Large-scale eHealth Systems:

Providing Information to Support Evidence-based Management

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***Abstract*—This article describes lessons from a large scale eHealth system implementation in Finland from the viewpoint of evidence-based management. All European Union member states have a documented policy on eHealth. A quick literature review showed that documented evidence-based management strategies for large-scale eHealth system implementation are rare. The Finnish framework for providing formative and summative evidence for the national eHealth system implementation was generated guided by some other large scale IS assessment frameworks, especially the Canadian approach. First results of the framework's implementation for collecting baseline data are presented together with a plan to use the data for decision making in the national eHealth system development. The main outputs of the paper are 1) the categories of evidence collected in Finland to support decisions in the national eHealth system implementation and follow-up, 2) demonstration of use of these categories in providing results from the baseline situation.**

Keywords - Medical informatics; eHealth Policy; electronic patient record system;, evidence based management; evaluation

I. INTRODUCTION

Evidence-based management (EBMgt) is an emerging management strategy, where the current, best evidence is sought for management decision-making. In evidence-based medicine (EBM) the idea is defined as: *"The conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients" [1]*. This definition has been modified for management by leaving the object of decision open. The idea of EBMgt is relevant particularly to large and complex systems like the national health systems [2].

We argue that a National Health Information System (NHIS) is also a complex system in itself. The Finnish NHIS with its elements and network of actors has been described elsewhere [3-4]. Legacy systems and regional systems with interfaces to the national archive and prescription database form an important element in the NHIS. The core system consists of a comprehensive electronic patient records including narrative text as well as summary and administrative data. This is augmented with integrated picture archiving and communicating systems (PACS) and electronic laboratory systems. Even though registry keepers are legally separate entities, patient data is shared on a secure manner with electronic referral and discharge letters and regional databases. Already today, much of this data is available regionally, and shared between primary and secondary care electronically following the care chain of the patient [5, 10-13]. Added with a national archive, ePresciption and eViewing system to be implemented by 2015, the NHIS fits well with characteristics of complex systems with many interconnected human and non-human components, which may interact unpredictably. It has a structure, defined by parts and their composition, behavior, which involves inputs, processing and outputs of material, energy and information (or data). It also has interconnectivity: the various parts of a system have functional as well as structural relationships between each other. Change in one of the components can have an impact on some or most of the other elements.

The evolving Health Care Information and Communication Technology Systems (eHealth Systems) need to project the features of evolving health care delivery systems. For example in Finland new legislation on health care service contents and organizational structures is being issued during the NHIS development. Decisions regarding the development of one complex system (NHIS) and its integrating in order to function as part of another evolving complex system (the National Health System) would undoubtedly benefit from current evidence.

Section II describes the state of the art of EBMgt in the context of NHIS implementation, shortcomings of it and how this study aims to contribute to EBMgt in NHIS implementation. Section III describes the materials and methods used in this study. Section IV elaborates the previously published assessment framework by defining data dimensions, categories and measures used in baseline data collection, as well as first results of the baseline

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situation from the viewpoint of one of the key actor groups: the doctors. Section V discusses use of the results, their shortcomings and future work needed.

II. STATE OF THE ART IN NHIS EBMGT

In European countries there has been considerable progress in both eHealth policy and deployment in the past years. By the end of 2006, 25 of the 27 European Union (EU) Member States and the four other European countries represented in the i2010 Subgroup on eHealth had a documented policy on eHealth [6]. In relation to the vigorous development of eHealth programs in different countries, national follow up and evaluation policies of these programs have emerged slowly [7].

The idea of basing decisions on evidence is embedded e.g., in the framework of health technology assessment (HTA). National HTA programs review and advice on adoption of new health care interventions. Telemedicine interventions have been assessed in this context, but complex national scale information systems are basically beyond the scope of (traditional) HTA focusing on single technologies.

In Finland, a national framework was constructed in 2009 for providing national level information to support implementation of the NHIS and monitor its success [3-4], with review of HTA information categories [8]. A quick literature review was conducted as part of the work in early 2009, where UK, Canada and Australia were found to have documented national evaluation frameworks, which were included in the review. Most EU Member States are now becoming aware that there is an urgent need for (continuous) evaluation activities, both to better control policy progress and learn from challenges and experiences [9], but documented comprehensive frameworks defining the needed information for EBMgt in different stages of NHIS implementation are still few.

The study questions are: 1) What kind of information is needed for EBMgt and monitoring success of NHIS? 2) What results can be obtained by collecting this information by a nation-wide questionnaire? 3) How can the results be used for concrete EBMgt of NHIS implementation?

III. MATERIALS AND METHODS

The materials and methods for creating an overall evaluation framework have been published elsewhere [3-4]. One set of data within it - diffusion and use of eHealth systems - has been collected in Finland three times [5, 10-13]. The study does not cover other aspects of system success defined in the overall framework. A complementary dataset was compiled in collaboration with the Finnish Medical Association, National Institute for Health and Welfare (THL), Aalto University (Usability experts) and University of Oulu/ FinnTelemedicum (impact assessment experts) using conceptual models described in Section IV. The first data collection was targeted at baseline prior to NHIS implementation focusing on the viewpoint of doctors. An electronic survey method with 5-point Likert scale questions was used. For the results, points 1-2 were combined to form category 'disagree', and 4-5 to category 'agree'. The Web-survey, conducted in early 2010, was targeted to all 14 411 doctors of working age in the Finnish Medical Association register, actively engaged in clinical work. Responses were received from 3 929 doctors. Respondents' age, gender and working sector distribution were compared to those of the target group. Women responded slightly more actively than men, younger slightly less than older. Distributions of working sector were identical. The respondents were thus regarded as forming a representative sample of the target group [14].

The respondents were asked to reply to questions from the viewpoint of the system they mainly use and the context where they mostly work. In the initial analysis, data categories defining the organization type (public inpatient vs. outpatient) and the legacy systems used were regarded as the first background variables against which the system success was viewed. The first results including cross tabulations depicting co-variation between the system success variables and varying legacy systems used in different contexts have been published in the Finnish Medical Journal [14, 15].

The 're-conceptualization' of the questions was needed to detect possibilities for creating sum variables as well as identifying categories, which require the collection of stronger evidence. It also helps in defining such indicators, which can be used to monitor (NH)IS success in a context and to detect interactions between the social and technical system elements. Two researchers first individually grouped the questions with the framework elements. An agreement was gained in a joint meeting, after which comments from others from the team were searched.

IV. RESULTS

Two main results are described in this section: Subsection A depicts the dimensions, categories and measures of evidence of NHIS success. Subsection B depicts the deployment of them in a national level questionnaire and consequent results.

A. Combining three models for definition of assessment dimensions, categories and measures

Complex systems are composed of many interconnected elements. The concept of network was thus used as a general concept depicting the entity of NHIS. Nodes of the network have been conceptualized with help of a *model of an activity system* used in activity-theoretical analyses of information systems, especially in the field of Computer Supported Cooperative Work (CSCW). Karasti et al. have investigated collaborative work in a telemedicine setting and noticed that molding two different organizations together with health ICT tools requires rethinking of the attributes that support actual patient work [16, 17]. Actor network theory and activity theory have been used as theoretical

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basis for a conceptual framework in assessment of the contexts of IS use and co-construction of social and technical systems [e.g., 18]. The framework sees the evolving NHIS elements as tools for the evolving social system (the National Health System). Inherent in the model of an activity system is its open nature and evolvement.

Model of an activity system as a node in the network depicts the elements of the context of NHIS use, and their interaction. With the help of the model, the contextual variables depicting the health care system - as well as those interrelated systems that provide e.g., norms for the health care activity - can be grouped into the following dimensions and categories:

- (network of) health care service users, providers and regulators (affected activity systems, nodes of network)
- Activity system (node of the network) consisting of:
  - inputs: actors (user characteristics), tools and resources, rules, environment, objects->objectives,
  - processes: combining the inputs, division of work
  - outcomes => impacts

Dimensions of *the IS system success model* [19, 20] fit within the model of activity system, helping to focus on the quality of the Information Systems as tools for an activity system (care providing organization). The elements of the model are:

- System quality
- Information quality
- Service quality
- Use
- User satisfaction
- Net benefits: quality, access, productivity

Dimension 'use' is an attribute of the activity system element 'processes'. Dimension of 'net benefits' is an attribute of 'outcomes' of the activity system that can be impacted by the NHIS. For defining these, the impact mechanisms of each element of the NHIS need to be known.

These dimensions and data categories were used to provide questions regarding the (baseline) NHIS success in context, against which post-implementation situation can be compared. They also help specifying the needs for development as problems detected in certain categories of the data. The elements in the two models thus provide data for both monitoring the NHIS success (summative evaluation) as well as for learning for the development.

The *model for human-centered design of interactive systems* [21] depicts phases of developing new tools for the activity system. The model has consequent elements interacting in iterative cycles that can be used as checkpoints for collecting evidence for management of the development (learning and system development):

- The plan and management of the HCD process
- Understanding & specification of the context of use
- Specification of the stakeholder and organizational requirements
- Producing design solutions to meet requirements
- Evaluation of designs against requirements (iterating with previous phase where appropriate)
- Introducing the system that meets user requirements

'Understanding the context of use' and 'specification of the stakeholder and organizational requirements' refer to information produced in the Activity and IS success models.

The original IS system success model has been criticized for not taking into account contextual and business process-aspects [22]. Suggestions to add contextual elements have included addition of meso-level categories of 'people', 'organization' and 'implementation' and macro-level categories of 'standards', 'legislation, policy and governance', 'funding' and 'societal, political and economic trends' [23]. The Finnish framework contains macro-level elements as interrelations between the activity systems in the network (e.g., norm- or funds-providers and health care providers) and meso-level categories within each activity system. The added value of the theory-based conceptual model used in the Finnish framework is depicting the inter-relations of the contextual elements on macro-, meso- and micro-level and IS system elements. It sets the IS system as part of this socio-technical system as a whole. The detailed categories and measures for context and success variables are presented in Table II in annex 1.

B. NHIS success (Baseline): doctors' views

There were 919 replies from public outpatient units/ health centers. 63 % of respondents were women, 37 % men. Average age was 48 years (from 24 to 64 yrs). Almost half of the respondents (48 %) were from units using system 'A' as the legacy system. Over third used system 'B' (39 %), 5 % used system 'C', and 5% used system 'D' (5 %). The rest used several other systems. Three out of four respondents had over 3 years experience in using the respective legacy system, and only 3% were novice users (less than 6 mths experience). [14]

Big differences in the baseline situation were detected between the two contexts (public sector outpatient units and hospitals) [14-15]. Results of the private sector have not yet been processed. Table I presents results within public outpatient units. There are differences between IS success variables as well as legacy systems used. Some of the IS system quality variables got poor scores from users of all systems, e.g., response time and IS compatibility, some better (e.g., error rate). Availability of radiology results and content of laboratory results (information quality variables) scored relatively well across legacy systems, availability of patient information from other organizations, including medication information and summary view got poor scores. IS system support for collaboration between workers within organizations scored better than collaboration between organizations (outcome variables). Major differences between the legacy systems were identified in ease of use, decision support systems, content of nursing record, medication list, prevention of medication errors and help in achieving health outcomes.

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TABLE I. CO-VARIATION BETWEEN IS SUCCESS VARIABLES AND LEGACY SYSTEMS USED IN PUBLIC HEALTH CENTRES: BASELINE SITUATION [15]. RED =VERY STRONG (≥ 75 % OF RESPONDENTS), PINK = RELATIVELY STRONG (50 - 74 % OF RESPONDENTS) AGREEMENT OF A PROBLEM. LIGHT GREEN = RELATIVELY STRONG (50 – 74 % OF RESPONDENTS), DARK GREEN = VERY STRONG (≥ 75 % RESPONDENTS) AGREEMENT OF SUCCESS. ALL DIFFERENCES ARE STATISTICALLY SIGNIFICANT (P<0,05)

Information system				A'		B'		C'		D'	
Dimension	Category	Measure	N	Disagree %	Agree %	Disagree %	Agree %	Disagree %	Agree %	Disagree %	Agree %
System quality	Stability [31] Reliability [32][34][17]	The information system I use as a tool in my work are reliable and stable	914	34	55	38	49	18	66	11	77
	Response time [31][34][17] Efficient to use [32]	The information system has a fast reaction time	912	25	58	56	28	22	62	16	77
		Compilation of statistics takes too much time	903	25	58	16	67	24	56	13	60
	Ease of use [31][17]	Fields and functions in windows are logically placed	907	22	60	60	20	30	54	33	62
		Searching, documenting, checking and editing patient information is easy	913	41	36	70	15	46	48	45	36
		The information system tells me clearly what is going on and the outcome (e.g. saving of data)	914	25	55	49	30	38	40	32	45
		Terminology (e.g. headings) is clear and understandable	910	17	65	42	39	14	57	30	61
		The system process model is stiff and does not fit to my work process.	908	29	49	10	76	36	42	24	57
		Performing routine tasks is simple and can be done without too many 'clicks'.	915	39	47	71	16	26	64	32	55
	Easy to learn [32][17]	Information system use logic is easy to learn	914	12	74	56	28	16	60	18	66
		Use of the system does not require long training	915	29	50	62	17	30	46	27	48
	System errors[31] Few errors [32] Error rate [17]	Documented data disappears sometimes from the system	912	51	29	53	26	58	28	51	23
	Compatibility [32] Integration of systems [17]	It takes too long time to sign in to use the systems	912	20	66	10	81	24	62	2	91
	Type of features and level of decision support [34] Usefulness of specific functions, DSS [17]	The systems offer enough reminders, warnings and other decision support.	906	46	30	46	26	30	42	73	9
		Usefulness of specific functions		Functions listed in questionnaire, respondents selected best and worst functioning							
Service quality	Responsiveness [34], User training, technical support [34]	I get enough help in problems related to Information systems use	912	23	55	34	44	28	66	16	63
		Big portion of my working time is spent solving the problems with information technology	911	40	33	27	48	56	24	30	52
Information quality	Availability [33], Accessibility (distance, availability)[34][17]	Radiology results are easily available	907	28	63	34	52	24	53	28	56
		Information about medication prescribed in other organizations is easily available	902	83	6	92	4	86	8	86	7
		Accessing patient information from other organizations takes too much time	905	22	67	12	82	14	84	16	82
	Content quality [33], Completeness, accuracy, relevance, comprehension, consistency [34][17], precision, currency, timeliness, reliability, completeness, format [17]	Laboratory results are presented in a logical format	908	22	66	20	66	36	54	34	57
		Patient data (also from other organizations) is comprehensive, timely and reliable	901	40	37	59	19	52	28	50	20
		Information system provides a summary view about the situation of the patient	559	70	15	82	8	50	32	60	27
		Nursing record content is easy to read	888	39	43	63	24	38	44	48	41
		Patient's medication list is clearly presented	897	58	27	57	28	42	52	35	49
User satisfaction	Satisfaction [34]	School grade given to the Information system (scale: 4-10), relative amount of A's (9-10 = excellent) and D's (4-5 = poor)		7,1		6,2		6,9		6,9	
Use	System usage	Frequency, duration, location, type and flexibility of usage [34]		Measured in a separate survey							
Net benefits/ outcomes	Productivity: Efficiency of care (resource utilization, output improvements, management improvements, effects on patient flow [34]	The Information systems help reduce duplicate tests.	911	50	37	49	38	37	47	57	32
	Quality of care [34]: Appropriateness effectiveness (Adherence to guidelines, continuity of care [34] Heath outcomes [34]	Information systems help to achieve continuity of care	914	26	49	31	43	28	48	32	43
		Information systems help improve health outcomes	910	25	40	34	32	22	54	30	48
	Quality of care [34]: Patient safety (preventable adverse events, near errors, reduction in patient risks)[34]	The system has caused or nearly caused a serious adverse event to a patient	902	45	25	39	32	48	30	31	36
		The Information systems help prevent medication errors	905	39	44	32	48	25	67	70	18
	Care coordination (doctor-nurses) [34]	The system monitors reception of orders I have given to nurses.	533	81	5	74	4	63	13	79	8
		System supports flow of information between doctors and nurses	908	17	62	25	50	14	66	23	56
	Care coordination (doctor-doctor within organisation) [34]	System supports flow of information between doctors in same organisation	916	10	75	19	63	14	74	11	73
	Care coordination (doctor-doctor between organizations [34]	System supports flow of information between doctors in different organizations	910	62	19	78	8	60	20	77	14
	Care coordination (doctor-patients) [34]	System supports flow of information between doctors and patients	897	59	10	61	7	58	12	62	5
	Patient-centeredness of care	The information systems use requires too much attention away from the patient	913	24	62	14	73	36	52	18	77
	Support for development of own work[31]	The information systems support development of my work	906	46	25	65	13	37	37	49	23

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V. CONCLUSIONS

The study offers for the first time a nationwide snapshot of success of the IS tools for patient care. The results show that the view of the doctors is relatively critical. The IS systems are regarded too slow, partly unreliable, not offering the type of information (e.g., summaries) needed, and they may even create patient safety problems. Similar results have been received from other studies [8, 24-27]. User experiences need to be better incorporated into IS development [8]. Results like the urgent need for summary data, comprehensive medication list and easier access to patient information across organizations can directly be used when making strategic decisions about trade-offs in NHIS implementation. The differences between legacy systems provide important benchmarking data for the vendors.

Establishment of an operational steering unit for NHIS development and implementation within THL in the beginning of 2011 paves way for integration of the evaluation framework as part of the EBMgt strategy of the NHIS implementation. The unit will use results of the study as one means in setting priorities for action.

There are several limitations in the study in respect of evidence required from the baseline situation for NHIS development, which need further work or consideration. ICT support needed by physicians' out-patient consultations is used as an example for the model use. Other set ups are needed for identifying critical elements in different processes such as chronic care or surgical theaters or emergency care settings.

Legacy systems form only one element in a complex NHIS, and doctors are only one user group impacted by the implementation of the NHIS. Reply rate (27%) was low even though sample was representative. The proportion of neutral ('3') responses was not reported.

Questionnaire-based studies offer a relatively comprehensive but shallow view to the phenomenon studied. Even though doctors were involved in formulating the questions, the method is prone to different interpretations of questions, and complementary methods are required for more detailed information on issues that are identified in a survey. Analysis of the data needs to be continued by comparisons between contexts as well as co-variation of different contextual variables with the success factors.

Further research is also needed regarding formulation of the measures in order to capture the potential impacts in varying clinical processes in a language that is meaningful to the doctors and at the same time true to the framework. The 24 questions used in the Canadian framework [22] were not regarded sufficient to reflect the different impact mechanisms of different elements in the NHIS for doctor consultations, where the clinical work processes were taken as the starting point for the questionnaire (to speak the doctors' language).

Re-conceptualization of the questions revealed several variables, which could be used to create sum variables. There are also variables, for which there is data available in national level statistics (especially for actor- and patient- as well as outcome-variables). Further research is required to achieve the long term aim of condensing the data and combining it to such indicators, which can be used to monitor (NH)IS success in varying contexts and processes and to detect interactions between the elements of social and technical systems.

Variation of the elements and conceptual frameworks in international studies makes it difficult to sum up previous experiences [28]. According to literature reviews [e.g., 29] many theoretical models exist for measuring IS success, and most of the studies only employ a subset of proposed dimensions, the relevance of which is still debated [30]. The indicator work that has started in Finland would greatly benefit from at least some level of international agreement on the 'minimum data set' for (NH)IS success and contextual variables in order to collect data that can be used also for international comparisons, as suggested in Medinfo 2010 panel on 'Monitoring the effects of health information systems' by the Danish, Canadian and Norwegian colleagues.

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TABLE II. DIMENSIONS, CATEGORIES AND MEASURES FOR IS SUCCESS IN CONTEXT. THE DARK FRAME DEPICTS THE IS SUCCESS MODEL DIMENSIONS AND MEASURES (DETERMINANTS OF THE IS SYSTEM) AS A TOOL WITHIN THE CONTEXT - THE SOCIOTECHNICAL SYSTEM - DIMENSIONS AND MEASURES (DETERMINANTS OF THE HEALTH CARE SYSTEM)

Dimension	Category	Suggested measure	Questions in questionnaire
Network of affected activity systems	Organizations, stakeholders	Network analysis with Organizational/ stakeholder characteristics	-
		Roles of and division of work of different organizations/ activity systems in the use network of (NH)IS	-
Activity system (organizations as "nodes" in the network)	Objects and objectives of activity system	*From the viewpoint of health care providing systems: The diagnosis related groups treated, short and long term objectives targeted*	*(from statistics)*
	Actors	Affected professional groups, client groups within each activity system, where NHIS is implemented: Age, gender, education, attitude towards information technology, experience with patient information system use	Age, gender, specialty, phase of residency, title, IS attitudes (3q:s), IS experience (3 q:s)
	Rules	Written and non-written "codes of conducts", norms, rules, strategies in relation to IS use	-
	Organization	The determinants of the physical environment of respondents that can impact (NH)IS adoption (including type of patients, occupancy rate, Diagnosis Related Groups (DRG) weight)	Hospital district, sector (public/private), type of unit (tertiary-secondary-primary inpatient/outpatient)
		Organizational culture	Decision making (7 q:s) participation possibilities (3 q.s), stress (3 q:s)
	Tools	Existing (health information processing) tools that actors have at their disposal to work towards the objectives (legacy systems, regional health information systems)	IS tools in use (4 q:s)
		Information system quality	Functionalities (5 q:s), reliability, response time, interoperability, errors, learnability, ease of use, flexibility
		Information quality	Content quality (5 q:s), availability (3 q:s)
		Service quality (For support for old tools and implementation of new ones)	Support (7 q:s)
		User satisfaction	Grade given to system
	Processes	*Use of (NH)IS tools*	*(monitored with a separate eHealth survey)*
		Key processes and tasks where tools are used, division of work between actors involved in different process phases	*(monitored with a separate eHealth survey)*
	Outcomes, impacts, net benefits	Measured outcomes and activity system impacts on quality, access and productivity (input, process, output, outcome quality and amount in relation to inputs**	Productivity, care coordination (3 q:s), care quality (appropriateness, safety, participation (2 q:s)), continuity, work development
Human-centred IS development	Actor participation	Willingness, role and participation of actor groups in development/ implementation/ of new IS	Willingness (3 q:s), Feedback (6 q:s), participation modes (4 q:s

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