Exploring improvisations in road safety in a low-income setting

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Abstract.

Road collision types repeat themselves, especially in low- and middle-income countries (LMICs), where countermeasures are often improvised and implemented with little planning. At the Shahbag intersection in Dhaka, Bangladesh, speed bumps were quickly constructed at the exit of the intersection as an improvised road safety measure following the occurrence of a fatal collision, which eventually contributed to another collision between a truck and a car. The events influencing the improvisation decision, and that action's consequences, have been analysed using the Impromap methodology, a variation of the Accimap approach that focusses specifically on improvisation. The applicability of the Impromap as a systems-based approach to the road safety domain is assessed using the predictions described in Rasmussen's risk management framework, and corresponding countermeasures are proposed. The analysis shows that improvisation in the road safety domain is undesirable irrespective of the economic setting as it is likely to eventually contribute to secondary collisions.

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1. Introduction

More than 10 million people are injured and nearly 1.35 million people are killed every year due to road traffic collisions (WHO, 2018). Low- and middle-income countries (LMICs) witness the majority of these collisions despite having fewer registered motor vehicles (per capita) compared to high-income countries. Low- and middle-income countries are the most affected by road trauma, accounting for more than 90 percent of global road traffic deaths despite having just 60 percent of the world's registered vehicles (WHO, 2018). In 2017, almost 4,284 people died and 9,112 were injured in road traffic crashes in Bangladesh, with the death toll being 26 percent more than in 2016 (Alam, 2018). According to traffic police in Bangladesh, 8 to 10 persons die on the roads every day, and approximately 84,000 road collisions have occurred in the last 20 years (ARI Database, 2014). In response, the Bangladesh government has implemented several countermeasures (Hamim et al., 2020a), but similar types of collisions are still occurring. As such, the effectiveness of the countermeasures and implementation strategies remains questionable. Hence, road safety researchers have focused on the recursiveness of events through analysing the countermeasures taken in response to those events (Turner, 1978; Grant et al, 2018; Salmon et al., 2020).

The capability of a system to adapt to a new failure by predicting or anticipating all external disturbances and flaws that may disrupt the proper functioning of that system has been a major point of interest for safety researchers over the last few decades (Hollnagel, 2006; Reason, 2008). Performance variability is considered as an influential factor to maintain the stability of a system since it helps to overcome external instabilities by adaptation to a new situation (Woods and Hollnagel, 2006; Westrum, 2006). Improvisation is considered a form of performance variability through which a system can adapt to completely new circumstances (Grøtan et al., 2008). In general, improvisation refers to a real-time adaptive plan used under completely new situations for which previously established policy or procedures do not exist (Trotter et al., 2013). In system level safety, less consideration is given to improvisation phenomena (Trotter et al., 2018).

Improvisation has been defined as "the concept of action as it unfolds—acting without the advantage of comprehensive prior planning" (Crossan and Sorrenti, 1997). "The deliberate and substantive merging of the design and execution of a novel creation" might be defined as improvisation (Miner et al., 2001: 314). It is vital to distinguish improvisation from the concept of "creativity" in general. In the case of individual improvisation, investigations have often concentrated on only one level of analysis at a time, either studying the relationship between individual-level improvisation and individual outcome (Weick, 1993) or that between team-level improvisation and team innovation capabilities (Vera and Crossan, 2005). Crossan and Sorrenti (1997) stated that more thorough cross-level analyses are needed in this field because individuals are likely to rely on existing cognitive, affective, social, and material resources in order to deal with an emergent scenario (Kamoche et al., 2003). Rasmussen's Risk Management Framework is used for systems viewpoint analysis in distributed improvisation framework (Rasmussen 1997). This investigates factors and interactions at six different system levels. One assumption is that central authorities may assist in tracking and addressing common decision bottlenecks when they occur among "improving" local governments as a result of shared, dynamic external constraints.

There are several ways that improvisation is an adaptive response to unexpected or unplanned conditions (Magni et al., 2009) that go beyond what an organization has prepared for. In road safety, there is always the possibility of confusing improvisations with bricolage, as there are numerous collision countermeasures available and the relevant road authorities have a panel of experts to choose among them. For a head-on collision at an intersection, for instance, a number of countermeasures could be used, including the installation of a caution sign, rumble strips, and speed bumps. Improvisation is not an alternative to well-designed emergency procedures; rather, it is a tactic employed exclusively in situations for which no processes exist or when circumstances prevent the employment of established procedures. (Woods and Hollnagel 2006), Even in highly safety-aware organizations, the ability of workers to improvise efficiently and appropriately adds another dimension to an organization's ability to preserve safety. Herein lies the dilemma of whether improvisation is truly tolerated in a world headed toward zero-collision (Kim et al. 2017) road safety. Even though improvisation is a purposeful response to an unexpected event, it is different from innovation, creativity, and adaptability in that it is time-based (Chelariu et al. 2002). This element of time has to do with how a response is thought of and then put into action in real time (Moorman and Miner 1998, Miner et al. 2001, Vera and Crossan 2005). In the road safety domain, implementing pre-existing intervention devices or strategies immediately after a road crash without fully considering potential knock-on safety aspects can be considered as an act of improvisation (Trotter et al., 2014). From the previous example, choosing rumble strips over speed bumps could be considered bricolage. But changing the conventional location of the speed bumps due to environmental effects and emergency actions and constructing it quickly would be improvisation. In such instances, improvisations are not studied beforehand because they are implemented immediately. This study will examine the interrelationships between factors of the road safety system that contribute to an improvisation following a traffic collision, as well as the efficacy of the improvisation.

In essence, the traffic engineer is improvising a solution to a new problem with the tools that they have immediately available, regardless of whether those tools are ideal for the context of use. In LMICs the practice of implementing modified versions of predetermined sets of countermeasures in reaction to the public or political pressure following the occurrence of a road traffic collision is common. This can manifest in a number of ways, for example through the placement of road dividers and speed bumps in urban areas at improper locations or without retro reflective markings, the widening of curves in highways, the construction of concrete guideposts as traffic delineators, and the installation of conventional signs and markings. Due to time and resource constraints, and a sense of urgency, this is typically done without proper collision investigation.

Improvisation also happens through the use of established countermeasures in novel or unintended situations; for example, the placement of speed bumps at the exit of an intersection in order to discourage buses from wanting to pick up passengers waiting at the exit of the intersections. Such improvisations create situations for future collisions as they do not meet the scenario-specific demands. The current research explores these improvised approaches to road safety intervention implementation.

1.1. Rasmussen's risk management framework and Impromaps

A collision analysis method should aid the analyst in developing safety recommendations (Katsakiori et al., 2009; Ryan, 2015; Sklet, 2004; Wagenaar & van der Schrier, 1997; Waterson et al., 2017); however, we would argue that most present analysis approaches do not give adequate assistance to the analyst. Systems thinkers argue that rather than addressing individual elements of a system, greater outcomes may be reached by incorporating the system as a single, integrated whole (Dekker, 2011; Hollnagel, 2012; Leveson, 2011); however, while developing preventative measures, organizations frequently fail to consider their potential implications for the broader system. (Drupsteen & Hasle, 2014; Johnson, 2003; Lundberg et al., 2009). Approaches that do not address the system as a whole risk failure, as modifying any single component of the system will have repercussions on others (Kirwan, 2011; Lundberg et al., 2009). Models for developing prevention strategies should also focus on identifying contributory factors at multiple system levels (Dekker, 2011; Goode et al., 2016, 2018; Rasmussen, 1997). There are systems based sociotechnical approaches that can depict the complex and nonlinear causal processes contributing to collisions. (e.g., STAMP, Leveson, 2011; Accimap, Rasmussen, 1997; FRAM, Hollnagel, 2012) among which Rasmussen's Risk Management Framework has gained the most popularity.

Systems are defined by Rasmussen as hierarchical organizations that have several interconnected levels, consisting of multiple actors contributing to the control of processes. Six system levels exist in Rasmussen's (1997) risk management framework; this was expanded by Parnell et al. (2017) to include two additional, upper levels (see Figure 1). Rasmussen's framework does not focus on the causal decision processes and human actions related to a collision, rather it identifies the decision makers in the system (Lintern, 2019).

Accimaps, based on Rasmussen's risk management framework, is an analysis method that graphically depicts the contributory factors (and their interrelationships) residing at different system levels of a complex sociotechnical system that lead to a system failure (Rasmussen, 1997; Svedung and Rasmussen, 2002). Impromap is a modification of the Accimap introduced by Trotter et al. (2014) and is used to bring attention to and analyse the use of improvisation in a particular incident. System failures resulting from a set of faulty countermeasures and/or the inappropriate decisions and actions of actors can be represented using Accimaps and through meta-analysis of the Actor Maps and AcciMaps, system-wide improvements could be identified (Stanton et al., 2023). Impromaps, on the other hand, focus exclusively on the actors that are pertinent to the improvisations from the perspective of conception and execution (Trotter et al., 2014). In these situations, the Impromap can be a useful tool for highlighting defective interventions to policymakers, decision-makers, and regulatory bodies to assist them in reforming the policies and strategies currently being followed.

Impromaps have thus far been used in explaining both positive and negative outcomes of improvisations in the led outdoor activity and manned spaceflight domains, and it has been argued that Impromaps could also be useful in other domains (Trotter et al., 2014). In the road safety domain in LMICs, the improvised application of pre-set countermeasures (e.g., setting up speed bumps) under public and political pressure is common and has been found in the past to have contributed to further road traffic collisions (The Daily Star, 2011; Manyara et al., 2016; The Times of India, 2021; Afukaar et al. 2003; Sayer et al. 1991; Habib 2010; The Star 2012; Bowrey et al., 1996). On the other hand, following a road crash in high-income countries (HIC), the history of traffic crashes, geometry of road, environmental considerations, road user needs, funding limitations, and other factors are assessed in order to select the most appropriate countermeasure for addressing the identified safety issues (FHWA, 2014). We argue that taking a systems perspective and representing the impacts of such improvisations following a collision using Impromap could help policymakers, decision-makers, and practitioners in recognising where such improvisations might negatively impact system performance. Although Trotter et al. (2014) focused on identifying key factors in Impromap, this research focused on not only the key factors but also understanding the combined effect of several factors leading to collisions due to improvised actions. We want to emphasize that focusing on a few selected aspects deemed to be more important than others alone will not bring holistic improvements argued to be necessary from a sociotechnical systems point of view.

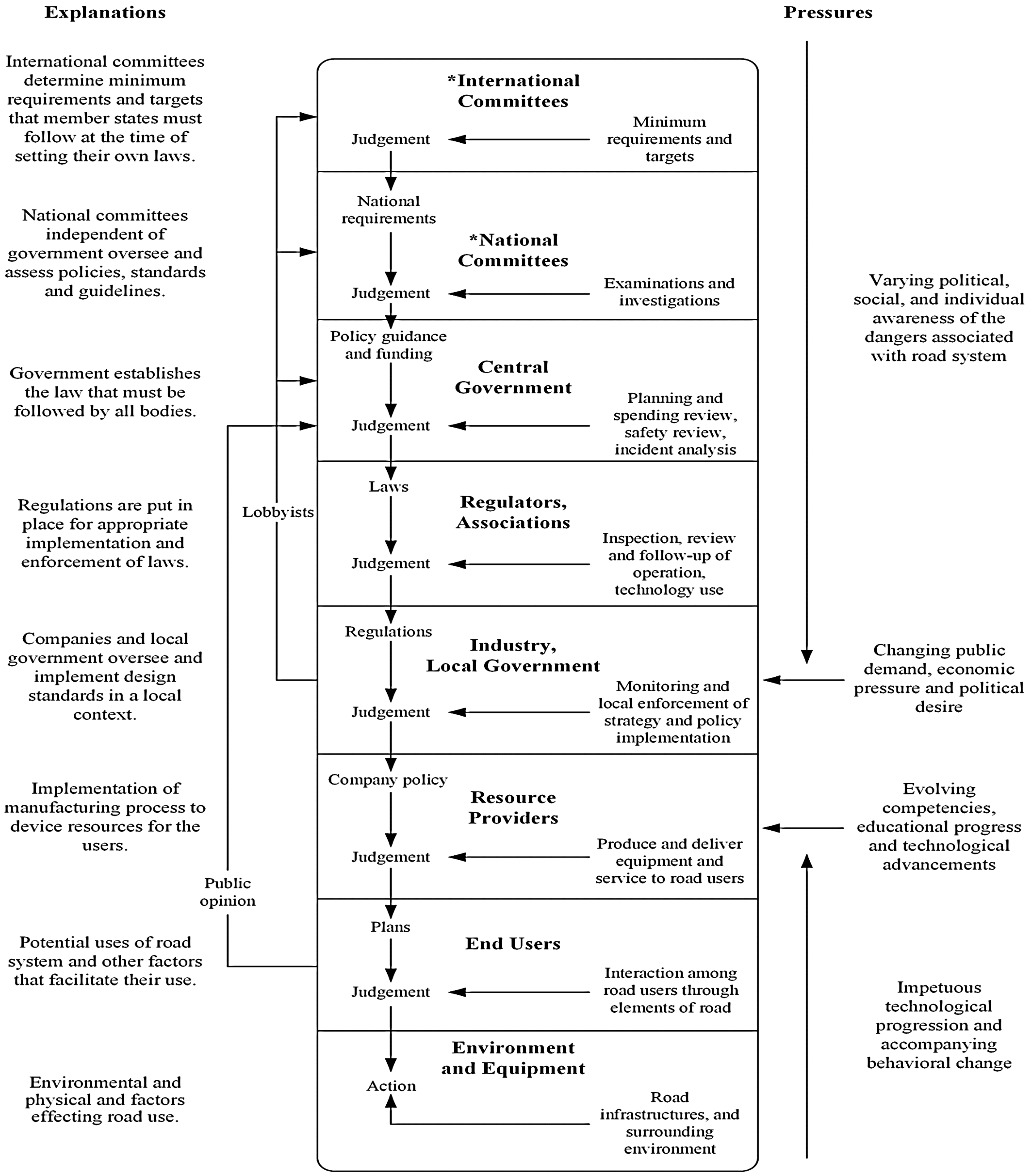

Figure 1. Rasmussen's Risk Management Framework expanded by Parnell et al. (2017) (*levels additional to those described by Rasmussen (1997)).

1.2. Improvisation as a system phenomenon in road safety domain

To illustrate the arguments presented in this research, a road traffic collision that occurred in Bangladesh, a least-developed, low-income country (OECD, 2020), has been analysed.

Improvised safety countermeasures were implemented following a primary collision, measures that then went on to be the primary contributory factors to a secondary collision. The Impromap methodology was applied in order to draw attention to the effect of the improvisations made and to illustrate the applicability of the Impromap as a systems-approach to the road safety domain. The outcomes of this research will help policymakers and decision-makers to evaluate the effectiveness of intervention measures corresponding to a road crash from a systems perspective.

To our knowledge, this research represents the first application of Impromaps to the road safety domain. Several of Rasmussen's (1997) predictions (see Table 1) have been used to evaluate the applicability of this framework in new domains with respect to performance and safety in complex socio-technical systems (Cassano-Piche et al., 2009; Salmon et al., 2010; Trotter et al.,2014). Trotter et. al. (2014) used these predictions to test the statement that improvisation in led outdoor activities is a systems phenomenon. Following on from this, we use the same predictions to evaluate the position that improvisation in the road safety domain can also be considered a systems phenomenon and recommend corresponding preventive measures.

Table 1: Prediction of Rasmussen's (1997) risk management framework regarding accidents in complex sociotechnical systems (adapted from Cassano-Piche et al., 2009).

No.	Prediction description
1.	Performance is a vital characteristic of a system which is influenced by actors spanning across system levels in decision making rather than only the frontline actors.
2.	Not a single catastrophic event but multiple contributing factors lead to sub-optimal performance of a system.
3.	Deficiencies of a single level do not cause a system to perform at a sub-optimal level instead it is caused by overall lack of vertical integration across the levels of a system.
4.	In a complex sociotechnical system, a lack of feedback across levels results in a lack of vertical integration, causing threats to safety before a collision as the actors

	of each level fail to see the interactions of their decisions with the decisions made by other levels' actors.
5.	Over time, work practices migrate in an aggressive competitive environment under the influence of financial pressure as well as also following the path of least resistance (i.e., effort) under the influence of psychological pressure.
6.	Work practices change dynamically across multiple levels of a complex socio-technical system.
7.	Deterioration of a system's defences occur gradually by the migration of work practices over time. Combination of migration in work practices and triggering events cause sub-optimal performance of a system.

2. Methodology

2.1. Case-study selection

In order to meet the aims of this study, a road traffic collision case study with sufficient information available to represent the nature of the improvised response, the factors influencing the improvisation actions, and the effects of those improvised responses were required. Improvisation may lead to both positive and negative outcomes; in the road transport domain, a negative result could be a reduction in efficiency and/or safety, with a road traffic collision being the most relevant system failure in terms of safety. In Bangladesh, road collision data is collected by the Bangladesh Police through accident report form (ARF) which includes information primarily related to collision type and location, type and level of injury, involved vehicles, pedestrians and roads etc. Since, the police reports lack sufficient in-depth on-scene crash information, Accident Research Institute (ARI), Bangladesh University of Engineering and Technology (BUET) carries out detailed investigation for revealing the causal factors by collecting data related to crash scene, road, vehicles, human and injuries. However, only a small sample of the road crashes in Bangladesh are investigated by ARI due to human resource and budget constraints. Between the years of 2005 and 2018, a total of 25 road crashes were investigated by ARI. After examining these 25 detailed road crash investigation reports by ARI, evidence of improvisation in the form of placing speed bumps at the exit of an intersection, widening curves at highways, and constructing road dividers was found in a few of the case-studies. But only one case-study, the Shahbag collision was involved in a road safety improvisation that resulted in a crash later which was selected for this research. The Shahbag collision matches the requirements for this study as improvisation was made in the form of the implementation of speed bumps at the exit of the intersection as a rapid safety intervention following a collision between a bus and a pedestrian under the immense pressure of public protests on road. The improvised speed bumps went on to cause a collision between a truck and a car just over a year later. In the author's earlier study, two bus-pedestrian collisions separated by 13 years were analyzed using the Accimap approach, which also accounted for the Shahbag collision. The two crashes were linked by the same circumstances that led to them (Das et al., 2021). However, the second collision that happened as a result of improvised countermeasures was not handled, raising the necessity to examine improvisations in road safety. The decision to place the speed bump had been taken by the authority through a local body. So, it can be considered a distributed improvisation.

2.2. Shahbag collision description

A fatal collision occurred on 29 May 2005, at around 11:30 am between a pedestrian and a minibus at the Shahbag intersection, an urban, multi-lane, four-legged intersection in Dhaka, Bangladesh. The minibus driver was trying to take a right turn from the left most lane of a three-lane road (the left-hand driving system prevails in Bangladesh) when it hit a pedestrian who was crossing the intersection. After the collision, people surrounded the vehicle, and an angry mob formed and set the vehicle on fire. The mob remained for several days demanding rapid actions from local authorities; however, it was impossible to apply conventional countermeasures given limited resources and time. An improvisation approach was therefore taken by Dhaka City Corporation whereby speed bumps were placed at the exits of the intersection (to arrest the speed of traffic) rather than placing conventionally at the approach. However, another collision occurred between a truck and a car on 3 July 2006 at around 11pm (fortunately, no fatal injury was recorded). The truck was approaching the intersection from the east side while the car was arriving at a high speed from the north approach to cross the intersection straight towards the southern direction. When the car approached the exit of the intersection, it faced a speed bump, forcing the driver to quickly reduce their speed. At the same time, the truck driver did not stop at the intersection upon seeing the arrival of the car, instead continued to cross thinking that the car would be able to cross in front of him in time given it was night-time and there was a relatively low amount of traffic ahead. The truck driver was unaware of the speed bump, hence the requirement for a speed-change, and therefore failed to anticipate the decrease in speed of the car. The truck collided with the car at a right-angle. The truck was moving at a relatively slow speed, so fatal injury was avoided, but it led to a more serious concern for improvisations made after a collision and their potential effects on the users of the road.

2.3. Development of the Impromap

Creation of an Impromap involves graphical mapping of the relevant actors and events across different system levels associated with the improvisation that took place (Trotter et al., 2014). The procedures are similar to that of Accimap development (e.g., Stanton, 2019) but only a subset of all actors is taken into consideration in developing an Impromap, i.e., those related to the improvised aspects. In this study, the actors included in the Shahbag Impromap were identified from the Bangladesh actor map described in McIlroy et al. (2019). In the Impromap presented in the results section, below (Figure 2), the probable interconnections between the relevant actors along with the direction of information flow within and across the system levels have been shown using unidirectional and bidirectional arrows. Solid boxes have been used to represent contributory events corresponding to a specific actor, and the grey shaded box represents the improvisation action. The sources of data from which necessary information were extracted are police investigation reports, newspaper articles, and Accident Research Institute reports (ARI; a collision investigation organisation affiliated with the Bangladesh University of Engineering and Technology, BUET). At the time of the collision, one of the current authors conducted the primary investigation while being the ARI director; this aided in the comparative analysis of the traditional and socio-technical approaches. Initially a draft Impromap was developed by one of the current authors, then discussed with the other authors to make refinements. Validation of the Impromap was performed by subject matter experts including two assistant professors of the ARI and one assistant professor of the Department of Civil Engineering, BUET. The subject matter experts individually assessed the Impromap and made comments regarding the inclusion of actors and the interconnections among them.

3. Results

3.1. Shahbag collision Impromap

The improvised response to the collision, namely the placing of speedbumps at the exit of the intersection, was implemented very quickly at the Shahbag intersection after the initial collision took place. This was done in order to placate the angry mob that had formed and was demanding action. The Impromap of the Shahbag collision presented in Figure 2 highlights the contributing events connected to that improvisation. The Impromap reveals the lack of initiatives at the higher levels of the system in focusing on developing appropriate countermeasures fitting to the collision. Inadequate enforcement, implementation, and monitoring at the middle levels of the system also contributed to the negative outcome that stemmed from the improvisation. At the lower levels of the system, the inappropriate design and construction of the safety intervention measures led to the improvised response's negative consequences. The interconnectedness of the events influencing the improvisation response and the consequent events indicates that systems level reformation is required to reduce the recurrence of such collisions.

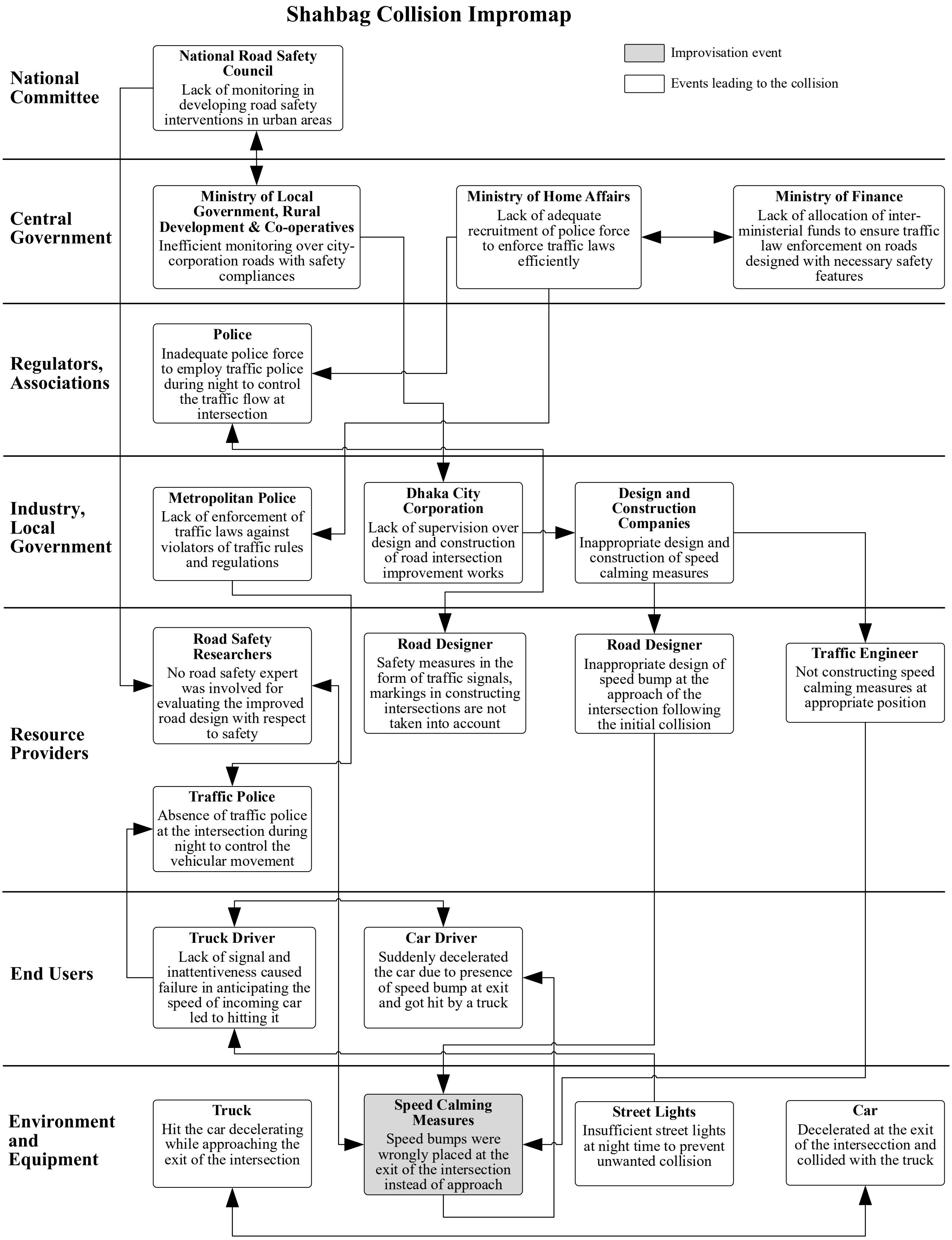

Figure 2. Impromap of Shahbag collision.

Improvisation as a systems phenomenon has not yet been validated in the road safety domain. In this study, the modified implementation of pre-set countermeasures immediately after a road traffic collision, without the appropriate safety analysis, have been recognized as improvisations. Whether improvisation provides benefits or not to road safety remains unknown from a systems perspective. Thus, the validation of the Shahbag collision as an improvisation phenomenon against Rasmussen's (1997) set of predictions has been performed, and corresponding preventive measures have been proposed. Results are presented in Table 2.

Table 2. Validation of Shahbag collision as an improvisation phenomenon against Rasmussen's (1997) predictions, and proposing corresponding solutions

No.	Prediction	Shahbag collision	Solution
1.	Performance is a vital characteristic of a system which is influenced by actors spanning across system levels in decision making rather than only the frontline actors.	In the Shahbag collision Impromap, contributing actors have been identified at different levels of the system rather than just at lower levels.	Preventive measures need to be taken at all levels of a system instead of focusing only on the lower-level actors.
2.	Not a single catastrophic event but multiple contributing factors lead to sub-optimal performance of a system.	The interconnected contributing events spanning system levels led to the failure. Countermeasures were improvised rather than based on careful analysis, and contributed to the secondary collision	While developing countermeasures, the interrelations among contributing factors at various system levels must be considered.
3.	Deficiencies of a single level do not cause a system to perform at a sub-optimal level instead it is caused by overall lack of vertical integration across the levels of a system.	Deficiencies at different levels of the system were found which were interconnected and occurred due to the lack of vertical integration within the system. For example, the inappropriate placement of the speedbumps occurred due to the faulty decision by the road designer and inadequate supervision by the Dhaka City Corporation.	Following a road incident, countermeasures should address systemic deficiencies in different levels rather than focusing exclusively on specific levels.
4.	In a complex sociotechnical system, a lack of feedback across levels results in a lack of vertical integration causing threats to safety before a collision as the actors of each level fail to see the interactions of their decisions with the decisions made by other levels' actors.	Speedbumps as a safety countermeasure were chosen from a pre-determined set of intervention measures rather than based on proper investigation of the primary collision. This occurred due to a lack of feedback from lower levels of the system, indicating a lack of vertical integration in the system.	Countermeasures must be developed and implemented based on the feedbacks acquired from all levels of the system by ensuring vertical integration in the system.
5.	Over time, work practices migrate in an aggressive competitive environment under the influence of financial pressures. Practices also follow the path of least resistance under the influence of psychological pressures.	Improvisations made depend on the economic condition of the system, hence are influenced by financial pressures. For example, the Ministry of Finance failed to distribute funds among ministries resulting in insufficient funds for appointing enough police officers. The lack of enforcement by	The allocation of funds among several ministries must be adequate to eradicate financial pressures while proposing and implementing road safety measures.

		police at night failed to meet the expectations of the drivers.	
6.	Work practices change dynamically across multiple levels of a complex socio-technical system.	In the Shahbag collision, deficiencies in work practices occurred at multiple levels of the system. For example, inadequate police staffing provided by the Ministry of Home Affairs caused the absence of traffic police officers at night-time. In addition, speedbumps were wrongly placed which together affected both drivers' speed choices.	Vertical integration and effective monitoring system need to be developed to minimize deficiencies in different system levels.
7.	Deterioration of a system's defences occurs gradually by the migration of work practices over time. Combination of migration in work practices and triggering events cause sub-optimal performance of a system.	Several factors significantly affect the whole system and lead to the occurrence of road traffic collisions. For instance, at the upper levels of the system, inadequate monitoring of practices regarding design and construction of speedbumps within city areas leads to inappropriate guidance and therefore placement of speedbumps.	The system's infrastructure and policies must facilitate the appropriate application of standard operating procedures when suggesting countermeasures.

4. Discussions

This study has contributed to the literature as the first application of a sociotechnical systems approach to analyse the effect of an improvised response to a road traffic collision in a low-income setting. Two studies have previously focused on the application of Grampians in the led outdoor activity and manned spacecraft domains (Trotter et al., 2014, 2018); however, our is the first to explore the potential of using Impromaps in the road safety domain. This is especially relevant in LMICs where interventions are often improvised rapidly following collisions, but with few resources. Also, it is common in LMICs that political leaders influence decision makers following a high-profile, highly reported collisions; this pressures decision makers into acting quickly, often resulting in hasty decision-making. The systems-based approach to road collision investigation is growing in popularity in high-income countries (Salmon et al. 2012; Larsson et al. 2010; Lansdown et al. 2015; Parnell et al. 2017), but this has only recently seen use by safety researchers in low-income countries (Hamim et al., 2020a, 2020b, 2021, 2022; Das et al., 2021; Hamim & Ukkusuri, 2022). To analyse an improvisation event, sufficient information should be available to the analysts regarding the events leading up to the improvised action, as well as the consequences of that improvisation. The road safety domain can be a potential domain in which to apply the Impromap if detailed information can be gathered from various sources (e.g., news media, police report etc.), with the reconstruction of the event based on available facts, often possible. The contribution of the Impromap to road safety is notable because it can systematically reveal how improvisations may lead to future collisions.

Although both the Accimap and Impromap methodologies are founded in Rasmussen's (1997) risk management framework, Impromap is an extension of Accimap focusing only on improvised events/actions. All contributing factors leading to the causation of a collision are represented in an Accimap, whereas an Impromap takes only a subset of these actions and events, i.e., those which influence the conception and execution of, or are influenced by the improvisation. In order to develop appropriate and effective improvisation techniques, potential factors across the system levels impacting improvisation need to be understood; Impromaps can support this understanding, as has been demonstrated in Figure 2. Accimaps and Impromaps both include multiple interconnected factors stemming from different levels of the system, indicating that improvisation is also an emergent property of systems (Trotter et al., 2014). Accimaps are utilized in developing interventions to improve the safety and performance of a system overall, while Impromaps are useful in determining the appropriateness and effectiveness of improvised countermeasures following a collision. From the analysis of the Impromap of Shahbag collision, it is evident that the improvisations were not appropriate nor effective, rather they contributed to a secondary collision. However, the improvisation action of installing speed bumps at the exit of the intersection was provoked by the angry mob and the subsequent political pressure following a primary collision which could not be included in the Impromap since this action was not directly associated with the case study. Therefore, it can be deemed as one of the limitations of the Rasmussen's risk management framework in analyzing the Impromaps. Additionally, the authors used Preventimap to offer advice on how to reduce the risk of a similar collision happening again in the prior study (Das et al., 2021). However, this research suggests a novel angle of characterizing a collision by discussing the immediate improvisatory action made following a major collision. The proposal has been revised to take into account the contributing factors that led to the improvisation, which will inform the policymakers' decisions regarding the improvisation.

Whether improvisations undertaken in the road safety domain result in negative or positive impacts remains unanswered in the literature. Research into how to help individuals respond efficiently in unexpected circumstances is important (Dekker, 2001), but systems-based analyses appear to concentrate on identifying variables that impact why things went wrong instead of why they went right (Trotter et al., 2014). Even though it is difficult to collect improvisation case-studies with adequate information, road collisions occurring due to the factors related to improvisations made following an earlier collision can be ideal candidates to be analysed using Impromaps. But it is worth noting that improvisations following a road collision are rare events and occur especially in LMICs where data reporting and collection systems are weak (Heydari et al., 2019). The improvised response to the Shahbag collision analysed here had an overall negative impact upon the system. This may be due to a lack of systems thinking in determining countermeasures. For example, the absence of police presence at night would not have been critical for safety had the speed bumps not been inappropriately placed. This event indicates that the actors at different levels of the system are not aware of each other's activities. As a result, the decisions taken at different levels of system do not complement each other, hence lead to failures in the form of new collisions. It has been found from previous Impromap analyses, in case of Apollo 13 Lunar Module consumables issue, a proficient teamwork resulted in a positive improvisation whereas lack of communication caused the deaths of many in Mangatepopo Gorge incident (Trotter et al., 2014). Hence, it is evident that the Impromap can help the decision makers understand the potential (or observed) negative impacts of an improvised response and take appropriate, fully considered decisions that take wider system implications into account.

The Shahbag collision Impromap highlights how the improvisation that led to the later collision was a result of several contributing factors, related to several actors, across different system levels. For example, the National Road Safety Council's lack of monitoring in developing road safety interventions in urban areas resulted in the lack of involvement of road safety researchers, something that would likely have highlighted the potential impact of placing speed bumps at the junction's exit, rather than its approach. Moreover, inefficient monitoring over the City Corporation (Roads) by the Ministry of Local Government, Rural Development & Co-operatives resulted in lack of oversight of the design and construction companies. This combined with the lack of road safety researcher involvement, leading to inappropriate countermeasure installation. The lack of adequate recruitment of police officers by the Ministry of Home Affairs was instrumental in the absence of traffic police at the intersection at night, something that could have protected against collision occurrence.

As aforementioned, the validity of improvisation as a system phenomenon has been evidenced in the domains of led outdoor activity and aviation, and it has been argued by Trotter et al. (2014) that the Impromap can be applied to improvisations occurring in different domains. From Table 2, above, it is evident that the improvisations of the Shahbag collision match with the predictions outlined by Rasmussen (1997). As such, we argue that the implementation of improvisation following a road traffic collision is indeed a systems phenomenon. For example, there was a lack of information flow and vertical integration across system levels whereby the National Road Safety council lacked monitoring capability over road safety in urban areas, leading to the fact that the improvisation made at Environment and Equipment level (i.e., the placing of speed bumps) was not monitored by the authorities at the higher system levels. Nor did the organizations at the lower system levels review the road designer's recommendation to place speed bumps at the exit of the intersection. This clearly represents an information gap between lower and upper system levels. Additionally, the Ministry of Home Affairs did not assign traffic police officers to the intersection at night; this can also be put down to a lack of vertical integration between system levels. Such problems are often overlooked, but it needs to be emphasized that strategies concentrating on reforming the system as a whole are likely to be more productive than merely changing lower-level factors without also addressing the conditions that contributed to these factors (Trotter et al. 2014). Instead of reforming various elements of the system individually, influencing the system as a whole should be the goal. The objective should be to find common intervention measures that will influence many elements across the system (Hamim et al., 2020a, 2020b; Hamim & Ukkusuri, 2022).

Usually in the road safety domain, determining the factors contributing to a collision through detailed investigation, and taking effective interventions measures without disrupting the interconnections between the actors across the system levels, produces positive outcomes, and thus improves road safety. But improvisations do not consider prior safety analysis, hence represent a potential threat which has also been found from the Mangatepopo Gorge Impromap (Trotter et al., 2014) analysis that inadequate or inappropriate planning and instructions from the concerned authorities can lead to failures in improvisations. Systems-based approaches can bring out these faults across different levels and make the overall system safer. For instance, if the police department took the information of the improvisation of wrongly placing speed bumps at the exit of the intersection rather than its approach and acted upon it by making the concerned authority aware of the potential threat to road safety, then it could have been rectified, and the secondary collision would have not occurred. Alternatively, the city corporation could have installed guard-rails at the exit of the intersection to stop the gathering of passengers waiting for buses at the intersection.

We would argue that improvisations following a road collision will seldom result into positive outcomes. Even though the collision under study occurred 15 years back but recurrence of similar traffic collisions can be observed in the present (Das et al., 2021), and unauthorized, faulty, and improvised speed bumps are still being found to cause more road crashes (The Daily Star, 2011). Although this study analysed a road collision occurring in a low-middle income setting, it is likely that improvisations will lead to negative effects in high-income settings as well. This would need to be assessed in future research. We argue that regardless of the economic condition of a country, improvisations should not be undertaken in road safety; rather, countermeasures need to be implemented following proper investigation. But it should also be noted that some deficiencies are observed to a greater extent in LMICs compared to high-income countries (HIC). For example, there is usually a greater information gap between system levels in LMICs (Hamim et al., 2021). While there is a lot of data available for road collisions in HICs, there is always a profound scarcity of crash data in the LMICs. Although comparable improvisations continue to occur and become a cause of future traffic crashes, such information is not routinely recorded in the database. In consideration of its constraints, the authors were compelled to select a 15-year-old incident as their case study. At the Shahbag intersection, the collision between the truck and the car occurred because the truck driver didn't expect the sudden deceleration of the car at the exit of the junction (since a vehicle heading towards the exit is expected to accelerate gradually) due to the absence of traffic signs and streetlights. Also, the lack of monitoring at the upper levels of the system was insufficient mainly due to absence of feedback mechanisms among system levels. Therefore, this research, through the use of Impromaps, recommends to policymakers, decision makers, regulatory bodies, and practitioners not to perform improvisations following a road collision in any circumstances irrespective of the economic setting as such actions may eventually lead to secondary collisions.

5. Conclusion

Deaths from road collisions in LMICs are increasing in number. This study has focused on the negative impacts created by an improvised response to a road traffic collision. An improvisation made in the form of placing speed bumps at the exit of an intersection after a fatal collision was analysed using the Impromap methodology to highlight the factors contributing to the improvised response, and the effects of that improvisation. A graphical representation of the interconnected events related to the improvisation across different levels of the system showed how an improvised countermeasure following a road collision can contribute to a secondary collision. Also, the prevalence of the information gap between system levels in LMICs hinders the implementation of improvisation eventually contributing to future collisions. Hence, the use of improvisation in the road safety domain is argued to be undesirable. This research suggests that the policymakers, decision-makers, and practitioners need to better understand the underlying factors contributing to collisions from a socio-technical perspective, and implement countermeasures following proper investigation, rather than relying on improvisations.

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