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Road Accident Data Collection Systems in Developing and Developed Countries: A Review

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Abstract: Over time, the rate of road accidents is increasing day by day. Eventhough with various advancements, the developing countries are still struggling to eliminate this issue. One such possible solution could be adopting the advanced automated tools for the road accident data collection systems, based on which the policymakers can adopt the necessary strategies to avoid the accidents. In this manner, a review has been conducted where a comparison of road accident data collection systems was made between developing and the developed countries. It was observed that to establish a standardized system for road accident prevention, records from prior accidents play a key role in the evaluation and prediction of the accident, damage, and consequences. Moreover, the manual and digital approaches of data collection were highlighted, which revealed that digital approaches are reliable and time saving for data gathering and its compilation. This comparison is beneficial in terms of future developments in developing countries and the developed countries can act as a role model and their strategies can be implemented to reduce the accidents.

Keywords: Road traffic accidents, data collection, road safety, developing countries, developed countries

1. Introduction

Road accidents have become an existential problem all over the world. Despite increased safety features in vehicles, the number of road accidents is rising with each passing day. Road accidents trigger major financial loss and casualties to the road users as well as to the state as a whole [1], [2]. The vehicles came into existence in the 19th century, since then, it has become a necessary possession of every human being [3]. The first unfortunate accident involved Nicholas Joseph Cugnot in 1777, in which a steam engine-built car collided against the wall [4]. Since then, road accidents became a nuisance to humankind. The number of casualties caused by traffic accidents soared to 1.3 million annually all over the world [5]. The developing countries comparatively suffer more than the developed countries as the accident fatality rate is significantly higher because the awareness to safety like seat belts are strictly followed in the developed countries along with the post-accident systems, meanwhile, there is a lack of awareness of

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road safety programs in the developing countries [6], [7]. Developing countries have witnessed a considerable rise in road fatalities from 1990 to 2014, where 85 % yearly fatalities and 90% disability adjusted-life years (DALYs) were observed [8]. From 1975-1988, the fatalities due to road accidents decreased in the developed countries to 27% and 63% United States of America (USA) and Canada respectively due to intervention of safety interventions but in the same period, the fatalities increased in developing countries like China and Malaysia by 243% and 44% respectively [9]. Similarly, in Pakistan, the situation reached an alarming rate and ranked first in Asia for the highest rate of fatalities in 2019 [10]. Around 36,000 lives were claimed in vehicular accidents in 2018 and this situation is expected to get worsened with the increase in the number of vehicles on roads in Pakistan [11]. One of the contributing factors towards an increased number of accidents is the increasing number of vehicles on the roads even though the development of the infrastructure remained the same [12]. In the past decade, the number of vehicles per 1000 capita in the past decade recorded a huge increase, resulting from the increased burden on the current infrastructure, thereby causing road accidents. The vehicles per capita in developed and developing countries as shown in the Table. 1. This table shows that in the developed countries like New Zealand and USA have more vehicles per capita as compared to other developed countries. Despite of higher vehicles per capita in developed countries as compared to developing countries, the number of accidents are more in developing countries rather than the developed countries, which hints that the increase in the vehicles is not the only reason for the accidents to take place and there are other contributing factors that make the accident happen. The countries in the Table 1 were selected such that it includes at least one country from every continent.

Table 1 – Vehicle/capita ownership in various countries

S. No	Country	Vehicles per capita	Year	Reference
		Developed		
1	USA	816	2019	[13]
2	UK	471	2017	[14]
3	Germany	561	2017	[15]
4	Norway	514	2017	[13]
5	Greece	487	2017	[14]
6	Israel	394	2019	[15]
7	New Zealand	837	2019	[16]
8	France	478	2017	[17]
9	Netherlands	487	2017	[18]
		Developing		
1	Pakistan	17	2018	[13]
2	Sri Lanka	157	2019	[14]
3	Kenya	70	2018	[15]
4	Iran	178	2015	[13]
5	North Korea	11	2006	[19]
6	South Africa	174	2017	[20]
7	India	70	2016	[21]
8	Bangladesh	4	2015	[22]
9	Malaysia	433	2015	[22]

To tackle the complications of the increase in road accidents, precautionary measures must be adopted to decrease the number of road accidents and minimize the damages caused by them. For that purpose, smart and intelligent measures must be implemented to overcome the consequences of road accidents. These safety precautions and smart measures can only be achieved based on the data that is collected without any major loss of information, which would be made available for future analysis. The policymakers, designers, and planners are focusing on strict traffic rules and regulations, the application of traffic control devices, and safety control systems in the vehicles that could tackle the accidental risk and reduce its numbers [23]. To develop a proper road accident reduction framework, the data about the past accidents play a vital role in analysis and forecasting the incident of accidents, its damages incurred and its consequences, which is highly dependent on accurate past accident records [24]. Accurate data collection of previous accident track records is critical to make the targets achievable. Although there exist many loopholes in the data collection and thus an absence of creating a proper database to store the record. In developing countries, the accident data collections assessment faces troubles such as lack of training for police and traffic departments and lack of standard protocol by the health officials while dealing the casualties, having inadequate analysis techniques, and insufficient automation tools [25]. For example, In 2007, the Netherlands police did not report 6% fatalities accidents, 86% injury accidents, and 40% in-patient accidents [26]. The presence of accident data information is extremely important because it is utilized in almost every field like research organizations, awareness campaigns, federal and local government agencies, national assembly, and non-government organizations (NGOs); therefore, these bodies raise concerns over the principal protocol for failing to achieve efficiency about the data set involving road accidents. Based on that accurate raod accident data is of utmost importance [25]. Therefore, by utilizing this data, the planners, developers, and engineers could implement safety protocols and assess every section of the road in the country.

The data collection plays an important role in defining the laws for road users that are safer to be adopted in the future. The collected data enable the decision-makers to identify the problem and economic burden, devise effective strategies, and advocate the stakeholders to invest in accident prevention programs [10]. The significance also extends to understanding the injury and fatalities trend, identifying the location with most accidents and increased injury severity features, and evaluating and monitoring the usage of the strategic plans devised for the reduction in accidents [26]. It was noted that due to absence of a standardized procedure for collecting accident data, acts as a major hurdle towards performing the fruitful analysis [27]. Thus, to count the fatalities and injuries of the accidents, the methods and sources for the accident data collection must be analyzed and recorded in such a way that the collected data is resilient with a minimum loss of data, least data collection mistakes that could prove beneficial for the planners, engineers, and policymaker. Thus, it would enable them to extract the hidden information in the collected data. Therefore, the objective of this study was to review and compare the current road accident data collection practices in developing and developed countries. Additionally, the problem with manual collection of accident data is highlighted along with the uses, compatibility, and framework of digital accident data collection techniques are identified. This review significantly assisted in pointing out the current flaws in the accident data collection methods and identified the problems due to which loss of data occurs in developing countries. This paper also took into consideration how individually installed recording devices could be used in developing countries to improve the data collection methods. In the end, a framework was proposed for the adoption of a novel digital accident data collection system that could be followed by the developing countries to prevent accident data losses.

2. Literature Review

To build a concept of the importance of the accident data collection, the Principal Component Analysis (PCA) was performed on the accident data from 2005-2013 in the Eskisehir area in Turkey. It was found that geometric features of the road like a service road, shoulder, concrete pavements, etc. contribute less towards materializing accidents [28]. The Spatio-temporal tools in ArcGIS were used to assess the number of accidents in the Hayatabad area of Khyber Pakhtunkhwa province in Pakistan. It was pointed out that road data collection limits the efficiency of results. The failure to get accurate results will lead to ambiguity in the analysis [29]. As an example, a study was conducted to assess the current accident data collection practices in Yemen due to its under-reporting. It was found that there was a full agreement of on-spot accidents between police and hospital records, a partial accuracy of fatalities occurred in the three days after the accident and there was no record found about the people who died after three days. It was also found that the official and actual accident reports were different and unreliable. The results of the official record are misleading and lead to underestimating the accidents [30]. The example conveys a message that the official records are not satisfactory. Performing analysis on only official records for road-related research will result in ambiguous results. The critical analysis of road accident data collection in the USA, Europe, and India shows that India still uses the First Investigation Report (FIR) that omits important recording data, which greatly lowers the efficiency of the collected data. With the help of precise data collection, the cause of the accident could be assessed in innovative pre-cash monitoring and post-crash support systems in developing countries [31].

The accident forecasting was performed in Pakistan based on the time series of 2009-2020. The forecasting of road accidents was greatly affected by the poor accident data collection as most of the accidents go unnoticed and are not reported under the official records [32]. The road accident data was analyzed in Kenya from 2015-to 2020 using a machine learning algorithm to identify the top accident reason in the country. The study suggested the fine-tuning of police records that could prove useful for analysis as there were missing data in the police records [33]. With the increase in traffic volume of roads, the efficiency of the collection of road data decreases, and therefore, modern tools are required to keep up with the rise in vehicles accident on the roads. For this purpose, the collection of road data of vehicles at intersections and pedestrians crossing the intersections is taken into account. A regression analysis was performed to improve the data collection of vehicles at the intersection. It was found that the regression technique handles the collection of road data effectively and there is minimal loss in the collection [34]. Similarly, with advances in automation tools, the analysis tool is greatly dependent on the real-time traffic accident data; therefore, the collection methods and their reliability greatly affect the output result [35]. The road data acquisition was assessed using seven variables on straight and curved roads. The results indicated that the sensing system performs accurately while recording the accident data and they are displayed effectively on the vehicle systems [36]. The road data was collected using a floating device that is placed on the road. To reduce the delay time in data collection sharing, the onboard devices on the car are used to save the collected data and once the car is parked the data is shared to the central system.

In this way, update interval, delivery ratio, and response time is reduced considerably based on the sharing using the mobile cellular data [37]. A study was conducted in Accra, Bandung, and Ho Chi Minh City with 119 observational periods to compare the effectiveness of the road data collected by paper-based methods and digital collection systems. It was found that digitally collected data productivity was higher due to less errors. It was also pointed out that the cost spent on digital recording devices prove useful in the long-term use despite of its maintenance costs [30].

3. Methodology

A methodology was developed to conduct a comparison of the current road accidents data collections systems in developing and developed countries. It comprises of three parts; the first part assesses the general introduction of sources of data collection. The second part focuses on the present practices being employed in developing and developed countries. In the last part, a brief overview of the innovative techniques used for data collection in developed countries is shown, which could be adopted by the developing countries to improve the data collection methodology using recent advancements. Various recent research studies regarding road accident data collection were made a part of this review paper to develop a conclusion. The review strategy of this review paper is shown in Fig. 1.

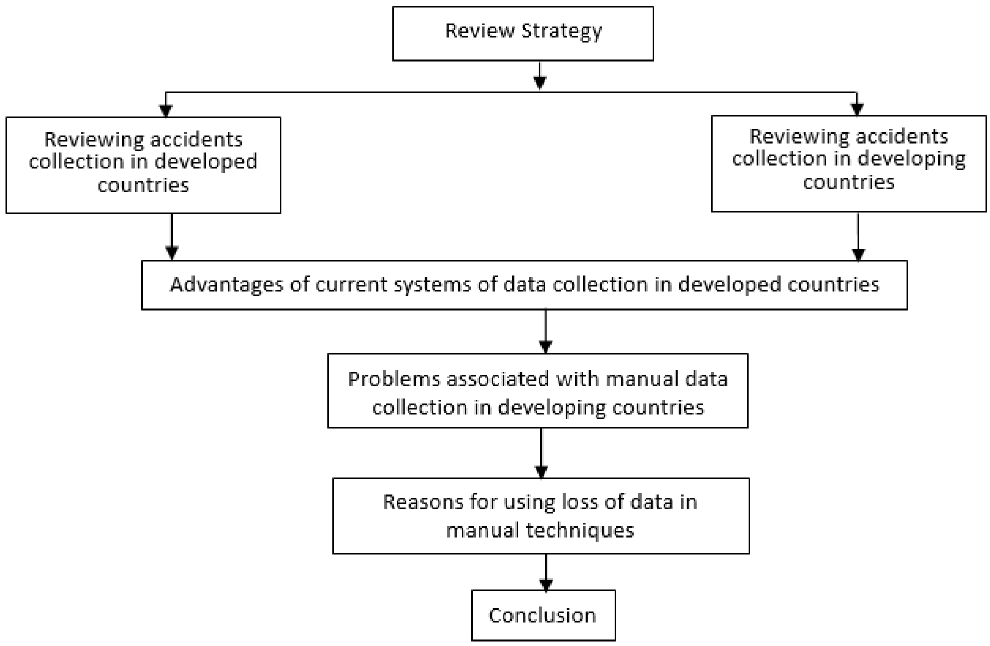

Fig. 1 - Review Strategy for accident data collection in developing and developed countries

4. Sources of Road Accident Data Collection in Developing and Developed Countries

Road accident data could be collected from a variety of sources. These sources differ from place to place and from country to country. The significant source of data collection in both developing and developed countries is the police recording system that keeps a record of accident type, location, time, gender, address, and presence of a license [38]. It could also be collected from the health sector like hospitals, which have the injury information, accident date, and the cost of the aid provided [39]. Insurance firms and vehicle ownership companies also gather their specific data containing damage sustained to the vehicle and the driver, severity of the accident, and driver's particulars.

In developing countries, government planning departments, NGOs, Red Cross, World Bank, World Health Organization (WHO) have an interest in the accident data collection as they identify the location, safety feature, population, exposure to the accident, fuel, pollution to research safety, and planning details to curb the severity of road accidents [40]. For instance, Sri Lanka drafted a National Road Safety Action Plan for the year 2011-2020 for road safety along with third parties and stakeholders for strategies, output, and implementation but there was little progress on the plan due to inadequate funding, and poor coordination among the concerned companies [13]. Hence, the developing countries mainly rely on manual recording, which fails ultimately due to poor management of the involved bodies.

In developed countries, International Traffic Safety Data and Analysis Group (IRTAD), and Cooperation for Assistance and Relief Everywhere (CARE) keep track of accident statistics all over the world [41]. This leads to a basic understanding of the difference between the methodologies of developing and developed countries. Developing countries solely rely on police records, which includes an abundance of inaccuracy, while the developed countries primarily depend on a recording of police officials along with other various tools like web-services, CCTVs and GPS systems, and Event data records (EDRs) to update their accident database [42]. For example, Sweden does not primarily rely on data collection from police, but it also keeps track of injuries and fatalities toll due to accidents from hospital records. These two departments exchange the information on a single platform known as Swedish Traffic Accident Data Acquisition (STRADA), which are forwarded to a responsible national department of the Transport Agency [43]. Similarly, data collection assessment in Japan does not include any contract to a third-party firm. Instead, Japan's traffic department ITARDA consists of an on-site police investigation of the accident. The data recorded by police is then combined with vehicle registration data, license data, and other comprehensive information, which is maintained by Japan Traffic Accidents In-Depth Database (J-TAD) [44]. Table 2 illustrates various road-related equipment to ensure the accurate collection of accident data utilized by the developed countries. There are several sources available besides the governmental bodies that can contribute to data collection, which shows that the collection of data is not just the responsibility of governmental bodies.

Table 2 - Sources of data collection in developed countries

Source of data	Description	Reference
Social Media	A recently developed source, which collects its data from Waze, Google Maps, Uber, and other GPS based applications	[45]-[49]
Road measurement recorders	Pneumatic recorder, loop detectors, radar cameras, and CCTV	[50], [51]
Road Users equipment	The recording devices are installed by the road users in vehicles like GoPro, Dash Cams, Pre-installed GPS in the vehicle.	[52], [53]
Open-source data	Infographics issued by the government and other stakeholders, brochures, and other statistical sources that convey the citizen about the number of accidents	[54]-[57]
Government collected data	Collected by the law enforcing agencies, NGOs working under a government contract, most of them are restricted and confidential even for analysis purposes.	[58]-[64]

5. Data Collection Techniques in Developing and Developed Countries

4.1 Data Collection Techniques in Developing Countries

This section gives an overview of current accident recording techniques and their effectiveness. It highlights the mechanisms adopted by developing countries to record the accident data for ensuring their road safety programs. Table 3 illustrates the data collection methods of various developing countries. Most developing countries have a special manual form to record accidents while other countries do not have a specific way of recording the accident data. It is evident that most of the developing countries still use the oldest method of recording accidents via manual recorders. They can be in the shape of forms or registries, which lose their integrity with time. In some developing countries, there is even an absence of a standard form that should be filled to register the record of an accident.

Table 3 - Developing countries' standard practice

S. No	Country	Standardized practice	Reference
1	Sri Lanka	Sri Lanka Accident Data Management System (SLADMS)	[65]
2	Kenya	P41 forms	[66]
3	Iran	Police KAM114 form	[67]
4	Korea	Traffic Cop Information Management System (TCS), GIS	[68]
5	South Africa	Accident Report (AR) Form	[69]
6	India	Police and other departments	[41]

7	Bangladesh	Police and other departments	[40]
8	Malaysia	Malaysian Institute of Road Safety Research (MIROS)	[70]
9	Pakistan	Police and other departments	[71]

Table 4 illustrates the current procedure of accident data collection using accident recording forms [72]. Most of these forms have either checkbox, alphanumeric, text space, and diagrams or a combination of them. The advantages and disadvantages are described with the recording process of the forms. The solutions are also presented that could be implemented to make recording more efficient with minimum loss of information.

Table 4 - Forms filling the recording procedure of road accidents [72]

Formats for accident reporting	Advantages	Disadvantages	Proposed Solution
Checkboxes	• Relevant data is obtained. • Ensures no information for subsequent analysis is left. • Makes electronic transfer easy. • Easily readable. • Standard terminology. • Eliminates misclassification.	• User-constrained to limited information. • Not feasible to report all or new types of accidents. • Not all information is recorded like weather, time of the day. • Extra space is required to add information that is not available in checkboxes.	A combination of a text field with checkboxes can be used to report unusual reporting.
Alphanumeric codes	• Consolidation of data • Ease of transfer to the database • Databases enhance statistical analysis. • Nationally standardized method	• Difficult to decipher. • Needs professional training. • A special legend form is needed to outline the code.	A table should be used as a reference to read and understand the codes.
Text fields	• Oldest and preferable • All information is recorded. • Useful when reporting unusual cases. • Non-constrained reporting method	• Consumes space. Difficult to store. • Electronic conversion takes a lot of time. • Non-uniformity of responses	It is advisable to convert text fields into alphanumeric and checkboxes for the user responses and facilitation of transferring to electronic devices
Diagrams	• Requires less space. • Can be understood easily by anyone. • An efficient way of communicating accident information. • Helpful for contemplating vehicle position	• Lack of transferability to electronic devices. • Contains less statistical information. • Diagrams are difficult to make. Cannot be used without printed forms.	The diagrams printed should be handed out to the patrolling officers to make more use out of them.

4.1.1 Road Accident Data Collection in Sri Lanka

The road collection data jurisdiction is with the traffic police department but the concerns are always raised because of its inefficiency, inaccuracy, and unreliability in the collection method, which often result in underreporting from the police side [73]. An NGO along with Sri Lanka police developed a system known as Sri Lanka Accident Data

Management System (SLADMS) to reduce duplicate entries of accident data, induct road safety policies by establishing a monitoring mechanism, which works using GIS by collecting their GPS coordinates [5].

4.1.2 Road Accident Data Collection in Kenya

The accident data collection and road safety in Kenya is monitored by the National Transport and Safety Authority (NTSA) [74], which collects its data from the police department using P41 forms. These forms are filled manually, which results in inaccurate information as the follow-up of accidents injury and fatalities counting is weak and is often ignored [75]. There is no other way of collecting the accidents officially; however, various researchers have developed electronic systems. One of these systems was developed using a web interface that can be viewed using google maps by locating the coordinates of the accident using mobile in-built GPS [76].

4.1.3 Road Accident Data Collection in Iran

Although Iran still relies on the police for data collection but there are many organizations like insurance companies, Red Crescent and Forensic Medicine that collect accident data. There is no statistical accuracy in all these collecting bodies, therefore, relying on a single source would greatly affect the analysis of road accident data [77]. Various companies have their mission of data collection and do not intend to share with third parties. For example, insurance companies only check whether their client is guilty of the accident or not. Red Crescent ensures collects the only number of injured people evacuated from the accident site and the role of Forensic Medicine is to count bodily damage, therefore the inaccuracies increase in the accident as there is an absence of a single parent body that collects, analyzes, and manages the collected data for analysis [67].

4.1.4 Road Accident Data Collection in Korea

Korea is a developing country, yet it has moved to the electronic systems of data collection as compared to other developing countries. Korea has developed three systems namely Traffic Cop Information Management System (TCS), Traffic Accident Analysis System (TAAS), Transport Safety Information Management Complex System (TMACS) [78]. The data collected by police, insurance agencies, general people, and traffic associations are combined in a single electronic database, which is further inserted into the GIS environment, and accidents are analyzed using crime information systems, hence, a complete statistical database is prepared for analysis and visualization [68].

4.1.5 Road Accident Data Collection in South Africa

Accidents are collected using the Accident Report (AR) forms by police and traffic authorities, which are forwarded to Road Traffic Management Corporation (RTMC). The fundamental responsibility of the collection of accident data lies with the South African Police Service (SAPS). RTMC does not only rely on police collection but it also combines the collected data from SAPS and Culpable Homicide Crash Observation Report (CHoCOR), which are combined in statistical form. The RTMC verifies the data for future engagements [79].

4.1.6 Road Accident Data Collection in India

India is facing an issue of under-reporting of road accidents. The collection responsibility falls upon local police authorities, which are transferred to the federal authority. Due to the considerable rise in accidents, the police officials were insufficient in number for the collection of reliable data, therefore, the data recording responsibility was given to NGOs that help raise the awareness among the locals with the help of stakeholders using the revenue collected from the fines of road violation fine laws [41]. The NGOs play an influential role in road safety and data collection by working under other governmental bodies that help them achieve the desired results, which remove the hindrances for the completion of the goal [80].

4.1.7. Road Accident Data Collection in Bangladesh

In Bangladesh, road fatalities are five times the number of countries that have the lowest accident fatalities [81]. These accidents mostly occur due to a lack of government attention in accident prevention, limited funding, lack of coordination of road safety stakeholders, untrained police officers, and inadequate research in road safety programs [82]. Like India, the police officials in Bangladesh are accountable for the accident data collection, but there are vague mechanisms for this purpose as many researchers have pointed out different primary departments for data collection. National Road Safety Council (NRSC) took some in vain steps to curb the data collection problem [82]. Hence, many NGOs like Bangladesh Rural Advancement Committee (BRAC) and the Centre for Rehabilitation for the Paralyzed (CRP) helped in collecting the data along with environmental factors, tackling injustice, economic prosperity, and health issues in the country. BRAC is an authentic source of collecting data as it is transparent, unbiased, uninfluenced by politics, well documented, and has trained personnel, therefore, making it unique from other NGOs [40].

4.1.8 Road Accident Data Collection in Malaysia

Malaysia has the highest road accident fatalities among the South-East Asian Nations (ASEAN) [9]. Underreporting of road accident data acts as a sabotaging catalyst for the analysis of safety measurements and accident prevention approaches. The police record and the actual number of accidents are significantly different from each other [83]. In Malaysia, the demographic details are primarily provided by the Royal Malaysian Police (RMP) reports, but hospital records have road injury and fatality information [84]. To illustrate the underreporting, the accident data collected from police records and hospital records were analyzed. It was found that out of 7625 accident records of police data and 362 cases recorded in the hospital, only 311 accidents were present in both the records, which accounts for the extreme underreporting of 4.7% of injuries to the police database. The data collection procedure of Malaysia falls under the supervision of the Malaysian Institute of Road Safety Research (MIROS), which was founded in 2007. This organization is responsible for the collection of road accident data, its generalization, and distribution of information for research in road safety. To expedite the research in road safety, a program was developed based on MIROS provided data that could visualize the data in a user-friendly environment [70].

4.1.9 Road Accident Data Collection in Pakistan

Like many developing countries, Pakistan also suffers from road safety issues due to underreporting [85]. It has got the same system as prevalent in other developing countries- the police department is responsible for the data collection and the data is later disseminated to the provincial and federal authorities [86]. The data collected is barren for analysis as only 10% of the accidents were recorded when compared to the numbers of police records and hospital records [71]. In 2006, the National Road Safety Secretariat (NRSS) was established with the prime objective of structuring an effective data bank for road accidents. NGOs have played a positive role in creating awareness and the results are commendable [87]. NGOs like the World Health Organization (WHO) and the Asian Development Bank (ADB) started working for the betterment of society. Till 2007, many NGOs were working, but none of them extended their efforts for road safety. In 2007, Road Traffic Injury Research and Prevention Center (RTIR & PC) was established in Karachi [40].

The need for the establishment of RTIR & PC was felt by the local doctors due to the difference in recorded data in police and hospital records. To cope with the difference in numbers, RTIR & PC was created to create interventions over the analytical study for road safety and to work with local bodies for their application [9]. Under this program, the data was analyzed of road accidents in 2007, it was found that police-reported 1004 fatal accidents in the province of Sindh, while RTIR & PC registered 1185 fatal accident cases just for the city Karachi. This body operates under many local hospitals in Sindh province only [83]. One success story of intervention by RTIR & PC is that of Shahrah-e-Usman Ramz, a point with most pedestrian injury reports was analyzed. It was found that insufficient sight distance and sharp curve of the road contributed to the accidents. The concerns were forwarded to the governing bodies and some road safety signs were introduced which solved the problem to a certain limit [71].

4.2. Collection Method in Developed Countries

4.2.1 Road Accident Data Collection in the USA

In the USA, many bodies operate under state departments of transportation, which collect the data and store it in the national database. For example, the two Application Programming Interfaces (APIs) that collect the data are Map Quest Traffic and Microsoft Bing Map Traffic [88]. The accident data is also extracted by the official departments in the USA using GIS and it provides a large image of maps with accident locations marked on them [89]. Similarly, another data collection geographical dataset, which operates in more than 100 countries, is called HERE Routing. Its APIs are used for traffic-enabled routing, intermodal routing, Transit routing, isoline routing custom fuel calculations, EV routing, studying road infrastructure, planning and optimizing the road signals, and much more [90]. International Traffic Safety Data and Analysis Group (IRTAD) was developed comprising of 32 countries including the USA that saves the accident data in a common format for analysis purposes [91].

4.2.2 Road Accident Data Collection in the UK

The UK police record accidents using STATS19 form but are not the sole organization that keeps track of accidents [92]. The official website www.gov.uk keeps track of driving licenses, Kaggle database contains STATS19 information regarding damages done in accidents, most gender involved in accidents, and coordinates of the accident. The number of injuries, vehicle details, and fatalities are collected from the Statista website. The UK also collects its accidents information from a local newspaper using known as The Guardian [93]. Similarly, Collision Recording and Sharing (CRASH) system, Road Accident Data Management System (RADMS), and Road Accident Data Recorder (RADaR) were developed that collect digital collection, transmission, and storage of accident cases, and police are only required to collect the vehicle registration number, which significantly reduces errors in recording [94]. It is further shared on the IRTAD database for universal compatibility for analysis [91].

4.2.3 Road Accident Data Collection in Germany

In 1999, the German In-Depth Accident Study (GIDAS) project was launched to improve passengers and vehicle safety. It is a combination of a multidisciplinary team that collects the accident data. The traffic officials, medical officials, insurance companies, and manufacturers collect the data that is combined at the state level, which is further consolidated on the federal level [95]. the breakthrough in GIDAS is that the accident reported by police is reconstructed by an inspection team that provides accurate and more information regarding an accident on the roads. The information collected focuses on three parameters namely the vehicle, environment, and the participants involved in accidents [96]. The consolidated data is uploaded on the IRTAD database [91].

4.2.4 Road Accident Data Collection in Norway

The accident data collection is performed by police and Statistics Denmark, Statistics Finland, and Statistics Sweden. This data is reported to Eurostat and International Transport Forum, which is saved in the oracle database. Since 2001, the police recording adopted electronic entering which reduces the mistakes and duplicating [97]. It is further uploaded on the IRTAD database, which is provided in universal formats for analysis purposes [91].

4.2.5 Road Accident Data Collection in Greece

In Greece, Traffic Police officers go to the accident site and collect complete road accident data in high detail forms. After the accident, these forms are forwarded to the Hellenic Statistical Authority which is responsible for the final checking and codification in the official National Road Accident Database. Moreover, these data are also uploaded on the IRTAD database. Besides this in Greece, data is collected by insurance companies and hospital management, but these three collection bodies are not linked with each other and cause mismatches and loss of information. A method was developed using GIS that could detect the accident and then upload the accidents based on their coordinates on GIS maps but it is not officially been used by the government of Greece [98].

4.2.6 Road Accident Data Collection in Italy

The accident data collection is performed by the local and provisional police on a CTT/INC paper form. The collected data is checked through many steps like double entry, out-of-range data, location of the accident. The collected data is sent to Automobile Club d'Italia (ACI), which checks the filled forms, check for missing or incomplete data [99]. Finally, the error-free data is sent to the Italian National Institute for Statistics (ISTAT) [91].

4.2.7 Road Accident Data Collection in New Zealand

Due to inaccuracies in police recording techniques for data recording, New Zealand has introduced Crash Analysis System (CAS) based on the Vision Zero approach, which states that no citizen gets injured or killed in the accident, that records the time, location, reason, and road and vehicular data. The advantage of using this system is that it consists of certain tools that show accidents on the map, locate high-risk locations and check the trends of accidents [100]. After consolidating the CAS information, it is updated and sent to IRTAD for worldwide cooperation for reducing accidents [91].

4.2.8 Road Accident Data Collection in France

France does not only rely on police records for accuracy in data collection. For this purpose, a specialized agency was formed named Bulletin d'Analyse d'Accident Corporel de la Circulation (BAAC) that works under the Ministry of Transport whose sole responsibility is from data collection to data consolidation for traffic accident analysis [101], [102]. The police report the accidents to BAAC, which is uploaded to the electronic system. The quality control of records is authenticated by the three-step verification process. Initially, the completeness and verification of the forms are checked. Then, the data is shared with the local road authorities for correction of collected data. Finally, a domestic data record is published, which is cross-checked with the media reports [103], which final report is uploaded on the IRTAD database [91].

4.2.9 Road Accident Data Collection in the Netherlands

The Netherlands makes use of three statistical bodies to bring accuracy in police recorded accidents. Firstly, the cause of fatality is noted by the coroner. Secondly, the unnatural causes are noted by the court. In the final stage, the collected data is matched with the police recorded data [104]. The reason for performing three-step verification is to point out the incorrect and under-recording are rules out. Also, to separate the suicide cases from the natural causes of fatality [105]. One fruitful outcome of this three-step verification was that in the accidents which happened between 2010 - 2015, 15% of the accidents were missing in the second step and those accidents were present in the third step [106]. Finally, the details are uploaded on IRTAD [91].

The following Table 5 shows that the developed countries do not rely on just police recording. There are many governments, and privately owned systems working together to effectively collect the accident data. These are maintained and updated daily and are saved on a web service that is accessible for analysis purposes.

Table 5 - Developed countries' standard practice

S. No	Country	Standardized practice	Reference
1	USA	Fatality Analysis Reporting System (FARS), The National Automotive Sampling System (NASS)-General Estimates System (GES), The National Automotive Sampling System (NASS)-Crashworthiness Data System (CDS), The State Data System (SDS), The Highway Safety Information System (HSIS), The U.S. Census Bureau, The Strategic Highway Research Program 2-Naturalistic Driving Study (SHRP2-NDS), The Center for Advanced Public Safety (CAPS), IRTAD	[107], [108]
2	UK	IRTAD, Kaggle, data.gov.uk, STATS 19, CRASH, RADMS, RADaR	[93], [94], [108]
3	Germany	International Traffic Safety Data & Analysis Group (IRTAD), GIDAS, Police agencies of the different states and then consolidated at the federal level	[108], [109]
4	Norway	Collected by the police and consolidated at the national level by Statistics Norway and the Public Roads Administration.	[108], [110]
5	Greece	Attica Tollway crash database, International Traffic Safety Data & Analysis Group (IRTAD)	[108], [111]
6	Italy	Police, National Institute of Statistics (ISTAT), International Traffic Safety Data & Analysis Group (IRTAD)	[108], [112]
7	New Zealand	Police, Crash Analysis System (CAS), IRTAD	[112]
8	France	Bullettin d'Analyse d'Accident Corporel de la Circulation (BAAC), IRTAD	[102]
9	Netherlands	Three-step police information, IRTAD	[91], [113]

6. Innovation in Data Collection Techniques

Since the inception of the digital age, the manual technique of recording has become obsolete as it lowers the data collection due to human error [114]. A mobile application was developed, which was based on Google Application Programming Interfaces (APIs) and Global Positioning System (GPS) to prevent the loss of valuable information while using the manual recording of P41 forms for accident data collection [66]. An accident data system was developed in Abu Dhabi in GIS to facilitate the police department and other stakeholders to efficiently collect the accident data [115]. One type of innovative system was introduced in Spain, which is known as Measuring and Recording Traffic Accident Sequence (METRAS). It records the accidents, attaches the coordinates, and shows up on the traffic system based on the accident severity. It was found to be more efficient, reliable, easily accessible than police record as compared to the statistical method of recording [116]. Another real-time application of GIS was shown for road accidents by designing a java-based platform that users can view, customize and change the layers of the software to check the accident locations. This gives the user an advantage to view accident spots using smartphones anywhere in the world [117]. Kentucky, USA uses a specially designed electronic accident collection system using bar codes and scanners to locate the accidents using GPS. This system is linked with the federal database that compares the driver details on the electronic form, thus reducing errors in recording and minimizing the human error of entry [118].

Iowa, USA developed a Traffic and Criminal Software (TraCS) for accident data collection as field-friendly by introducing various options like bar codes, CCTVs, digital cameras, and electronic data entry along with the GPS. The officials can take a photo and upload it with the GPS coordinates on GIS software, which can be viewed easily and results can be deduced with full confidence [119]. Illinois uses a combination of custom-developed software along and TraCS. This data system works by using GPS in vehicles for accident locations. A sketching tool is used along with the electronic filing of forms in which the accidents are graphically represented, hence, adding accuracy and in-depth analysis of the accidents [120]. Romanian researchers developed an electronic system for traffic accident data collection. The electronic system consists of forms, distance, contact, and witness'. This operates on a handheld device and its user interface is easy to work with [121]. Similarly, a low-cost accident detection system was used in vehicles as an on-board unit, consisting of many sensors like GPS, accelerometer, gyroscope, and Wi-Fi module, the accident was recorded and sent to the database system called as V2X communication technology. This unit searches for a nearby hospital and requests medical assistance [122].

7. Discussion

This study explained and compared the common practices of accident data collection in developing countries and developed countries and a major difference was observed. The developed countries utilize public and private instruments on the road to extract useful information, which is then sent to the recording agency. The developed country's citizens are well-equipped with the accident detection systems, safety features of the car, as well as the constant connectivity of the internet. It gives developed countries an edge over developing countries in the field of accident data collection. This shortcoming is one of the major contributing factors in accident data collection, which leads to under-reporting and under-recording of accident data.

A lot of studies suggest that small-scale prototypes for digital accident data collection have already been developed with full confidence but due to the high initial cost and non-serious attitude of the governing bodies involved in the implementation of road safety programs, the innovation techniques are still not considered in many countries.

The developing countries suffer considerably due to the underreporting of the data by collecting bodies. The underreporting of the road accident often leads to confusion and unfertile results of the analysis. In most countries, the collection of road accident data falls under the jurisdiction of local police authority but due to deficiency of trained and professional personnel, lack of recording devices, inaccessibility to the data bank, inability to take a correct history of the accident, and a dearth of advanced collection techniques in the field often leads to the problem of underreporting. There is an absence of a committed organization whose prime task is to collect the road accident data by utilizing advanced tools and techniques. The developed countries have demonstrated that accident severity can be reduced by incorporating the dedication of governing bodies and the implementation of advanced road safety systems by collecting the data efficiently. The collected data can be used for target setting in accident reduction, to evaluate the impact of interventions, to indicate the road safety conditions, and to create awareness regarding the accidents among the public. The developing countries suffer the most, where the lack of funding and mismanagement among the involved departments creates unwanted interventions. The situation of accident cases is worsening in developing countries as the accidents are increasing day by day and the number of vehicles on road are growing at a fast pace, which is a clarion call for the officials to act promptly.

The police officials in developing countries only collect the accident data and keep the data with themselves as there is an absence of a centralized body that consolidates the data and removes the over-reporting or duplicating reports and makes the data ready for analysis purposes. As a result, the analysis of the road accident data generates misleading results. Although the police is a prime department for data collection, the only difference between developing and developed countries is the approach for utilizing the reported accidents by combing it from various sources for the confirmation of the accident cases. The developed countries have made certain bodies whose sole responsibility is to collect, analyze, manage, and store the collected data in a specialized format, which the developing countries lack.

The data collection systems in developing countries are still old, faulty, and contain a significant number of mistakes due to human error. It is due to malpractice in reporting or insufficient accuracy in recording the accidents that lead to a plethora of problems like lack of education for filling the forms correctly, under-reporting of accidents due to mutual consent of the vehicle owners, less space for noting down the pre-defined scenarios on the form, unavailability of space on the accident forms, loss of record due to negligence, under-reporting and poor coordination for sharing accidental data for analysis purposes among the various road-related departments as shown in Fig. 2.

8. Framework

The data processing needs a framework that is robust and ensures compatibility in the analysis. A centralized data handling agency must be the one, whose fundamental objective is to obtain and compile the data, remove unwanted information and noise, store the data in an organized way, and prepare it for analysis. This data can be useful for accident prevention, planning of future highway infrastructure, identification of hotspots, and future change in the geometric design of the roads. The collected data can prove useful to deter people from not following the road rules using infographics, social media ads, context diagrams, and banners. With this understanding, the framework has been proposed as shown in Fig. 3.

9. Conclusion

This paper demonstrated the accident data collection methods and techniques that are followed all over the world and the consequences of poor data management. It was concluded that the developing countries still rely on manual recording, while developed countries have incorporated the latest technology to collect the accident data. Among many contributing reasons, the one reason for most accident cases to happen is due to the absence of awareness of road safety programs in developing countries. There is an absence of centralized data collection systems that are passed from several steps, which increases the accuracy of the data collection. There is also a lack of proper training that is necessary to ensure the correct collection of the accident data. The discussion on the current data recording techniques illustrated that the government sector has collaborated with private firms to prevent loss of data and efficient application of data collection in a few developing countries. Most developing countries are deprived of this scientific collaboration, which results in the under-recording of the accident data. Moreover, most of the manually collected data consists of duplicate cases and some important variables in the collection stage go un-reported. Finally, the solution for form-filling collection techniques was introduced along with the use of the proposed framework.

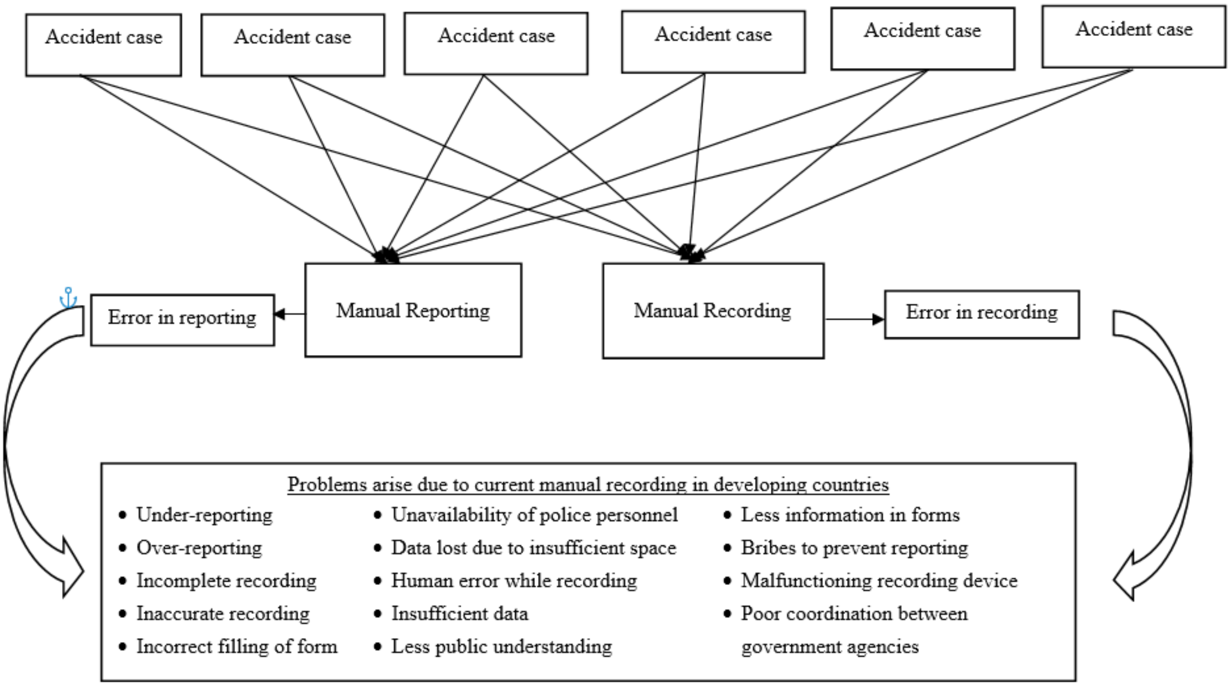

Fig. 2 - Problems associated with manual measurement

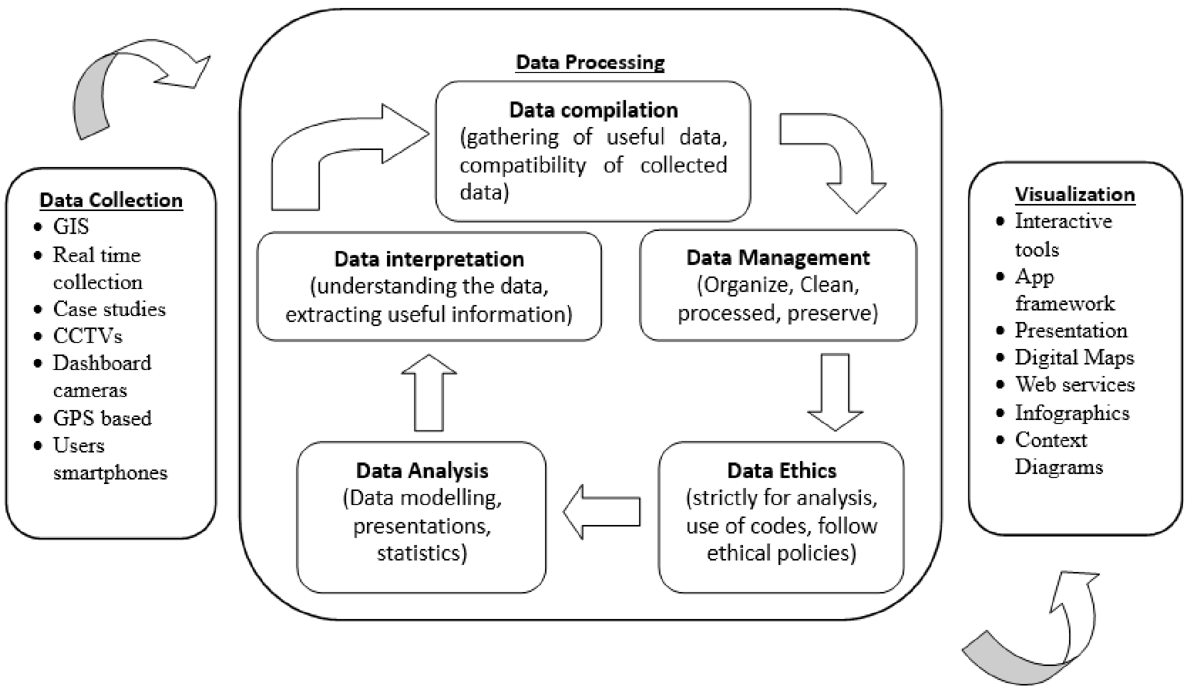

Fig. 3 - Framework for a digital collection of accident data

The manual collection of accident data is faulty because of a lot of the aforementioned errors associated with it. This is the reason why developed countries ceased to rely on it and moved to the next age of data collection methods. The current practices of road accident data collection of developing countries are obsolete in developed countries. The framework of DDC shows three stages of data collection, which minimizes the loss of data and ensures that each accident is recorded.

In developing countries, the police perform data recording and are the prime source of data collection. It is unreliable and inefficient in most cases. This kind of data collection needs quality control and requires proper training for filling out the forms to bring accuracy in the data for the researchers. Training will ensure logical data entry, completeness, and reliable results. Currently, it is time-consuming, resource-intensive, expensive, and difficult to compile. These reasons show that there is a substantial need for innovation in this area of study.

Accidents are increasing day by day with more vehicles on the road and their data collection is becoming more challenging, which results in loss of data and under-reporting of the accidents. The local bodies and government must understand the gravity of this situation and the manual recording must be changed to digital recording, which could unravel precious information for road safety analysis before it is too late.

It is recommended that a centralized collection system must be used, and the developing countries should adopt or follow the framework of data collection using digital techniques to prevent the loss of useful data as the NGOs operating in many developing countries will work till their funding and therefore, it is not the viable solution of accurate data collection. The locals must be encouraged to install the road accident recording cases like dash cameras or report the accidents via mobile applications to bring accuracy to the police records of road accident data collection. Also, the data recorded by the private device should be shared with a centralized body. The basic concern is to save human life and property for which road safety measurements are needed. Practical road safety arrangements can be made only when the data collection procedures become trustworthy. Not only this but also a shift from manual towards digitalization is the need of the hour.

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