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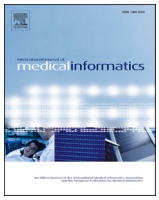

Assessing the design of road traffic death information systems in Iran: A participatory systems approach

Maryam Tavakkoli [a,b,*], Amirhossein Takian [c], Mahtab Mohammadi [d], Hamid Heidari [e], Leila Kouchakinejad-Eramsadati [e], Shahrokh Yousefzade-Chabok [e], Don de Savigny [a,b], Günther Fink [a,b], Nino Künzli [a,b], Daniel Cobos Muñoz [a,b]

[a] Swiss Tropical and Public Health Institute, Basel, Switzerland
[b] University of Basel, Basel, Switzerland
[c] Department of Global Health & Public Policy, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[d] Deputy of Public Health, Guilan University of Medical Sciences, Rasht, Iran
[e] Guilan Road Trauma Research Center, Guilan University of Medical Sciences, Rasht, Iran

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ABSTRACT

Aim: To describe and analyze the information architecture and information pathways of the road traffic death recording, registration and reporting system in Guilan Province, northernIran.
Methods: We used Business Process Mapping, a qualitative approach. This participatory and iterative approach consists of a document review, key informant interviews, development of a process map and a participatory workshop with key stakeholders to illuminate and validate the findings. We classified the tasks performed in the system into three phases: (1) Identification and recording; (2) Notification and registration, and (3) Production of statistics.
Results: We identified 13 stakeholders, with operating and influencing roles in the process of identification, registration and production of statistics about road traffic deaths in Guilan province. The three main sources of road traffic death statistics are the Ministry of Health and Medical Education, the National Organization for Civil Registration and the Forensic Medicine Organization. Our results reveal a highly fragmented system with minimal cross-sectoral data exchange. Each stakeholder operates in a silo resulting in delays and redundancies in the operating system. In the absence of an effective communication among stakeholders, the information exchange was dependent on the family of the deceased. These fragmented information silos alter the compilation of cause of death statistics and result in under-reporting and discrepancies in road traffic deaths figures.
Conclusions: Designing a comprehensive road traffic information system that provides accurate and timely information requires an understanding of the information flow and the entangled web of different stakeholders operating in the system. Participatory systems approaches such as process mapping can assist in capturing the complexity of the system and the integration process by facilitating stakeholders' engagement and ownership in improving the design of the system.

1. Introduction

Road traffic injuries are the 12th leading cause of death globally and the number one leading cause of death in the 5–29 year age group [1,2]. In the past two decades, road safety has attracted growing public health concern worldwide. At the national level, authorities implemented several policies in response to the large number of road traffic casualties [3]. Recent progress in policy-making and efforts towards improving road safety have emphasized the importance of reliable and timely information on crash characteristics for setting priorities, developing effective policies and monitoring progress [4]. Nonetheless, according to the latest Global Status Report on Road Safety, there are reliable sources of information regarding road traffic mortality in only half of all countries [3].

One of the key actions to strengthen country information systems is to improve national death registration systems [5,6]. The road transport

* Corresponding author at: Swiss Tropical and Public Health Institute, Kreuzstrasse 2, 4123 Allschwil, Basel-Landschaft, Switzerland.
E-mail address: Maryam.tavakkoli@swisstph.ch (M. Tavakkoli).

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system is a complex adaptive system with multiple stakeholders. Consequently, the road traffic death information system is at the intersections of several sub-systems from different sectors such as health, police and civil registration [7–9].

Given that the road transport system span multiple sectors, integration of existing information subsystems is recommended to provide a better picture of road traffic casualties [4]. However, the integration of different information sources operating in silos usually stumbles over administrative boundaries with poor understanding of the fragmented information flows among stakeholders. Previous studies investigating the factors influencing the information exchange among stakeholders in the road transport system have identified lack of coordination, security concerns, and technical and financial constraints as the main barriers to cross-institutional information exchange [10,11].

We present a case study to explore the effectiveness of information systems in communicating road traffic deaths among stakeholders in Guilan Province, northern Iran. We used the process mapping method to describe the information architecture of the road traffic death registration systems, aiming to identify root causes of system underperformance.

In Iran, according to the national mortality profile, road traffic injuries are the 4th leading cause of death, accounting for 4.26% of total deaths [12]. Previous research investigating road traffic information systems in Iran has identified factors such as lack of a systems approach, inter-institutional trust and absence of a lead agency as responsible for the so-called "separated registration" and non-systematic data collection [13]. What is still less clear is the information architecture and information flows in road traffic deaths information systems including key stakeholders, information flows and key operations.

Systems approaches and the use of systems thinking tools can assist in capturing the complexity of the system and facilitate the integration process. Process mapping is a systems thinking method that fosters a mutual understanding of the complexity of a system and the roles of stakeholders by visualizing its elements and information flows [14]. This facilitates stakeholders' engagement and ownership in improving the design of the system [15,16]. Therefore, our approach provides new insights into the application of systems thinking approaches to improve the design of road traffic information systems.

2. Material and methods

2.1. Design

We adopted a qualitative approach using Business Process Mapping (BPM) [15,16] to describe and analyze the information architecture and information pathways of the road traffic death registration system in Guilan Province, northern Iran. This participatory and iterative approach consists of a document review, key informant interviews, the development of a process map and a participatory workshop with key stakeholders to illuminate and validate the findings.

2.2. Study setting

We conducted this case study in Guilan Province, a northern province in Iran with over 2.5 million population and an area of 14,042 km^2. 63% of the population live in urban areas and 37% of people live in rural areas [17]. Guilan has 1,902 km of roads, mostly concentrated around the provincial capital of Rasht, including 487 km highways and 56 Km of freeways that connect Guilan to the rest of the country in the south as well as to the border with Azerbaijan in the north [18]. Guilan accounts for 3.2% of the national population and 3.4% of the national road traffic death [19].

There are three main sources of information about mortality and causes of death in Iran. The National Organization for Civil Registration (NOCR) under the Ministry of Interior, is mandated by law to register vital events (birth, death, marriage and divorce). The Forensic Medicine Organization (FMO) under the juridical system is responsible for issuing the Medical Certificate of Cause of Death (MCCD) for suspicious or non-natural manners of deaths. This list includes 19 causes and manners of death, including death due to road traffic injuries [20]. Lastly, the Ministry of Health and Medical Education (MoHME) Deputy of Public Health integrates data from different sectors (NOCR, FMO, cemetery, hospitals, etc) [21]. MoHME initiated the death registration project in 1997 intending to improve the completeness of death registration and quality of cause of death classification.

2.3. Data collection

We conducted a literature review, including scientific publications, reports and guidelines, to collect information about the business and information architecture of the road traffic death registration system in Iran and to identify relevant stakeholders and their roles in the system. In addition, we conducted two key informant interviews with the members of the Road Traffic Accident Prevention Working Group of Guilan Province. This helped to validate the list of stakeholders identified from the literature review.

In the next step using a classification suggested by Bordier et al. [22] we classified the identified stakeholders based on their role in the registration system:

- Operating: Stakeholders who are officially in charge of core activities such as issuing death certificates, burial permits, and registering road traffic deaths.
- Influencing: Stakeholders with direct or indirect influence on the registration process (on the pathway of registration).
- Absent: Stakeholders without any direct influence on the official registration process (e.g. users of the information).

We conducted 11 interviews with individuals representing 7 stakeholders. We used purposive sampling to select participants representing health facility staff members (physician, matron nurse, medical records unit, information technology unit, emergency unit secretary), the Deputy of Public Health of Guilan University of Medical Sciences, the Prehospital Emergency and Incidents Management Center of Guilan (EMS), the Traffic Police, the Iran Red Crescent Society, the firefighting and safety services organization of Rasht –the capital city-, and the Forensic Medicine Organization (FMO). The interview guide included questions about: 1) the professional expertise of the informant; 2) the role of their attributed organization in the system; 3) interaction with other stakeholders; 4) information flow and the activities related to recording, registering and reporting death; 5) challenges and opportunities to improve the system.

Semi-tructured interviews were administered in one of three forms: phone, face-to-face and written, over 5 weeks in December 2021 to January 2022 by the first author. Interviews were conducted using a predefined interview guide and they ranged in length from 15 to 40 min. We also recorded our observations in field notes.

In the next step, we developed a process map, visualizing stakeholders with operating or influencing roles, system processes and information flows from end-to-end, using Business Process Model and Notation (BPMN) in Software solution Bizagi Modeler version 3.3.0.076.

We validated the draft process map in a participatory manner involving a group of subject matter experts. We conducted a multidisciplinary meeting where all identified stakeholders involved in the process of registering road traffic deaths were invited [23]. Participants of the workshop represented the Forensic Medicine Organization, the Traffic Police, the Road Police, the Guilan University of Medical Sciences (the Deputy of Public Health and the Deputy of Treatment), a hospital physician and a medical records technician, EMS, NOCR, insurance, the Iran Red Crescent Society, and the Rasht Firefighting and Safety Services Organization. Researchers organized a facilitated discussion by presentign a draft of the process map. Participants provided feedback on the

map by presenting their roles in the system and how they communicate information with other stakeholders. They also discussed the root causes of the design flaws they observed in the operating system. The inputs from the discussions were collected during the workshop and were integrated into the final map shown in Fig. 1.

2.4. Data analysis

To breakdown the complexity of the processes and obtain a better understanding of the tasks performed by stakeholders in the system, we used an adaptation of the ten Civil Registration Vital Statistics milestones [24] and classified the tasks performed in the system into three major phases:

1) Identification and recording; the processes associated with the collection and recording of information about the persons injured in a fatal crash by the first responders to the crash.

2) Notification and registration, the transmission of sufficient information about the fact of death to support the eventual formal registration of the death.

3) Production of statistics; the tasks including producing and

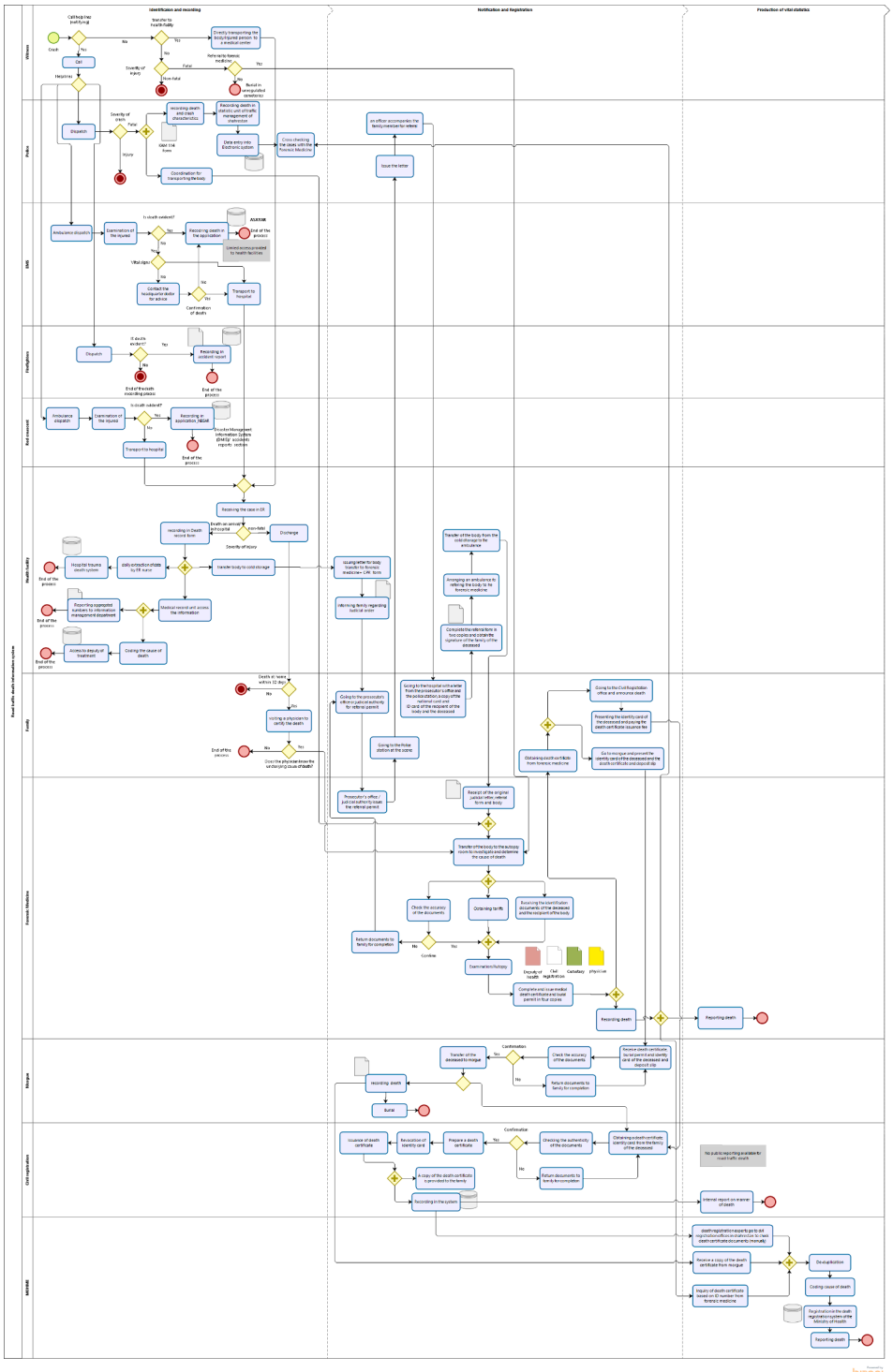

Fig. 1. Process map of the registration of a road traffic death in Guilan province of Iran. Tasks performed in the system are classified into three phases: 1) Identification and recording; 2) Notification and registration, and 3) Production of statistics. We used three main elements to describe the information flow in the map including tasks, gateways and events: Task (blue box): A task within a process flow that is performed by a stakeholder. Exclusive gateway (empty diamond): showing alternative paths within the Process, when only one is chosen. Parallel gateway (diamond with plus): showing alternative paths within the Process, when all are chosen. Start event (green circle): the occurrence of a fatal crash and initiation of the process. End event (empty red circle): End of the core process. Terminate end event (filled red circle): End of the process when the following tasks are not related to the core process. The map includes Operating and Influencing stakeholders. We also paired the juridical office with the forensic medicine, and road police with traffic police in joint lanes. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

disseminating the of annual national statistical reports.

We analyzed the structure of the revised map using the qualitative content of the interviews, field notes, and notes from the group model-building workshop to capture the complexity of the system, constraints and opportunities affecting the performance of the system in recording, registering and reporting a road traffic death event.

2.5. Ethical considerations

Ethical approval was obtained from the Ethics Committee of Northwest and Central Switzerland (EKNZ) (Statement ID: AO-2020–00055) and Tehran University of Medical Sciences (IR.TUMS.SPH.REC.1399).

3. Results

3.1. Design of the local system

We identified 17 individuals and organizations contributing to the process of collecting, recording, registering and reporting road traffic deaths at the province level (Table 1). The National Organization for Civil Registration (Ministry of Interior), the Deputy of Public Health (MoHME) and the Forensic Medicine Organization (Judicial system) have operating roles and are at the core of the road traffic death information/surveillance system in Iran. Nine actors had influencing roles and four did not have a direct role in the registration system but were users of the information.

We describe the characteristics of the system, the role of stakeholders and the information flow in three phases as illustrated in the process map (Fig. 1).

Table 1
Role of stakeholders of the road traffic death registration system at the province level, classified into three major phases: Identification and recording, Notification and registration, Production of statistics.

Stakeholders	Role	Identification/ recording	Notification/ registration	Production of statistics
National Organization for Civil Registration	Operating		*	*
Forensic Medicine Organization	Operating		*	*
MoHME- Deputy of Public Health [H]	Operating			*
Prehospital Emergency [H]	influencing	*		
Health facility [H]	influencing	*		
Deputy of treatment [H]	absent			
Information management [H]	absent			
Trauma care [H]	absent			
Family	influencing		*	
Witness/first responder	influencing	*		
Road police	influencing	*		
Traffic police	influencing	*		
Juridical office	influencing	*		
Firefighters	influencing	*		
Red Crescent society	influencing	*		
Cemetery	influencing		*	
Insurance	absent			

H: Health sector.
Role of stakeholders is classified into three categories: “Operating” Stakeholders officially tasked with core activities such as issuing death certificates, burial permits and registering road traffic deaths; “Influencing” Stakeholders with direct or indirect influence on the registration process (on the pathway of registration); and “Absent” Stakeholders without any direct influence on the official registration process (e.g. users of the information).

3.1.1. Identification of the deceased and recording of information

The process initiates when a road traffic crash results in a fatality. We track the pathways in which a death is recorded in different sub-systems. In this phase, road police, traffic police, EMS, the Red Crescent, firefighters and health facilities have prominent and different operational roles depending on the location of the crash (Table 1).

Road and traffic police are responsible for crash site management including coordinating rescue teams’ activities in rural and urban roads respectively. EMS is in charge of providing medical support to the injured. The Red Crescent and firefighters are responsible for releasing the victim from the scene of the crash in rural and urban roads respectively. These organizations collect data of the crash characteristics including information about the deceased. In a scenario where the victim is transferred to a health facility before death, the patients’ characteristics are also recorded in the medical records.

3.1.2. Notification and registration of road traffic death

Key actors in this phase are the FMO, the NOCR, the cemetery and the family of the deceased (Table 1).

Ordinarily, the MoHME is responsible for issuing a Medical Certificate of Cause of Death (MCCD) for natural causes of death in Iran. An MCCD is a legal document issued by a medical doctor, to confirm the death and its cause; it has two sections: 1) death certificate and 2) burial permit. However, road traffic deaths are classified as non-natural manners of death and only a medical doctor affiliated with the FMO is allowed to issue the MCCD for these cases; therefore, the body should be transferred to a forensic medicine autopsy laboratory for investigation of the cause of death. Upon receipt of the death certificate for a road traffic death, the NOCR initiates the death registration process and issues the legal death certificate document. The burial process in cemeteries is regulated by law and should be documented by a burial permit.

3.1.3. Production of road traffic vital statistics

Three operating stakeholders produce road traffic death statistics at the provincial and national levels. The MoHME is not responsible for issuing MCCDs for road traffic deaths; therefore, in these cases the MCCDs are collected from other sources. As illustrated in Fig. 1, the Deputy of Public Health (at the provincial level) collects information from cemeteries, the NOCR and the FMO. Mortality profile reports are published once every three to four years by the MoHME and are publicly accessible. The reports present provincial data based on the place of residence of the deceased (Table 2) [12]. The Vital Statistics department of the NOCR publishes national reports on aggregate vital events, including deaths, based on the place of residence.

The FMO publishes monthly and annual reports on the number of road traffic deaths, which are publicly accessible. The local offices report the deaths based on the place of the crash and the place of examination. This information is integrated at the national level and the national report is published with a breakdown by province where the crash

Table 2
Number of deaths due to road traffic injuries in Guilan province, March 2019-March 2020, reported by operating stakeholders.

Stakeholder	Number of reported death	Reported based on
Ministry of Health and Medical Education	391	Place of residence
Forensic Medicine Organization	530	Place of crash
National Organization for Civil Registration	427	Place of residence

occurred.

3.2. Constraints and opportunities of the operating system

The analysis of the process map during the multidisciplinary workshop with stakeholders exposed design flaws and inefficiencies that limit the performance of the system (Fig. 1). We describe the characteristics of the system as well as the strengths and weaknesses identified at different phases of reporting a road traffic death.

3.2.1. The need for an integrated system

Various stakeholders record different aspects of the event –crash resulting in road traffic death– for different organizational purposes. Fragmentation exists at both inter-organizational as well as intra-organizational levels. For instance, as shown in Fig. 1, at the health facility level, information about a death event is recorded in multiple forms and the data is extracted multiple times by different individuals. This is not only an inefficiency of the system, but also has implications for data quality, particularly in paper-based systems, as they are susceptible to human transcription errors.

> *"There are parallel information systems…. even in one sector (health), while we have electronic data collected on the HIS [Hospital Information System], we have to extract information from [paper] medical records and report to Farabar [the statistical automation system]" -Medical records technician at health facility.*

We also found organizations that collect information using their own electronic/paper forms. This information is mainly used for internal organizational purposes and there is no platform to integrate information from different stakeholders. This isolation could result in some cases being missed and, ultimately, the number of deaths being under-reported in national statistics.

> *"We collect data on the characteristics of the event, date, time, weather and the* procedures *we have done….This information is used by the statistics unit of the organization at the province level. The information we collect is not shared externally with other organizations." -Firefighters.*

Our study participants expressed concern about the fragmentation of the information and emphasized the need for an integrated crash data system that collects information about the casualties and the crash scene.

> *"We should have an integrated information management system that integrates all of these* existing *subsystems taking into account [data] security [concerns]…..… at least with the minimum data elements that can be shared... [the system] integrates this information into one set of integrated information management system" -Deputy of treatment.*

3.2.2. Family as an information broker

Due to the absence of effective communication channels among key stakeholders during the registration phase, the family of the deceased bears the burden of administrative tasks for registering deaths through coordinating the referral process to the forensic medicine (Fig. 1). The family of the deceased acts as the communication channel between five stakeholders (the health facility, the FMO, the NOCR, the police and the cemetery).

> *"We [the health facility] inform the FMO about the death event…. [meaning that] the family of the deceased takes the CPR report to the juridical office/court…" -Emergency unit secretary.*

The administrative process of transferring the body to the forensic laboratory involves visiting different organizations to obtain transfer permits (Fig. 1). This process can take more than one day, depending on the distance between the organizations.

> *"If the forensic laboratory and the police had a station at the [trauma] hospital, referral process would be faster by reducing commute time [for the family of the deceased]" -Nursing office.*

At the FMO, a paper-based MCCD is issued in four copies to be used by the physician issuing the MCCD, the cemetery, the NOCR and the MoHME Deputy of Public Health in yellow, green, white and red respectively. However, there is no automated communication system for sharing these documents. The map shows a pull system where the FMO does not take active action in sending the MCCDs to the relevant stakeholders.

> *"…death is announced/notified [to NOCR] in the form of automation (incomplete), fax, government or sometimes through close relatives." -NOCR.*

The process map assisted stakeholders to reassess their roles and responsibilities. For example, despite the inter-organizational agreement between the FMO and the MoHME for sharing data, the direction of communication was not clear—in other words, whether it was a pull or a push system— and the communication channel between two stakeholders was limited to an inquiry of MCCDs – for identified cases – based on ID numbers. Thus, the cases not identified by the MoHME through other sources of information, will not be included.

3.2.3. Classification of causes of deaths

Mortality statistics are based on the underlying cause of death. An unknown or unspecified underlying cause of death in the MCCD makes it difficult to assign the death to the specific ICD codes for road traffic injuries (V01-V79).

> *"Determining and declaring [the cause of] death is not [done] in accordance with the ICD codes. What is often recorded in the MCCD is for juridical purposes, which lacks information about the sequence of the events. This may cause difficulties [for mortality coding] in matching the cause [written on MCCD] with the ICD codes, for example, in the event of an accident … "striking against or struck by other objects" [is the cause of death stated in the MCCD]….. This information is unusable for planning and performing interventions."-Deputy of Public Health.*

Classification of the causes of death for reporting is performed independently by the FMO and MoHME Deputy of Public Health. In cases hwre the underlying cause of death is unclear and background information from medical records or police reports is not available or sought after, the cause of death may be classified with an unspecified cause of death (e.g., V98-V99, W00-X59, X58-X59 and R99). This results in an under-estimation of the number of deaths due to road traffic injuries.

In addition, the quality of the cause of death statistics could be affected by a shorrtage of statistical officers trained in mortality coding. According to the Deputy of Public Health, this task is usually carried out by the staff of the Deputy of Public Health who are responsible for coding causes of death in parallel with their routine tasks.

3.2.4. Lack of compliance with legal requirements

As mentioned earlier, MCCDs for road traffic deaths should be issued by the FMO. However, the registration of a death with an "unknown" cause at the NOCR does not necessarily require MCCD from the FMO. In cases where the death due to road traffic death is not notified as a non-natural manner of death, the testimony of two witnesses is sufficient for civil registration to issue a legal document certifying the death. However, according to the NOCR report, only 4% of all registered deaths in Guilan are documented by witness testimony [25]. In addition, although the burial process is regulated by law, unregulated cemeteries such as family burial plots do not follow the standard procedures and they could bury the body without a burial permit.

> *"… Unregulated cemeteries in the province, especially in the western areas and highlands, bury the body without legal documentation. There are no*

registries or documents indicating the number and information about the deceased"- Deputy of Public Health.

3.2.5. Standardization in the system

Even though having a paper-based system is not a problem per se, collecting data on paper forms limits the potential to integrate the different sub-systems. Worse still, information from the cemetery and the NOCR is sent to the MoHME in paper format.

Differences in the definition of death in the identification and reporting phase can lead to major differences in the reported number of deaths by organizations. In the identification phase, different definitions of death and inefficient communication between EMS personnel and the police result in discrepancies in the reported number of deaths at the scene of the crash, on the way to the health facility, or upon arrival and in the hospital.

"…at the scene of crash, if the death is evident, we [EMS] announce the death as death at scene of crash. However if we [EMS] transfers the *body to health facility, the police will not record the [same] event as death at the scene of crash". –EMS.*

In addition, at the reporting phase, there is no standard definition of death among the main stakeholders. The MoHME, the FMO and the NOCR use their own definition of death, which varies from the definition of the population, and at the time of the crash (Table 2). We also found that although the recording of the ID number is not compulsory for organizations in the identification phase, the MoHME, the FMO and the NOCR use the same unique ID number to register deaths, which facilitates the potential integration of information at the inter-organizational level.

4. Discussion

Through process mapping, our case-study describes the structure and information flows within the road traffic death registration system and identifies factors influencing system performance in Guilan Province.

We found that, the system has some of the key elements of a comprehensive system ready for integration, such as common unique identifiers and institutional agreements across sectors [10]. However, the lack of well-functioning communication channels among stakeholders, problems with the classification of the cause of death, and lack of standardization in the system often result in discrepancies and under-reporting of road traffic deaths.

The system is highly fragmented and has with minimal cross-sectoral data exchange. The information systems are designed to assist organizations in fulfilling their functions and they are incomplete, inconsistent, and operate in silos. Each stakeholder operates in a silo, leading to delays and redundancies in the operating system. The fragmentation and information silos alter the compilation of cause of death statistics and results in under-reporting of road traffic deaths and discrepancies in reporting. The process map (Fig. 1) also shows that despite inter-sectoral agreements between the MoHME and the FMO, their respective responsibilities have not been clearly defined. Ambiguity in the direction of the information flow between the MoHME and the FMO led to under-reporting in the MoHME's death registration system. As shown in Table 2, contrary to expectations, the "integrated" death registration system at the MoHME, which was established to improve the completeness of death registration, did not accomplish its aim and, recorded the lowest number of deaths.

Our findinggs are in line with a recent report that found parallel data collection mechanisms and information silos in road safety information systems in Iran [26] as well as in other countries. In Iran, while the death registration system and the forensic medicine system captured almost 90% of estimated deaths in one province, only 43% of cases overlapped between the two information systems, meaning that both sources under-reported the number of deaths [11] Similar results were also found in a recent study of Nigeria's death registration system which highlighted parallel activities and redundancies in the system [27]. A study in Uganda found that police and hospital records captured 14% and 60.4% respectively, of the estimated total number of road traffic deaths, respectively [10]. Whereas in Sweden, the National Board of Health and Welfare registers and reports the cause of death statistics with 99.1 % completeness. This is the result of a direct digital link between the forensic pathology data management systems and the Swedish cause of death register [28].

Another consequence of ineffective communication channels among stakeholders is that the information exchange among stakeholders depends on the family of the deceased to make the information available to various stakeholders. Reliance on the families is one of the characteristics of a passive system. Reliance on the family introduces potential barriers to the death registration process such as lack of knowledge about legal requirements, financial and administrative hurdles, etc [14,29].

Many studies have explored factors influencing cross-sectoral health information exchange. In their review, Edwards et al. identified security concerns, the need for standards, economic loss to competitors and federal systems as the main barriers to information exchange among different sectors [10]. Another review identified a lack of coordination and financial factors as the most important factors influencing the integration of information systems [11]. In Iran, the road traffic data registry is affected by a lack of trained human resources, coordination and inter-institutional trust resulting in so-called "separated registration" [13]. One example of an intervention that attems to address fragmentation in the system is the development of the Comprehensive Traffic Injury Registry (CTIR) by the Iranian Traffic Knowledge Development Trustee, which was piloted in four provinces [30,31]. No report from the implementation phase of this project has yet been publicly published.

Another reason for under-reporting is related to the quality of the cause of death reports. This occurs when the immediate causes of death (e.g. intracranial hemorrhage) are reported without specifying the underlying cause of death (road traffic cras) [6,29]. Bhalla et al. found that in almost half of countries, more than 20% of road traffic deaths are reported as unspecified categories of cause of death [32]. In Iran, 10–19% of all deaths are recorded with an ill-defined or unknown cause of death [5].

Previous research suggests that the quality of the cause of death registry is influenced by two major factors; the skill of the physician certifying the death and the competence in statistical coding practices according to the ICD [33]. A study in Iran, reported that only 34.4% of physicians and information management unit staff were aware of the regulations for death registration. 79% (76 participants) reported a need for training on death certification [34]. Another study found that providing various training strategies in the forms of training of trainers, direct training of physicians and online training reduced incorrectly completed certificates 28–43% [35]. In many countries, training in death certification is inadequate [6]. In Tanzania, quality of cause of death statistics improved by 17 % through interventions aimed at governance, training, practice and the process of certifying the cause of death [36].

In addition, automated coding systems could improve the cause of death statistics and reduce the workload for medical coders. Harteloh found that IRIS, an automated coding system, require no manual intervention to code 68.5% of the death certificates. However, such systems are strongly affected by the quality of death certificates [37]. In Sweden, adopting electronic aids for coding death certificates and identifying the underlying cause of death improved the quality of the registration system. This was achieved through standardizing language and facilitating the assignment of appropriate ICD codes to the conditions listed on the death certificate [28]. According to Edwards et al., health information systems in which information is collected in different forms, including unstructured documents (e.g. scanned copies, image files), require

standardization at different levels such as data collection point, practice, institution, regional or national level [10].

The scope of our study was limited to a medium-size province in Iran. Given that the system characteristics could be influenced by contextual factors, our study has limitations in terms of generalizability to all road traffic death information systems. However, it does demonstrate a systemic approach to describing the system and identifying challenges. Second, since the study was limited to "death" registration, we did not include the processes related to injuries or the crash recording and reporting system. Further work is needed to engage stakeholders in the design of an improved system and to develop performance metrics to monitor the progress of the system.

Despite the limitations, we believe this study contributes to our understanding of how the road traffic death information systems are designed, how they work and identifies their strengths and weaknesses. The insights gained from this study may assist designing comprehensive national crash information system that provide accurate and timely information for decision-making. Designing such information systems requires understanding of the information flow and the entangled web of different stakeholders operating in the system. Participatory systems approaches such as process mapping can help capture the complexity of the system and the integration process by facilitating stakeholder engagement and ownership in improving the design of the system. We are currently investigating the characteristics and completeness of the road traffic deaths information systems to quantify the existing fragmentation in the system.

5. Summary table

What was already known on the topic?

- There is reliable source of information for road traffic death in only half of all countries
- Various stakeholders collect information about road traffic deaths; however, there are discrepancies among reported number of deaths.

What this study added to our knowledge?

- This study contributes to our understanding of how road traffic death information systems are designed, how these systems work and where the strength and weaknesses of the systems are.
- The fragmentation in the system highlights the importance of inter-institutional and intra-institutional information exchange.
- Provides new insights into the application of systems approaches in improving the design of road traffic information systems.
- The insights gained from this study may be of assistance to developing national crash information systems that provide accurate and timely information for decision-making.

CRediT authorship contribution statement

Maryam Tavakkoli: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. **Amirhossein Takian:** Conceptualization, Supervision. **Mahtab Mohammadi:** Data curation, Writing – review & editing. **Hamid Heidari:** Data curation, Writing – review & editing. **Leila Kouchakinejad-Eramsadati:** Data curation, Writing – review & editing. **Shahrokh Yousefzade-Chabok:** Data curation, Writing – review & editing. **Don de Savigny:** Conceptualization. **Günther Fink:** Conceptualization. **Nino Künzli:** Conceptualization. **Daniel Cobos Muñoz:** Conceptualization, Supervision, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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