



System dynamics simulation modeling of health information exchange (HIE) adoption and policy intervention: A case study in the State of Maryland



Emad A. Edaibat*, Jason Dever, Steven M.F. Stuban

Department of Engineering Management and Systems Engineering, the George Washington University, Washington, DC 20052, USA

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ABSTRACT

In this paper, health information exchange (HIE) adoption barriers, challenges, influencing factors, and the impacts of policy interventions among ambulatory providers and acute-hospitals in the State of Maryland health care system are examined. The main areas discussed are HIE sustainability, financial benefits, return on investment, and the correlation between HIE and hospital readmission reductions. The proposed policies include financial incentives to adopt HIE (policy 1), awareness and education to integrate HIE into the workflow (policy 2), and a combination of policies 1 and 2 to address the most frequent barriers identified in the literature. System dynamics simulation modeling combined with statistical analyses were utilized based on monthly time-series datasets. The design for each policy was developed considering HIE adoption barriers, challenges, and influencing variables. The simulation focused on presenting the findings of many HIE adoption studies. The results suggested significant financial advantages of using HIE (an approximately \$3.3 billion cumulative gain over 10 years). Ambulatory provider adoption of HIE is slow but contributes the most to the overall HIE portal queries. Three datasets were analyzed with regard to hospital readmission reductions, HIE portal query usage, and encounter-notification service alerts. Strong positive correlation coefficients of 0.75 and 0.8, respectively, were determined. Finally, the designed policy interventions (policy 1, policy 2, and combination) showed a positive effect on HIE adoption rate by 15.87%, 8.36% and 21.17% respectively. This research can be used as a framework to provide policy makers and strategic thinkers with a methodology for analyzing such complex systems and generate well informed HIE adoption policies.

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1. Introduction

1.1. Overview

A health information exchange (HIE) is a mechanism to securely share and access medical records and other data electronically across health care providers. The concept of HIE is widely used and well established; however, HIE is a relatively new system that was initiated in 2009 by the Health Information Technology for Economic and Clinical Health (HITECH) Act. The HITECH Act allocated federal and state funds toward accelerating the adoption of health information technology, including HIE, to improve health care quality, efficiency, and costs [1]. The potential HIE benefits include reducing hospital readmissions, unnecessary

hospitalizations, and duplicative laboratory and radiology testing; improving care management, patient satisfaction, and safety; and avoid emergency department (ED) visits and adverse drug events [2–7].

Several barriers and challenges to HIE adoption exist, including high implementation costs, integration and use in workflows, difficulty in quantifying cost savings and financial benefits, privacy and security concerns, high competition among health care providers, lack of technical standards, and lack of interoperability [8–11]. Despite these challenges, many HIE systems across the United States have been implemented and have evolved. Long-term HIE financial sustainability is a concern for the post-implementation phase [12–16]. Hence, the continuous improvement in HIE adoption and usage plays a role in reforming and shaping the quality of health care and its associated costs.

Since the initiation of HIE, a clear and rapid increase in its adoption has occurred each year. In 2014, 76% of non-federal acute-hospitals nationwide electronically exchanged health information

* Corresponding author.

E-mail address: emad@gwu.edu (E.A. Edaibat).

with external health care providers compared to 44% in 2010. The rate of HIE adoption in the state of Maryland, for example, was 88% in 2014 compared to 53% in 2010 [17–19]. However, apart from drug e-prescribe data, no clear public data or reports on ambulatory-provider HIE adoption rates with nationwide external health care providers exist. Using data from the National Ambulatory Medical Care Survey in 2013, Furukawa [20] determined that 39% of ambulatory providers reported using HIE with other external providers, which is significantly lower than hospital HIE rates. However, Furukawa did not address the frequency of HIE usage among ambulatory providers.

1.2. Research objectives

The aim of this study was to develop a system dynamics (SD) approach to build a framework for evaluating, analyzing, and presenting a solution for an HIE system with consideration of all related challenges. The proposed SD simulation model can be used to model other HIE systems across the United States because it is both replicable and adaptable to different settings. In addition, policy interventions to foster the accelerated adoption and utilization of HIE were designed.

The proposed simulation model links policy interventions, costs, variables, causality, and decision making in a collaborative information-sharing environment. The present paper reviews aspects of the HIE system considered for the creation of our model and discussed by other researchers: HIE evaluation [21], implementation [22], adoption and benefits [12,13], usage [2,5,6,23], return on investment (ROI) [3,5,24], sustainability [14,15,25], role in hospital readmission reduction [6,24], policies [26], and financials from the establishment phase to the post-implementation phase.

Several existing SD models (causal loop and simulation models) were previously proposed for the adoption and cost benefits of health information technology (HIT) and electronic health records (EHR); SD models of HIE, HIT, and EHR are not new. The novelty of the present work is the calibration of the SD model to describe HIE use and uptake and to study HIE adoption and cost benefits for the State of Maryland.

1.3. Background

Based on a review of the literature and the collected datasets (discussed in Section 2.1), we posit a set of problems that we address regarding HIE adoption and use.

First, in terms of HIE ROI, the difficulty of quantifying the financial value added by HIE is a common issue [3,5,8,11,24]. The financial benefits of the HIE system are significant to the adoption discussion. However, relationships among ROI and other HIE system elements exist that should be examined as well.

The fragmentation of information among health care stakeholders is not surprising and necessitates the creation of lean practices to eliminate waste. Waste can take the form of duplication of laboratory and radiology tests, hospital readmissions, repeated ED visits, and time required to search for medical records. Augmenting the effectiveness of health care systems and decreasing waste will ultimately increase the influence of HIE adoption. However, HIE system implementation incurs additional costs, such as investment in new infrastructures, operation, and research and development, i.e., for enabling EHR and HIE system interoperability. Moreover, training medical providers on using new platforms and the time required in using the EHR/HIE systems in the day-to-day workflow have additional related costs. We thus determine if the State of Maryland HIE will realize a significant financial gain and ROI.

Second, HIE usage in hospitals and ED settings has been the focus of previous works [2,5,6,23]. Nevertheless, no adequate studies have been conducted in terms of other health care

providers (such as ambulatory services). The rationale behind this problem statement is to highlight the importance of future studies in focusing on HIE adoption and usage by ambulatory providers with consideration of the large population of these providers compared to hospitals and EDs. We therefore investigate the validity of previous works using a graphical representation of a real-world dataset and provide our subsequent perceptions.

Third, the HIE effect on hospital readmission reduction is examined. A promising benefit of HIE is the reduction of hospital readmission [6,24]; therefore, HIE can be used as a tool to provide better care management. We therefore specifically investigate if a correlation exists between HIE and hospital readmission reduction.

Fourth, HIE sustainability should be addressed. The Chesapeake Regional Information System for Our Patients (CRISP) received state funding of \$10M dollars for HIE establishment (2009) to build an HIE infrastructure and core services (e.g., portal queries, the Encounter Notification Service (ENS), and the Prescription Drug Monitoring Program (PDMP)). The CRISP initial financial sustainability application for state funding asserted that CRISP would be a self-sustainable organization by the fifth year of the grant [27]. The CRISP request for application (RFA) response stated that, in its HIE sustainability business model [28], the use of participant subscription fees is a method used to reach this goal. As of May 2015, out of all participants, only payers (insurance companies and government agencies) and hospitals pay the subscription fees, which is then used to cover ongoing operation costs and core HIE services (approximately \$4M). According to CRISP, the State of Maryland HIE is sustainable, and many current studies and reports concur with this assertion [12–14,16].

However, today's HIE requires integration within the existing health care provider workflow, i.e., interoperability of the HIE system with EHR [9]. The uncertainty of future HIE expansion projects was not considered [28]. We thus present the research question: Provided the demands for interoperability across different EHR platforms, is the State of Maryland HIE sustainable in the long term?

Finally, in terms of policy interventions, Kruse et al. provided a systematic study of HIE barriers over time by reviewing the literature from 2009 to the first half of 2014 [8]. Their study provides a summary and breakdown of each barrier frequency over that period and found that cost and efficiency/workflow are the top two barriers hindering HIE adoption. Based on their study and the available datasets, the following policies are herein proposed: Financial incentives to integrating HIE into the provider workflow, and promoting awareness and education to foster that integration.

Financial incentives (Policy 1). As discussed earlier, a holistic HIE system ROI in the State of Maryland is an important factor for its success. Comprehensive reform, including overhaul of the legislation and strategic planning, is required. If a significant ROI is realized, it should be distributed in the form of financial incentives back to the health care providers to accelerate HIE adoption and advance current HIE to HIE 2.0 and beyond (e.g., big data concepts, data analytics, early prediction of epidemics, and improvement of patients diagnoses and prognoses) [9,11].

Advancing awareness and education for integrating HIE into the provider workflow (Policy 2). This policy relates to the subjective response to any change, such as that of potential HIE adopters to using the new system. Addressing aspects of human nature necessitate cautious planning to eliminate and/or reduce any resistance to change. According to [29], factors that negatively influence the integration of HIE in the workflow include changing the work patterns and/or introducing new processes to existing job workflows. Health care providers may believe that HIE can add more complexity and cause workflow interruption. HIE is not intuitive in the sense that it requires additional logins and access to different platforms, thereby adding extra efforts in daily work activities [8,30].

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