Applying systems thinking concepts in the analysis of commercial motorcycle drivers' safety culture

Oluwasegun O Aluko

Department of Civil Engineering
Ekiti State University, Ado Ekiti, Nigeria
Email: alukosegun@gmail.com

Abstract
Safety in vehicular transportation is an important subject amidst transport professionals. Various methods are used to investigate causes of accidents and how to mitigate it. Recent statistical methods for accident analysis note that several factors are involved in accident causation and analysis should be able to take cognizance of this multivariate nature. Statistical models however are not able to incorporate dynamic variations in these factors. A causal loop diagrammatic representation of systems approach is presented in this paper. This approach has the capacity to bring in the dynamic nature in some accident causation factors. It is therefore used to study the safety challenge of commercial motorcycle trade. It identified six feedback loops and describes how these loops interact to shape the safety challenge in the trade. It further points out how a mix of measures might be adopted to improve the situation. This method is therefore shown to be able to provide an avenue to frame better debates and obtain a procedure for the elaboration of plausible future pathways in dealing with systemic problems.

Keywords: causal loop diagram, commercial motorcycle, safety, system dynamics.

1.0 INTRODUCTION

Drivers' behaviour research often adopts organisational safety culture to understand the relationship between safety and behaviour, especially when the vehicle is considered as a work place (Oz et al., 2014). A number of these research have used causal relationships to identify links between factors involved (Ozkan et al., 2006; Davey et al., 2007). This is more so as there are a wide range of causal analysis tools which can be used to ensure thorough and systematic analysis. Many of these tools however only identify a string of events that leads to an incident and its consequences (Goh et al., 2010). They view cause and effect linearly as they are not designed to model changes in the system across time. In this way, these causal analysis tools are generally not designed to facilitate the development of strategies that will enable high leverage interventions. As shown by Goh et al. (2010), a causal analysis tool that can model dynamic complexity is a better tool. Such tool is what is provided by systems approach.

Systems approach is an approach that shows the connections between the elements of a system. It is a paradigm that is rooted in non-linearity and feedback concepts (Carhart and Yearworth, 2010) and has different names such as systems thinking, systems theory and systems approach. Systems approach attributes the behaviour of a system to the feedback control structure of the system itself. This view does not mean that the effect of external factors should be ignored. Rather, what it points out is that the way a system responds to external factors depends on the dynamic structure of the system itself. This paradigm challenges conventional wisdom to view a problem from a wider perspective as against the usual narrow linear cause-and-effect perspective. As noted by Conroy and Allen (2010), systems approach helps to see the bigger picture of challenging situations so as to be able to develop solutions that are more reliable. In this way, it is useful for understanding the nature of a challenging problem better. This approach has been used in transportation field to address safety problem in many studies (Leveson, 2004; Leveson, 2011; Underwood and Waterson, 2013; Rasmussen, 1997). Systems approach can be represented by a system dynamics model.

2.0 SYSTEM DYNAMICS CONCEPT

System dynamics (SD) is a representation of systems approach. It reflects the fundamental principle that the structure of a system gives rise to its behaviour. It is founded in the theory of nonlinear dynamics and feedback control, but also employs psychology, economics, and other social sciences (Sterman, 2000). Generally, in real life systems, a problem and its symptoms may be separated by time and space. It is also possible that the system behaves in a counter-intuitive manner. Moreover, real life systems have been found to demonstrate policy resistance and characteristics such as unpredictability and disequilibrium condition (Radzicki and Taylor 1997). In SD, a model is developed to understand how these situations emerge within the system which might otherwise be too difficult for the human mind to process (Kirkwood, 1998). SD models offer a transparent and easy to follow analysis by displaying maps that show the cause and effect relationships between individual system variables. It conceptualises the system as being controlled by a process of information, action, and consequences (feedbacks) in order to maintain its purpose. As a result, SD has often shown to be superior to other analysis methods.

SD representation can be of two types: qualitative SD model (SDM) and quantitative SDM (Coyle, 1996; Coyle, 2000; Wolstenholme, 1999). The qualitative SDM is usually referred to as causal loop diagrams (CLD) and will be used in this paper.

CLDs are maps that show the relationships between the components of a system in a manner such that a cause is linked to its effect(s) in a way that a closed loop emerges. They are unique for the ability to visually display relations in a cause and effect manner as well as reveal the feedback processes within the system being represented (Kirkwood, 1998). They help to depict the basic causal mechanisms of the system, thereby providing the opportunity to “improve the process of thinking about the structure underlying a problem” (Homer and Oliva, 2001, p.349). They are able to illustrate poorly understood systems and provide insight about the system even before any form of analysis is initiated (Smith, 2000). Sterman (2000,p.137) observes that CLDs have a number of important functions including eliciting and capturing the mental models of individuals or teams, showing hypothesis about the causes of dynamics, and revealing feedbacks that might be responsible for a problem within the system. He further notes that they are a flexible tool and good for diagrammatically representing the feedback structure of systems “in any domain”(Sterman, 2000, p.102). Similarly, Ülengin et al. (2007, p.83) observe that they represent “domain knowledge” more descriptively than other models, such as regression models or structural equation models. They also help to improve transparency (Shepherd et al., 2009). These benefits are the basis for the choice of this tool in this paper. In the next section, a background of the problem to be investigated is provided. This is followed by how data is captured for developing the CLD. The fifth section describes the development of CLD while the sixth and seventh sections give discussion and conclusion respectively.

3.0 BACKGROUND

Road transport is the main mode of transport in Nigeria today. But it did not start that way. The colonial masters in the pre-independence period who were more interested in exploitation concentrated on developing the rail system. However, in the post-independence period, investment in the rail sector declined while road development improved. As a result, road dominated the transport system and accounted for more than 90% of both passenger and freight movement. This over-concentration of transport on road was made worse by the high ratio of vehicle growth to road development and high population growth rate. For example, motorisation increased at a rate about 14 times the rate at which road was developing (Akinbami and Fadare, 1997; Ogunbodede, 2008). As motorisation increased, so did congestion, especially in the big cities. Similarly, the high population growth rate resulted in increasing travel needs. Those who could not afford a car depended on public transport. Unfortunately, at a time in the late eighties/early nineties when transportation need increased most was the time government’s capacity to fund public mass transit was also at its lowest due the economic down turn. The rising population, attendant increasing mobility need, rising road congestion, and collapsing government public transit system in big cities led to the emergence of various para-transit modes (Gbadamosi, 2006; Olubomehin, 2012). One of these is the commercial motorcycle mode (Fasakin, 2001).

Commercial motorcycle is now a dominant mode of transportation for many urban trips in Nigeria. Oyesiku and Odufuwa (2002)find that as much as 80% of commute trips involved the use of commercial motorcycle, a situation which is not likely to have improved today. Nevertheless, commercial motorcycles are perceived as risky and are over-represented in safety incidences relative to their share in traffic. This paper therefore intends to apply systems concept to understand the dynamics responsible for this safety challenge. The following are of particular importance:

- Identifying the feedback structure of the system to helps provide useful understanding about what is amenable to changes in the system.
- The representation the structure of the system pictorially to provide an opportunity for thinking through the interactions within the system.

4.0 DATA

The data collection method employed is more similar to Turner *(2013*) than the GMB method (Andersen and Richardson, 1997) in system dynamics modelling. A semi-structured interview method was adopted to elicit information from stakeholders about commercial motorcycle operation. The semi-structured interviews adopted some general lead-questions; other questions raised during the interview resulted from responses to the lead questions. 25 respondents from seven stakeholder groups participated and granted 13 interview sessions in all. Most of these interviews were audio recorded while others that could not be recorded were documented by hand-written notes. The entire data was transcribed for the ease further analysis. Other written documents such as newspaper reports and literature on commercial motorcycle safety provided information that influenced the researcher's frame during data analysis.

The data collection phase was followed by data coding using Miles et al. (*2014*) *causation coding* and Burnard's (1991) steps for coding interview data. The codes obtained were first sorted into small clusters as a starting point for generating meanings in the analysis. Both Miles et al. (*2014*) and Saldana (2013) suggest the use of graphical representations called *causal networks* for the outcome of a coding process to support "sense-making". Causal networks are graphical illustrations of cause and effect as they are deduced from the data. They are drawn with the use of arrows and codes. Arrows link codes to one another and indicate how one thing leads to (or is affected by) the other. In all, five networks were obtained. The causal networks obtained were combine to form a single network. There were redundancies in the form of repetitions that were removed in preparation for the next step in the data analysis process.

The next step was the generation a worded description of all the links present in the causal network. This description helps to provide a story-like account of how and, often, why one cause leads/ relates to its effect. This description is called a "narrative" (Miles et al., *2014*). A narrative provides a complete description of a system's causality relationship as found in the data without including illustrations, examples, and other less important information that make the original data bulky. There are no rules about the starting and end points of the narrative. It is however important that all the links and codes in the causal network are included in the description..

From this narrative, the processes/cycles/dynamics in the system were extracted as summary points. These summary points are what make dynamic hypothesis required for building a (CLD). This summary is different from the narrative in that while the narrative is a story-like description of all the links identified in the data, the summary is a list of bullet points/ statements of the content of the story. The summary identifies processes/ events in the story and why they happen the way they do. More specifically, for the purpose of the development of a CLD, these summary statements describe processes and their feedback loops in a manner that they form a dynamic hypothesis for the problem structure in the system being analysed. These dynamic hypothesis and the feedback loops they represent are listed below in table 1 and described in the next section.

Table 1: Dynamic hypothesis and corresponding feedback loop

	Dynamic hypothesis	**Loop Name**
1	A growing drivers' population is causing further growth through the increasing awareness of the high profit margin in the trade.	Drivers' population growth
2	Expensive ownership options available are promoting population growth but raising work pressure within the trade.	Expensive ownership options
3	Increasing competition should reduce population growth but its effect is weak.	Competition and drivers' population
4	Strenuous working condition is making drivers to turn to violations and career-switch plans.	Trade is strenuous
5	Career-switch plans are promoting savings habit and adding to or sustaining earning pressure	Career-switch
6	Training deficiency is reinforcing itself with drivers needing to work more, having no time for driving education, and ignorantly taking further risks	Time for training

5 SYSTEM ANALYSIS USING CLD

In this section, a description of each of the hypotheses is first provided. This is followed by the description of the CLDs

5.1 Dynamic Hypotheses descriptions

Hypothesis 1:

A growing drivers' population is causing further growth through the increasing awareness of the high profit margin in the trade.

Commercial motorcycle trade is a lucrative one with evidence that drivers make above the national minimum wage from the trade (Arosanyin et al., 2011; Ogunrinola, 2011). Unlike most other informal trades, commercial motorcycle trade does not require long apprenticeship or training. This is the reason why more people (including those from other trades) switch job to commercial motorcycle trade on full time or part time basis. The awareness of this high job returns contributes to the rising number of drivers. This awareness will normally be created as drivers interact with members of the public so that the more the number of drivers the more people become aware of this highly profiting trade. This structure is shown in a CLD in figure 1.

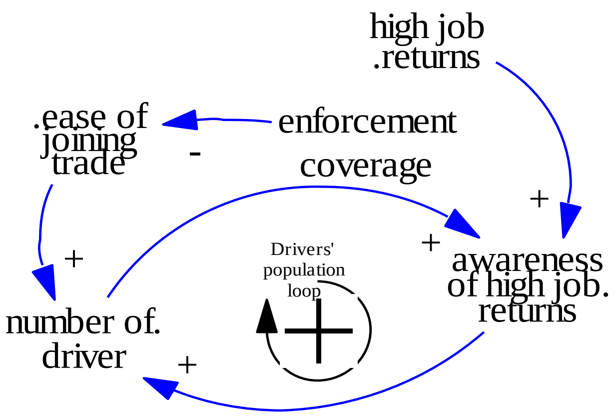

Figure 1: Drivers' population growth loop (Aluko, 2014)

Hypothesis 2:

Expensive ownership options available are promoting population growth but raising work pressure within the trade.

Motorcycle acquisition has been made easy by a hire-purchase system where drivers can collect a new motorcycle and pay the cost later with minimal collateral, though at a high interest rate. Another acquisition option is to rent a motorcycle and make daily payment. These two options make joining the trade very easy for many who could not afford the cost of a motorcycle. New drivers take these options based on the perception that the trade is lucrative, and they are able to pay back and become motorcycle owners after a short time based on what they realise from the trade. This is because they usually work more. The increasing number of commercial motorcycle drivers is therefore substantially fed by the increasing number of drivers who acquire their motorcycles by hire-purchase or rent.

Hypothesis 3:

Increasing competition should reduce population growth but its effect is weak.

Furthermore, the increasing number of drivers results in competition for picking passengers and affects drivers' income. Mahlstein's (2009) study shows that drivers are willing to pick passengers for a lower fare than they would have otherwise done due to this rising competition. This has an implication on how drivers work. For example, to make a desired target amount, drivers might have to work more than they would otherwise do. Arosanyin et al. (2013) finds drivers' average working period to be as high as 13 hours a day. In addition, drivers who join the trade through hire-purchase and rent need to make payments for the cost of the motorcycle and raise enough for their personal maintenance. Such drivers work more and are more pre-occupied with the income they want to make (when compared with others who own their motorcycles). Nevertheless, those who are unable to cope drop out. This structure is shown in figure 2.

Hypothesis 4:

Strenuous working condition is making drivers to turn to violations and career-switch plans.

Working longer brings more income (earning). Drivers therefore have incentives to work more. They increase their average working time per day in order to realise their desired target. This pressure to work longer so as to earn more money is termed *earning pressure*. Earning pressure results from the high projected amount (high target income) set by drivers and from the increasing competition for passengers. Many meet up with their high projected income, especially drivers who work longer. As drivers reach their target, the perception that commercial motorcycle trade is lucrative is maintained. But working for a longer time would normally result in fatigue as drivers stretch their capacity for work (*work capacity*) to the limit. One of the reasons why *drink driving/ driving under influence* was common is that these substances enhance drivers' capacity to work. The adverse effects are notable, particularly in causing violations and accidents. In addition, it also brings the impression that the trade should not be a permanent career.

Hypothesis 5:

Career-switch plans are promoting savings habit and adding to or sustaining earning pressure

The impression that the trade should not be a permanent career results from the strenuous working condition of many drivers. The implication on drivers is the plan to switch job. Thus, drivers decide to raise capital for a different trade by making savings (thrift savings). Engaging in thrift savings makes them work more, generating another vicious cycle or at least maintaining drivers' work pressure. Figure 2 shows these relationships.

Hypothesis 6:

Training deficiency is reinforcing itself with drivers needing to work more, having no time for driving education, and ignorantly taking further risks

Finally, just anyone could start the trade at any time as competence was not a pre-requisite for joining. The implication is that drivers are often not trained and may not be qualified to drive. This leads to an army of risky and dangerous drivers. Earlier in the history of the trade, competence was not a problem. The literature notes that early commercial motorcycle drivers were motorcycle owners (proficient in driving motorcycles) who turned their motorcycles into taxis (Ogunbodede, 2008). But as the number of commercial motorcycle grows, there are fewer of such expert drivers and those who are newly joining do not care about training (Iribhogbe and Odai, 2009; Oluwadiya et al., 2009). Now, drivers are not trained and often have to work over a long time. Working over a long time contributes to drivers' unwillingness to commit time to training[1].

5.2 Loops description

Drivers' population growth loop:

The drivers' population growth loop shows that as the **number of drivers** increases, so does the **awareness of high job returns** of commercial motorcycle trade. As the awareness that the trade offers a high return increases, so does the **number of drivers** increase. It is a reinforcing loop. The structure is a common concept in diffusion theory (Rogers, 1962 in Struben and Sterman, 2008).

Expensive ownership loop:

The expensive ownership loop indicates that if the number of drivers taking **hire-purchase and rent** options increases, **target income** within the system on the average will increase. If **target income** increases, the pressure to earn more money will increase. As the pressure to earn more money increases, drivers work for longer hours which lead to high drivers' income. High drivers' income further gives the impression that

[1] For training here, emphasise is laid on driving education as current training opportunity is limited to driving education and awareness campaign about safety tips.

commercial motorcycle trade is lucrative so that more drivers come in through **hire-purchase and rent** option. This is a reinforcing loop.

Competition-and-drivers'-population loop:

The competition-and-drivers'-population loop shows that as the number of drivers increases, competition amidst drivers increases, which lowers drivers' income. As drivers' income falls, the impression that the trade is no longer as lucrative as it was arises. This reduces the awareness of the public about the profitability of the trade (with some delay), a situation that should lead to a reduction in the number of drivers and thus less competition.

Trade-is-strenuous loop:

The trade-is-strenuous loop indicates that as drivers increase their working period, fatigue sets in which reduces their capacity to work, bringing down their working period again (e.g., through occasional sicknesses). This cycle makes drivers see commercial motorcycle trade as strenuous. But it also makes some drivers to turn to the use of alcohol and other drugs for support while others plan to switch to other trades.

Career switch loop

This is also known as " …not a lifetime trade" loop as shown in figure 2. This loop in shows that as increasing working period results in fatigue, drivers contemplate a job switch and so raise their thrift savings to raise money for an alternative trade. As the thrift savings rises, target income rises too, leading to increased earning pressure. The rise in earning pressure further leads to increased working period causing a reinforcing loop.

Time for training loop:

The time for training loop shows that as working period increases, drivers have less free time. As the free time available to drivers reduces, their willingness to give time for training activities reduces too. This results in a lower level of training amidst drivers in the system than it should otherwise be. A lower level of training makes drivers more risky and dangerous and leads to more violations. Violations do often increase/ conserve drivers' income and so support the high drivers' income that reinforces the high job returns perception about the trade. This is a reinforcing loop too.

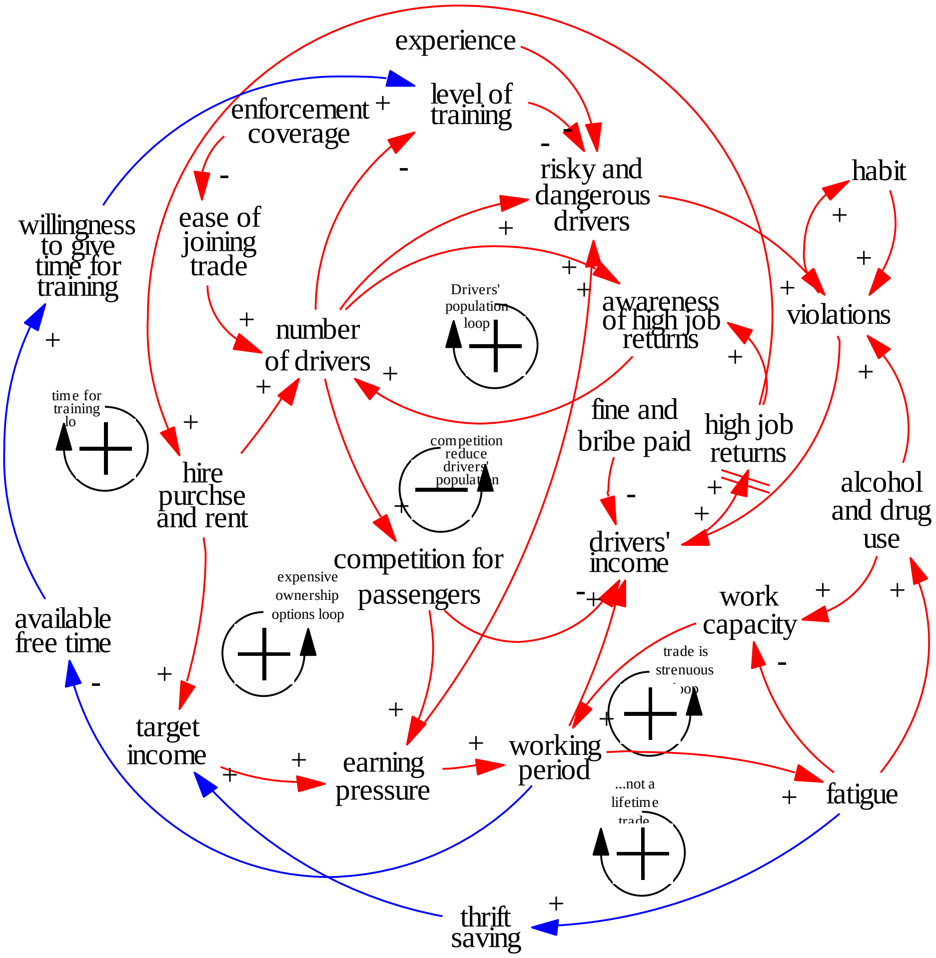

Figure 2: CLD showing all the six feedback loops (Aluko, 2014)

6. DISCUSSION

The previous section described the loops in the system dynamics model developed using a causal loop diagram in this paper. It is shown that there is an increasing interest in commercial motorcycle trade. But there is very limited structure and regulation in the trade. The fact that there is an increasing interest in commercial motorcycle trade is an opportunity for designing policies that support the trade and make for its regulation. When such is done in conjunction with the drivers, it is likely to be acceptable and supported by them.

The second hypothesis indicates that the workload of drivers affects their behaviour. Once this behavioural pattern is acquired, it is usually difficult to change it. This model suggests that drivers are enlisted to working under pressure as soon as they join the trade due to competition and repayment pressure. They however continue to work under pressure even when they no longer have repayments to make. This is not good for safety in the system. While this is self inflicted from within the system, an external intervention may be required to overcome it. This is more so as improving safety requires dealing with how this behaviour is initiated. Particularly, avoiding unnecessary competition and expensive repayment is important to improve safety. This can be by controlling how new drivers join or running a shift system to control how long drivers can work for.

On the other hand, competition amidst the drivers is supposed to reduce the number of drivers or at least reduce the rate at which new drivers join the trade. The feedback loop may, however, not be a strong one as the growing population of commercial motorcycle drivers does not clearly reflect it. This might be due to the time delay between the actual reduction in profit and the awareness about it by the drivers. It might thus have created a cycle of high and low growth rate with a positive absolute growth. This cycle is not expected to change as long as the population of passengers continues to increase. Competition may therefore not be able to reduce the growing population of drivers.

The desire to switch trade to a less strenuous one is another challenge of the system. It makes many drivers initiate a savings scheme. While a savings scheme is good, saving to raise sufficient capital to switch to another trade may often times means working extra hard. Working extra hard on motorcycles cannot be safe. This is partly why the drivers are not driving safely. A regular educative programme that informs drivers on the necessary caution to take while driving is necessary to address this. Such a programme needs to be mandatory and will also address the general lack of training amidst the drivers and can contributes substantially to safety improvement.

7. CONCLUSION

This paper has been able to identify and describe six key causal summaries important in shaping drivers' safety culture in commercial motorcycle trade. These key causal summaries are presented as six feedback loops and developed into a CLD shown in figure 2. This CLD shows that the population of drivers is growing and causing competition amidst drivers as well as forcing some of them to take expensive motorcycle ownership schemes to start the trade. This, in addition to the desire to switch jobs, is contributing to making the trade a strenuous one and contributing to unsafe driving behaviours and violations. Notwithstanding, the high-job-return characteristic of the system is still preserved. Unfortunately, many of the drivers are not qualified and are doing nothing to become qualified. This explains why the system is in perpetual state of risk. This description offers a clear representation for thinking through what the problems are in the system and how they influence the system. As noted by Goh et al. (2010), this type of analysis identifies points of leverage within the system. An analysis using CLD may therefore be able to provide a framework that can guide in formulating an efficient management policy that is able to treat system problems more holistically. As Videira et al. (2014) show, it is possible to frame better debates and obtain a procedure for the elaboration of plausible future pathways with the use of this analysis method.

Nevertheless, CLDs have their limitations. While they are able to show the feedback structures in a system, they are not able to indicate which feedback structures are more important that the others. They do not provide sufficient information about what feedback loops should be prioritised in dealing with system problems. Nevertheless, their ability to provide an opportunity to think through the structure of a problem is their benefit.

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