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Integrating IoT with Tactical Considerations Towards Improvements in Punjab Emergency Service Rescue 1122 Pakistan

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Abstract- Emergency services contribute a lot for the wellbeing and comfort of the society by promoting the virtues of goodwill gestures. In Pakistan, emergency services took a long time to start in the form of Punjab Emergency Service (PES) Rescue 1122 in the year 2004. The PES has put its remarkable efforts to provide quality emergency services as acknowledged by the community. However, it still needs improvements from different perspectives. The inclusion and integration of Internet of Things (IoT) based apparatus and incorporation of emergency medical services (EMS) with e-health systems are the core aspects. The integration of call monitoring software (CMS) with the vehicle tracking system and the need for having a technology-based decision support system are other perspectives. The advancements in operational communication, safety and protection of rescuers during operations and the addition of helicopter emergency service, etc. are also considered. The state of the art literature is still deficient to comprehensively cover the topic under reference. The study successfully addresses this deficiency by thoroughly exploring different aspects of the PES in a critically constructive that leads towards technological and tactical improvements. The study also proposes an innovative IoT based EMS inclusive E-health Architecture and a Unified Emergency Operational Model to improve the service quality of the PES. These proposals set the basis for the optimal performance of the PES through various perspectives like collaborative quality emergency response with real-time monitoring and care, machine learning-based analysis of emergencies prevention, etc. along with the future research directions..

Keywords-Decision Support System, E-health, EMS, ICT, IoT, Punjab Emergency Service, Response, Safety, Trauma, Unified Emergency Operational Model.

I. INTRODUCTION

Health is no doubt an invaluable wealth for human beings and they strive for it through different means. It is a need of the time to incorporate state of the art technologies in the existing setup of health and emergency services to get the optimal output. Consequent upon the emerging healthcare requirements, e-health puts its ever-growing demands like efficient coverage, appropriate facilities and prompt provision of its quality services mainly through IoT. The IoT has a fundamental role in the emergence of e-health systems and its further extension for the provision of integrated pre-hospital healthcare through EMS. IoT is an evolving technology which enables quick and precise data collection and communication through sensing devices [1-3]. The smart environment is established through the connection of various devices (things) under the core concept of IoT where such devices may also have their computing capabilities[4].

EMS provides the services of pre-hospital treatment and hospital shifting to the people suffering from illnesses, injuries or any other conditions that require an urgent medical response to save invaluable lives. It delivers its services in collaboration with other systems that work for maintaining and enhancing the health and safety of the community. As a matter of fact, the operation of EMS lies among the intersections of healthcare, public health, and public safety.

A. Emergency Services in Pakistan

The day by day increase in population, hustle and bustle of life and the alarming evolution of different interactive entities like the expansion of industries, heavy road traffic, etc. have increased the chances of going something wrong that may lead to an emergency. The emergency services including EMS are being provided in Pakistan but it took much time for its initialization like in many other developing countries of the world. Despite its too much-delayed provision, EMS is no doubt a blessing and fortune for people, particularly the critically ill and poor one. The Punjab Emergency Service (PES) publically renowned as Rescue 1122, is a leading emergency service in

Pakistan which is run by the provincial government of Punjab. After its success and heightened demands by the community, the PES has also been replicated in some other provinces of Pakistan. In [5], it is discussed that in some areas of Pakistan different NGOs operate ambulance services with varying quality of services. It is further pointed out that, only in the city of Karachi more than five (Edhi, Chhipa, Khidmat-e-Khalq, St. Johns and Aman Foundation) 'private' ambulance services work. Most of the aforesaid ambulance services provide just shifting facility to the victims without providing any pre-hospital treatment to them, while Aman Foundation is considered a good private EMS among these. However, the PES is acknowledged as the only versatile emergency service in Pakistan with an extensive scope of its services.

B. Emergency Care Status in Absence of the Punjab Emergency Service (PES) Rescue 1122

A few years back before the advent of the PES there was no formal and well-organized EMS in Pakistan [6-10]. In the absence of EMS, all the patients of emergencies either medical or road traffic accident (RTA) used to be shifted to hospitals by their family members or bystanders through privately managed vehicles having at the most a stretcher and a siren. Such patients were just shifted through a private transport without the supervision of any emergency medical technician (EMT); having no emergency-related tools, equipment and accessories (TEAs), no communication system and even no oxygen delivery system was installed in the transport [11, 12].

C. Initiation of EMS in Punjab

Punjab is a top populated province of Pakistan [16] having about 110 million population as per the latest census in the year 2017. In 2004 for the first time in Pakistan, the government of Punjab launched a well-organized EMS in the form of PES Rescue 1122. It was a pilot project for the provincial capital city Lahore with a plan to deliver professional pre-hospital emergency services with an aim to extend it further on getting the desired results [14].

D. Legislative Support to the Punjab Emergency Service (PES) Rescue 1122

On marvelously achieving its milestones in the pilot project for the city of Lahore, it was twenty months later since the establishment of the PES when the Punjab Assembly approved the "Punjab Emergency Service Act 2006" on June 09th, 2006. This act formally authorized to establish the emergency services in order to meet a state of preparedness for dealing emergencies with timely response and the provision of pre-hospital treatment. Furthermore, the PES was supposed to give recommendations to the concerned organizations for the avoidance of emergency situations.

E. Service Domains of the Punjab Emergency Service (PES) Rescue 1122

At the start, the scope of the PES was limited to just the provision of EMS through rescue ambulances but later on, it was expanded to cover its following service domains:

- Medical Emergencies
- Road Traffic Accidents
- Fire Emergencies
- Collapsed Structure Search & Rescue
- Water Search & Rescue
- Motorbike Ambulance Service
- Community Safety & Awareness

While responding any emergency from the aforesaid domains, the PES starts its operation by dispatching relevant emergency teams along with the emergency vehicles like ambulance, rescue vehicle, fire vehicle, and water rescue van, etc. according to the requirement as depicted in Fig. 1. All the PES emergency vehicles are fully equipped with the relevant TEAs including a wireless communication system. But there is still a dire need to enhance its capacity and to improve its working mechanisms in order to ensure its better performance along with the safety and protection of the teams during rescue operations. Moreover, recently the PES has launched its motorbike ambulance service at the divisional level in all over Punjab. The main purpose of the motorbike ambulance service is to provide emergency services by overcoming the inaccessibility issue especially in congested areas as well as to minimize the burden on ambulance service by not engaging them in situations where just motorbike service can do the job.

Fig. 1. Service Domains of the PES

Like the PES toll free emergency helpline 1122, there are many other emergency helplines operating around the world for example, 911 in United States, 112 in European Union and other European countries, 000 in Australia, 108 in India, 999 in United Kingdom, Bangladesh, Singapore, Malaysia, Hong Kong, United Arab Emirates and some other countries. All of these emergency services provide almost the same services

but their service standards and quality differ a lot from one another on the basis of their infrastructural and technological advancement level as well as the expertise of their staff.

The PES is the only governmental emergency service in Pakistan which has proved itself as a successful EMS along with its significant achievements for responding emergencies in other domains as well like fire, collapsed structure search & rescue, water search & rescue, etc. But the perception of its successfulness and level of public satisfaction is based on the fact that it is an emergency service of a developing country operating in a resource-constrained environment and lacking advanced technologies as compared to the developed countries. It is a very comprehensive and unique study in the sense that the topic of improvements in the PES has not much discussed in the literature. There are many reasons due to which the PES lags behind the other emergency services that adopted the required infrastructural, technological and other tactics at an appropriate pace.

It is evident that a constructive focus on the development and improvement of the emergency services has saved people from a large number disabilities and deaths that could be caused by various reasons like head injuries, trauma, stroke, cardiac problems, suicidal conditions, etc. [15-17]. In this perspective the study aims to put its significant role for deeply investigating the topic, identifying the deficient areas and proposing marvelous improvements in the PES including IoT based integration to save precious lives and to reduce disabilities caused by the emergencies.

F. Significance of the Study

The study is tremendously significant as it contributes a lot for improving the overall healthcare in general and particularly the response quality as well as other aspects of emergency services. The contributions of the study can be utilized for the welfare of the society at different levels i.e. worldwide, nationwide in Pakistan as well as particularly in the province of Punjab. The proposed improvements, IoT based EMS Inclusive E-health Architecture and Unified Emergency Operational Model would also play an effective role in the enhancement of the service standards and to ensure the overall optimal resource utilization. The resultant optimal resource utilization is considered a crucial point especially in the budgetary constrained developing countries like Pakistan. Moreover, the study can be taken as an important initiative and a pathway that would lead towards numerous research directions especially in the field of emergency services and e-health.

G. Limitations of the Study

The limitations of the study are as follows:

1. The scope of the study has been constrained due to the reason that Information & Communication Technologies (ICT) and IoT have not much implemented in the existing infrastructure of the government departments in Pakistan.
2. The study proposes improvements in the PES keeping in view the fact that as per the existing general SOPs of the PES two Emergency Medical Technicians (EMTs) are moved to respond through an emergency vehicle (ambulance). Moreover, the doctor (District Emergency Officer) is generally not supposed to move like EMTs for treating patients in the ambulance rather he/she supervises the overall district-level setup of the PES.
3. There may be some other potential additions in the proposed improvements, architecture, and model but the existing isolated nature of operations by the government departments in Pakistan is a great hurdle in this regard.

H.Delimitations of the Study

The delimitations of the study are as follows:

1. The study has specifically focused the existing setup and the requirements of the PES as well as the relevant functions of the Punjab Health Department. In addition to it, the collaborative role of other relevant provincial-level departments like the Provincial Disaster Management Authority (PDMA) and the Punjab Police has also been considered. The feasibility for having the required level information, access to the system and the organizational environment of the concerned department determined its inclusion in the study.

However, the proposed improvements, architecture, and model can be implemented by any emergency service and e-health system with respective adaptation if required. The study can be effectively utilized especially in order to have an expansion of both the emergency services and e-health systems at the country-level in Pakistan or elsewhere.

2. The study has proceeded particularly regarding the relevant provincial-level government departments instead of incorporating the concerned private sector due to unfeasibility regarding access to the required information and the systems for investigation.
3. The scope of the study can be extended by allowing the researchers to go ahead for further proposals subject to the feasible conditions and accessibility to the required systems.

II. Hindrance Factors For Emergency Services

The urge for the delivery of emergency services is further heightened in the presence of hindrance factors for the availability and accessibility of appropriate healthcare services. The lack of health insurance facility is one of the main hindering factors that result in

the deficiency of preventive and routine healthcare services [14]. The healthcare requirements, resources, and cultural environment in the developing world have potential effects on the scope, structure, functionality and financing modes of emergency services.

Like most of the developing countries around the globe, in Pakistan, the scarcity of required EMS resources has resulted in an easily affordable and accessible EMS model but limited to provide only basic quality of services. Moreover, the underdeveloped infrastructures, lack of Internet accessibility, absence of automation trends, underutilization of IoT and are working of interrelated departments are the major hindrance factors for the development of emergency services. Apart from it, another limiting factor is that very little literature works are available regarding quality-focused governmentally run pre-hospital healthcare services in developing countries [18].

III. Literature Review

The state of the art literature has been thoroughly reviewed for exploration of the topic and to find out the optimal solutions leading towards the desired improvements in the PES.

In most of the developing countries including Pakistan, the focus remained on the provision of the structural healthcare facilities to cure diseases while ignoring an essential need to improve the emergency services both at the hospital as well as pre-hospital level in the form of EMS [15, 19]. Injuries put their 16% share in the overall worldwide sum of illnesses that devastatingly suffers the citizens around the globe in general and the citizens of the low to middle-income countries in particular [20, 21].

In the current era of technology and development, emergency services especially EMS and e-health are closely interrelated for the delivery of healthcare services both at pre-hospital and in-hospital levels. So the improvements and enhancements in the capacities of both the sectors augment each other. It has been discussed in [2-5, 22] that different areas of life have been revolutionized through the utilization of IoT. It is further added that consequently the concepts of smart home, smart city, IoT based transportation, traffic monitoring, and health systems have been materialized. The implementation of technological advancements in the form of e-health system increases efficiency and upscale healthcare services [23]. IoT contributes significantly to the enhancement of service quality provided by e-health and eases access to healthcare through its incorporation with the existing technologies [24-27]. E-health systems improve the capacities of its different stakeholders such as doctors, patients, and paramedical staff by supporting them to consistently monitor the health conditions of patients and tracking their previous health record. Most of the e-health systems operate for improving their services, caring, and linkage with their patients by utilizing embedded technologies [28].

R. Waldron et al. have raised a very important point in [29], they emphasized that physicians available at the emergency departments of health units must be well aware of the on-scene physiological conditions of the emergency victims along with procedural activity performed and medication administered by the EMS staff while shifting them to hospital. Moreover, the significance of communication protocol for the delivery of required pre-hospital information to hospitals has also been considered in the study.

In [30], Zorab et al. have discussed that in case of emergency response by EMS, it becomes difficult to know about the patient's previous medical condition, history of treatments and other required health information. But accessibility to such information is important for EMS staff to ensure proper care and procedures for the patients. Such inaccessibility to the health history of the patients may result in fatal consequences especially when a patient is contraindicated or allergic to some medication.

Lori Moore et al. [31] have suggested for removing barriers between the departments by eliminating their cross-departmental or cross-organizational resistance and noncooperation which causes delays, errors, wastage of resources and unwanted redundancy of efforts. However, the authors have not pointed out any type of prioritized departments in this regard. In this study, the under reference substantial issue has been properly addressed by proposing a unified emergency operational model for the top concerned departments that have their vital role in the provision of quality emergency services.

The emergency response time is one of the major factors that affect a lot the survival rate of emergency victims. The arrival time of emergency vehicles at the emergency location is conditioned with peak traffic hours. In order to overcome this issue and to save precious lives, various approaches have been proposed which are based on increasing the number of ambulances, geographically relocating the emergency vehicles, and taking measures for the prompt initiation of defibrillation programs, etc. [32-38]. There are several EMS systems operationalized around the globe that have their domain of motorbike ambulance service, but little research-based works have been presented in the literature so far. Lin et al. [35-37] have presented a scenario where an emergency motorbike responded to the emergency with lesser response time than a regular ambulance. On the basis of the discussion in [32-34], it is proposed that motorbike emergency service should be included in EMS of the PES mainly in the traffic-congested areas, especially during the peak hours. It is further suggested to utilize this service when speedily provision of the emergency services is crucial for managing life-threatening

conditions or when it is uncertain to shift the emergency victim as in case of minor illness or injury. However, in any type of emergency, the provision of the regular ambulance should be preferred on the motorbike ambulance if its provision is feasible.

Helicopter emergency medical service (HEMS) is being utilized for the last 40 years for providing pre-hospital care and shifting of trauma patients even with the inconsistency of evidence regarding its advantages in civilian trauma systems [39-43]. In various European countries, there exist well-established systems to ensure prompt emergency medical treatment at the incident site. Especially in France and Germany, such emergency systems are augmented with the helicopter service. There is a huge network of EMS along with the bases for rescue helicopters to provide countrywide services in Germany [44]. Unlike other countries, HEMS being operated in Germany is entirely physician employed [45]. In [46], Trunkey has investigated the German trauma care delivery system and graded it as outstanding. He further added that the prompt shifting of the traumatic victim to the emergency room and subsequently to the operation theatre results in the reduction of morbidity and mortality rates. HEMS is considered as an efficient emergency service because helicopters are capable to provide the direct approach at the incident site for shifting the emergency victims mostly from road-inaccessible areas, thus providing quick care to the critically injured traumatic victims by shifting them to high-level trauma care center when it would otherwise not be in the nearby vicinity [47]. In [39, 40] as well, HEMS has been discussed as a service covering longer distances for providing direct and definitive treatment for the victims by shifting them to a specialized trauma center.

It is significantly important to know the quality indicators and relevant performance measures to follow the way towards improvements in any system, the same is the case in emergency services. It can be safely stated that not much literature works have been there to comprehensively cover the topic of performance quality and the ways to measure it, especially in case of emergency services. However, considerable efforts exerted by some researchers are highly notable in this regard. The Department of Emergency Medicine at the University of Pittsburgh carried out a study which can be considered as an extensive effort to establish quality indicators for pre-hospital EMS [48]. In the study paramedics were surveyed in the City of Pittsburgh Bureau of EMS for knowing the indicators of quality care based on their opinion which resulted in eighteen potential quality indicators as given in Table I. However, most of the identified quality indicators vary from the conventional EMS quality assurance and accreditation curriculums.

The research in pre-hospital EMS is scarce [49]. However, the literature suggests that researchers have

TABLE I: POTENTIAL QUALITY INDICATORS PROPOSED BY PARAMEDICS FOR PRE-HOSPITAL EMS

1	Job satisfaction
2	Timeliness of care
3	Patient satisfaction
4	Quality of training
5	Public confidence in the system
6	Crew and equipment appearance
7	Change in complaints
8	Patient outcome
9	Quality of calls
10	Internal satisfaction
11	Symptomatic improvement
12	Cost-effectiveness
13	Mutual aid relationships
14	Research activities
15	Quality of supervisors
16	Vehicle safety
17	Availability of resources
18	Accuracy of 911 communication

usually tried to evaluate EMS systems on the basis of *structural*, *process* and *outcome* measures regarding patient care. For instance, the research has presented a system having promptly responding firefighters with defibrillators as the first responders (*structure*), with paramedic intervention initiating within 08 minutes from the alarm (*process*), resulting in the positive effects from sudden cardiac arrest (*outcome*) [50]. In [51], *structure* has been defined as the characteristics of the setup where care is provided, *process* has been defined as what is actually performed when care is given or received including the activities of the patient and practitioner, whereas *outcome* has been defined as the result of care regarding health status of both the patient and population. It is further stated that the degree of patient's satisfaction and his/her knowledge and behavioral changes also come under the broader definition of health status outcome. Regrettably, most of the research work has kept its focus on the incidence of cardiac arrest and timely response by skilled EMTs while providing little proof of the system efficiency out of this scope.

It is a dire need to devise appropriate and valid mechanisms for measuring quality indicators for the EMS with reference to the structure, process and outcome performance. Furthermore, it is desirable to design some statistical analysis tools for analyzing variations in the aforesaid quality indicators. In [52], Harbour proceeded further and proposed the criteria for the performance measures of the EMS system as presented in Table II.

Moreover, a very beneficial acronym *SMART* has also been coined which emphasizes that performance measures must be *specific, measurable, action-oriented, relevant and timely*.

TABLE II
CRITERIA FOR PERFORMANCE MEASURES OF EMS SYSTEM

1.	Structure-, process-, and outcome-oriented
2	Able to measure the quality and effectiveness of various system components
3	Practical and relevant
4	Based on scientific evidence when possible
5	Subject to ongoing review
6	Designed for ease in data collection
7	Adjustable for system demographics
8	Continuously evaluated for relevance
9	Accompanied by explicit instructions for consistency in use and interpretation application
10	Reproducible, precisely defined, and specific to ensure uniform

• *Operating & Monitoring Mechanisms of the Punjab Emergency Service (PES) Rescue 1122 [53]*

The Rescue 1122 pilot project achieved its defined milestones with a remarkable success which resulted in its phase-wise expansion in all the 36 districts of Punjab and service extension process is continued even to tehsil-level. The PES has now been replicated in some other provinces of Pakistan as well. Moreover, at the district-level, it operates through a control room offering a toll-free helpline 1122 which is accessible through both the landline and mobile phone callers. All the calls on the helpline 1122 are managed through the CMS which is a customized local area network-based software with a number of emergency call agents (operators) connected through a database and an emergency call center server. The calls on helpline 1122 are received by emergency call agents (operators) having the designation of computer telephone wireless operators (CTWOs). On receiving any emergency call the concerned call agent (operator) forwards it to the CTWO deployed at the dispatch desk who responds the call by dispatching emergency vehicle through wireless communication system accordingly. The control room also monitors and controls all the emergency vehicles through a vehicle tracking system to ensure their proper utilization with the minimum emergency response time. While at the provincial-level, all the district-level operational activities of the PES are monitored and controlled through the Provincial Monitoring Cell (PMC) situated at the provincial capital city Lahore. The success of the PES is evident from the fact that till 31st July 2019 it has responded 6432428 emergencies of different natures by providing emergency services to 7223112 victims. Besides its countless efforts for rendering its emergency services, it has ensured to achieve its goal for maintaining average response time within 07 minutes all over Punjab.

Recently the PES has introduced an Android-based Mobile Application named as *Rescue Monitoring System* (RMS). This mobile application is used to upload attendance of the PES employees as well as some emergency-related data to the database of the Punjab Information Technology Board (PITB) which is accessible through an electronic dashboard. The PITB is a provincial-level department that works as a coordinating body among different departments in the province of Punjab by providing e-services as per their requirements. On the basis of the aforesaid situation, there is a dire need to integrate EMS of the PES with IoT based e-health systems to improve its emergency response time, effective patient management and to improve the quality of healthcare especially its pre-hospital emergency services.

Although different aspects of the emergency services have been discussed in the state of the art literature with varying detail. But the literature lacks to comprehensively discuss the gaps, operational difficulties and potential improvements regarding emergency services in general and in context of the emergency services being operated in Pakistan especially the PES in particular. The study successfully addresses the issue of deficient research perspectives by presenting deep insight into the matter along with the spectacular solutions accordingly. It emphasizes some major deficient areas in the PES like its operations in isolation from e-health systems, lacking IoT based integrated apparatus, non-availability of technology-based decision support system, inaccessibility to health history of emergency victims via e-health systems, lacking integration of its call monitoring software and vehicle tracking system, lacking monitoring & communication system for underwater search & rescue teams, non-utilization of machine learning techniques for analysis of emergency data, missing IoT based mechanisms for safety and protection of rescuers during operations, lacking helicopter emergency service, etc. Moreover, the study significantly contributes to the welfare of human beings in general and the citizens of Pakistan in particular by proposing two marvelous models i.e. *IoT based EMS inclusive E-health Architecture* and *Unified Emergency Operational Model*.

IV. METHODOLOGY

It is an exploratory study where different relevant aspects regarding emergency services and e-health have been thoroughly examined within the scope of the study. Keeping in view the respective requirements of the study, the existing functions and operational procedures of the PES, as well as the interactions among all the concerned provincial-level departments

like the Health, PDMA, and Police have been deeply explored and investigated. Such thorough exploration and investigation are based on focusing the real emergency scenarios and the resultant response leading towards the identification of deficiencies in the PES and the relevant operational mechanisms, especially in the e-health system. Afterward, the identified deficient areas paved a way for suggesting IoT based integration and other tactical improvements including the proposed architecture and model to achieve the desired optimal results. In the study, vast field related personal experience of the authors, expert opinion, findings from state of the art literature, community feedback regarding emergency services and e-health system, and other relevant aspects have been considered. The study adopted a methodology that relies on both the primary and secondary approaches for conducting the research.

V. Proposed Improvements in the Punjab Emergency Service (PES) Rescue 1122 Through IoT Integration

Currently, in the EMS ambulance fleet of the PES different types of medical apparatus/TEAs are used to monitor the physiological conditions of emergency victims through measuring their vital signs. However, in order to improve the quality of emergency services, it is required to have IoT based apparatus/TEAs for the real-time monitoring of the physiological conditions including vital signs of the emergency victims, especially while shifting them to hospital. Some basic medical apparatus/TEAs are currently available in the PES ambulances which are mostly manual and few are digital that work in isolation as well as without IoT. The study suggests that it is desirable to convert the listed medical apparatus/TEAs of the PES ambulances from manual or digital to IoT based and then their integration with the nearby concerned IoT based e-health units is required for improving the quality of pre-hospital healthcare:

i. B.P. Apparatus used for monitoring the blood pressure of the victims.

ii. Thermometer used to measure the body temperature of the victims.

iii. Pulse Oximeter used for monitoring pulse rate and oxygen level in the victim's blood.

iv. Glucometer used for monitoring glucose level in the victim's blood.

v. Oxygen Delivery System used to administer oxygen to the victims.

vi. Airway Management Apparatus used for reviving breathing and easing the airway mechanism of the victims.

vii. Automated External Defibrillator (AED) used for automated diagnosis of the life-threatening cardiac arrhythmias of ventricular fibrillation and pulseless ventricular tachycardia along with their treatment through the defibrillation process. It is not the case that all the PES ambulances are equipped with AED and even if it is available then its usage is not much noticed in real scenarios.

In addition to the aforesaid apparatus/TEAs, the provision of the following important IoT based medical apparatus/TEAs in the ambulance fleet of the PES may significantly improve its quality of emergency healthcare:

i. End-tidal Carbon dioxide (ETCO2)
ii. EMS/Transport Ventilator etc.

The inclusion of IoT based apparatus/TEAs in EMS ambulance fleet of the PES and their integration with IoT based e-health systems would enhance the quality of its emergency healthcare services. Such integration would enable the specialist doctors available at nearby concerned e-health units to know the victim's condition in real-time while also having an interactive mechanism with the EMTs taking care of the victims during shifting to health units. Such an interactive system would help a lot the e-health units to become well prepared by arranging the required resources in advance especially in case of mass casualty incidents etc. The currently operated EMS setup of the PES can be integrated with the e-health units in a very effective and secure way by implementing the *proposed IoT based EMS inclusive E-health Architecture* as depicted in Fig. 2. The physiological conditions, pre-hospital medication and any procedural activity performed by the EMS staff must be shared with the doctors and paramedical staff of the health units. But in case of the PES, it is not being complied with that results in extensively increased efforts and too much time consumption while assessing to treat the shifted victims at the emergency department of a hospital. Furthermore, the absence of such information-sharing mechanism between the EMS staff and hospital staff may become very dangerous to emergency victims due to the possibility of overdosing the medication or not administering some essential medicine because of the wrong assumption by the hospital staff that the EMS staff would have already administered it.

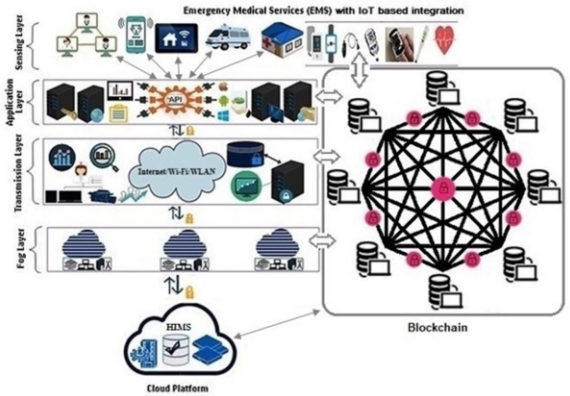


Fig. 2. Proposed IoT based EMS inclusive E-health Architecture

The proposed *IoT based EMS inclusive E-health Architecture* is a marvelous solution to many problems which hamper the provision of quality emergency services by the PES. The proposed architecture depicted in Fig. 2 comprises of four different layers namely sensing layer, application layer, transmission layer, and fog layer. In this architecture, all the entities are assumed to link and communicate with each other by utilizing cloud computing under the blockchain technology that provides a secure and reliable way of information sharing. Moreover, through the inclusion of the EMS as depicted in the proposed architecture, effective patient management can be ensured at all the levels i.e. on the emergency scene, in the ambulance as well as in the hospital. The importance of communication protocol for the dissemination of the required pre-hospital information to the concerned hospitals has also been highlighted in the studies.

It has been pointed out in the literature that in case of emergency response by the EMS, it becomes difficult to know about the patient's previous medical condition, history of treatments and other health-related information. But the access to such information is essential for the EMS staff to ensure proper emergency care and procedures. Such inaccessibility to patient health history may result in fatal consequences if a patient is contraindicated or allergic to some medication. This problem also exists in case of the PES but it can be effectively resolved by implementing the proposed *IoT based EMS inclusive E-health Architecture* depicted in Fig. 2 where its EMS system would be provided access to *Health Information Management System* (HIMS).

The PES also lacks a technology-based *decision support system* which is utmost important especially in case of mass casualty incidents or some other disastrous emergency situations. It would enable the PES to manage the *incident command system* much more effectively and efficiently through the prioritized and triage-based response to the patients. Such decision support system would guide the PES for ensuring its proper resource utilization as per the emergency scenarios. Such type of systems help in making priority-based decisions more quickly and precisely, for example in deciding which patient to be shifted to which hospital in order to provide the best possible available healthcare. In [54], M. Scerbo et al. have discussed a decision support system based on the implementation of *machine learning algorithms* that work by matching a patient's condition to the symptom severity index. Furthermore, another triage tagging based technology employs beacon sensors, barcode stripes or radio-frequency identification (RFID) tags to transmit triage data from the emergency scene to the EMS authorities and hospitals [23].

Although the PES strongly emphasizes to perform scene size up and to adopt some basic *Personal Protective Equipment* (PPE) for protecting its staff and the victims from on the scene potential hazards as well as the infectious diseases. However, there is a dire need to implement very important but still missing *safety and protection mechanisms* for real-time monitoring of the vital signs through IoT based devices attached to the body of rescuers while taking part in different rescue operations. In this way, hazardous and risky effects on such rescuers may easily be noticed and then avoided or mitigated to save their precious lives. For instance, rescuers taking part in different operational activities like fire cases or collapsed structure search & rescue operations may have to face too much hot and suffocated situations respectively. Similarly, in case of some chemical fires or deep-well extrication, they may have to face the same situation in addition to fatal risks from poisonous toxic gases.

The proposed solution for improvement is to use sensory IoT based system which is quite feasible as [55] discusses the safety and protective *"smart garments"* named as *ProeTEX*. The ProeTEX is a good example of safety uniform which is very protective for firefighters. This protective suit consists of two parts i.e. inner garment (T-shirt) and outer garment (jacket) as depicted in Fig. 3. The inner garment consists of sensors and electrodes that sense the physiological parameters of the firefighters like their heart rate, respiratory rate, body temperature, ECG signals, etc. The same technology can be used to monitor emergency victims but used in the form of a patch that gives a more comfortable solution. Similarly, the outer garment consists of thermocouple and accelerometers to monitor environmental temperature and position status including the activity of firefighters like moving, falling to the ground, etc.

Fig. 3. ProeTEX Smart Safety Garments

The ProeTEX is a GPS based system that enables the firefighters to share their physiological conditions among each other as well as with the control room monitoring them. This system is already being utilized by French firefighters and Italian Protection's rescuers. Similarly, the usage of *smart shoes* may further improve the safety and protection by detecting toxic gases as well as other hazardous elements in the environment.

There is much need to use *technology-based searching*

mechanisms especially in case of water search & rescue and collapsed structure search & rescue operations. Such mechanisms would maximize the chances of a successful search for drowned victims in floods, deep-well extrication, etc. as well as for the buried victims underneath the collapsed structures, etc. Moreover, it would also significantly minimize the time to rescue, efforts exerted and risks faced during operations. It is worth mentioning that in Pakistan mostly water search & rescue operations have to be conducted in muddy and unclear water that needs an advanced technology-based solution. In the PES, if a water search & rescue team proceeds for an underwater operation then all the team members have to work in isolation because there are is no underwater communication system available. Similarly, there is no monitoring mechanism to know the physiological conditions including vital signs of the underwater teams for ensuring their safety and protection. Keeping in view the situation, there is a dire need to have a well-defined *underwater monitoring & communication system* for water search & rescue teams of the PES. Such systems would help the PES to ensure the safety and protection of the operational rescuers by enabling them to share their operational information along with the safety status among each other, on the ground *rescue command post* and the intra/inter-teams as depicted in Fig. 4.

Fig. 4. Proposed Underwater Monitoring & Communication System for the Rescue Teams

VI. Proposed Improvements in the Punjab Emergency Service (PES) Rescue 1122 Through Tactical Mechanisms

In addition to the aforesaid proposed IoT based integration and improvements in the PES, some more significant improvements can be made by adopting the required tactical mechanisms. The integration of the PES's currently running *CMS* and *vehicle tracking system* along with the *e-health system* is required. Such integration may enable the PES to know the caller location, nearby available emergency vehicles and the nearby concerned e-health units (having the capability to accommodate the emergency victims being brought through the EMS ambulance) on the same system screen of the *emergency call agents* (operators) that would make them capable to take appropriate decisions to respond the emergency calls.

It has been noticed with great concern that on some occasions (like religious, political and national events, etc.) the cellular network operators block their *cellular network services* by applying *jammers,* etc. on the governmental directions or whatsoever the reason may be. Such type of cellular networks' jamming even halts the emergency calling facility on helpline 1122 from cellphones which may result in the irreversible loss of precious lives and property. On the basis of the aforesaid highly alarming situation, it is proposed that such a system may be devised and implemented so that the jammers or any other such technologies may not halt the emergency services' helplines like 1122.

There is much need to improve the quality of the currently installed *wireless communication* system in the PES. It is desirable to have a long-ranged and distortion-free wireless communication between the PES control rooms, incident command posts, emergency vehicles, motorbike ambulances, and rescue posts, etc. It is worth mentioning that there is no wireless radio communication system available in the newly operationalized *motorbike ambulance service* of the PES. The motorbike ambulance service relies only on the cellphone-based communication system through cellular networks that tends to become halted on a frequent basis due to area coverage problems, jammers or some other technical issues. In order to ensure uninterrupted and flawless operational communication, it is required to review and redesign its existing communication system.

A *Unified Emergency Operational Model* is a need of the time to tackle emergency situations in the light of the *disaster management cycle* for avoiding its evolution to become a disaster. However, it can be achieved effectively only when all the concerned departments come to a single page for rendering their services in the corresponding phases of disaster management cycle in accordance with the proposed *Unified Emergency Operational Model* as depicted in Fig. 5. All the top concerned provincial-level departments i.e. the *PES (Rescue 1122)*, *PDMA*, *Health Department* and *Punjab Police (one of the major Law Enforcement Agencies)* may render their services much effectively and collaboratively by following the proposed *Unified Emergency Operational Model*.

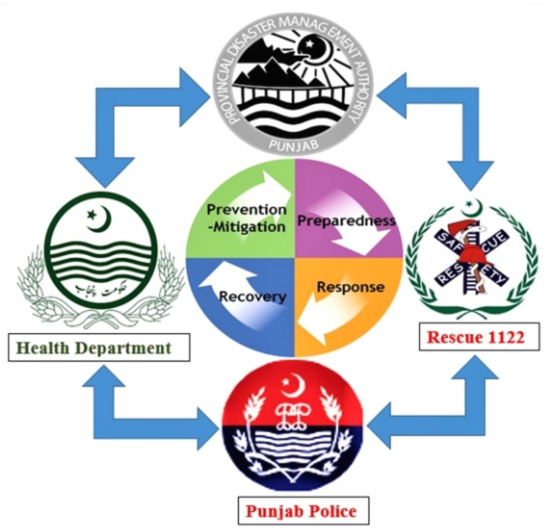


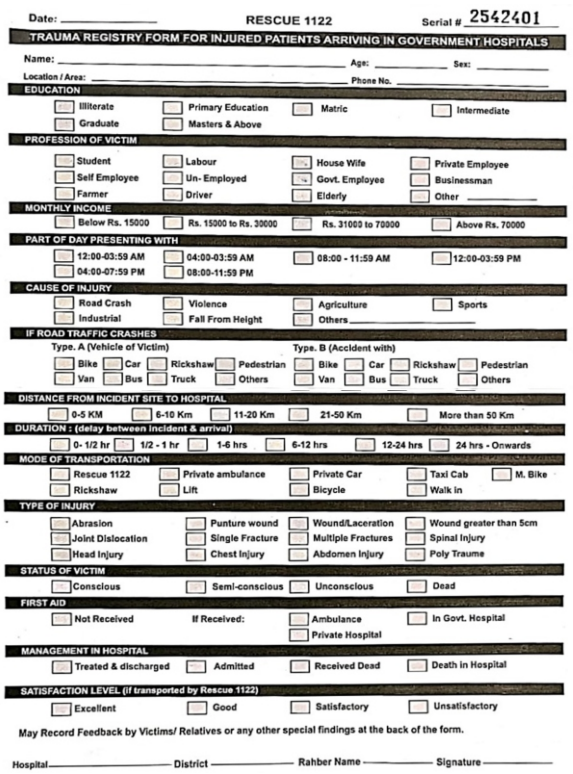
Fig. 5. Proposed Unified Emergency Operational Model

The study has primarily focused and investigated the PES Rescue 1122 which is being operated in the province of Punjab. Moreover, the other relevant provincial departments like the PDMA Punjab, Punjab Health Department, and the Punjab Police Department have also been considered and modeled by depicting their provincial-level scope. However, the proposed Unified Emergency Operational Model can be further utilized by replicating it at the country-level as well in accordance with the requirements and the existing setup of any candidate system in this regard.

While responding flood and drowning emergencies, the PES responds by dispatching its water search & rescue teams equipped with motorized boats having boat tracking units installed in their OBM engines. These boats are monitored through the concerned electronic dashboard at district control rooms and PMC. But there exists a major problem in the currently installed boat tracking units that these can be charged only through some external source of electricity while having a very limited battery backup. Such type of charging system and battery backup is quite undesirable rather unaffordable in an emergency service. The situation becomes much problematic especially in heavy floods when all the infrastructure is collapsed by halting the essential services including the electricity. Consequently, the monitoring of the operational water search & rescue teams is also ceased. Such an alarming situation increases the chances of irreversible loss to precious human lives and public property. In order to avoid the aforesaid highly unwanted situations, it is strongly proposed that the PES should devise such a boat tracking system that is capable to run its boat tracking units directly powered by the OBM engines. At the same time, the battery of the boat tracking units should be chargeable through the same OBM engine instead of any other external source of electricity. Furthermore, in order to minimize the chances of interruption in response and monitoring, such boat tracking system should have an additional backup source of electricity generated through a solar system.

The PES has tried to build its capacity for dealing the emergencies regarding floods, water search & rescue, and deep-well extrication, etc. Currently, the operational staff for water search & rescue operations and other related emergencies is mostly managed through the staff already recruited for the other cadres. But there is a dire need to recruit the specialized staff for water search & rescue wing as well as to incorporate advanced technologies to go-ahead for the provision of quality emergency services in this domain as well.

In developing countries like Pakistan, the pre-hospital services based research has primarily focused on the causes and effects regarding trauma and injuries. Similarly, the PES has also considered its importance by focusing on traumatic incidents through a well-defined analysis mechanism where traumatic incidents are analyzed through a specialized trauma registry form devised by the PES as depicted in Fig. 6. These trauma registry forms are filled by the PES staff deployed at each of the district headquarter (DHQ) hospitals and uploaded for analysis on daily basis through the electronic dashboard of the PES from all over Punjab.


Date: _____ RESCUE 1122 Serial # 2542401

TRAUMA REGISTRY FORM FOR INJURED PATIENTS ARRIVING IN GOVERNMENT HOSPITALS

Name: _____ Age: _____ Sex: _____

Location / Area: _____ Phone No. _____

EDUCATION
Illiterate | Primary Education | Matric | Intermediate
Graduate | Masters & Above

PROFESSION OF VICTIM
Student | Labour | House Wife | Private Employee
Self Employee | Un- Employed | Govt. Employee | Businessman
Farmer | Driver | Elderly | Other _____

MONTHLY INCOME
Below Rs. 15000 | Rs. 15000 to Rs. 30000 | Rs. 31000 to 70000 | Above Rs. 70000

PART OF DAY PRESENTING WITH
12:00-03:59 AM | 04:00-03:59 AM | 08:00 - 11:59 AM | 12:00-03:59 PM
04:00-07:59 PM | 08:00-11:59 PM

CAUSE OF INJURY
Road Crash | Violence | Agriculture | Sports
Industrial | Fall From Height | Others _____

IF ROAD TRAFFIC CRASHES
Type. A (Vehicle of Victim): Bike | Car | Rickshaw | Pedestrian | Van | Bus | Truck | Others
Type. B (Accident with): Bike | Car | Rickshaw | Pedestrian | Van | Bus | Truck | Others

DISTANCE FROM INCIDENT SITE TO HOSPITAL
0-5 KM | 6-10 Km | 11-20 Km | 21-50 Km | More than 50 Km

DURATION : (delay between incident & arrival)
0- 1/2 hr | 1/2 - 1 hr | 1-6 hrs | 6-12 hrs | 12-24 hrs | 24 hrs - Onwards

MODE OF TRANSPORTATION
Rescue 1122 | Private ambulance | Private Car | Taxi Cab | M. Bike
Rickshaw | Lift | Bicycle | Walk In

TYPE OF INJURY
Abrasion | Punture wound | Wound/Laceration | Wound greater than 5cm
Joint Dislocation | Single Fracture | Multiple Fractures | Spinal Injury
Head Injury | Chest Injury | Abdomen Injury | Poly Traume

STATUS OF VICTIM
Conscious | Semi-conscious | Unconscious | Dead

FIRST AID
Not Received | If Received: Ambulance | Private Hospital | In Govt. Hospital

MANAGEMENT IN HOSPITAL
Treated & discharged | Admitted | Received Dead | Death in Hospital

SATISFACTION LEVEL (if transported by Rescue 1122)
Excellent | Good | Satisfactory | Unsatisfactory

May Record Feedback by Victims/ Relatives or any other special findings at the back of the form.

Hospital _____ District _____ Rahber Name _____ Signature _____

Fig. 6. Trauma Registry Form devised by the PES

The significance of avoiding traumatic incidents and its bad impacts through pre-hospital and hospital-based

emergency services is evident from the two trauma relevant publications of the World Health Organization (WHO) i.e. *Guidelines of Essential Trauma Care 2005* and *Pre-hospital Trauma Care Systems 2005*.

Tlimat et al. [56] have elaborated the utilization of *machine learning techniques* for achieving interoperability between the EMS and HIMS for ensuring accessibility to the required information. Accordingly, as an effort to reduce the occurrence of traumatic events, different machine learning techniques can be used for the in-depth analysis of all the concerned points presented in the trauma registry form as depicted in Fig. 6. Keeping in view the output of such machine learning-based analysis, the concerned authorities like the PES and other relevant departments would be able to make better decisions to ensure the better implementation of the required precautionary measures by the community to minimize the occurrence of traumatic incidents. Such type of analysis would include the cause of the traumatic incident, incident timing, type of injury, education and economic level of the patient, mode of transportation to hospital, satisfaction level (if transported by the PES), etc. may be considered to formulate the necessary precautionary measures and to target the concerned community sectors to get the maximum desired results.

In order to improve the quality of services provided by the PES, it is crucially important to prescribe a well-defined and standardized list of medications which are allowed for EMTs of the PES to administer the emergency victims. In [53], it has been stated that as yet EMTs of the PES are allowed to advise just analgesia and sublingual glyceryl trinitrate in the complaint of chest pain while the further guidelines for administering medication is under review. However, it has been noticed that in current practices the EMTs of the PES also used to administer the medications other than the aforesaid allowed ones.

In [57], the National Disaster Management Authority (NDMA) of Pakistan has reported the adverse impacts of the disastrous Indus River flood in the year 2010. According to its statistics, 1980 people died, 2949 people injured, and hundreds of thousands of livestock were killed by the flood. Moreover, it destroyed the public infrastructure, buildings, stored seed grains and standing crops to a mass level. Consequently, a vast area was inundated and a large number of people in far-flung areas could not be rescued because of the road-inaccessibility and infeasibility to perform rescue operations through boats. Similar situations occur in case of earthquakes, landslides or any other catastrophic events, etc. Keeping in view the aforesaid situations it is highly desirable to augment the existing setup of the PES with the *Helicopter Emergency Service (HES)* to ensure prompt response and shifting of the highly critical emergency victims in general and the victims at far-flung inundated and road-inaccessible areas in particular.

At last, it is strongly recommended that the PES should sincerely consider the proposed EMS quality indicators and performance measures as stated in the given Table I and Table II for its general improvement and particularly for the proposed improvements in the study.

VII. Conclusion

Like many other developing countries in the world, the initiation of well-organized emergency service in Pakistan took much time to come in the form of the PES. The PES is the only governmental emergency service which has proved itself as a successful EMS while contributing its remarkable role in dealing the other emergency domains as well like *fire*, *collapsed structure search & rescue*, *water search & rescue,* etc. with a satisfactory level of services even in a resource-constrained environment. But still, there is much need for the improvements in its emergency operational mechanisms for providing enhanced quality of the pre-hospital healthcare services. The PES requires to improve its services for the inundated and road-inaccessible areas with a minimum response with the help of HES. The community safety & awareness wing of the PES has exerted its countless efforts for the reduction of emergency occurrences through community awareness but there is a dire need to do much for the safety and protection of the rescuers during operations.

The study has set many new guidelines for achieving all the aforesaid and other required improvements in the PES. These guidelines are a result of the comprehensive exploration of the PES operational strategies with a critical view but having a constructive thought. Many crucial solutions have been proposed for the betterment of the PES like inclusion and integration of IoT based apparatus in its ambulance fleet. Such IoT inclusion depends upon the proposed IoT based EMS Inclusive E-health Architecture and other essential features for having better interactive pre-hospital healthcare. The implementation of the proposed Unified Emergency Operational Model presents a core methodology for having a well-defined operational strategy leading towards a collaborative quality response. The integration of all the emergency-related software systems including the CMS is a key element for improving emergency response and care by the PES. The utilization of "smart gadgets" like sensor-equipped garments and shoes etc. are vital for achieving the safety and protection of the rescuers working for different types of operations. The study has also emphasized the crucial need and significant role of the technology-based decision support system in the PES. The utilization of machine learning techniques for analysis of the emergency data for

avoiding or at least minimizing the emergency occurrences has also been recommended by the study. Moreover, the extension of the PES through the inclusion of helicopter emergency service (HES) with its current setup has also been strongly suggested. The proposed HES is essential for the prompt shifting of highly critical victims and to respond the distant road-inaccessible victims especially in flooded areas.

In the future, the study may be further extended by deeply focusing and analyzing the implementation of all the proposed improvements, architecture, and model along with the consequent changes in the services offered by the PES. Moreover, the presented quality indicators and performance measures for the EMS may be further investigated for devising some standardized quality metrics for an appropriate quantification. Such metric based quantification of the quality indicators and performance will lead to towards the optimal standardized quality of all the emergency services in general and the PES in particular.

VIII. Disclosure Statement

No potential conflict of interest was reported by the authors.

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