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Research, Design, and Validation of a Normative Enterprise Architecture for Guiding End-to-End, Emergency Response Services

Michael Marich
Claremont Graduate University, mmarich@gmail.com

Benjamin Schooley
Claremont Graduate University, ben.schooley@cgu.edu

Thomas Horan
Claremont Graduate University, tom.horan@cgu.edu

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Michael J. Marich
Claremont Graduate University
mmarich@gmail.com

Benjamin L. Schooley
Claremont Graduate University
ben.schooley@cgu.edu

Thomas A. Horan
Claremont Graduate University
tom.horan@cgu.edu

ABSTRACT

The purpose of this paper is to provide a synthesis and overview of a multipart research study involving the design, exploration, and validation of an enterprise architecture and framework. The methodology includes the use of two case studies and validation through a national conference. While the authors have reported on the elements of this research, only recently has its completion allowed for this synthesis and overview of the process and outcomes. A normative architecture, developed from comparative cases involving San Mateo County and Mayo Clinic Emergency Medical Services systems, provides a collection of characteristics that guides an emergency response system to operate as a high performance system. At a national symposium, academics and practitioners involved in promoting effective emergency response information systems provided validation for the architecture and next steps for enhancing emergency response information systems. Normative architecture characteristics and symposium findings are integrated into a framework that offers an enterprise approach for delivering time-critical emergency response services.

Keywords

Emergency medical services, emergency response, normative architecture, performance, time-critical information services.

INTRODUCTION

Recent surveys have shown that a top management concern is the ability for an enterprise system to make better use of information, while high on the list of applications and technology is business process management (Luftman and Kempaiah, 2008). There has been less research regarding cross-organizational enterprise information sharing and collaboration to support the delivery of end-to-end public services to citizens, especially as it applies to a more specific type of public service where *time* is a critical factor, such as in the case of emergency medical services (EMS), homeland security, law enforcement, crisis response, hazardous material response, fire, search and rescue, and other disaster relief services (Horan and Schooley, 2007).

Within the realm of emergency services organizations where there exists a diversity of stakeholders, dissimilar technologies and processes, operational characteristics, and many other factors, a service oriented architecture (SOA) is one approach that has been recommended (Dwarkanath and Daconta, 2006). According to Melvin Greer from Lockheed Martin, "SOA can be a key enabler for aligning technology with an organization's mission function, but only when SOA is linked with business processes can an agency reap tangible benefits from a process and flexibility perspective." (Yasin, 2008, Government Computing News).

This paper aims to review findings from a multipart research project and apply them to enterprise architecture concepts for emergency services, generally, and for the specific domain of emergency medical services. This paper integrates research findings from conceptual framework development, two comparative case studies, and an expert practitioner symposium with

an enterprise architecture framework referred to as the Emergency Services Enterprise Framework (ESEF). The ESEF is a framework "that provides an integrated process and technology methodology … [t]o ensure efficiencies and to promote collaborative information-sharing in the complex Emergency Services enterprise" (Dwarkanath and Daconta, 2006, p. 7). This paper applies a set of architectural imperatives to the ESEF derived from prior research and defined by EMS practitioners. These imperatives were designed to drive the EMS enterprise "away from inherent business silos and towards greater levels of standardization and integration of information and technology across all stakeholder groups" (Marich, Horan, Schooley, 2008, p. 452). Recommendations are also made on how to navigate towards a more incremental approach to developing enterprise-oriented emergency information services. This research approach is illustrated in Figure 1.

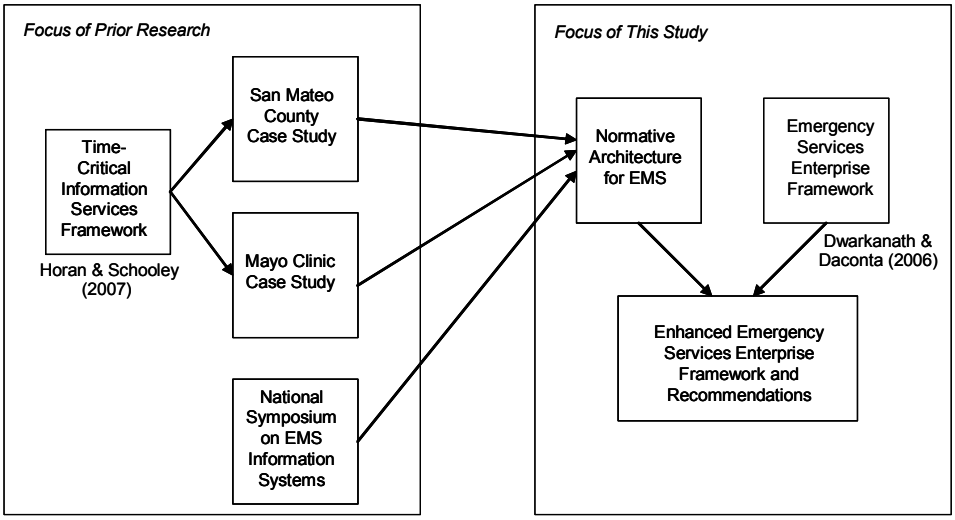

Figure 1. Research Approach

ENTERPRISE ARCHITECTURE AND NORMATIVE ARCHITECTURE

The Time-Critical Information Services (TCIS) framework suggests that there are several overlapping and simultaneous phenomena that should be understood and analyzed to better understand the nature and performance of a multi-organizational emergency medical services information system (Horan and Schooley, 2008). While the TCIS framework has been determined to be most appropriate for exploring key architectural elements, its usefulness is largely limited to its descriptive, conceptual nature. The research presented here is chiefly focused on the performance aspects of an EMS system and is, therefore, biased toward providing guidance that will inform practice.

An examination of the literature published by the Association of Computing Machinery (ACM) and the Institute of Electrical and Electronics Engineers (IEEE) revealed numerous articles related to the development of high performance architectures for computer hardware involving various processor and memory devices. On the software side, there are numerous articles related to high performance architectures resulting from compiler and programming optimizations. Published research also exists for the development of high performance architectures for communication systems, such as those used in wireless networks. However, there is currently no published research available from the ACM or IEEE related to developing high performance architectures for enterprise-wide, multi-organizational information systems such that support emergency services.

While there is limited published material to work with regarding the development of a high performance architecture, the well-documented concept of enterprise architecture maturity contains many similarities to which a normative architecture for an EMS system would subscribe. Schekkerman (2004) describes an enterprise architecture as "a master plan which 'acts as a collaboration force' between aspects of business planning such as goals, visions, strategies, and governance principles" (p. 13). Baltzan and Phillips (2008) describe the three components of enterprise architecture as: (1) information architecture – that "identifies where and how important information, like customer records, is maintained and secured"; (2) infrastructure architecture – "the underlying foundation to support the organization's goals" that includes primary characteristics such as

performance, availability; and (3) application architecture – that "determines how applications integrate and relate to each other" (p. 154). Ross (2003) indicates that there are four stages that can be used to describe the maturity of an IT architecture: business silos, standardized technology, rationalized process, and business modularity. Ross and Beath (2006) state that as firms move through these stages it "incrementally increases the strategic value of IT to the enterprise and enhances enterprise effectiveness" (p. 182).

The operational, organizational, and governance dimensions of the TCIS framework were designed to align with the definition, components, and the concepts of effectiveness associated with an enterprise architecture. In this regard, then, the conditions or qualities that would lead an EMS system to be classified as high performance would center on those related to what Baltzan and Phillips (2008) term as a "solid enterprise architecture" (p. 153).

The development of prescriptive or normative designs, implementations, or architecture of information systems is not uncommon in the literature. For example, prescriptions for the design and implementation of Southern California Edison's crisis information system were provided many years ago (Housel, El Sawy, and Donovan, 1986). A prescriptive architecture for crisis response, an area of study that is quite similar to emergency response in that it shares many of the same stakeholders, was proposed in the late 1990's (Hale, 1997). Given the prominence associated with the topic of enterprise architecture, and especially the significance of enterprise architecture maturity, we posit the importance of also including a prescriptive or normative architecture within this context to provide guiding principles to aim towards. For the purpose of this research, a normative architecture embodies those high performance qualities that system stakeholders believe are required for the end-to-end provision of emergency medical services information systems across operational, organizational, and governance dimensions. The effectiveness of the normative architecture is a function of its alignment with the high performance architecture, the qualities of which will be discussed further in this paper.

OVERVIEW OF THE EMERGENCY SERVICES ENTERPRISE FRAMEWORK

Dwarkanath and Daconta (2006) developed the Emergency Services Enterprise Framework (ESEF) based upon practitioner insights into emergency response. These authors recommend the adoption of a service-oriented enterprise approach in order to handle the interactions between the numerous stakeholders that participate in the provisioning of emergency services. The ESEF as described by Dwarkanath and Daconta is depicted in Figure 2 and consists of the following elements:

(1) A governance structure composed of an operational component associated with people and processes "to identify the strategic outcomes and objectives for the enterprise" (p. 3) and a technology component that "governs the actual technical, information technology and communication issues, and seeks to ensure the application of policies and re-use of services in the enterprise" (p. 3).

(2) Enterprise services composed of line-of-business services that are "domain-specific services offered within a single domain" (p. 4), shared services that are "horizontal services shared across a subset of the enterprise COI [community of interest] and among two or more domains" (p. 3), and core services that are "horizontal services that are shared and used across all domains" (p.3).

(3) An enterprise platform that "includes the methods and tools that enable the enterprise services … [including] the various sets of integration technologies, systems, and standards that are used by the entities" (p. 5) and the enterprise infrastructure that consists of the "access and delivery channels and the various transport modes like terrestrial and satellite communications" (p. 5).

The ESEF provided a context-specific enterprise architecture to apply and integrate research findings from a multi-method, multipart National Science Foundation sponsored research project.

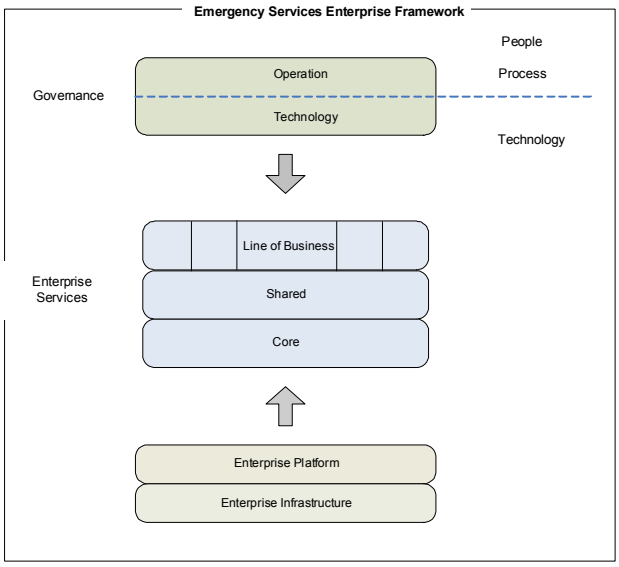

Figure 2. Emergency Services Enterprise Framework (adapted from Dwarkanath & Daconta, 2006)

METHODOLOGY

In prior research, a conceptual framework referred to as the time critical information services (TCIS) framework was developed in order to better understand the operational, organizational, and governance structures in which emergency medical services information services are delivered (Horan, Marich, and Schooley, 2006; Horan and Schooley, 2007). The TCIS framework served as a tool to help define and align the multi-organizational enterprise architecture desired by EMS stakeholder groups. Findings from several focus group sessions, conducted with the San Mateo County EMS Agency in San Mateo, California and with the Mayo Clinic in Rochester, Minnesota, were organized according to this framework. For San Mateo, focus group sessions included participants from across the end-to-end emergency services provisioning chain, as referenced in Table 1 (Marich, Horan, and Schooley, 2008).

A preliminary set of normative architecture qualities, aligned with the TCIS framework, was developed from the focus group sessions. The main purpose of the normative architecture was to provide a collection of characteristics that will allow an EMS system to operate as a high performance system. The Steering Committee, which was comprised of key members from various subcommittees, agreed with the preliminary architecture qualities that were presented to them and used this information to guide the county's long-range, EMS procurement strategy involving public and private service contracts (Marich, 2008).

Organization	Position
San Mateo County EMS Agency	Administrator
	Medical Director
	Emergency Preparedness Specialist
	Clinical Coordinator
	Injury Prevention Coordinator
	Consultant
American Medical Response	Administration Supervisor
	Operations Manager
	Director of Operations, San Francisco/San Mateo
	Information Technology Director, Western U.S.
	Information Technology Manager
	Information Technologist
County Fire Joint Powers Authority	Coordinator-North Zone, Fire Battalion Chief
	Coordinator-South Zone, Fire Battalion Chief
	Coordinator-Central Zone
	Fire Chief-Millbrae
	Fire Chief-Redwood City
	Fire Chief-San Bruno
	Fire Chief-Belmont
	Fire Chief-Woodside
	Administrator
	EMS Lead, South San Francisco
Care Facilities	Emergency Department Manager-Sequoia
	Emergency Physician-San Mateo Med. Center
	Executive Director-Hospital Consortium
	Information Technology, Kaiser
San Mateo Communications Center	Program Manager, Public Safety Communications
	CAD Manager, Public Safety Communications
	Systems Specialist, Public Safety Communications
Police	Chief-Belmont
County Manager's Office	Assistant County Manager
Consumer Advocate	Emergency Medical Care Committee
Payer	Director of Health Plan of San Mateo
Total Expert Participants: 33	

Table 1. San Mateo County Focus Group Participants (Marich, 2008)

The preliminary architecture qualities that were explicated through the San Mateo County case study were then applied to the findings from a second case study location – the Mayo Clinic in Rochester, Minnesota. The Mayo Clinic was chosen as a research site for its similarities as well as differences with San Mateo County. During the case study selection process it was envisioned that these like and unlike characteristics would provide opportunities for comparison and contrast. Both sites are similar in that they serve both urban and rural populations. Excluding the Rochester area, the Mayo Clinic is also similar to other places in the United States, such as San Mateo County, where emergency transport services are used to take patients to a variety of non-associated care facilities for treatment. Both San Mateo County and the Mayo Clinic are also similar for their innovation in applying information technology across their services. San Mateo County, for example, was an early adopter of electronic patient care records and their hospital availability reporting system. The Mayo Clinic continues to be a pioneer in providing quality patient care and is recognized as a world leader in the use of technology in all aspects of the medical field. Focus group sessions conducted at the Mayo Clinic included participants from across the end-to-end process of the emergency services provisioning chain, as referenced in Table 2 (Marich, 2008).

Organization	**Position**
Mayo Clinic Emergency Communications Center	Manager
	Program Coordinator
	Supervisor
Mayo Medical Transport	Administrator
	Chief Financial Officer
	Clinical Nurse Specialist
	Chair of RescueNet Committee
	Director of Air Operations, Mayo MedAir
	Regional Process Coach
Mayo Clinic Corporate Communications	Director
Information Technology	Lead Analyst Programmer
Dept. of Emergency Medicine	Physician, Co-Medical Director—Air
	Physician, Co-Medical Director—Ground
Trauma	Surgeon, Co-Medical Director—Air
Total Expert Participants: 14	

Table 2. Mayo Clinic Focus Group Participants (Marich, 2008)

While there were several similarities between both case study locations, there were also several notable differences. The geographical area served by the Mayo Clinic covers a multi-state region, whereas San Mateo is a single county within a single state. The Mayo Clinic has control over much of the end-to-end system in the immediate Rochester area, whereas the San Mateo County EMS Agency uses contractual agreements with business partners in the provision of emergency services. Within San Mateo County, emergency medical first response is provisioned by the Fire Department under the control of a Joint Powers Authority, which eliminates geographical boundaries for first responders. San Mateo County also has a consolidated communication center (Marich, 2008).

OVERVIEW OF A NORMATIVE ARCHITECTURE FOR EMS

Figure 3 depicts the normative architecture qualities for an EMS system as obtained from both case study locations. This figure implies that there exists a performance continuum from low to high; and a set of qualities that comprise the operational, organizational, and governance aspects of service provision. This figure also implies that end-to-end performance is related to the architecture type (low or high).

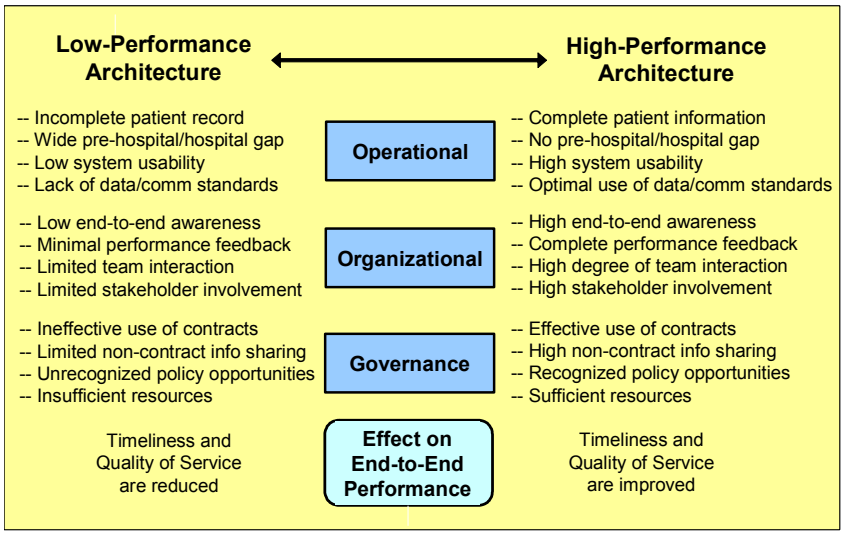

Figure 3. Normative Architecture for EMS Systems (adapted from Marich, 2008)

The following subsections outline the general details of the normative architecture as derived interviews and focus group discussions with case study participants. Further details are provided in (Marich, Horan, and Schooley, 2008).

Normative Architecture Details – Operational Level Qualities

The operational level is focused on the performance aspects of the EMS system process, with specific emphasis on the information needs across the inter-organizational service process.

Having complete patient information can generally be equated to the availability of a unified, end-to-end patient record. In order to achieve greater overall system performance, an end-to-end patient record would provide critical information about what is happening as the patient moves throughout the EMS system.

The capability to integrate and share data, especially between pre-hospital system elements (dispatch, ambulance provider, fire, and EMS Agency organizations) and the hospitals that serve a particular geographical area is essential to measure system performance and determine health outcomes. Removing the gap between the pre-hospital and hospital elements will allow the ability to tie patient outcomes to each of the activities that occur within the pre-hospital environment, potentially improving patient survival and quality of service.

While much has been done in the past to improve information system usability, designing a better user interface to more easily collect and present information within the emergency context is needed. While it is true that many of the calls answered by emergency responders are not time-critical, those that are answered when a person's life is at stake require a different level of system usability than information systems used for less time-critical activities.

End-to-end data standards for storing and sharing data, as well as inter-personal communication between system elements, such as paramedics and care facilities are vital for relaying information. For an EMS system to be classified as one that operates at the highest performance, end-to-end data standards have been established and each of the system elements can trust that the data made available to them will not require extensive and unforeseen modifications in order for it to be useful.

Normative Architecture Details – Organizational Level Qualities

The organizational level deals mainly with the organizational and inter-organizational actions that support the collection and use of EMS information, such that information sharing supports timely and high quality end-to-end performance.

End-to-end awareness means that organizational stakeholder not only track their own resources using information technology, but are aware of current conditions throughout the system. This condition leads to a better understanding of what is occurring in near real-time with respect to available personnel resources (such as dispatchers, ambulances, emergency medical technicians) and hospital availability status.

A system that attains high end-to-end performance feedback not only gathers and reports performance within each of the EMS organizations, it has the capability to draw upon an "Organizational" Performance Feedback System to report various types of performance outcome information to a wider range of system elements. Providing feedback for the events that occurred during a previous quarter would serve to fulfill the human side of the services provided by such system elements as the emergency medical technicians and emergency physicians, to name a few.

End-to-end team interaction fosters both formal and informal opportunities for discussion across service silos, where practitioners across organizations meet and talk among themselves. Informal communication is especially important to allow team members to discuss issues that they may be more reticent to discuss in the formal environments.

End-to-end stakeholder involvement for high performance not only includes EMS stakeholder participation in system design, but more importantly, innovative and full participation across all of the stakeholder groups, especially among those groups that that are paying for the majority of the services (i.e., the health insurance providers).

Normative Architecture Details – Governance Level Qualities

The governance dimension involves the structures, in terms of policies, regulations, and funding decisions that guide the EMS system. Such things as policy and political factors facilitate the deployment of a timely and high quality EMS system.

End-to-end contract relationships can be used to encourage information sharing and include information sharing elements in the contracts that are awarded. A high performing system effectively deals with the issues and challenges that occur due to public and private relationships, as well as contractor and subcontractor relationships.

Besides formal contracts, there are considerations that are necessary to facilitate end-to-end non-contractual relationships. One important goal is to achieve consistency in such areas as information sharing. Exploring incentives to handle non-contractual situations may be challenging, but will be necessary in order to keep the system performance at optimal levels.

The realization of policy opportunities (such as concurrent interests in healthcare and homeland security initiatives) that may occur between various system elements, needs to be aggressively pursued. Top performers in this area will find parallel and overlapping policy initiatives to help drive enthusiasm from a range of local, state, and national agencies on the issue of improved information technology for EMS.

The provision of sufficient resources (such as personnel and funding) needed to complete the myriad of tasks can be challenging. High performers look for ways to act with agility and continuous improvement of their processes.

In sum, these performance imperatives described above and organized along operational, organizational, and governance dimensions represent the characteristics of a high-performing EMS system as derived through several phases of research.

SYMPOSIUM RECOMMENDATIONS FOR IMPROVING EMS INFORMATION SYSTEMS

The normative architecture was presented and discussed at a national symposium in Washington, D.C. consisting of 33 academics and practitioners involved in promoting more effective emergency response communications. Expert panelists confirmed the importance of the multi-leveled TCIS framework, noting how each level contains critical elements for the overall end-to-end system to perform well. Moreover, representatives from each of the (two) case studies confirmed principle findings of the case studies as well as the overall framework in which they were analyzed. Organizational representatives came from the case study locales as well as such emergency response practitioner organizations as the National Emergency Number Association (NENA), the National Highway Transportation Safety Administration (NHTSA), the U.S. Department of Transportation, Intelligent Transportation Systems Program, Health and Human Services (HHS), COMCARE, GM OnStar and other agencies as well as representatives from industry and academia (Schooley, Horan, and Naomani, 2008).

The forum provided additional insight and validation for the normative architecture as a way to address the vision for high-performance EMS information systems. The forum also provided a set of next steps and recommendations including the need to take targeted, incremental steps towards the larger enterprise vision for emergency medical response information systems. The need for an incremental approach is largely due to numerous contextual, organizational, and policy challenges and barriers to implementing enterprise systems, as well as risks associated with making changes to a large-scale, socio-technical system that fundamentally "works", but needs improvement. As such, participants noted the importance of making changes in a manner that does not worsen the existing system for practitioners and ultimately citizens using the service; but rather to aim to achieve the imperatives described in the normative architecture over time. A summary of the recommendations from the symposium are listed in Table 3 (Schooley, Horan, and Naomani, 2008).

Conduct Regional Demonstration Project and Evaluation
Take Targeted, Incremental Steps Towards the Larger Vision for integrated emergency response communications
Demonstrate the Business Case(s)
Drive Change by Understanding the Health Care System and Leveraging Existing Institutional Initiatives
Demonstrate the Clinical Value of Information Sharing
Conduct More Research, Including More Active Sharing of Research on the Topic

Table 3. Summary of Symposium Recommendations

INTEGRATION OF ENTERPRISE AND NORMATIVE ARCHITECTURE

The Emergency Services Enterprise Framework addresses many aspects of a high-performance architecture, for example, with respect to the governance and operational characteristics. Our research has illustrated that the architecture qualities that strongly affect end-to-end system performance may also include a robust inter-organizational dimension. As such, there are several key inter-organizational qualities that we posit should be accounted for in order to increase the performance of multi-organizational emergency response enterprise information systems. The addition of these elements is illustrated in Figure 4 below.

Adding the Performance Dimension to the Emergency Services Enterprise Framework

For those entities involved in emergency response to achieve a high degree of performance, there are several qualities that they must exhibit. These qualities are shown under the headings labeled organizations, operations, and governance in Figure 4. This figure highlights the need for inter-organizational linkages, where an exchange of information occurs between the organizations and operations within the emergency services enterprise. Line of business, shared, and core enterprise services are enabled by enterprise and infrastructure platforms. The operational and technology governance components are imposed across each of the elements within the enterprise. Further, the normative aspects of each enterprise layer (organizational, operational, governance) are embedded within the definition and meaning as illustrated on the right hand side of Figure 4. In other words, when developing line of business, shared, and core services, the strategic objective should be to aim towards the high-performance features of the normative architecture.

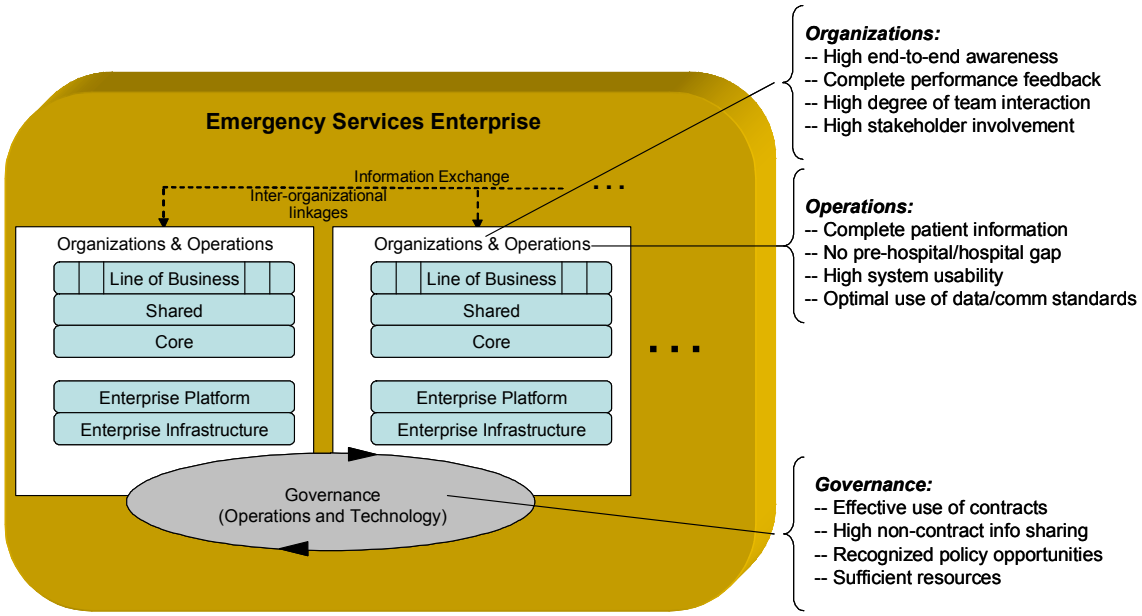

Figure 4. Revised Emergency Services Enterprise Framework

Taking an Evolutionary Stance toward a Service-Oriented EMS System

The day-to-day services that EMS organizations provide to citizens are highly structured and regulated, with each of the organizational entities responsible for performing specific tasks. Hutchinson et al. (2008) argue that a progressive evolution approach, whereby a system migrates "through a series of relatively discrete development cycles" (p. 42), would minimize the risk involved in moving an organization to a completely service-based type of system. From our research experience and the National Symposium described above, we have observed that EMS organizations have to deal with difficult policy environments (e.g., tight budget constraints) and organizational relationships (e.g., long contractual timelines (e.g., 10 years)), while attempting to meet public demand to increase the timeliness and quality of services that they provide. While enterprise architecture can provide guidance on moving towards a greater degree of process integration and standardization, the complexities of EMS environments lends itself to a more risk averse enterprise architecture approach. Embedding normative architecture within an enterprise architecture may allow for a long-term view of what and how the emergency services enterprise should operate and be governed.

CONCLUSION

As we observed in our research, the personnel involved in providing emergency response face numerous obstacles as they try to help injured citizens. Information technology should assist, rather than detract from the job that these personnel perform. A rich set of qualitative and quantitative data was acquired from numerous practitioners during focus group sessions at the San Mateo County EMS Agency and the Mayo Clinic, with a goal of bringing suitable information technology solutions to bear. The experts in the field of EMS that were involved in these studies cut across all aspects of these services and their insight formed the basis for a set of key normative architecture qualities. These results were then validated at a national symposium comprised of academics and practitioners, whose expertise came from the emergency response field as well as disciplines where similar issues were successfully resolved. The Emergency Services Enterprise Framework, independently developed through practitioner insight, was reviewed based upon the key architecture qualities and presented here. It is envisioned that the resulting framework will be useful in driving requirements development for successful information system deployment in the field of emergency response.

Our research findings indicate that the development of a normative architecture through end-user and stakeholder engagement is a valuable step within the larger scope of enterprise architecture development within the complex, multi-organizational, emergency response context. First, having a well-defined conceptual framework allowed for the expression, classification, and validation of research findings. Second, developing a normative architecture through a close, working relationship with the actual stakeholders of a system provided a significant advantage to the design team assigned to perform

architecture analysis and formal requirements definition. The normative architecture, especially in distinguishing between features such as low and high performance characteristics, clearly delineates the goals that system analysts and designers should strive toward.

Similarly, the normative architecture can provide guidance, or act as a measuring stick for architecture maturity migration. As suggested by the participants in the national symposium, future directions for this research should include additional case study work that focuses on the incremental design and migration of emergency response information systems to increased levels of data and process integration and standardization.

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