management was characterized by dispersed, uncoordinated, and insufficiently resourced institutional units performing isolated single functions by individual departments within the Ministry of Roads and Transport. Currently, the National Road Safety Commission (NRSC), Police MTTU and DVLA together with other stakeholder organizations were mandated to address the incidence of unacceptably high levels of road traffic crashes in the country by enforcing and regulating road traffic rules and regulations [1]. Yet, due to the ever-increasing vehicular fleet in the country, the notoriously bad attitude of road users and the weak enforcement of traffic rules, the absolute number of deaths and injuries still fluctuate within unacceptable ranges. Additionally, there appeared to be legislative, institutional, administrative and procedural inadequacies which were also aggravated by problems of inadequate logistics and funding for road safety activities [1]. Many researchers have come out with the causes, effects and recommendations to vehicular accidents in Ghana and elsewhere. For instance, the results from a survey conducted by [7, 18]; indicate that over speeding, overloading and disregard to road signs or regulations are the first-three main RTA causing factors in Ghana. Road accident is becoming more and more common today and contributes to a significant number of deaths. [17], found that over 90% of RTAs are caused by human behaviour.

2.3 Accident Models

Accident modelling is a methodology used to relate the causes and effects of events that lead to accidents. This model effectively seeks to answer two main questions: Why does an accident occur, and How does it occur [5]. Understanding accident causation is intrinsic to their successful prevention. To shed light on the accident phenomenon, over the years, researchers have developed a plethora of conceptual models. At first glance they seem as diverse and disparate as the accident problem they purport to help solve, yet closer scrutiny reveals there are some common themes. There are linear models which suggest one factor leads to the next and to the next leading up to the accident and there are complex non-linear models which hypothesizes multiple factors are acting concurrently and by their combined influence, lead to accident occurrence [20].

James Reason gave a clear distinction between a person approach of accident analysis and system-based approach as follows:

1. Person Approach: The longstanding and widespread tradition of the person approach focuses on the unsafe acts—errors and procedural violations—of people at the sharp end. It views these unsafe acts as arising

primarily from aberrant mental processes such as forgetfulness, inattention, poor motivation, carelessness, negligence, and recklessness. Naturally enough, the associated countermeasures are directed mainly at reducing unwanted variability in human behaviour. These methods include poster campaigns that appeal to people's sense of fear, writing another procedure (or adding to existing ones), disciplinary measures, the threat of litigation, retraining, naming, blaming, and shaming [23].

2. System Approach: The basic premise in the system approach is that humans are fallible, and errors are to be expected, even in the best organizations. Errors are seen as consequences rather than causes, having their origins not so much in the perversity of human nature as in "upstream" systemic factors. These include recurrent error traps in the workplace and the organizational processes that give rise to them. Countermeasures are based on the assumption that though we cannot change the human condition, we can change the conditions under which humans work. A central idea is that of system defence. All hazardous technologies possess barriers and safeguards. When an adverse event occurs, the important issue is not who blundered, but how and why the defence failed [23].

Swiss cheese model is the most widely used system-based approach of the accidental analysis model. In this model the concept of safety layers was used while holes in the safety layers correspond to the deficiencies due to latent errors (e.g. Organizational errors, environment, etc.). [25]; gave a detail explanation of Reason's Swiss Cheese Model (see figure 1 below) and reported that according to the Swiss Cheese model, systems comprise various organizational levels that contribute to the production of system outputs like decision makers, line management, productive activities and defenses. Each of the levels has various defences in place that are designed to prevent accidents and safety compromising incidents. Holes or weaknesses in the defences created by latent conditions and errors create 'windows of opportunity' for accident trajectories to breach the defences and cause an accident. Accidents occur when the holes line up in a way that allows the accident trajectory to breach each of the different defences that are in place. On most occasions, accident trajectories are halted by defences at the various levels in the system. However, on rare occasions, the holes or windows of opportunity line up to allow the accident trajectory to breach all of the defences, culminating in an accident or a safety compromising incident. Although this model also has some limitations, which are even acknowledged by James Reason but still this model can provide a detailed insight about the system. The main aspect of this model is that latent conditions interact with the local triggering conditions and in case of safety barriers are unavailable, this could lead to an accident [4,28]. [22]; indicates that accidents come in many sizes, shapes and forms. It is therefore naïve to hope that one model or one type of explanation will be universally applicable. Some accidents are simple, and therefore only need simple

explanations and simple models. Some accidents are complex and need comparable models and methods to be analysed and prevented. This model is chosen because of its simplicity and since the case study is a simple one, it does

not require a complex model for its analysis and also because of the direct clarity of its simple and memorable metaphor as reported by [16].

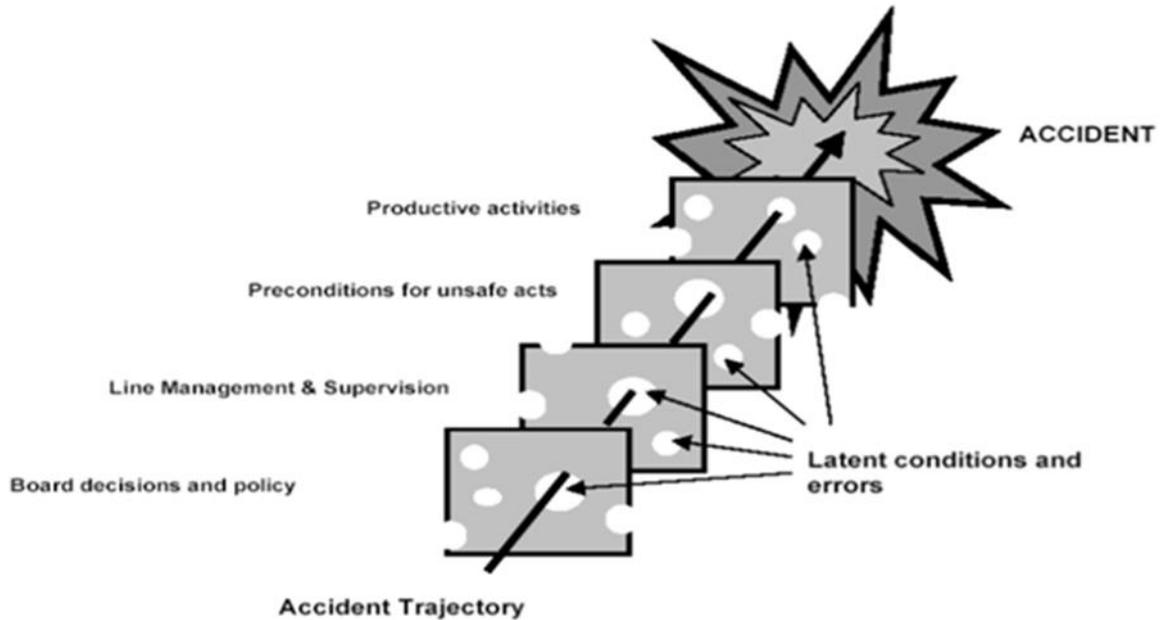


Figure 1 The Swiss cheese model of how defences, barriers, and safeguards. Source [25]

As shown in figure 2 below, [4]; presented categorization of different accidental models which are commonly used for accident analysis. These are: Sequential, Epidemiological, Systematic and Dynamic Sequential Models (DSAMs) are the main classes of accident models. Sequential models follow the chain of events while

epidemiological models focus on the performance deviations and also on the environmental condition. Since the aim of this study is limited to the application of the Swiss Cheese Model, detail review has not been conducted on other accident models mentioned in this work.

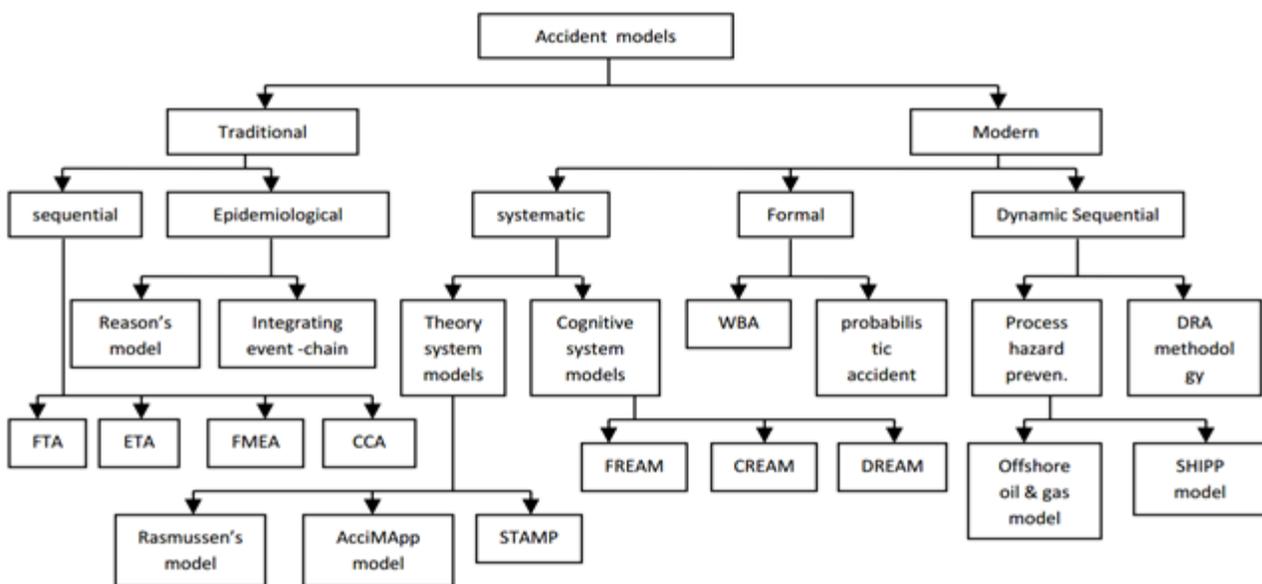


Figure 2 Accident Model Classification. Source: [4]

3. Materials and methods

The data for this study was collected from a driving school in Ghana after one of its vehicles was involved in a crash in 2018. Interview was the main method of data collection. The manager, driving instructor, learner driver and two eyewitnesses participated in the study.

Swiss Cheese Accident Causation Model was used to analyse the data. That is, since the model is a system thinking approach of accident analysis, the interview was structured to obtain information on latent and active errors which was later assigned to the layers of the model. The factors identified to have contributed to the accident associated with the decision of management were assigned to the latent error layers and action of the driving instructor and the learner driver were identified as active errors. This enables us to identify the cause of the accident as a system failure or in other words, why the accident occurs rather than who caused the accident. A study conducted by [28]; to consider whether the Swiss Cheese Model (SCM) can provide a system thinking approach and remain a viable option for accident analysis concluded that the SCM remains a viable model for accident analysis. By using an accident causation framework such as Reason's model, adverse events may be analysed in a way that allows for the underlying causes to be isolated thus helping to improve safety and prevent future adverse events [10].

3.1 Case Study.

The accident that occurred in the driving school was selected because, driving schools are set up and given legal backing by the government so that they can train learner drivers and help reduce accident on the road. However, if these driving schools are getting involved in an accident themselves, then it means the road is not safe for other road users, especially when accident has become the second killer in Ghana. Also, Driver Vehicle and Licensing Authority (DVLA) of Ghana in 2008 closed down more than 31 driving schools that have failed to meet the set standard because the affected schools were using unroadworthy vehicles and untrained staff as a driver instructor which this study has interest in finding out about the qualification status of the instructor on duty before the accident occurred.

3.2 Description of the Accident

On 12th July 2018 one of a Driving School's Vehicles was involved in an accident at 10: 40 am in Accra. The vehicle involved in the accident was an automatic transmission design. Two people were supposed to be in the vehicle, the instructor and learner driver, but after the accident, the learner driver was the only person in the vehicle before the incident took place. The learner driver sustains a minor injury after the accident. According to the instructor and other eyewitnesses, the learner driver was trying to maneuver and could not control the vehicle and instead of

braking she rather accidentally accelerated and turned the steering wheel towards a wall and collided.

3.3 Background facts gathered from the interview.

The manager of the school does not know how to drive and has no driving license.

The instructor was not a trained or qualified driving instructor certified by Driver Vehicle and Licensing Authority (DVLA) of Ghana.

There were no supervision measures in the school.

Driving schools are to employ only DVLA certified driving instructors

The learner driver was on night duty previous day and didn't have enough rest before starting her driving lessons.

4. Results and Discussion

4.1. Results.

The following four failure layers were identified from the interview after using the swish cheese model.

[23] indicates that holes in the defences arise for two reasons: active failures and latent conditions and that nearly all adverse events involve a combination of these two sets of factors. By adopting the Swish Cheese Model, which is a system thinking approach of accident analysis, two latent and active failure layers were identified (layer 1,2 and 3,4 respectively).

Layer 1 failure: Refusal of the driving school to abide by the law governing the operation of driving schools, thus employed uncertified driving instructor with no driver instructorship education or training. This was identified as a latent error because, an instructor which is not certified may not be able to apply principles governing instructing learner drivers safely which is a failure on the part of the management lying down for other factors to align. According to [22] latent errors are present in the organization long before a specific incident is triggered.

Layer 2 failure: The head of the instructor department or management not putting measures in place for supervising instructors. The defence of the school for supervising has also failed because, management should have put measures in place to supervise the instructor knowing that he was not a trained or certified instructor. This has also been identified as a latent error from the management side.

Layer 3 failure: The instructor getting out of the vehicle allowing the learner to drive alone thus, exposing her to hazard. Also, the instructor over trusted the confidence and experience of the learner driver. The instructor getting out of the vehicle for the learner driver to drive alone was identified as an active error because, the instructor operates the dual pedal in case the learner is making a mistake, but in this case since the instructor was not in the vehicle, no one could operate the pedals to help prevent the accident.

Layer 4 failure: The learner inability to accept the fact that she was tired and needed rest, especially after working all

night without having a sleep, thus putting herself at risk. Tiredness is one of the factors that affect physical fitness of a driver's ability to drive and since the learner driver was on night duty the previous day, the driving lesson should

have been rescheduled. This has affected her concentration level and could not react to the situation appropriately leading to missing the exact pedal at the time leading to the accident.

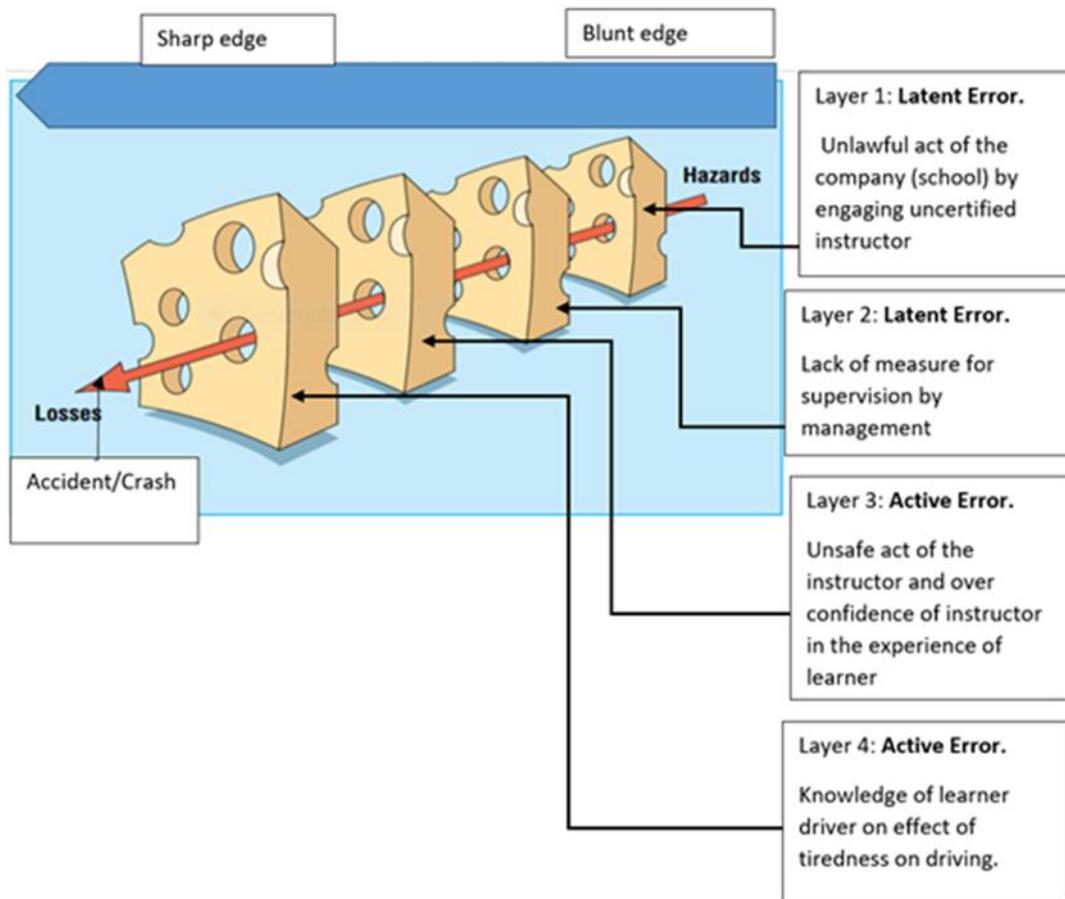


Figure 3 Active and Latent causes of the accident (Swiss Cheese Accident Model)

4.2 Discussion

This study adopted a system-based accident analysis approach to identify factors that contribute to an accident of a driving school in Ghana with the aim of proposing this method of accident analysis approach into the road transport domain. It could be identified that the results from the model show multiple causational factors that triggered the accident. This is because, weaknesses in the driving school system's defences, created by inappropriate or inadequate decisions and actions made by actors at all levels of the system, allow accident trajectories to breach defences and cause the accident [26]. It is obvious in this study that weaknesses in four system defences of the driving school, which can be seen in layer 1,2,3,4 of figure 3 above altogether caused the accident. This confirmed the result of [4]; which concluded that usually an accident is caused by number of active and latent errors and that mainly latent errors are associated with the organizational characteristics. It could be concluded that all the four causal factors were necessary, but individually could not trigger the accident until they were jointly enough to produce the accident. It is also evident that, what could produce the accident was with the school since its inception and waiting for other factors to join which confirm the findings of [22].

According to [23], the person approach has serious shortcomings and continued adherence to this approach is likely to thwart the development of safer institutions (healthcare). This is an indication that road transport researchers should now be looking at a combination of both approaches rather than giving all attention to person approach of accident analysis. By using the system approach, we discover that driver tiredness which has a negative impact on driving could have been the conclusion of what caused the accident, or the driving instructor would have been the only person blamed for the occurrence of this accident if the person approach of accident analysis was to be used. However, by using the system approach why the accident occurs was identified rather than who caused the accident. Accident prevention is the most basic of all safety management paradigms. If safety management is effective, then there should be an absence of accidents. Conversely, if accidents are occurring, then effective safety management must be absent. Therefore, understanding how accidents occur is fundamental to establish interventions to prevent their occurrence [20]. We are also of the view that a system approach of accident analysis can help reveal how accidents occur in the transport domain if given the necessary attention. According to [26], Reason's Swiss cheese model is highly applicable in a road transport context, with each of the

levels specified applicable to road transport systems, and yet it does not appear to have been widely accepted or applied in such a fashion. A study conducted in Ghana also suggested that road accident in the country needed to be looked at from different approach rather than what is commonly known as the person approach probably as a health problem [9]. It is believed that by adopting both approaches of analysing road transport accidents, and the measures proposed by various researchers if implemented by policy makers', road transport safety should see a significant improvement.

5. Conclusions

In this study, we analysed a road transport accident by adopting a system-based accident analysis approach using Swiss Cheese Accident Causation Model. Multiple factors were found to be the cause of the accident. Although, many advanced and modified accidents models have been developed after the James T. Reason invented the Swiss Cheese Model, the model have been successfully applied in identifying the latent and active failures of the driving school.

This study concluded that by adopting system-based accident analysis approach in the road transport domain, a better understanding of latent conditions and road user error could be provided which in turn could inform the development of intervention strategies within a road transport domain as suggested by other studies. The study suggests that a system approach of accident analysis should be encouraged by policy makers, especially fatal accidents so that the root causes of these individual accidents which add up to become a major concern will be addressed.

In order to prevent similar future accident occurring, this paper recommends that the authorities should do a thorough background investigation of all existing driving schools taking into consideration the instructors, vehicles, and training materials used to teach learner drivers.

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References

- [1] Elaish, M. M., Shuib, L., Ghani, N. A., & Yadegaridehkordi, E. 2019. Mobile English language learning (MELL): a literature review. *Educational Review*, 71(2), 257-276.
- [2] Al-Emran, M., Mezhuyev, V., & Kamaludin, A. 2018. Technology Acceptance Model in M-learning context: A systematic review. *Computers & Education*, 125, 389-412.
- [3] Uzunboylu, H., & Genc, Z., 2017. Analysis of Documents Published in Scopus Database on Foreign Language Learning Through Mobile Learning: A Content Analysis. *Profile Issues in Teachers' Professional Development*, 19(Suppl. 1), 99-107. https://dx.doi.org/10.15446/profile.v19n_sup1.68624
- [4] Stockwell, G., & Hubbard, P. 2013. Some emerging principles for mobile-assisted language learning. Monterey, CA: The International Research Foundation for English Language Education. Retrieved on April 12, 2015 from http://www.tirfonline.org/wp-content/uploads/2013/11/TIRF_MALL_Papers_StockwellHubbard.
- [5] Baran, E. 2014. A review of research on mobile learning in teacher education. *Journal of Educational Technology & Society*, 17(4), 17-32.
- [6] Bozdoğan, D. 2015. MALL revisited: Current trends and pedagogical implications. *Procedia-Social and Behavioral Sciences*, 195, 932-939.
- [7] Elaish, M. M., Shuib, L., Ghani, N. A., Yadegaridehkordi, E., & Alaa, M. 2017. Mobile Learning for English Language Acquisition: Taxonomy, Challenges, and Recommendations. *IEEE Access*, 5, 19033-19047..
- [8] Uzunboylu, H., & Genc, Z. 2017. Analysis of documents published in Scopus database on foreign language learning through mobile learning: A content analysis. *Profile Issues in Teachers' Professional Development*, 19, 99-107.
- [9] Bravo, J., Frances B., Isaac. C. & S. 2018. Data mining in foreign language learning. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*. 10.1002/widm.1287.
- [10] Glaser, B. G., & Strauss, A. L. 1967. *The discovery of grounded theory: Strategies for qualitative research*. Hawthorne, NY: Aldine de Gruyter.
- [11] Viberg, O., & Grönlund, Å. 2013. Cross-cultural analysis of users' attitudes toward the use of mobile devices in second and foreign language learning in higher education: A case from Sweden and China. *Computers & Education*, 69, 169-180.
- [12] Ghanbarpour, M. 2017. A Qualitative Meta-synthesis of Research on Dynamic Assessment of Second/Foreign Language Learning: Implications for Language Teachers. *Journal of Language Teaching and Research*. 8. 731. 10.17507/jltr.0804.12.
- [13] Limone, P., & Pace, R. (2016). The Learning by Design Framework in School and Out-of-School Contexts: Research Experiences and Perspectives. In *A Pedagogy of Multiliteracies*(pp. 157-171). Palgrave Macmillan, London.
- [14] Toto, G.A. (2017). The influences of musical learning on psychophysical development, intelligence and technology. *The online journal of educational technology*, 16(1), 604-610.
- [15] Toto, G.A. (2018). From Educational Contexts to Addictions: the Role of Technology in Teaching Methodologies and in Prevention as an Educational Function. *Journal of e-Learning and Knowledge Society*, 14(2), 203-212.
- [16] Wang, S., & Smith, S. (2013). Reading and grammar learning through mobile phones. *Language Learning & Technology*, 17(3), 117-134.