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Understanding the Operation of Motorcycle Taxi Drivers in Nigeria Using Causal Loop Diagram

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Abstract

Road safety is a subject of concern the world over and many studies have looked into how to improve safe travel. Motorcycles, including motorcycle taxis, are particularly vulnerable. This paper reports the outcome of a study conducted on motorcycle taxi safety problems using a system dynamics method. Qualitative data was obtained from the field and analysed using qualitative analysis methods. The outcome of the qualitative analysis led to the formulation of a dynamic hypothesis for a system dynamics approach, whose first step was to develop and analyse a causal loop diagram [CLD]. This CLD demonstrates how deterrence, a behavioural pattern that can be produced by the appropriate application of sanctions, is both strengthened and weakened within the system. The paper uses this analysis to provide insights about the behavioural patterns of motorcycle taxi operation in Nigeria. These insights include the possibility of maintaining the system at equilibrium for a desired level of deterrence as well as the possibility of breaking undesirable cycles of bribery and jumping arrest loops. These insights can also be useful in other countries of the world where motorcycle taxis operate.

Keywords: *System Dynamics, Causal Loop Diagram, Safety Culture, Motorcycle Taxi.*

1. Introduction

Road traffic accidents account for approximately 1.3 million deaths per year globally, of which more than half are among vulnerable road users including motorcyclists [1]. The United Nations General Assembly in 2020 thus declared improving road safety a major international issue with the target to reduce road traffic deaths and severe injuries by at least 50% until 2030 [2]. Policy makers and transport planners require modelling tools that provide information for the identification of efficient and effective road safety measures to achieve this target. In order to build such models it is essential to understand which factors influence the risk of road accidents. However, the problem of road safety is highly complex with many interacting factors in which behavioral factors play an important role. Data on these factors is often sparse, particularly in developing countries and countries in transition where motorcycles and, in particular, motorcycle taxis play an important role in transport but also contribute significantly to the road safety problem [3, 4, 5].

Therefore, in our work we apply a qualitative systems dynamics approach using causal loop diagrams [CLD] as a first step towards the development of a quantitative, dynamic stock-flow model for the operation and safety of motorcycle taxis in Nigeria. CLDs offer explanations for the dynamics evident in a complex system by identifying the underlying feedback structures. Through interactive development with stakeholders they support model development as well as mutual learning during the development process that is useful for the real world application. They are therefore helpful in providing some insight on the operation motorcycle taxis in a way that its safety index can improve.

In the next section, we provide the background and related work on motorcycle taxi safety followed by section 3 describing data sources and their initial analysis. In section 4 the statements that form the dynamic hypothesis are listed. This is followed in section 5 by the development of CLDs from the dynamic hypothesis. Finally, a conclusion is drawn for future work in section 6.

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2. Background and Related Works

Motorcycle taxis provide an essential service to patrons with certain advantages over alternative transport modes specifically in developing countries. In particular, they offer affordable transport, reduce waiting and journey times where public transport provision is poor, and they can more easily traverse narrow and poorly maintained roadways and congested roads than larger vehicles [3]. However, they have very serious safety problems: for example, they are regarded as the most dangerous transport mode in Vietnam, Taiwan and Malaysia [4]. In Nigeria and Cameroon, hospital wards have been named after them because most patients in these wards were victims of motorcycle taxi accidents [5, 6].

Owing to both the benefits and problems of motorcycle taxis, there is a growing body of literature on motorcycle operations and safety [7, 8, 9, 10, 11]. Various methods, including statistical and descriptive methods, have been applied in these studies to identify factors that affect motorcycle taxi safety. These include risk taking behavior of drivers [7], weak enforcement [12], drivers' earning [9] etc. However, these factors are considered in isolation, and the outcome is the provision of recommendations that only reflect linear cause-and-effect relationships without considering possible feedback effects. In particular, no study has used a systems approach to look into the relationships between the different factors identified. Systems approaches comprise a method that can assist stakeholders and policy makers to understand the big picture through identifying several possible outcomes of decision-making so as to better weigh options. Since maintaining motorcycle taxi operations safely is essential to sustainable mobility and accessibility, from a perspective of good decision-making it is thus necessary to investigate the possible systems relationships and feedbacks that may arise from the combination of the different factors that may affect motorcycle taxi safe operation. This paper attempts to fill this research gap by using available and newly collected information to develop a systems representation of motorcycle taxi operations, showing how various factors affect its safety. This is done by the development of a causal loop diagram [CLD] to generate the system structure and identify important feedback loops. CLDs are a very important tool in system dynamics for dealing with complex problems due to its ability to expose hidden feedback structures and point to leverage points in a system. This method has also been widely used in health and transportation planning fields, amidst others [13].

3. Data Source and Analysis

Using- interview methods [14, 15], information was extracted from stakeholders [motorcycle drivers, law enforcement agents and transport safety researchers] involved with motorcycle taxi operations in Ado Ekiti, a medium size city in Nigeria. Information concerning safety and the factors that affected safety was extracted. This was augmented with information from the literature. In this city motorcycle taxis provided intra-city transport. A phenomenological approach [16, 17], was adopted for the study in order to capture the subjective experiences of the stakeholders. The data analysis was then conducted using a content analysis method [18, 19]. Content analysis methods provide for a systematic coding process [20]. Coding of the interview transcripts was done following an inductive approach to identify both the factors that affected taxi safety as well as the relationships between the factors. Codes related in the analysis were linked together and later developed into a causal network and then a narrative [for more detail, see 21]. A narrative is a description of cause and effect found from the qualitative analysis of a problem [22]. This narrative helped to define the problem that would eventually be developed a causal loop diagram [CLD]. This problem definition is called dynamic hypothesis.

4. Development of Dynamic Hypothesis

The problematic structures in the operation of motorcycle taxis were extracted as a summary of the narrative. This process, as pointed out by [23, 24], helps to generate theories that can be further probed in qualitative research. This set of theories derived from the narrative is called dynamic hypothesis.

The narrative identified three interacting actors in the taxis' operation that contributed to its safety characteristics: the drivers, the political class, and the law enforcement officers. The drivers did not always operate by the rules. The political class provided some illegal cover for drivers so that they would not be arrested and prosecuted even when they were culpable. The law enforcement officers were required to enforce traffic regulations and enhance road safety but their efficiency was limited by corruption and interference by the political class. These are re-presented as follows:

1. Law enforcement involved detecting and sanctioning violators.
2. Sanctions should deter drivers from committing violations and encouraging safe driving behaviour
3. Corruption in the enforcement process, through the payment of bribe, weakened deterrence

Some road users which included other non-motorcycle drivers, pedestrians, and passengers were not included as stakeholders in this study as [24] points out that these groups have only a very little influence on motorcycle drivers' behaviour.

The three summary statements listed above represent the description of the problem. They are the theories of the problem structure for the system. In the next section, the theory is developed into a causal loop diagram.

5. Development of Causal Loop Diagram

The three theories listed above are converted into a CLD. This CLD is developed progressively over four stages. Each stage presents different loops, with the first stage loop being a sub-loop of the second stage loop and the second stage loop being a sub-loop of the third stage loop and so on. These loops are the detection and escaping arrest loops, deterrence loop, and payment of bribe loop. The three stages are now described further. Where relevant, literature on the relationships between factors is cited, thus pointing out that these relationships are found in the literature

5.1. Detection and Escaping Arrest Loop

The narrative points out that drivers' decision on whether to commit violations or not was partly influenced by the awareness of the possibility of being caught or not. For example, it was observed that when there were more police posts on the highway, fewer drivers were prepared to work as it was more difficult to get away with violations without being caught. Nevertheless, increased police posts did not eradicate violations. These findings are also established in the theory of deterrence and studies on crime and policing [25, 26, 27]. In this paper, the number of police posts per unit length of roadway is described as *enforcement coverage* while the likelihood of a driver being caught for a violation by enforcement agents is called *probability of detection*. *Violations* refer to the various infractions committed by the drivers. Figure 1 below depicts this.

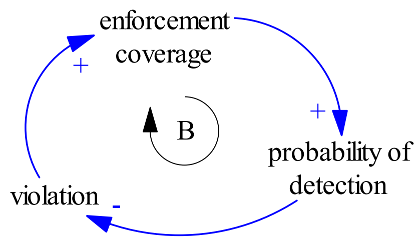

Fig. 1. Detection loop

Figure 1 above is a loop named detection loop. It shows that as **enforcement coverage** increases, so does **probability of detection**. Furthermore, as **probability of detection** increases, the number of **violations** falls which, also results in a fall in **enforcement coverage**. This closes the loop and the cycle continues. The relationship in the figure shows a balancing loop. A balancing loop is a loop that preserves a system in equilibrium. In this equilibrium, the system does not degenerate further or improve. This is probably the reason why in spite of various police interventions, there is no noticeable improvement in motorcycle taxi safety culture. It is suggested that discouraging violations may not be achieved by mere response to the level of violations committed by drivers. More effective measures than what is currently in place is necessary to address this problem. An example of such is the use of traffic cameras which are able to maintain a constant level of enforcement coverage.

Extending figure 1 further, we included another loop named *escaping arrest* loop. This is an extension of detection loop. Drivers often fled from enforcement agents when they sight them from a distance. In some instances, some of these drivers noted that they fled for fear of extortion as some of them had assumed that money would always be collected from them whether they followed the rules or not. This group of drivers did not care about violations as they did not see arrest as a consequence of violation but as a means of extortion by the enforcement agents. When this additional information was added to figure 1, a new CLD emerged as shown in figure 2 below. The information is denoted by the thin arrows. In figure 2, *corruption in enforcement and regulation* is used to describe the corrupt practices in the implementation of sanctions. On the other hand, the proportion of those who were able to flee from enforcement agents is named *escaping arrest*.

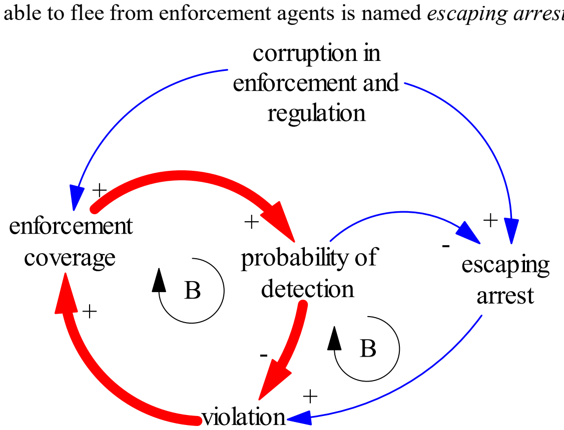

Fig 2. Escaping arrest loop

The new loop in the figure above runs such that if the **probability of detection** of violations increases, the number **escaping arrest** would reduce. If **corruption in enforcement and regulation** increases, the **enforcement coverage** and number of drivers **escaping arrest** would increase. **Enforcement coverage** would increase as officers would create more illegal posts to extort money from drivers while the number of drivers **escaping arrest** would increase because more drivers would think that the police was out to extort money and would try to dodge the police. If the number **escaping arrest** increases, the number of detected **violations** would reduce. Reduction in **violations** would lead to reduction in **enforcement coverage** which also would cause the **probability of detection** to fall, completing the cycle. This loop is a balancing loop. It also points out the relatively higher cost of enforcement due to the effect of corruption. More effort needs to be put into road management to reduce the impact of corruption. The use of automatic traffic camera earlier mentioned may help.

5.2. Deterrence Loop

Extending figure 2 further generated another loop named deterrence loop. Deterrence is a behavioural pattern that can be produced by appropriate application of sanctions. Law enforcement is not only intended to discourage crime, it is also designed to discourage criminal tendencies [25, 26, 27]. Nevertheless, as shown in the narrative, law enforcement could only produce very little amount of deterrence due to the impact of corrupt practices in the implementation of sanctions. In addition, it was shown that increase in enforcement coverage was often intended to provide avenues for extortion rather than to instil deterrence. This thus affected the drivers' attitude to violation of traffic rules. In fact, some drivers were in the habit of fleeing from police. When this additional information was added to figure 2, a new CLD emerged as shown in figure 3 below. The information is denoted by the thin arrows. In figure 3, *prosecution rate* describes the percentage of violators that were prosecuted. It is necessary to state that not all arrested got prosecuted. The number of violators arrested and prosecuted is named *arrested and prosecuted* while *deterrence* refers to the attitudinal change resulting from the effect of sanction.

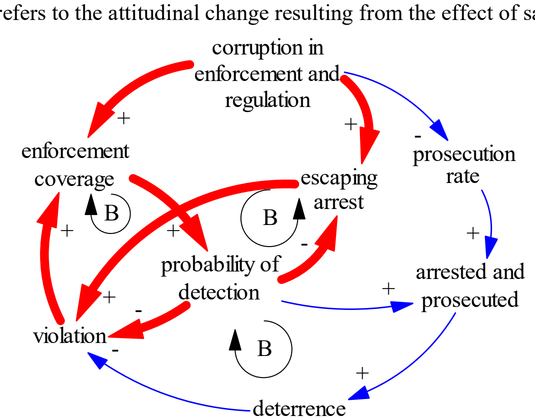

Fig. 3. Deterrence loop

The new loop in the figure above runs such that as the **probability of detection** increases, the number of **arrested and prosecuted** increases. As the number of **arrested and prosecuted** increases, the **deterrence** effect of sanction increases. As **deterrence** increases, the number of **violations** committed reduces. Reduction in **violations**, reduces **enforcement coverage** since there are now fewer violations. This eventually causes **probability of detection** to fall and the **arrested and prosecuted** falls too. This loop, described as deterrence loop is a balancing loop too. It points out the possibility of maintaining a certain level of equilibrium within the system if the system is understood and appropriate measures are implemented. Particularly, it should be noted that it is possible to attain and maintain a certain level of deterrence within the system if this loop is understood. This is with reference to maintaining a certain level of probability of detection that would give the desired deterrence level.

5.3. Payment of Bribe Loop

Corruption in the implementation of sanctions is a factor that affects deterrence. The police extorted the drivers especially after they had violated rules. This extortion called bribe was paid to the police officers directly. [24] points out that this practice has a way of reinforcing itself: the more bribe officers collected, the more they wanted to collect [and so the more corruption in enforcement and regulation] and the less violators were deterred from committing violations. The lower the deterrence built, the more the number of violations. The feedback loop that resulted was a reinforcing loop which further entrenched corrupt practices and increased the number of violations than it should ordinarily be. This happened whenever, in the bid to extort money from drivers, illegal police post were mounted. At such times, prosecution rate was low. Thus, the number of violations did not reduce as it should be even though the number of arrest increased. This structure is therefore included in the emerging CLD to generate figure 4.

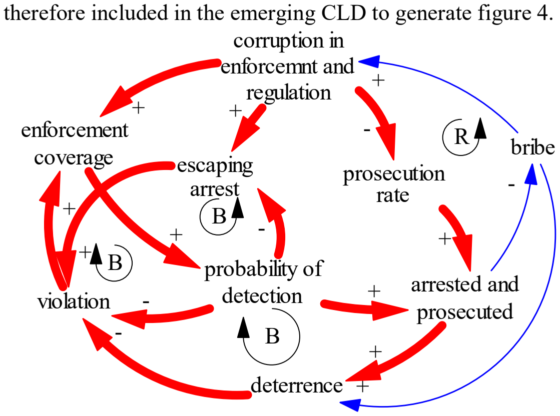

Fig 4: Payment of bribe loop

The figure above shows the payment of bribe loop with the new thin lines added. It shows that as **bribe** paid by violating drivers [instead of being prosecuted] increases, the **corruption in enforcement and regulation** increases. As corrupt practices gets more entrenched, **prosecution rate** reduces. As **prosecution rate** reduces, the number of **arrested and prosecuted** reduces. As the number of **arrested and prosecuted** drops, **bribe** paid increases and the cycle continues. This is a reinforcing loop. It is important for policy makers to note that dealing with the problem of corruption in enforcement and regulation is essential to improving safety. Specifically, how policing is done on the highway requires some innovations to reduce the problem of corruption. With increasing deployment of technology to enhance human systems [29], addressing this problem is essential. The use of automated systems in addition to the regular police is particularly emphasized. This is more so as figure 4 indicates that increase in bribery further reduces the deterrence effect.

3. Conclusions and Future Work

From the analysis above, three loops have been identified which explain the characteristics of motorcycle taxi safety culture. These loops are cycles that run in the system. Recognising them is therefore a first step in tackling the problems that characterise the system as it may be possible to break undesirable cycles and prevent unwanted structures from persisting in the system.

Moreover, this paper shows how three causal summaries that explain the safety problem in motorcycle taxis' operation is developed into a CLD. This CLD is the dynamic hypothesis of motorcycle taxis safety characteristic. The process of extracting and converting these summaries into a CLD follows the recommendation of [30, p.308] who note that it is helpful to adopt causal analysis tools to identify the "facts of the case and key causal summaries systematically. The key causal summaries can then be further analysed in causal loop diagrams" to highlight the interplay amidst the structures in the system. Figure 4 therefore describes motorcycle taxis' operating system. It shows how the drivers' violation behaviour can be influenced by different factors supported in one feedback loop or the other. It provides more insight into the internal workings of the system and how changes in one area may affect the others. [30] notes that points of leverage are easier to identify in this type of analysis. A system dynamic analysis can therefore provide a good basis for holistic policy formulation. For example, our findings point out that increased use of police posts alone does not necessarily improve system safety or drivers' behaviour. We suggest the use of automated systems in addition to the regular police to deal with traffic infractions.

These recommendations however depends on government policy direction with respect to road safety and law enforcement. As suggested by [31], government policy is an important factor in the uptake of new technology for a more functional city.

Nevertheless, while CLDs reveal the feedback structures in a system, they do not tell which structures have stronger influence on the system. They do not provide information on how to prioritise feedback loops in addressing the system's problems. This is a drawback of CLDs as a purely qualitative analysis tool.

In future work, this analysis will be enhanced by transforming the qualitative evaluation into a quantitative analysis. This requires collection of quantitative data relating to the loops identified and formulating the data into mathematical relationships. Generating such mathematical relationships and implementing them in a quantitative simulation model will help to identify which structures have stronger influence on the system. It will also inform policy makers on how to prioritise the feedback loops in addressing the system's problems.

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