Development of a Hierarchical Decision Model (HDM) for Health Technology Assessment (HTA) to Design and Implement a New Patient Care Database for Low Back Pain

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Abstract--**Decision-making in healthcare towards the use, implementation and design of assistive information technologies like patient care database is looked from multiple perspectives. We propose utilization of Hierarchical Decision Model (DHM) for new patient care database design for low back pain at Oregon Health and Science University (OHSU), Portland, Oregon. Extensive literature review provides justification for the criteria used. The model could be used for other patient care software assessment in healthcare. The strategies (2nd layer of the model) could be revised to further fit the needs of a particular department. The next stage of current research is model implementation, expert quantification gathering and analysis at OHSU.**

I. INTRODUCTION

According to StartUp Health, investment in digital health hopped $1.35 billion in the first quarter of 2014. Six themes (representing about 50% of last year's funding) emerged, including EHR/clinical workflow, analytics/big data, digital medical devices (clinically-oriented products with specific disease/condition focus), wearables/ biosensing (consumer-oriented products with generalized biosensors), population health management, healthcare consumer engagement (purchasing of health insurance, healthcare services and products, intended for B2B and B2C markets) [1].

Analyzing the results to the 2009 Oregon Ambulatory EHR survey [2], some of the most noticeable barriers to implementation of this information technology are:

- poor product availability in accordance to the needs of the customer (18.2% of organizations and 20.8% of clinicians);
- training requirements (26% of organizations and 31% of clinicians);
- costs of purchase (80.2% of organizations and 84.1% of clinicians) and costs of implementation (58.6% of organizations and 68.4% of clinicians);
- inadequate ROI (36.1% of organizations and 29.8% of clinicians).

Some other important characteristics were also privacy and security issues, lack of leading expertise, concerns about product failures and size of practice [2].

While these concerns were survey in regards to EHR, a type of information technology currently being implemented throughout the United States, those problems resonate as general technology implementation concerns. Those issues call for the necessity of multi-dimensional decision-making model, which would enable physicians and administrators to look at the multiple perspectives of the problem, including goals, objectives and strategies of the healthcare unit, analyze those through their judgments and make their decision toward a particular information technology from the possible alternatives.

Americans spend at least $50 billion each year on low back pain, the most common cause of job-related disability and a leading contributor to missed work. While most occurrences of low back pain resolve within days, some cases persist, resulting in chronic disability.

Historically, the surgical treatment of low back pain with spinal fusion has had relatively poor success with only 25% of patients reporting vast improvement following surgery. Because of this, health care insurers are demanding better methods for tracking surgical indications and outcomes. The Oregon Health and Science University (OHSU) Multi-disciplinary Spine Clinic utilizes the Integrated Survey System (ISS, Dynamic Clinical Systems, Hanover, NH) to collect patient research data (e.g., SF-12, Oswestry Disability Index(ODI)) via a computer questionnaire (data is stored in a secured database).

II. PROBLEM STATEMENT

In June of 2007, OHSU started to use electronic database in order to track patients before their first visit and throughout their entire care at OHSU [3]. Patients would fill out confidential surveys tracking factors like pain level, mobility, overall quality of life and level of disability. Since then the database has not been integrated well into physicians' routines so it could be impactful in physician-patients relationships and communication levels. OHSU is looking to design and establish the database that would correspond to the needs of physicians, analyze important patient characteristics, and give a useful snapshot of patients' issues that could lead to additional guidance and better treatment successes.

The ISS system started at OHSU has roughly 14,000 patients with over 225,000 patient visits. The patient questionnaire takes roughly 8 – 10 minutes to complete and can be accomplished on computer or paper. Roughly 20% of patients do not attempt the questionnaire reporting insufficient time as the number one reason. 25% percent of patients that start the questionnaire do not complete it. This high proportion of patients that fail to record their response results can be attributed to a database designed in the 1990's

that does not take advantage of current graphic-user-interface (GUI) technology, mobile phone technology, has difficulty in quick data extraction, and finally, does not integrate with recently developed electronic health record (EHR) systems (Table 1). Finally, the system is onerous for surgeons to obtain data during patient clinical visits leaving these important patient measures out of point-of-care decision making.

TABLE 1. PROS AND CONS OF THE CURRENT OHSU SPINE PATIENT OUTCOME DATABASE (INTEGRATED SURVEY SYSTEM (ISS, DYNAMIC CLINICAL SYSTEMS, HANOVER, NH)).

Pros:	**Cons:**
Validated research outcome measures (e.g., SF-12, Oswestry Disability Index (ODI)	Roughly 20% of patients to not attempt questionnaire (June 7 – March 2014; 847/5040 ((17%))
Excellent patient reminder system	75% questionnaire completion rate (June 7 – March 2014; 3807/5040 (75%)). Note: insufficient time quoted as number one reason for not completing (takes roughly 20 minutes to complete).
	No physician graphic user interface for ease of data inquiry
	Labor intensive data input and data extraction (e.g., paper questionnaires manually inputted)
	Failure to integrate directly with OHSU Electronic Health Record (Epic)

III. RESEARCH OBJECTIVES

This paper reflects the stage of the project that is focused on developing a hierarchical decision-making model (HDM) that will incorporate important aspects of the needs of neurological surgery and orthopedics department (OHSU) with the possible alternative solutions. Future steps in the research, planned for 2014 and 2015 include model validation through the expert panel collaboration; gathering data – opinions of experts with the method of pairwise comparisons among all variables at every hierarchical level of the decision model; establishment of desirability curves for the factors of the model; analysis and interpretation of the data with the possibility of model generalization for possible hospital-wide and nation-wide acceptance. After examining a large body of literature on health technology acceptance and evaluation (Table 2), major research gaps that will be addressed are the following:

1. A comprehensive decision-making model of patient care software selection in departmental hospital settings has not been successfully introduced.
2. Combination of elements of human criteria (perceived usefulness and ease of use) and multi-perspective approach utilizing financial, technical, organizational, personal and interpersonal criteria in one decision-making model has not been introduced.
3. There is a lack of studies in the United States using HDM for software selection decision-making in departmental hospital setting.

TABLE 2. BIBLIOGRAPHICAL REVIEW OF TYPES OF STUDIES PERFORMED IN HEALTH TECHNOLOGY ASSESSMENT AND ADOPTION.

Type of study	Research works
Qualitative or empirical evaluation of Technology Acceptance Model or other acceptance models	[4], [5], [6], [7], [8], [9], [10], [11]
Exploration of particular aspects of the HIT adoption	[12], [13], [14], [15], [16], [17]
Applications of TAM and its derivatives in other countries	[18], [19], [20], [21], [22]
Frameworks of IT adoption in healthcare (stage process and heuristics)	[23], [24]
Frameworks of IT adoption experimental in nature	[25], [26], [27]

IV. METHODOLOGY

Researchers note that software application selection involves balancing factors like cost, ease of use, availability of technical support and maintenance, recognition of limitations inherent by the software, considerations of database platforms and compatibility of other applications. Some of the important attributes of medical databases, especially patient care databases for spine management include regular storage of patient data, managing the follow-up process in detail, and swift access of any data at any time [28].

Hierarchical Decision Model (HDM) developed by Kocaoglu, gives an opportunity to look at the program under consideration as a network of relationships among decision hierarchies, quantified by subjective judgements of experts in a systematic process so as to provide a sound basis for those complex evaluations [29]. HDM is widely used in Engineering and Technology Management discipline and has gained popularity in various industries [30], [31], [32], [33].

Multi-criteria decision tools like Saaty's Analytic Hierarchy Process (AHP) [34] and Hierarchical Decision Model (HDM) [29] have some important steps in the application process:

1. Structuring the decision problem into levels consisting of objectives and their associated criteria
2. Eliciting decision maker's preferences through pairwise comparison among all variables at every hierarchical level of the decision model
3. Processing the input from the decision-maker and calculating the priorities of the objectives
4. Checking consistency of the decision maker's responses to ensure logical and not random comparison of the criteria.

In HDM, a variance-based approach is used for the inconsistency calculations and 10% limit is recommended on it in the Constant Sum Method (CSM). While the HDM approach is similar to Saaty's Analytic Hierarchy Process, the computational phase uses the Constant Sum Method instead of the Eigenvectors [29]. As explained by Kocaoglu, in the hierarchical decision process, the problem is considered as a

network of relationships among major levels (impact, target and operational) of hierarchy, with multi-criteria objectives at the top leading to multiple benefits and at the bottom – multiple outputs resulting from multiple actions [29].

The constant-sum method [29] consists of the following:

1. n(n -1)/2 are randomized for the n elements under consideration.
2. The decision-makers distribute a total of 100 points between elements with respect to each other. (It they are of equal importance both elements get 50 points, if one is four times higher/more important with respect to another, the allocation will be 80 to 20 points etc.
3. The data is written into matrix A, through comparing column elements with row elements.
4. Matrix B is obtained by taking the ration of comparisons for each pair from Matrix A.
5. Matrix C is constructed through division of each element in a column of Matrix B by the element in the next column.
6. The values of the elements get normalized.

V. HDM MODEL

The hierarchical decision model consists of 5 levels. The first level is the mission of the study and is self-explanatory: health technology assessment (using HDM) for the purposes of designing and implementing a new patient care database for low back pain. Four goals in Table 3 below were outlined through talks with OHSU and literature review. The alternatives will be software choices, configurations/ selections, specific to the problem at hand, and not an objective of description in the current paper.

TABLE 3. STRATEGIC GOALS FOR THE PATIENT CARE (SPINE HEALTH) DATABASE AT OHSU.

On-line and mobile versions (Goal, improve questionnaire completion rates)
Develop intuitive GUI for administrators and surgeons (Goal, point-of-care decision making)
Develop interface with OHSU Electronic Health Record (EHR) (Goal, point-of-care decision making)
Correlate biometric technology (e.g., pedometer) with short-form 12-item survey (SF-12), Oswestry disability index (ODI), Patient-reported outcomes measurement information system (PROMIS) outcome measures.

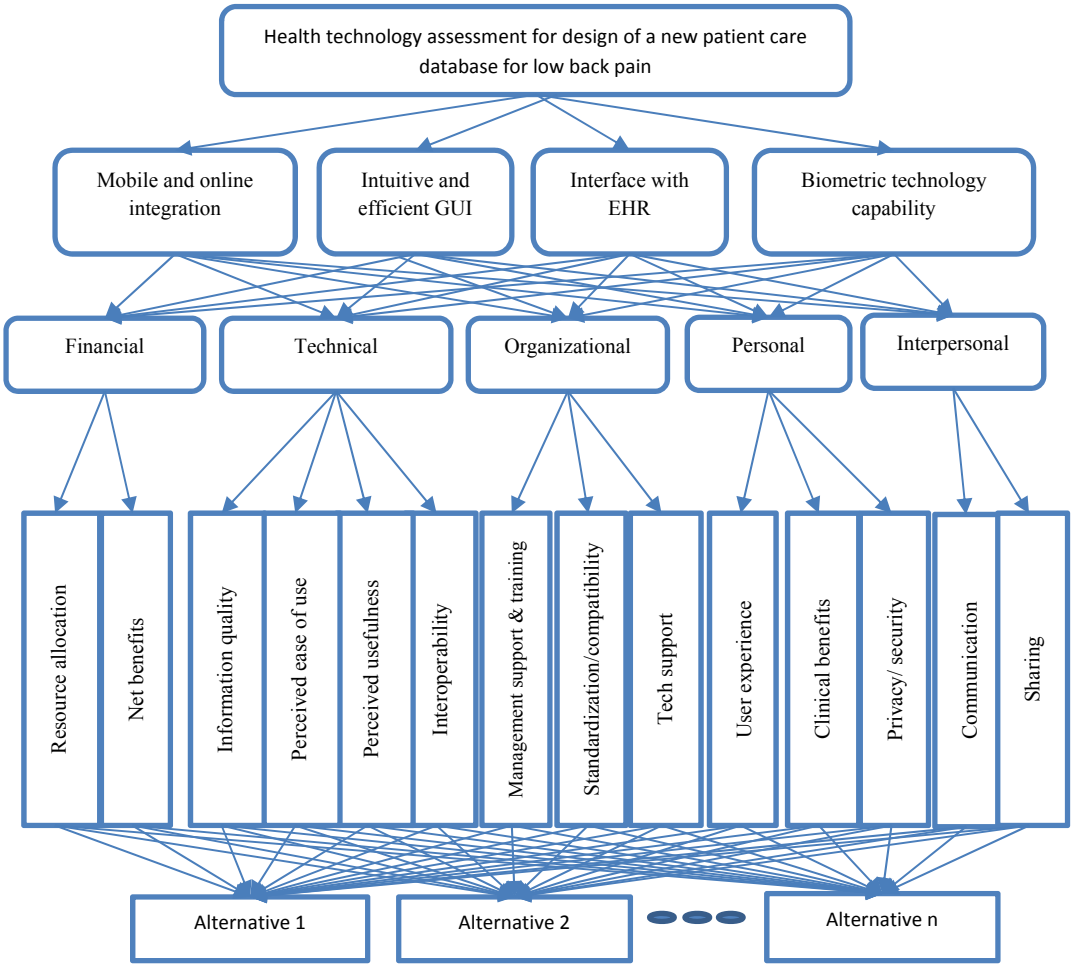

Fig. 1. Hierarchical Decision Model: new patient care database for low back pain

A. Mobile and online integration

Gurses and Xiao provided systematic review of literature on multidisciplinary rounds to design information technology [35]. According to their study, which was also illuminated by Cresswell and Sheikh, they suggest that the positive impact on communication and collaboration in hospital care could be achieved through a range of attributes of IT, particularly use of mobile technologies to increase flexibility, checklists and supporting informal communication. [13], [35]. Mendonça and a group of researchers, in their study on mobile information and communication for health care, noted that they anticipate hand-held wireless applications will improve patient care by reducing proximal causes of medical errors and other adverse events [36].

B. Intuitive and efficient Graphical User Interface (GUI)

Efficient and intuitive system is very important for the users in general, for example the time spent for the patient survey should be short enough, yet optimal enough to capture valuable information. Design of the GUI needs to be very user-friendly, not confusing, so the right information is captures. One group of researchers was very successful in interface design, because they were able to audit physician interactions with the clinical information system and analyze usage patterns and gain objective data about performance [37]. In a study of lessons learned from health information systems implementation in seven countries, the researchers outlined that systems GUI quality, feature functionality, project management , procurement and users' previous experience affect outcomes of IT implementation [38].

C. Interface with EHR

Increased emphasis on preventive measures and early detection of diseases, primary care, intermittent healthcare services and continuity of care is prevalent in our ever-changing healthcare domain [7]. Information and communication technologies are taking lead in this dynamic environment with the need for improved quality of healthcare services and costs control and movement towards shared and integrated care (integrated electronic health record – iEHR) [7]. The need for other software and particularly patient care systems to be able to seamlessly integrate with EHR system is a part of the coordinated care system. McGinn et al. note that inadequate interfacing with other IT systems was perceived as a barrier by users according to the literature review and in some cases led to negative outcomes [39].

D. Biometric Technology Capability

Smartphones gained sophistication over the years with an array of sensors either built into the phone, or with the capability to be affixed to the phone in order to collect biometric and other data about consumers or patients to support remote health monitoring [40]. In another example, researchers also stressed the needs of medical community of biometric systems for identification and authorization [41]. Having tested those systems based on fingerprints, hand morphology, facial structure, voiceprints and other contact and non-contact technologies, they have identified iris scanning as the most suitable technology meeting the healthcare community needs in identification and authorization category [41].

E. Multiple Perspectives Criteria and their Subcriteria

Five criteria were chosen based on the extensive literature review. The subcriteria of perceived usefulness and perceived ease of use, which will be discussed later in detail, are based on the elements of the Technology Acceptance Model [42]. Since the above-described research indicates that the acceptance of the technology is based on perceptions of users, those subcriteria criteria were included in the model. It is assumed that the software systems or their building components for review will have legal compliance. In further study those five criteria and their subcriteria will also be reviewed and justified by the experts in the field. Experts will be chosen from academia in the field of healthcare and healthcare management, and physicians.

A *financial criterion* is mentioned in the literature from rising costs of healthcare to high costs of systems implementation and management as well as loses from unsuccessful software applications. Some researchers indicated that facilitating conditions like financial rewards have been main factors to positively affect behavioral intention [43]. The conclusions from study by one group of researchers stated that financial position indeed relates to HIT adoption in mid-term and long-term planning [44]. *Resource allocation* is defined as capability to provide more focused and appropriate use of resources [7]. In one study on defining and measuring successful emergency care networks, the researchers conclude that there are large gaps in understanding and measuring effects of those networks on outcomes, what disease conditions to target and how to best allocate resources [45]. *Net benefits* subcriterion is defined as expected financial benefits from the patient care database. For example, those could be thought as financial benefits as a result of improvements and/or savings in cost, service, task performance, productivity, time, participation rates, error reduction, and accuracy of diagnoses [46].

While technical subcriteria are difficult to keep current, because of ever-changing capabilities of the system and the types and brands of software coming out on the market, we would ask the experts to closely examine the subcriteria and assess the additional technical aspects based on the selection of software. *Technical criterion* is mentioned extensively in the literature [7], [13], [47], [48], [49]. For the purposes of this evaluation *information quality* will be defined as ability of the software to capture information in accurate and qualitative manner. Information quality has been widely discussed in the literature as an important technical attribute of information systems [13], [47], [48], [49]. The concept of *ease of use* has been known from Davis's Technology Acceptance model and it is the user's perception of the extent to which using a particular system would be free of effort

[42], [50]. *Perceived usefulness* is "the degree to which individual believes that using a particular system would enhance his or her job performance" [42], [50]. The system should be able to function well with other applications in the network, local and shared. Alper and Olson note that *interoperability* is important to improve and coordinate care delivery [51]. While in the United States most patients receive care from several providers, a lack of interoperability in the network would mean that physicians do not have access to a complete record for a patient and a "master record" might not exist or might not be complete at any point in time [51].

In addition to the technical and financial aspects of patient care database selections, it is also important to consider *organizational aspect* that plays a crucial role in a decision-making process. Box et al. state that throughout health information technology implementation, success requires a careful balance of technical, clinical and organizational factors [52]. Cresswell and Sheikh dedicate an empirical and interpretative review study on organizational issues in HIT adoption and implementation [13]. With any new system, there will be some time for adjustment from an organizational point of view and some *training and management support* required. Some systems may require more or less training, and physicians need to be aware of those variables. The system must also fit the needs of the user; however, some users may require higher degree of *compatibility* due to specialization of the practice, certain procedures and particular processes in place, while others may not perceive it as such a deciding factor in software selection. Conforming to specific standards is an important issue and as various IT systems exists as well as various standards; some systems might be more standardized than others. McGinn and a group of researchers write about a lack of uniform standards at all levels (local, regional, national), which may contribute to physician's and manager's disorientation when choosing an IT system [39]. The availability of *tech support* is important in software selection, with some that may have straightforward, personalized system, or online-only system, or the vendor might not provide tech support. Depending on the IT infrastructure and the in-house capabilities, physicians need to carefully examine this aspect to decide how important tech support is for them and how much tech support they will require.

Some researchers articulate concern about IT systems infringing on physicians' personal and professional privacy and acting as management control mechanisms [39]. In one example, Boonstra and Broekhuis also discuss physician's *personal issues* about the questionable quality improvement associated with EHR and worry about a loss of professional autonomy [53]. Piliouras et al. note that some practitioners use personal references and place high reliance on the experiences of other practices to help them make decision on which package to select [54]. User experience refers to personal experience with the system, in our case patient-care database [55], and is described in the Clinical Information Systems Success Model and IT End-User Satisfaction Model [56]. Clinical benefits measures give opportunity to physicians to track, to report and review their notes, procedures, routines and diagnoses. *Clinical benefits sub-factor*, sometimes called patient-related benefits of HIT, is an important and measurable factor in healthcare [57]. This study is primarily focused on spine health and improvement in patients with low back pain. The necessity of one or several clinical benefits measures will be further studied through engagement of healthcare expert panels. *Privacy concerns* have been some of the well noted issues for physicians while choosing a software system [58], [59].

Interpersonal criterion has some elements of social, organizational and personal dynamics [13]. The importance of *sharing and communication* among various levels in the organization and outside (doctor-patient) and the ability of EHR software to provide that capability and perhaps improve the communication and important flow of information should be considered during the software system selection process. Interpersonal issues have been discussed in the research literature [22], [48], [49].

VI. CONCLUSIONS, EXPECTATIONS AND FUTURE STUDIES

Developed HDM model for patient care database for low back pain will be further implemented at OHSU, which will give us the opportunity to learn which criteria and subcriteria matter most in health information technology design and implementation. It would be interesting to see whether financial and personal aspects will dominate in expert opinions across the main strategic goals. Healthcare industry is very concerned about clinical benefits, however, the realization that those are difficult to achieve without good user experience, especially in hospital settings, is apparent. With mobile applications overwhelming the market and becoming more common for everyday use, healthcare industry will be more involved, hoping for more involvement from the patients and better clinical results and use from the doctors. This project will enable healthcare professionals to look at the problem from multiple perspectives. Looking from the top-down view, learning which factors are significant may lead to better incentives and programs for clinicians and help overcome certain barriers in their information technology implementations. The four strategic goals may be impacted by criteria in different ways, which may be an important facet of this research and can help healthcare decision-makers in prioritization of their resources in solving problems of technology acquisition and evaluation. The model should provide a tool for decision-makers in patient-care software selections, potentially improve clinician satisfaction with IT and aid in betterment of quality of care.

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