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SPECIAL FOCUS PAPER

Cost, Coordination, and Clinical Readiness: The Economic Case for Digital Triage, Telemedicine, and Interoperable Emergency Response Systems

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ABSTRACT

Beginning with the idea that digital triage tools, telemedicine support, and interconnected systems for emergency response are important for both economic and practical purposes for healthcare providers experiencing mass casualty events, surge capacity demands, and other emergencies that place substantial pressure on acute care services, this paper will explore what they provide in terms of efficiency for coordinating responses during high-stress situations. In particular, it discusses how a lack of integration among emergency response teams (and their associated systems) leads to inefficiency, including treatment delay and the poor use of available resources. Building upon research from emergency medicine, digital health, Health Information Systems (HIS), and disaster management, this paper provides an organizational framework for understanding how various digitally-enabled systems can be used to enhance cost-efficient decisions and improve resilience within healthcare systems. Finally, this paper views digital integration as both a technological tool and an economic mechanism for providing sustainable emergency care. It provides strategic suggestions for healthcare organizations and policymakers regarding the design of electronic triage and unified response systems.

KEYWORDS

digital triage, telemedicine, mass-casualty incidents, interoperability, emergency response systems, health economics

1 INTRODUCTION

1.1 Background: Mass-casualty healthcare settings as economic and clinical stress tests

Healthcare organizations face a unique type of pressure when an unexpected increase in the number of people requiring urgent treatment quickly surpasses the amount of available clinical, organizational, and logistical capacity. The types of

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situations where such an event could occur include a pandemic, natural disaster, terrorist attack, or major accident [1], [2], [3]. These events require decision-making on behalf of hospital emergency departments, EMS, and regional response agencies with no time to gather data, all while operating under high levels of uncertainty and time constraints [4].

Therefore, it is not just a clinical issue. As well as the need to identify, stabilize, and treat patients based on their level of urgency, there will also be a need to allocate available personnel, beds, transportation, medical equipment, and specialized skills [1], [3], [5], [6]. When roles are ambiguous and communications networks are fractured or information flow is slow, this will likely result in wasted use of too few available resources. Therefore, treatment delays, redundant process steps, and poor coordination in patient transfer can reduce the ability of the entire emergency response system [7], [8], [9].

1.2 The hidden economic burden of poor coordination

The economic burden of emergency healthcare is not limited to visible expenditure on treatment, personnel, infrastructure, or medical technology. In mass-casualty situations, a relevant share of system cost emerges from coordination failures that are less directly captured in conventional budgets. Delayed information, unclear patient routing, fragmented communication, and limited visibility of available capacity can reduce the efficiency with which scarce resources are used [7].

These inefficiencies are economically relevant because they affect both operational performance and clinical risk. When decision-makers lack reliable information about patient needs, resource availability, or system load, the response may become slower, less targeted, and more resource-intensive than necessary. Poor coordination can therefore amplify the pressure created by the incident itself. For this reason, coordination should be understood not only as an organizational requirement but also as an economic determinant of emergency response performance.

1.3 Digital triage, telemedicine, and interoperability as response mechanisms

Digital triage, telemedicine, and interoperability are examined in this paper as complementary mechanisms of digital emergency response. Digital triage relates primarily to structured prioritization and patient tracking, telemedicine extends clinical expertise across distance, and interoperability enables relevant information to move across organizational boundaries. Their economic relevance lies not in isolated technological functionality but in their combined ability to reduce uncertainty, support patient routing, and improve resource allocation under surge conditions.

1.4 Aim and contribution

This paper aims to develop an economics-based rationale for digital triage, telemedicine, and interoperable emergency response systems in large-scale casualty healthcare emergencies. The study examines these technologies not as isolated tools but as complementary mechanisms for improving cost efficiency, coordination, and clinical readiness under surge conditions.

The study pursues five research objectives:

Research Objective 1: To identify the economic and organizational pressures created by mass-casualty healthcare settings.
Research Objective 2: To examine digital triage as a mechanism for structured prioritization, patient tracking, and resource allocation.
Research Objective 3: To analyze telemedicine as a mechanism for distributed clinical expertise and remote decision support.
Research Objective 4: To assess interoperability as the backbone of cross-organizational information exchange and coordinated emergency response.
Research Objective 5: To synthesize the economic value and implementation requirements of digitally integrated emergency response systems.

The main research question is: How do digital triage, telemedicine, and interoperable emergency response systems support efficient collaboration and clinical preparedness in large-scale casualty healthcare emergencies?

2 MATERIALS AND METHODS

2.1 Review design

The author used a combination of a narrative review as well as a conceptual integration for this study. The author chose this methodology due to the interdisciplinary nature of the subject matter, which has relevance to various areas of scholarship such as emergency medicine, digital health, information systems, disaster management, and health economics. The author was interested in identifying potential contributions of digital triage, telemedicine, and interoperable emergency response systems to improving both cost-efficient coordination and clinical preparedness for mass casualty care through an integrated review of the literature. A narrative approach was considered appropriate because the available literature differs considerably in terms of disciplinary focus, methodological design, technological scope, and healthcare context.

2.2 Search strategy and sources

The academic literature concerning digital emergency response, digital triage, telemedicine, interoperability, and health systems resilience was assessed through a targeted review of sources that are both academically based and practical. A comprehensive electronic search strategy was employed to locate appropriate material. The searches were conducted in the following databases: PubMed, Scopus, Web of Science, and Google Scholar. This combination of database searching provides access to both clinically-based literature and inter-disciplinary literature from fields of health services research, information technology, and disaster management. Additionally, reference lists for identified papers were examined to determine whether additional relevant references existed. Relevant policy documentation and reports from international and national institutions (including the World Health Organization, public health authorities, and emergency management authorities) providing contextual or strategic relevance to the study's objectives were also considered.

Literature dating from 2000 to 2026 has been reviewed. Literature relating specifically to digital health, telemedicine, and interoperability has received particular focus since 2015 due to this period representing a time when significant advancements in digital infrastructure and emergency care systems have occurred. The search terms used have consisted of "mass casualty incident," "digital triage," "telemedicine," "emergency response," "interoperability," "hospital surge capacity," "disaster medicine," "health information systems," and "cost-effective." A total of 36 sources were retained for conceptual synthesis.

2.3 Inclusion and exclusion criteria

Sources were included if they were written in English and addressed at least one of the following areas: mass-casualty healthcare, emergency care, triage, telemedicine, health information systems (HIS), hospital surge capacity, or health economics. Priority was given to peer-reviewed articles, review articles, conceptual papers, and selected policy reports that connected clinical, organizational, technological, and economic aspects of emergency response. Sources were excluded if they focused only on technical software architecture, individual-patient triage without systemic relevance, or topics unrelated to emergency medicine, disaster management, mass-casualty response, or healthcare system resilience.

2.4 Data extraction and thematic synthesis

The selected sources were analyzed through structured thematic synthesis. Information was extracted on the relevant digital or organizational mechanism, the coordination problem addressed, the implied economic mechanism, and the contribution to clinical readiness. The findings were then grouped into three analytical mechanisms: cost, coordination, and clinical readiness. These categories formed the basis for the conceptual arguments presented in the results and discussion sections.

2.5 Limitations of the method

This review does not attempt to give a comprehensive overview of all studies available. A formal quality assessment did not take place. Therefore, the results can be interpreted conceptually. In addition to being interpretative, they cannot be generalized statistically as well. The main advantage of this methodology is that it integrates evidence from several different disciplines relevant to the delivery of digitally enabled emergency care.

3 RESULTS

The narrative synthesis was organized into a conceptual framework linking mass-casualty pressures with three digital response mechanisms: digital triage, telemedicine, and interoperability. Figure 1 summarizes how these mechanisms can reduce avoidable inefficiencies, improve coordination, and strengthen clinical readiness under surge conditions.

Figure 1 summarizes this relationship by showing how digital emergency response systems can transform fragmented emergency information into more coordinated, resource-conscious, and clinically prepared response processes.

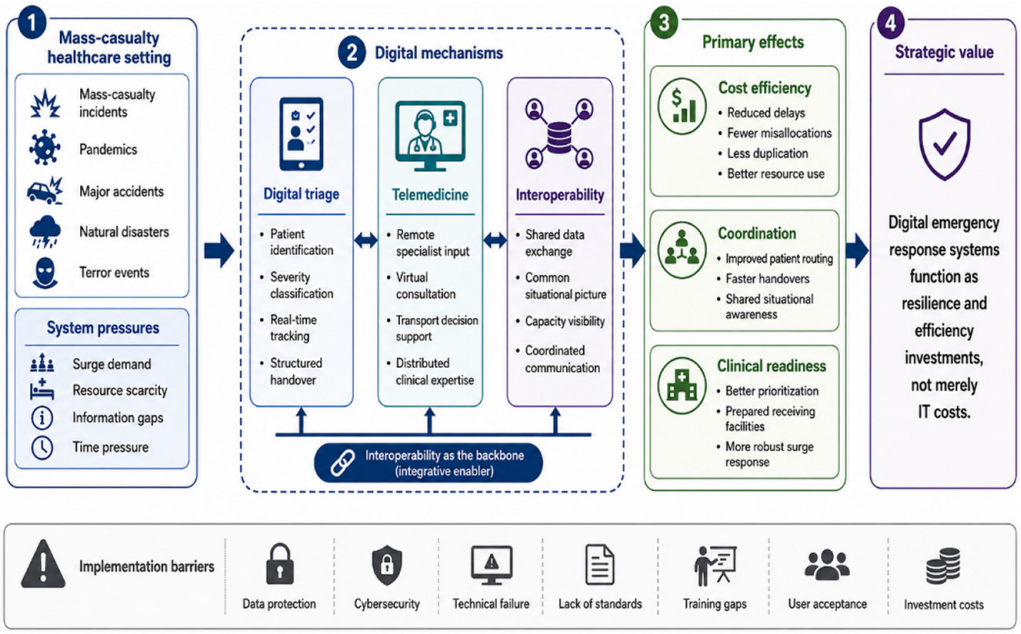


Fig. 1. Conceptual framework of the economic case for digital emergency response systems in mass-casualty healthcare settings

3.1 Cost pressures in mass-casualty healthcare settings

Mass casualty healthcare settings create financial burdens due to clinical overloads, operational fragmentation, and resource shortages [10], [11]. However, the cost issue is not solely related to the number of wounded or critically sick people. It also stems from a lack of congruence between demand, access to appropriate information, and availability of deployable resources [11], [12]. As such, when hospitals, EMS, and coordination centers function under circumstances of either inadequate or delayed information regarding available resources, those same resources may be utilized in a manner that is both clinically rational but economically inefficient [9], [12], [13].

Several cost drivers can be identified. First, overburdened emergency departments may become logistical bottlenecks if patients are transported to them without adequate information on the availability of hospital bed space, specialists, and anticipated surge volumes [7], [11], [13]. Second, inappropriate or inefficiently managed patient dispositions will often result in unnecessary transportation(s), repetitive evaluation processes, or delays in providing definitive treatment [9], [13], [14]. Third, redundant communication and documentation practices consume valuable staff time during periods of greatest constraint on clinical personnel [4], [8], [12]. Fourth, ambiguous command structures and fragmentary situational awareness can impede decision-making relative to where patients should receive their care and what resources should be activated [4], [12], [15].

In addition to direct expenditures, there are also opportunity costs associated with the economic impact of mass casualties. Clogged emergency departments, delayed surgical interventions, preventable utilization of Intensive Care Unit (ICU) beds, and exhausted staff can all limit the healthcare systems' ability to provide care to both individuals affected by incidents and those who were unaffected [11], [16]. Therefore, coordination has become an additional economic factor within mass casualty environments. Inefficient coordination can potentially transform a clinical surge into a system-wide resource management problem [9].

3.2 Digital triage as a mechanism for resource prioritization

The application of digital triage is rooted in the literature as a method that will make prioritization more structured, transparent, and operationally useable. Paper-based tagging systems, verbal hand-over systems, and local documentation routines have been traditional methods for triaging patients. These methods have some merit during typical or slightly increased volumes, but they fail during large surges of patients or involvement of multiple agencies. Patient information may get lost, delayed, or incorrectly communicated throughout the emergency care system [8], [17].

Digital triage systems have the capability to improve upon the shortcomings of the previous systems through linking initial assessment data with standardized documentation (e.g., patient data) and real-time information flows. The core components of a digital triage system include [8], [17], [18], [19]:

- digital identification of patients
- severity classification
- time-stamped triage decisions
- location tracking
- transmission of relevant clinical data

Some advanced configurations may connect triage data to hospital capacity data to allow clinicians to consider bed availability, specialty resources, and transportation options when making patient priority determinations [9], [13], [20].

Economically speaking, the value of digital triage is reduced misallocation. If the status of the patient, urgency category, and destination decision-making process are documented and shared early in the process, resources can be deployed more selectively. This would enable ambulances to deploy their resources according to expected need. Emergency room teams, trauma units, and operating theaters can prepare based on expected resource needs rather than approximations. This could potentially lead to reduced avoidable waiting times, unnecessary re-assessment decisions, and reduced inefficient routing decisions [9], [13], [17].

Conversely, digital triage should not be viewed as a replacement for clinical judgment. Digital triage's function is to support clinical judgment under pressure—not automate responsibility. The benefit of using digital tools depends on whether the tools are embedded into clinically accepted workflows used by trained personnel and connected downstream systems. Therefore, digital triage has the most potential when it converts individual triage decisions into usable system-level data [8].

3.3 Telemedicine as distributed clinical capacity

Telemedicine provides a second path through which clinical preparedness and resource utilization can be improved during mass casualty events. The primary advantage of telemedicine is providing specialist expertise to areas across geographic and organizational distance [21], [22]. When responding to significant emergencies, the distribution of relevant expertise may be uneven. Emergency departments in smaller hospitals, distant emergency sites, and field personnel or ambulances may find themselves confronted with an immediate need for expert opinion from specialists. At the same time, larger centers may have their own critical shortages due to overwhelming numbers of patients. Telemedicine can assist in bridging this gap by expanding the reach of clinical decision-making to places where such expertise is not physically or not in sufficient quantities located [23].

Examples of how telemedicine has been successfully applied include real-time support provided to EMS, provision of virtual consultations to specialist physicians for remote location emergency staff, and advance evaluation of patient needs and advice concerning transport destination prior to arrival [22], [24]. In certain instances, telemedicine can assist with determining if a patient requires transfer to a specialized center for care, stabilization locally, or transfer to an alternate facility. This is particularly important when large, central hospitals are experiencing surges in volume, and routing of patients to those hospitals could exacerbate crowding [23].

The financial benefits of telemedicine directly correlate with enhanced ability to manage patient flow. Remote consultation may prevent unnecessary secondary transports and usage of high-end specialty resources. Additionally, telemedicine will enable quicker decision-making regarding treatment options. Also, since the expertise is no longer tied to one physical location, specialty capacity can be utilized more effectively. Receiving hospitals can utilize telemedical data to prepare for anticipated patient severity, required resource utilization, and potential escalation needs [22], [25].

From a clinical perspective, telemedicine increases the preparedness of teams by enhancing the quality of decision-making made under uncertain conditions. Telemedicine enables inexperienced teams to make informed decisions, assists in making timely escalation decisions, and grants access to multidisciplinary expert opinions. While effective application of telemedicine depends upon reliable communication, clearly defined clinical protocols, and coordination within existing emergency response systems, telemedicine itself is not simply another communication medium. In mass casualty healthcare, telemedicine can be viewed as a type of distributed clinical capability [24], [26].

3.4 Interoperability as the backbone of coordinated emergency response

Interoperability is the essential element of integrating digital triage, telemedicine, managing hospital capacity, and operational command. Fragmentation has been identified as one of the key deficits of emergency response systems. Frequently, dispatch centers, ambulance services, hospitals, public health departments, and specialized teams utilize separate information systems, documentation standards, and communication practices. While such fragmentation may cause some inconvenience during day-to-day care in a mass casualty setting, such fragmentation can become an obstacle to taking collective actions [27].

There are a number of operational difficulties created through non-interoperable systems. The data collected concerning patients is duplicated but is not reliably transferred. Hospital capacity data may be accessible within individual hospitals; however, they are not readily visible to regional coordination processes. There may be no real-time data available to EMS regarding emergency room crowding, trauma capacity, or ICU availability. Conversely, there may be no prior knowledge provided to the hospital regarding the type(s) of injuries sustained by patients, their assigned triage category, or estimated time of arrival. All of these contribute to poor situational awareness and delayed responses [8], [20], [27].

Through connecting triage information, transportation decisions, and hospital capacity data, emergency response can evolve from sequential reactive processes toward coordinated allocations [9], [12], [13].

The economic value of providing an interoperable emergency response process includes cost savings associated with reduced search, coordination, and hand over expenses. As a result of having access to similar sources of information, staff will have less time spent to recreating lost information, confirming capacity via telephone calls, or duplicating documentation. Furthermore, decisions made in regard to allocating patients will be based upon better and timelier information, potentially increasing the effective use of resources and reducing unnecessary delays. This is particularly important in multi-hospital/emergency service environments [28], [29].

Interoperability also enhances system resilience. Through the use of common information bases, decision makers will have the ability to identify bottlenecks at earlier stages in the event evolution. Therefore, they have the chance to redistribute patients more efficiently and to adjust resource deployment as the event changes. Overall, while interoperability is a functional aspect of information systems, it is a fundamental requirement for coordinating emergencies throughout government [7], [8], [12].

3.5 Economic value: From technology costs to avoided system inefficiencies

The synthesis suggests that the economic value of digital emergency response systems should not be assessed only through direct technology costs. Acquisition, implementation, maintenance, cybersecurity, and staff training are relevant cost components, but they provide only a partial view. In mass-casualty healthcare settings, the more important economic question is whether digital systems help avoid inefficiencies that would otherwise emerge from delayed, fragmented, or poorly coordinated response processes [30].

A systems thinking approach to cost will thus include the avoided time wasted waiting for others to complete a task, the avoided transportation time wasted taking patients to incorrect locations, the reduction in duplicated efforts in completing diagnostic tests or documenting care activities, the increased efficiency in the utilization of personnel, and the better allocation of bed space, Ors, and other specialized services. While quantifying each of these potential benefits prior to experiencing them can be difficult, at best, they form the core of the economic rationale for investing in digital systems that reduce uncertainty and allow decision makers to make early decisions regarding patient priority, destination, and resource allocation [8], [9], [13], [14], [17], [29].

Thus, rather than simply viewing digital triage, telemedicine, and interoperability as just new IT spending or modernization initiatives, their true economic benefit

lies in their ability to prevent unnecessary coordination breakdowns during times of maximum operational stress. As such, digital emergency response systems can be viewed as investment in organizational resilience [25].

3.6 Implementation barriers and risk factors

Effective implementation is required for the identified advantages. The introduction of new technological solutions comes with risks with regard to data privacy, cyber security, system failures, lack of interoperable standards, employee training, user acceptance, and investment costs [17], [24]. Systems that have poor design could potentially increase the amount of work employees are required to perform instead of reducing their workload by duplicating pre-existing documentation processes and failing at times when there is maximum pressure [17]. These risks should not eliminate the justification for digital integration from an economic and clinical perspective. Rather, these risks suggest that digital systems must first be integrated into all relevant governance structures, emergency plans, training, and routine operations prior to being called upon to operate in the event of a crisis [8], [17], [24].

4 DISCUSSION

4.1 Main interpretation: Digital integration as an economic resilience strategy

The findings suggest that the economic relevance of digital emergency response systems depends primarily on integration. Digital triage, telemedicine, and interoperability each address a specific weakness in emergency response, but their strongest contribution emerges when they operate as connected elements of the same response architecture. A triage system that is not linked to capacity data, a telemedical consultation that is not visible to receiving facilities, or an interoperable platform without clinically meaningful input would create only limited value.

In essence, therefore, the author concludes that economic efficiency in large-scale casualty care comes from having a mechanism for coordinating responses to uncertain events. Digital integration provides an opportunity to decrease the information gap between field assessments, transportation decisions, hospital preparedness, and regional resource allocation. Therefore, digital emergency response systems may serve as part of the resilience infrastructure for healthcare organizations because they support the preservation of coordinated actions during periods of simultaneous increases in demand, time pressure, and uncertainty.

4.2 Strategic implications for healthcare organizations

Healthcare organizations need to build their digital emergency response abilities in advance of a natural disaster—clinical readiness is contingent on digital readiness. Hospitals must clearly determine where they will embed digital triage, remote consultations using telemedicine, interfaces with EMS, and real-time operational data into their current emergency management procedures. Training for hospitals needs to include both training for the technical aspects of the systems used

during emergencies and how those technologies can affect responsibilities and the decision-making process surrounding handoffs and escalations.

4.3 Policy and system-level implications

At the policy level, interoperability requires a system-wide approach. No single hospital can create coordinated emergency performance alone. Shared standards for data exchange, stable funding, governance roles, and regional coordination structures are required to connect hospitals, EMS, dispatch centers, and public health authorities. Digital emergency infrastructure should therefore be treated as part of public health preparedness. Funding isolated tools may improve local capacity, but it does not necessarily create coordinated system performance during large-scale events.

4.4 Ethical, legal, and operational considerations

The digital emergency response system creates legal, operational, and ethical responsibilities. The primary issue remains the safety of patients' data during a high-pressure emergency situation. This is especially true when transferring data among different organizations. In addition, triage-based decision-making processes must remain transparent with respect to accountability through clinical audits. These requirements have increased importance when using either an algorithmic or artificial intelligence (AI)-based decision support tool for determining priority.

Technical output from a digital system cannot replace responsibility. Therefore, there needs to be human oversight to interpret technical output within the appropriate context so that the ultimate decision is made based on medical rationale. Similarly, interoperability has to be controlled as well. Data should not be able to flow from one organization to another without some degree of control over what data can be transferred. Therefore, in order to effectively implement these systems, there need to be established guidelines for who will have access to this data, documented standard procedures for access, and defined parameters for auditing how this data is being accessed and/or used.

4.5 Limitations of the article

This study has limitations due to being based on a narrative review. Since it is a narrative review, there was no meta-analytic synthesis that allowed for pooled quantitative effect size calculations. Additionally, while there is variability among studies with respect to the setting (e.g., urban vs. rural), technology employed, healthcare delivery system, and methodology used, the heterogeneity of these factors makes direct comparisons between studies difficult. Also, the financial implications of the study were conceptualized as opposed to empirically estimated using a singular evaluation framework. Therefore, future research will need to investigate actual implementations of digital triage systems; telemedicine; and interoperable emergency response systems to evaluate cost/benefits to patients; impact on organizational workloads; and overall system-level resilience.

5 CONCLUSION

Mass casualty healthcare environments represent both clinical emergencies and also crises in terms of cost, coordination, and readiness. These events reveal the limitations of everyday emergency care by putting immediate strain on hospital bed capacity, available resources, specialists, and the decisions made in an operational environment. This paper's conclusions demonstrate how digital triage, telemedicine, and interoperable emergency management systems will complement each other in responding to the pressure created by mass casualty incidents. Digital triage enables improved structure around priority assessment and transforms a patient evaluation into useful data regarding the operational processes within an EMS. Telemedicine allows clinical expertise to be applied at remote sites and assists teams working at multiple remote sites with making more timely decisions relative to the urgency of the situation. Interoperable systems integrate these processes by providing the means for sharing necessary information among EMS, hospitals, coordination centers, HIS, etc.

The financial value associated with these types of systems is derived from their capability to reduce avoidable inefficiencies within a system. Inefficiencies may include delays, fragmentation in communication, duplication of documentation efforts, wasted transport, or poor resource use based upon incomplete or inaccurate information. Therefore, digital emergency management systems have value when they provide means to enable coordinated actions to occur efficiently under conditions of surge.

Digital emergency response capabilities should therefore not be viewed as optional technology additions. They are strategic infrastructure for maintaining resilience in the delivery of healthcare. Their value as a source of revenue is directly related to the integration of three elements: coordination, clinical preparedness, and reduced uncertainty in operation. The economic rationale for implementing digital triage, telemedicine, and interoperable emergency response systems represents not just the need for technical upgrades. It is the basis for developing healthcare delivery systems that continue to operate effectively in a clinical context and remain economically efficient regardless of the level of demand placed upon them.

Therefore, hospitals and policy makers should establish plans for testing, funding, and training these capabilities prior to their necessity. Digital triage and telemedicine capabilities along with interoperability should become established as components of pre-incident preparedness strategies rather than being developed during responses to emergencies.

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