AI Enabled Healthcare Services During Cross-Border Medical Emergency and Regular Patient Services (ESCORT project): System architecture and first results in Emergency Medicine Scenario

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ABSTRACT

The ESCORT project (*ESCORT Project*, 2024) aims at connecting up-to-date IoT Wearables, Artificial Intelligence and Machine Learning towards building a framework for a better cross border response for medical emergencies and public health protection and resilience. The ESCORT project brings together healthcare providers from five European member states and one associated member Israel specialized in emergency medicine and offering regular health and care services. New and better integrated digital services have been designed in consultation with stakeholders including patients, patient advocacy groups, health and care service professionals and providers. This paper presents a detailed outline of the project goals and ambitions supplemented by the requirements considered in the development of the overall platform architecture. Out of the 10 tools identified for integration in the project, two will be further elaborated with initial requirements that have been collected, and a first analysis of the solutions will be presented.

Keywords

Artificial Intelligence (AI), Machine learning (ML), European Health Emergency Preparedness and Response Authority (HERA), Internet of Things (IoT), Emergency Medicine, Chronic Diseases, Emerging Pathogens.

1 INTRODUCTION

The genesis of the ESCORT project could be traced to the needs of strengthening European health and care services resilience enabling patients to continue receiving uninterrupted treatment when needed while managing emerging situations as it has been identified by European Health Emergency Preparedness and Response Authority (HERA). HERA has outlined two modes of healthcare service operations: (i) the preparedness mode to anticipate and respond to threats before they turn into crises and (ii) the crisis mode empowering HERA to coordinate and act against health emergencies. The need for adopting HERA's holistic approach requires bringing together several health and care organization activities such as (i) intelligence gathering and threat assessment; (ii) promoting advanced research and development of medical countermeasures; and (iii) ensuring sustainable access to medical countermeasures through the coordination of purchase, manufacturing, and (iv) stockpiling activities (Delsaux, 2022). Addressing the growing need for the integration of an interdisciplinary approach for strengthening Europe's public health resilience, the ESCORT project was developed with the vision of enabling an integrated approach for public health that will establish synergies between the pre-clinical healthcare demand complemented with the in-hospital care while capitalizing on the seamless collaboration and data exchange among healthcare stakeholders and governmental authorities to identify as early as possible emerging pathogens.

A high-level overview of the ESCORT platform is presented in ***Figure 1***, that showcases the need for integrating innovative medical devices and the knowledge generated from the use of new hardware devices such as wearable devices, Internet of Things (IoT) that are specific to the scenarios of health and care demand being placed on the European health services.

To this extent, the project has broadly identified as the scope of innovation, not choosing by principal or precociously inside the ESCORT platform a specific tool or toolkit, but to rely on the input by the end users on which tool or toolkit is of major benefit to the patient services and the adoption of digital transformation strategies to the population they serve building in this was a bottom-up consensus among all the stakeholders (such as patients, decision-makers, policymakers, health and care providers and professionals). The integration of different tools and services will include the use of IoT devices, wearable toolkits, and the use of Artificial intelligence (AI) algorithms to enable the extraction of unique patterns and anomalies that needs further medical attention from an appropriate medical professional. Each of the health and care services developed in the project aims to address stakeholder needs across the three stages of patient lifecycle management within healthcare.

The main outcome of ESCORT's integrated tools and services aims to minimize the overhead within the healthcare sector and improve operational efficiency of health and care services to enable efficient management of organizational resources.

The rest of the paper is structured as follows. In Section 2, an overview of the requirements collection summarizing the needs of the stakeholder for addressing the three scenarios is presented. In Section 3, an overview of the ESCORT project architecture and innovation is presented, highlighting some of the design challenges that have been considered addressing the holistic needs in strengthening the European public health. Sections 4 and 5 present an overview of two of the 10 tools that have been identified for integration are summarized. In Section 6, a brief conclusion is presented as a summary of the early-stage results from the ESCORT project along with outlining the steps for future activities to be carried out in the project.

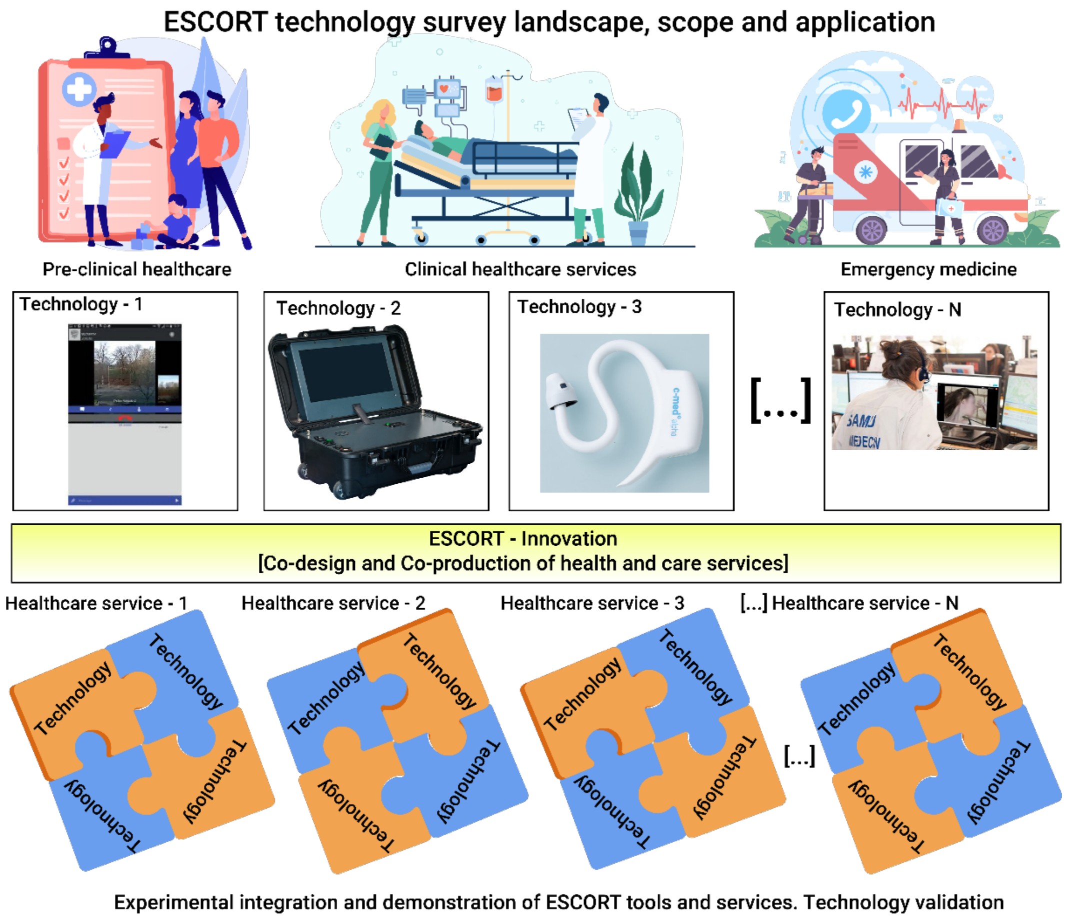

***Figure 1**. ESCORT project innovation*

2 ESCORT SYNERGIES FOR PUBLIC HEALTHCARE DEMAND

In this section, a summary of the research outcomes is presented which aims to address the synergies across the three different forms of healthcare demands, namely, pre-clinical care (or primary care, as is often referred in the UK), the in-hospital care and the emergency medical care. The ESCORT project has identified that primary care and in-hospital care will be categorized as routine care systems that are being carried out at a specific location. However, emergency care is not considered a part of the routine services and considered to be required at any time without a specific reference to a location. Following extensive consultation with the stakeholders, the collected user requirements have been translated into functional and non-functional requirements. The methodology for our approach was developed to ensure a comprehensive and structured approach to gathering, analyzing, and refining user requirements for the ESCORT platform. The process was centered around three key scenarios, each representing different healthcare challenges. The methodology is broken down into several steps: scenarios, stakeholder identification, participant involvement, limitations and challenges, and user requirements extraction. These elements were supported by focus groups, interviews, and system analysis. More specifically, the development of user requirements for the ESCORT platform was driven by three carefully constructed scenarios. These scenarios represent diverse healthcare challenges across emergency response, chronic care management, and pandemic preparedness. Each scenario was designed to mirror real-world situations, ensuring that the requirements reflect the needs of various stakeholders and capture the complexity of modern healthcare systems

- **Scenario 1: Health and Care Resilience During Hospital Surges Due to Natural Disasters** This scenario simulates a sudden natural disaster that results in an influx of patients overwhelming local hospitals. The scenario includes the initial response by first responders, patient triage, and the coordination of emergency departments to manage the surge in patient numbers. It emphasizes the need for seamless communication between paramedics and hospitals, real-time monitoring of patient vitals, and efficient allocation of resources (such as ambulances and hospital beds). This scenario serves as a critical testbed for user requirements related to emergency response tools, resource management, and patient data flow between first responders and hospital systems. The stakeholders in this scenario encompass the entire emergency response and hospital care continuum, ensuring that all stages of the healthcare process during a disaster are accounted for. Key stakeholders include:

  - **Casualties**: As the primary recipients of care, the needs of injured patients were prioritized, particularly regarding rapid identification, continuous monitoring, and timely access to medical services. Ensuring patients receive accurate and efficient care, even under hospital surge conditions, is critical.
  - **First Responders (Doctors, Paramedics, Emergency Technicians, and ambulance nurses)**: These stakeholders play a vital role in triaging patients at the disaster site and stabilizing them during transport. Their needs include having reliable tools for patient identification, real-time vital sign monitoring, and enhanced communication with hospital emergency departments to ensure efficient patient handover.
  - **Hospital Managers and Administrators**: These stakeholders are responsible for managing hospital capacity, resources, and patient flow. Their concerns revolve around optimizing resource allocation, ensuring adequate supplies, and maintaining staff readiness to handle surges of patients.
  - **Hospital staff of the Emergency Department (Doctors, Nurses, and allied healthcare professionals)**: Hospital staff receiving patients from emergency responders require timely access to accurate patient information. Their focus is on ensuring the continuity of care from the field to the hospital and making critical decisions as to patient destination and management based on real-time patient data.

- **Scenario 2: Improved Primary Care Services for Managing Chronic Conditions** This scenario focuses on the long-term care of patients with chronic conditions such as diabetes, hypertension, and chronic obstructive pulmonary disease (COPD). The scenario spans one year and emphasizes the role of continuous, remote monitoring of patients in their homes using wearable devices and AI-based tools. The goal is to reduce hospital visits, provide timely interventions, and enhance patient-doctor communication through telemedicine. It also explores the integration of patient feedback via digital tools and the use of AI to predict potential health deteriorations. This scenario highlights user requirements around remote monitoring, patient engagement, and integration with electronic health records (EHRs). The management of chronic conditions involves a longer-term approach and a wider set of healthcare providers, as well as patient engagement. Key stakeholders in this scenario include:
  - **Patients**: Central to this scenario are individuals living with chronic conditions such as diabetes, hypertension, and heart disease. Their primary concerns include the ease of use and reliability of remote monitoring devices, the security of their personal health data, and regular communication with their healthcare providers to ensure timely interventions.
  - **General Practitioners and Primary Care Physicians**: These healthcare providers are responsible for ongoing patient management, relying on accurate, real-time data from monitoring devices. Their focus is on ensuring that remote data integrates seamlessly into electronic health records (EHRs) and that they can make informed decisions based on predictive analytics.
  - **Nurses and Home Healthcare Workers**: These stakeholders are involved in hands-on patient care and monitoring, particularly for elderly or less mobile patients. Their requirements include access to user-friendly tools for data collection, communication with patients, and ensuring that any alerts or health warnings are acted upon promptly.
  - **Caregivers**: Family members or paid caregivers also play an important role in this scenario, particularly in assisting patients with the technology and ensuring their health data is continuously monitored. They need systems that are easy to understand and operate.
- **Scenario 3: Pandemic Preparedness and Cross-Border Health Emergencies** This scenario reflects the global challenge of responding to pandemics, with a focus on cross-border health crises. It simulates the emergence of a highly contagious virus that rapidly spreads through a densely populated urban area, overwhelming healthcare systems and triggering the need for coordinated international responses. The scenario explores the deployment of AI for real-time monitoring of epidemiological data, predictive algorithms for outbreak management, and tools for communicating public health advisories. User requirements in this scenario center on large-scale data integration, predictive analytics, secure communication channels, and the ability to scale healthcare operations across borders. In the case of a pandemic, the range of stakeholders expands considerably, incorporating local, national, and international

actors to ensure coordinated responses to large-scale health crises. Key stakeholders in this scenario include:

- **Citizens and Patients**: General citizens, both affected and unaffected by the pandemic, are stakeholders in ensuring public compliance with health guidelines, such as quarantine and social distancing measures. Infected patients require efficient access to healthcare services, while unaffected citizens rely on accurate information to protect themselves.
- **Public Health Officials and Authorities**: These stakeholders, at the local, national, and international levels, are responsible for managing and coordinating the response to a pandemic. Their concerns include the timely collection and dissemination of epidemiological data, the implementation of containment measures, and communication with healthcare providers and the public. Tools that provide real-time data on the spread of infections and resource allocation are essential.
- **Emergency Response Teams**: These teams are tasked with transporting patients, supporting healthcare facilities, and enforcing public health directives such as quarantine orders. Their focus is on efficient patient transfer, minimizing exposure risks, and maintaining clear communication channels with hospitals and public health authorities.
- **Hospital Staff (Doctors, Nurses, Respiratory Therapists)**: Hospital personnel are on the front lines of treating infected patients. Their primary concerns are managing patient surges, ensuring the availability of personal protective equipment (PPE), and maintaining physical and emotional resilience while providing care. Real-time health monitoring and resource management tools are crucial in this scenario.
- **International Health Organizations (e.g., WHO, ECDC)**: These organizations play a critical role in overseeing the global response to pandemics across cross-borders of states, thus enabling coordination efforts across countries, and providing up-to-date information to national health authorities. They require access to large-scale epidemiological data to track and predict the spread of the disease.
- **Media**: The role of the media in pandemic scenarios is crucial for disseminating accurate information to the public. Their primary concern is ensuring transparency, avoiding the spread of misinformation, and maintaining public trust in health authorities and institutions.
- **Hospital Administrators**: Individuals responsible for healthcare facility management, including resource allocation, staffing, and supply chain management, provided critical insights into the operational side of healthcare delivery. Their input emphasized the importance of resource management tools, real-time data visibility, and coordination with first responders.

A key component of developing robust and relevant user requirements for the development of the ESCORT platform was the identification of stakeholders across the various scenarios. Stakeholder involvement ensures that the system addresses the specific needs, concerns, and operational realities of those who will interact with the platform. For each scenario, a broad range of stakeholders were identified to capture the diverse perspectives of individuals and groups involved in healthcare delivery, emergency response, and public health management. Each group of stakeholders brings its own set of priorities and challenges, which must be addressed to ensure that the ESCORT platform meets the diverse needs of its users. By identifying and engaging these stakeholders, the project can ensure that the requirements capture real-world complexities, improve the usability of the platform, and enhance its effectiveness in addressing healthcare and emergency challenges.

Finally, it is important to notice that the effectiveness of the ESCORT platform depends heavily on gathering insights from a wide range of participants who are directly involved in healthcare delivery, emergency response, and public health management. To ensure comprehensive and representative user requirements, the data collection methods combined both qualitative and quantitative approaches, leveraging the expertise and experiences of diverse stakeholders.

3 ESCORT PROJECT ARCHITECTURE AND INNOVATION

In this Section, an overview of the ESCORT platform architecture is presented (refer to ***Figure 2***) along with the rationale for the selection of the data sources, the technology developed for the ingestion of the heterogeneous data sources and the processing of information aggregated from the devices. The architecture design has been presented as a result of the requirements collection and aggregation activity that has been carried out in close consultation with the stakeholders. The methodology of collecting requirements included the organization of focus group discussion across the clinical representatives from Belgium, Ireland, Italy, Greece, Sweden and Israel. During the focus group discussions, a case study was presented outlining the available healthcare resources, the patient profiles, and a scenario in which the cross-border integrated healthcare services would enhance the quality of patient care. Following the presentation of the case-study, all the representatives were distributed questionnaires to rank the relevant requirements. From the aggregation of such a large quantify of requirements, the ones which are considered to be included in the ESCORT architecture is summarized in Section 4 and 5.

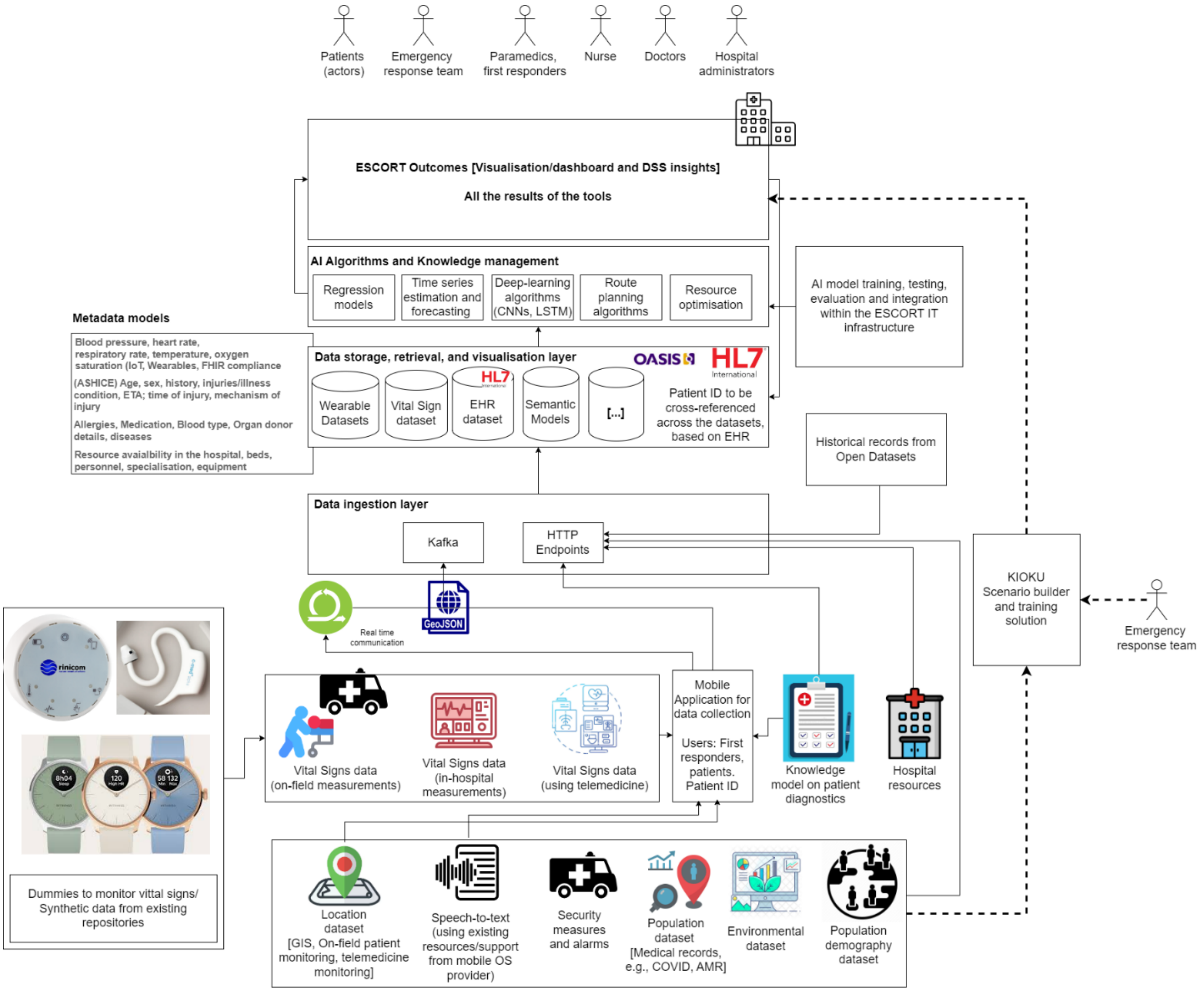

Figure 2*. *ESCORT overall project architecture and proposed innovation

Following the detailed analysis of the aggregated requirements from the stakeholder list outlined above, the conceptual architecture of the ESCORT platform has evolved. The architecture identifies initially the different forms of data sources that are required to be integrated into the platform. These data sources identified for the needs of the urgent care domain of the project represent a range of information sources that are related to patients' vital sign monitoring on-field, where the paramedics are trained to treat the patients and transport the patients to the emergency department of the hospitals. Additionally, for the healthcare demand forecast and prediction, relevant datasets on the population density, demographic and environmental datasets have also been identified to be of use and inform decision making. After the identification of the different datasets, architecture also outlines the use of different IoT and wearable devices that are currently available in the market to be integrated within the platform. Among the list of the hardware devices, PrimtIoT® and in-ear wearable sensor for monitoring vital signs have been identified to be relevant to be integrated within the platform. Additionally, as a CE marked (*CE Marking*) product, the consortium has also identified the use of Withings® (*WITHINGS Watch*) wearable devices for the integration of patient data. As a next layer of support, the integration of the real-time, temporal streams is expected to be achieved via two technological pathways, namely (i) Kafka (*Kafka*) or through HTTP (Lafon, 2014) endpoints (Hawke, 2025) (also referred to as RestAPI (Hawke, 2025) endpoints).

The ingested data streams from the devices for vital sign monitoring and the static integration of batch data will be interfaced with the data lake (Azzabi et al., 2024) layer that offers support for the modelling and storage of large volumes of data sources that are being ingested, and which capitalizes in the Interoperable Data Lake (IDL) and UNIFY-DATA platform. The data persisted in the data lake will be made available for training in the diverse

AI algorithms. The specification of the primary metadata models for the standardized annotation of ingested data in the data lake and the interoperable access to those is presented in ***Figure 2***. Additionally, a high-level specification of the different forms of AI development has been highlighted which could include (not limited to) the use of algorithms for regression models, time series forecasting, deep-learning algorithms (CNNs, RNN, LSTM), route planning resources and resource optimization for the hospital management. In the overall design of the architecture, the relevant stakeholders to whom the platform will be delivered have also been identified. This includes the patients (who will be actors taking part in the pilot and demonstration activities), emergency response teams responsible for emergency care resources, paramedics, nurses, doctors in emergency care units and other physicians. The last category of the stakeholders considered are hospital administrators.

4 URGENT AND EMERGENCY RESOURCE MANAGEMENT TOOLKIT

This toolkit has been identified to improve the capacity of decision-makers and policymakers to effectively manage urgent and emergency medical resources in times of crisis. The information made available from the toolkit ensures readiness for unexpected hospital surges by enabling careful tracking and management of personnel, resources, and logistics. The goal of the toolkit is to standardize and optimize emergency medical responses and the overall requirements are presented in ***Table 1***.

Table 1. The system requirements for urgent and emergency resource management toolkit

Identifier	Technical requirements	MoSCoW	User requirements
R1.1	The system must simulate various emergency scenarios for training purposes.	**MUST**	The system should provide real-time feedback during training scenarios.
R1.2	The toolkit must include the ability to demonstrate wearables, sensors and other technologies used in emergencies to support practicing of resource allocation.	**SHOULD**	Users should be able to practice resource allocation during simulations using the demonstrated technologies.
R4.3	The system must provide a clear, intuitive interface for non-technical users to interact with during the training.	**MUST**	Users must receive feedback on their performance during and after the training scenarios.
R4.4	The toolkit should allow updates to reflect new protocols or emerging technologies in emergency response.	**COULD**	Users should be able to customize training scenarios based on different types of emergencies (e.g., earthquakes, floods).
R1.5	The system must not rely on real-time data integration but should use predefined scenarios.	**MUST**	Users should have access to predefined scenarios, without needing real-time data for training purposes.
R1.6	The system should be scalable, allowing for large group training sessions, but will not integrate with real-time data.	**MUST**	The toolkit should allow for EMT coordinators to practice with different scenarios

The toolkit includes resource optimization features (integration with optimization engines like OptaPlanner (De Smet, 2006), Drools, OR-Tools, etc.), which optimize patient admission schedules, hospital bed planning and ambulance routing to reduce response times and maximize resource utilization. Also, automated scheduling and routing further enhance the efficiency of the hospital workflow and decrease waiting times. Another capability of the toolkit includes strategic planning and management that are supported through scenario-based planning tools that improve preparedness, and reaction plans by enabling dynamic simulations and analysis for a range of disaster scenarios. The project also considers the need for emergency medical services that requires cross-boundary resource coordination with the involvement of many different departments and geographical areas while considering the larger health and care requirements of the impacted populations. Infrastructure and technology necessities of the toolkit include a network server configuration and a high-performance computer system to handle large amounts of data from different hospital departments from the hardware aspect.

Following an analysis of the different data models that have been presented in the literature two of the most suitable data models have been identified that would correspond to the needs of ESCORT for the implementation of resource optimisation. These two solutions include (I) Danphe (*Hospital Management EMR*) (refer to ***Figure 3***) and (ii) Hospital Management System (*Hospital Managment Systemz*) (refer to ***Figure 4***).

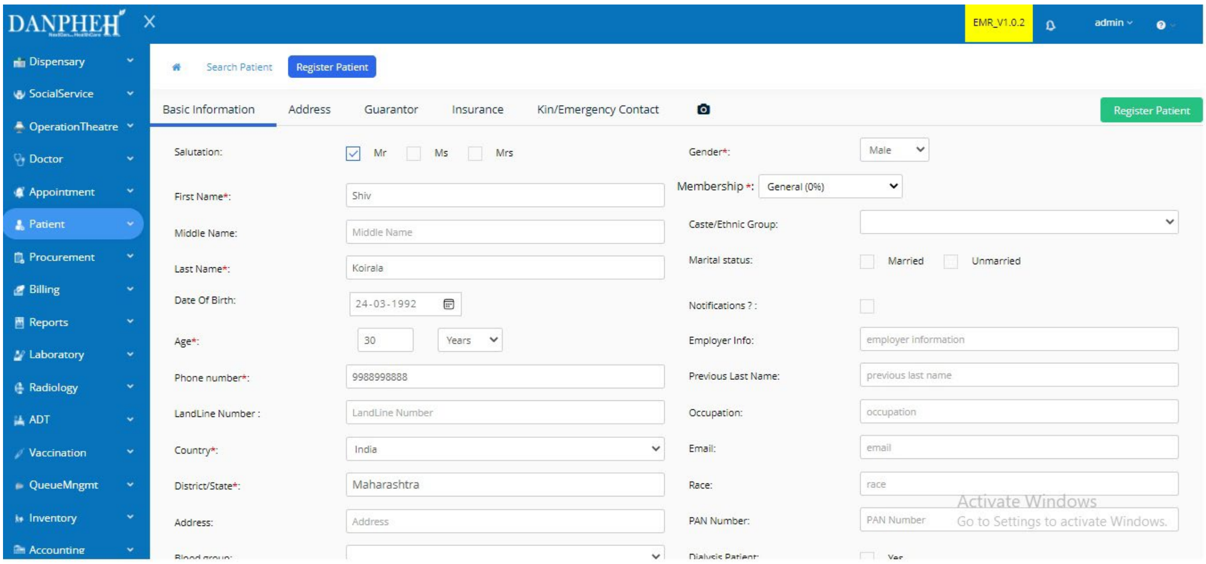

***Figure 3**. Digital healthcare hospital management system*

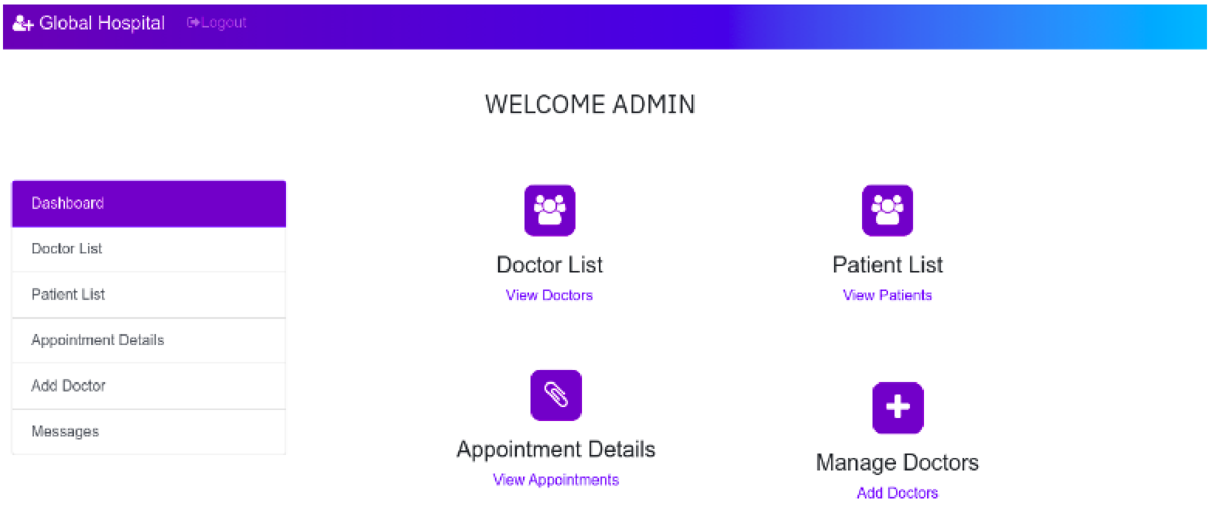

***Figure 4**. Administrative dashboard*

While the use of a health management system offers the ability to generate data about healthcare, there is also a critical need for the development of time-series forecasting model for estimating and forecasting the patient flow through the hospital systems. It is noted in the literature that, demand for health care services has become unsustainable (Gopakumar et al., 2016). This is largely due to increase in population and life expectancy, escalating costs, increased patient expectations, and workforce issues (Mackay & Lee, 2005). Despite increased demands, the number of inpatient beds in hospitals has come down by 2% since the last decade. Efficient bed management is key to meeting this rising demand and reducing health care costs. Daily discharge rates can be a potential real-time indicator of operational efficiency. From a ward-level perspective, a good estimate of next-day discharges will enable hospital staff to foresee potential problems such as changes in the number of available beds and changes in the number of required staff. Efficient forecasting reduces bed crisis and improves resource allocation. This foresight can help accelerate discharge preparation, which has huge cost on clinical staff and educating patients and family, requiring post discharge planning. However, studying patient flow from general wards offers several challenges. Ward-level discharges incorporate far greater hospital dynamics that are often nonlinear (Harper & Shahani, 2002). Accessing real-time clinical information in hospital ward can be difficult because of administrative and procedural barriers, such data may not be available for predictive applications. Because the diagnosis coding is performed after discharge, there is little information about medical condition or variation in care quality in real time. In addition, factors other than patient condition play a role in discharge decisions. The current practice of bed allocation in general wards of most hospitals involves a hospital staff/team, who use past information and experience, to schedule and assign beds (Daniels et al., 2005). Modern machine learning techniques can be used to aid such decisions and help understand the underlying process.

Among the algorithms that have been presented in the literature, Autoregressive Integrated Moving Average (ARIMA) has been presented as forecasting tool (Zhou et al., 2018). Further modelling of patient flow data corresponds to the consideration of characteristics of seasonal fluctuation of new admission inpatients, the seasonal ARIMA (SARIMA) model was reported in the literature. The SARIMA $(p, d, q)(P, D, Q)s$ model is developed from the ARIMA model (Song et al., 2016). There are seven main parameters in the SARIMA model: the order of autoregressive (p) and seasonal autoregressive (P), the order of regular difference (d) and seasonal difference (D), and the order of moving average (q) and seasonal moving average (Q), and finally, the length of seasonal period(s). Stationarity is a necessary condition in building a SARIMA model and differencing is often used to stabilize the time series data. The main methods to check the stationarity of time series include the sequence trend diagram, autocorrelation function (ACF), partial autocorrelation function (PACF), augmented dickey-fuller (ADF) unit root test, Phillips and Perron (PP) test, nonparametric test and so on. In this study, the ACF, PACF plots, and ADF test were used to identify the stationarity of time series and the possible order of autoregression and moving average. The most suitable model was selected according to the Akaike Information Criterion (AIC), schwarz Bayesian criterion (SBC) and the Ljung-Box Q-test.

The operational workflow of the toolkit includes data collection and processing that gathers real-time data concerning patient hospital admissions, bed availability in the health units, and ambulance logistics. These data are processed by the optimization engine, to generate optimized scheduling and routing solutions. Dynamic optimization continuously updates and improves planning based on real-time changes in hospital resource availability.

One of the toolkit's advantages is that it ensures efficient allocation of hospital resources, reducing bottlenecks and enhancing overall patient care. It also supports decision-making with real-time analytics and historical data insights, to create an adaptable healthcare environment. Additionally, it helps in reducing costs by improving resource utilization and operational efficiencies. Future enhancements include investigating the use of Generative AI to augment datasets and generating realistic planning scenarios, which will improve the constraint-solving capabilities of the optimization engines and allow for more complex planning solutions.

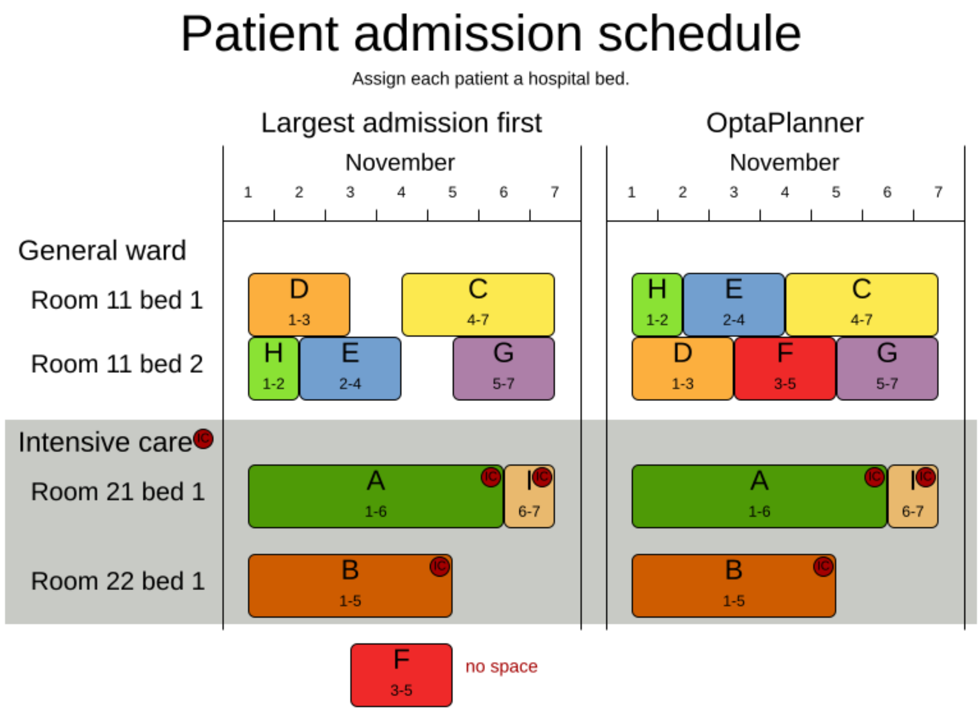

***Figure 5*. OptaPlanner examples presented to solve constraint optimisation problem (Hospital bed planning (PAS - Patient Admission Scheduling))**

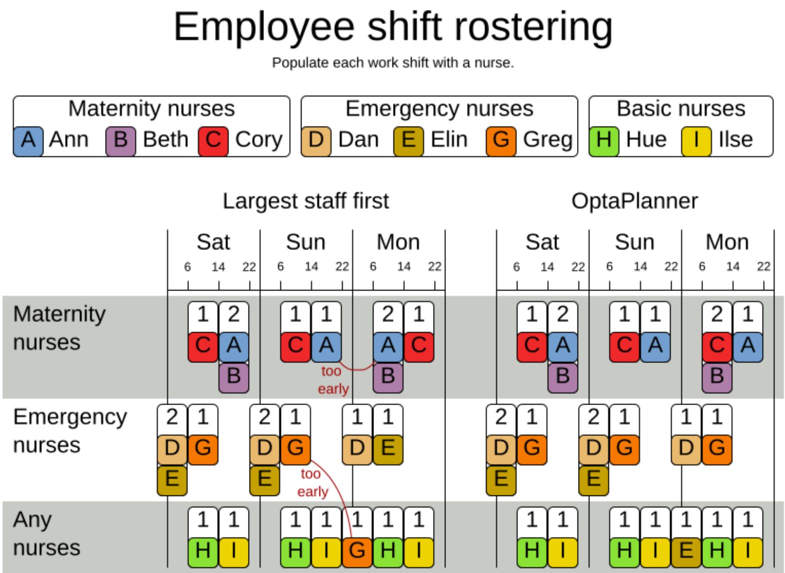

***Figure 6**. Employee resource management (Nurse rostering (INRC 2010))*

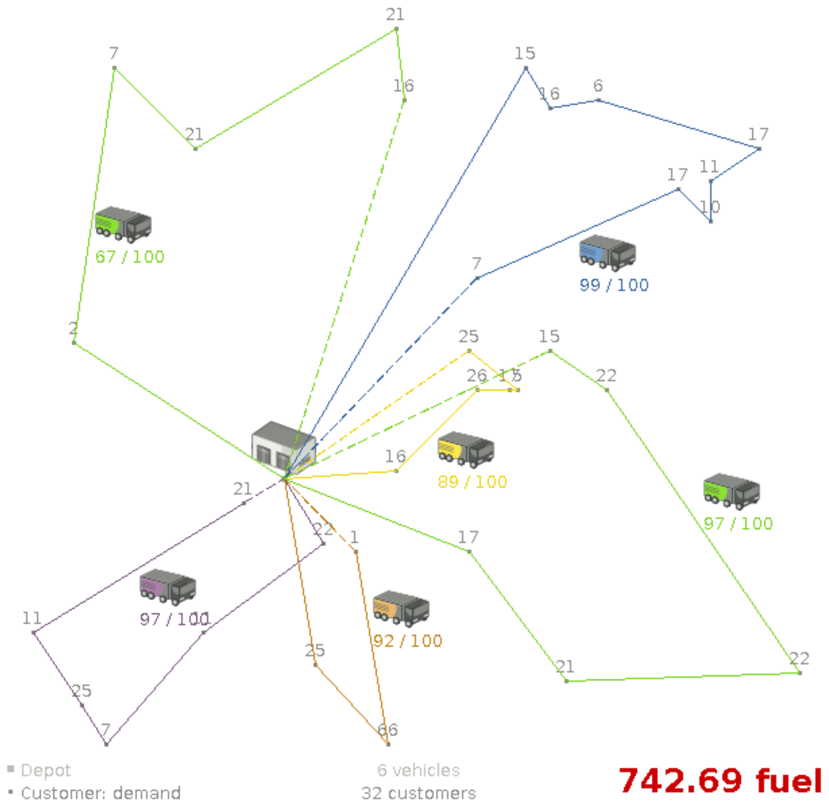

***Figure 7**. Vehicle route planning (Vehicle routing)*

As a part of the overall investigation, the ESCORT consortium also conducted a detailed study on literature related to optimization and problem solving. To this end, the one of the tools that will be considered for further development relates to Constraint Problem solver (as referenced in D2.3, Annex). One of the solution toolkits that delivers upon the optimization relates to OptaPlanner (Smet & Wauters, 2020), which implements optimization algorithms related to constrained resources. The triple synergy offered by OptaPlanner relates to (i) achieving the optimization goal; (ii) with limited resources (such as personnel, equipment and others) and (iii) under constraints (measured in time and others). The performance of the toolkit will be evaluated in consultation with the clinical experts, which will be defined as NP-complete/NP-hard problems. A detailed description of the implementation of mathematical techniques detailing the OptaPlanner internal operation is presented in Smet, G. D. and T. Wauters (2020). A list of examples supported by the OptaPlanner is presented in ***Figure 6*** to ***Figure 8***. The ongoing implementation of the toolkit that brings together several research outcomes will continually engage with the clinical community to process the needs of pre-hospital (emergency care) and intra-hospital resource management. The toolkit includes resource optimization features (integration with optimization engines like OptaPlanner[1], OR-Tools, etc.), which optimizes patient admission schedules, hospital bed planning and ambulance routing to reduce response times and maximize resource utilization. Also, automated scheduling and routing further enhance the efficiency of the hospital workflow and decrease waiting times. Another capability of the toolkit includes strategic planning and management that are supported through scenario-based planning tools that improve preparedness, and reaction plans by enabling dynamic simulations and analysis for a range of disaster scenarios. Also, cross-boundary resource coordination manages resources across departments and geographical areas while considering the larger health and care requirements of the impacted populations.

The urgent and emergency resource management toolkit will build on the observations from literature that will focus on the implementation of the time-series forecasting algorithms, ARIMA. While in the literature several variations of the ARIMA models have been presented, it is noted that in the literature the discharge of patient statistics does not include the consideration on the telemedicine requirements for patient monitoring. Additionally, the urgent need for patient beds has also not been considered to accommodate acute and severe patients who are being hospitalized. In the context of ESCORT, these two parameters will be further considered towards developing a model for the release of patients from the hospital. From the literature review it is also evident that there is not a single unified dataset which can be used as a benchmark for the performance evaluation. To this end, the ESCORT project will lead the effort on creating patient profile with information encoded in the hospital management system and using ARIMA model for the patient outflow estimation.

5 AI – DRIVEN INTEGRATED TREATMENT SOLUTION

The goal of AI driven integrated treatment solution to enable remote monitoring of patients using advanced biosensors. In the context of the project design, two specific devices have been selected namely PrimtIoT® and in-ear wearable device. The requirements gathered from the relevant stakeholder are presented in Table 2.

Table 2. The system requirements for AI driven integrated treatment solution toolkit

Identifier	Technical requirements	MoSCoW	User requirements
R2.1/R3.1	The system must assign a unique, unchangeable ID to each patient.	**MUST**	Patients need to be identified by a unique ID that doesn't change from primary triage to the delivery to the hospital emergency department.
R2.2/R3.2	The system must enable continuous monitoring of the patient's vitals and display the data in both the front-end (FE) and back-end (BE) interfaces using secure data transmission protocols.	**MUST**	The patient's vitals (i.e. Heart Rate – HR, Respiratory Rate – RR, Temperature – T, Oxygen Saturation – SpO_2, Blood Pressure - BP) need to be continuously monitored and visible (both in the FE and in the BE).
R2.3/R3.3	The system must continuously update the patient's triage status based on the selected triage algorithm.	**MUST**	The patient's status, as current triage result according to a preselected triage algorithm, needs to be continuously evaluated and visible (color tagging – both in the FE and in the BE).
R2.4/R3.4	The system must allow the configuration of different triage algorithms.	**MUST**	The triage algorithm to be used to assess the patient's status needs to be configurable.
R2.5/R3.5	The system must record the location of the incident / patients.	**MUST**	The patient's position needs to be always known.
R2.6/R3.6	The system must support real-time, encrypted communication protocols to facilitate secure messaging and data sharing among paramedics, hospital staff, and first responder coordinators.	**MUST**	Improved communication between paramedics and hospital emergency department personnel and first responder coordinators

[1] https://www.optaplanner.org/

R2.7/R3.7	The system must implement secure data transmission methods to ensure the confidentiality and integrity of patient data during transfer between all parties involved.	**MUST**	Transfer of patient data between parties must be secure
R2.8/R3.8	The system must be designed for ease of use, with minimal training required for effective operation by end users.	**MUST**	Tools must be easy to use and easy to learn.
R2.9/R3.9	The system must have diverse interactive data visualizations and customized intuitive dashboards for decision support during management of Mass Casualty/ Incident (MCI)/response.	**MUST**	The tool must have data visualizations and dashboards for decision support during the management of MCI.
R2.10/R3.10	The system must have diverse interactive data visualizations and customized intuitive dashboards used for generating after-action reports and KPIs measurements.	**MUST**	The tool must have data visualizations and dashboards for post-MCI analysis.
R2.11/R3.11	The tool should detect and offer warnings/alerts for patient/victims' health deterioration exceeding the upper/lower thresholds of the normal health condition value ranges.	**SHOULD**	The tool should provide warnings/alerts in case one or a group of vitals violate the range of measurement gathered from the medical devices.

PRIME-IoT facilitates seamless communication and data aggregation from multiple wearable IoT devices, enabling efficient management of connected devices in dynamic environments. PRIME IoT's wireless suite of sensors include an SPO_2 pulse oximeter, wireless stethoscope, tympanic thermometer, wireless blood pressure monitor and 12 lead ECG – all contained in a foam-lined, lightweight, protective case. This state-of-the-art ensemble allows a clinician to access a complete range of vital sign data. The PRIME IoT hub, included with the kit, collects the data captured by the suite of sensors. It is a standalone module that can then transmit this data to any compatible device. With a long battery life and convenient design, it is the ideal solution for remote vital sign monitoring. The transmitted data is received by the PRIME app which is easily installed on any compatible iOS, Android or Windows device. The data can then be visualized, monitored and stored on the user's own preferred device. ***Figure 9*** illustrates PRIME-IoT hub and set of wearable sensors (Marshall et al., 2007), (Zvikhachevskaya et al., 2009).

Figure 8 - PRIME-IoT Hub and Wearable Sensors

In-ear sensor: The c-med° alpha in-ear sensor is a state-of-the-art wearable biometric monitoring device (medical CE marked, Class IIa) that delivers continuous, real-time monitoring of critical vital parameters such as pulse rate, oxygen saturation, and body temperature. With advanced algorithms developed by cosinuss°, the device ensures an initial evaluation of recorded values, complete with a quality indicator for each data point. This innovative sensor merges medical-grade precision with superior ergonomics and comfort (Langenhorst et al., 2024), (Bubb et al., 2023). Weighing just 6.5 grams and measuring 5.5 x 6 cm, the compact device leverages patented earconnect™ technology to redefine vital sign monitoring. ***Figure 10*** illustrates the sensor, which was successfully integrated with VisualFusion+ and demonstrated to consortium partners and stakeholders for an initial validation.

Figure 9 - cosinuss° in-ear sensor

Furthermore, Netcompany-Intrasoft's innovative Interoperable Data Lake provides with the crucial data management, data interoperability and data-driven Decision Support with intuitive information visualizations to lead to the envisioned next generation digitally transformed emergency management operations, by: i) seamlessly integrating existing in situ or required open data, ii) timely aggregating, preprocessing, managing, storing and providing access to live triage and other generated data from a variety of components to be fed to other data and AI-driven components for decision support as well as managing the results of the latter and follow-up respective actions, iii) providing Interactive Visualization Dashboards with customized aggregated information visualizations of different types per need and temporal instance, iv) providing a data-driven Decision Support System, which offers filtered and processed data visualizations and enables real-time alerting to Command and Control Systems in case of abnormal monitored vitals trends and potential victim's health status deterioration, v) ensuring data interoperability in terms of unified, standards-based data descriptions and timely interoperable data access, vi) providing support for both during the management of an emergency and in post-emergency incident reporting and KPIs generation, as illustrated in ***Figure 10***.

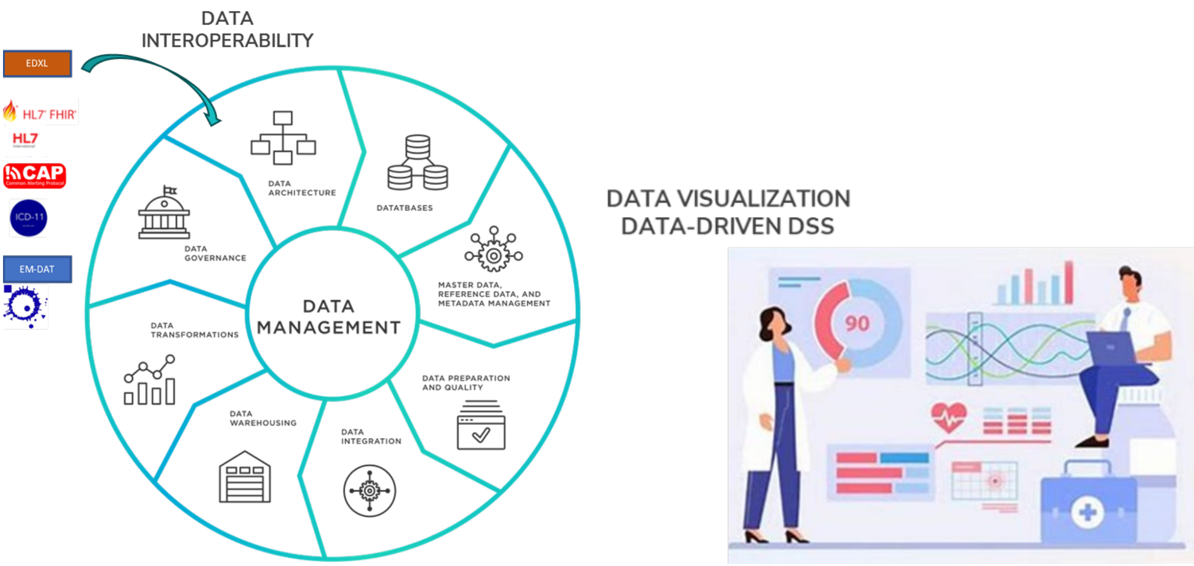

Figure 10. Netcompany-Intrasoft Interoperable Data Lake (instance of UNIFY-DATA)

6 CONCLUSION AND FUTURE WORK

This paper presented the design and initial development of the ESCORT platform, which addresses the critical challenges in urgent and emergency care management. By integrating advanced digital technologies such as IoT, wearable devices, AI algorithms, and data lakes, the platform is designed to enhance healthcare services across emergencies, chronic, and pandemic preparedness scenarios. Architecture prioritizes stakeholder involvement and ensures the incorporation of user-centric requirements for improved operational efficiency and decision support in healthcare systems.

The research highlights the applicability of tools such as ARIMA models for patient flow forecasting, along with optimization engines for resource allocation and management in hospitals. However, the study also underscores the limitations in existing datasets and methodologies, emphasizing the need for more comprehensive and standardized data sources to evaluate and refine these technologies. Furthermore, the inclusion of telemedicine and other digital health solutions highlights a forward-looking approach to increasing hospital capacity and managing patient flow effectively.

Moving forward, the ESCORT project will focus on further refining the tools and systems discussed, including the integration of Generative AI to simulate planning scenarios and enhance constraint-solving capabilities. These advancements aim to create a robust, adaptive, and scalable healthcare solution for cross-border health emergencies and everyday public health needs. This work represents an essential step toward the realization of a unified, AI-driven healthcare platform capable of addressing contemporary challenges in healthcare and emergency management. The findings presented in this paper will serve as a foundation for ongoing research and implementation efforts in the ESCORT project.

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