Towards Sustainability of Health Information Systems: How Can We Define, Measure and Achieve It?

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Abstract

Health information systems (HIS) in their current form are rarely sustainable. In order to sustain our health information systems and with it our health systems, we need to focus on defining and maintaining sustainable Health Information System building blocks or components. These components need to be easily updatable when clinical knowledge (or anything else) changes, easily adaptable when business requirements or processes change, and easily exchangeable when technology advances. One major prerequisite for this is that we need to be able to define and measure sustainability, so that it can become one of the major business drivers in HIS development. Therefore, this paper analyses general definitions and indicators for sustainability, and analyses their applicability to HIS. We find that general 'Emergy analysis' is one possibility to measure sustainability for HIS. Based on this, we investigate major enablers and inhibitors to sustainability in a high-level framework consisting of four pillars: clinical, technical, socio-technical, and political/business.

Keywords:

Health Information Systems, Electronic Health Records, Sustainability, *open*EHR, Computerized Medical Record Systems

Introduction

Information, knowledge management and communication technologies are crucial enablers of system change that can play a vital role in substantially transforming healthcare systems and prevent their failureT[1]. From this perspective, we argue further that the sustainability of our health systems depends largely on the sustainability of our Health Information Systems (HIS).

The past few years have seen a myriad of developments and deployments of HIS. Some have very limited focus, other operate on a regional scale, and a few initiatives are underway to establish nationwide HIS, for example in the form of Shared Electronic Health Record (EHR) Systems. The World Health Organisation (WHO) requests international collaboration [1] - good examples include the *open*EHR (http://www.openEHR.org), HL7 (http://www.hl7.org), and the joint Detailed Clinical Models (DCM, http://detailedclinicalmodels.org) initiatives.

With patients being increasingly mobile and treatments and health care providers increasingly specialized, interoperability of HIS has become critical for sustaining current processes. Patient data can be relevant for over 100 years, thus sustainability of patient data is critically important. Not only will sustainability and interoperability save money, we also expect a significant positive clinical impact (cp. e.g. [2]).

While defining HIS failure and success is complex, and current evidence on HIS success and failure rates is insufficient, the "*best current estimate is that HIS failure is an important problem*" [3]. If current customs prevail, very few of these systems will be sustainable, let alone semantically interoperable, costing lives and money. According to Haux, a lot of research and application is necessary to further develop and investigate HIS architectures and infrastructures, in order to identify sustainable approaches [4]. In this context, the aim of this paper is to

- Review general definitions and measurements of sustainability
- Analyse their applicability to HIS
- Investigate major inhibitors and enablers of sustainability in a high-level framework for building sustainable HIS. In this framework, we will relate to the *open*EHR architecture as one candidate for an approach to sustainable development of HIS.

[1] Cp. Medinfo 2007 Call for Papers.

Materials and Methods

We conducted a literature review on 'sustainability', a summary of which is presented in this paper. In addition to being heavily involved in many of the following, we reviewed the literature and web resources available on socio-technical issues, Electronic Health Records (EHR), failures of Health Information Systems, recent reports from national EHR initiatives, *open*EHR (http://www.openEHR.org, [5]) as an advanced architecture for EHRs and interoperability, Interoperability Frameworks like the one provided by NEHTA [6], and initiatives like the Detailed Clinical Models initiative.

The enabling/inhibiting pillars for sustainability described in in the second part of this paper are derived from common threads found in the Health Informatics literature on successful and failed systems implementations as well as own experiences. These pillars are related to the structure of Interoperability Frameworks like [6].

Results

Definition and Metrics for Sustainability

It is believed that the word *sustainability* (German: *Nachhaltigkeit*) was used for the first time in 1712 by the German forester and scientist Hans Carl von Gilinscee in his book *Sylvicultura Oeconomica* [7]. While according to the Canadian *Sustainability Now* initiative more than 300 definitions of sustainability exist (http://www.sustainability.ca), the probably best-known definition stems from the World Council on Environment and Development [8]. It defines sustainable development as that which "*...meets the needs of the present without compromising the ability of future generations to meet their own needs*". From the authors' perspective, the simplest, most generic and compelling definition is found on Wikipedia: "*Sustainability: the ability to continue a defined behavior indefinitely".* However, this simplicity is spoilt, once more specific definitions are required – given that the "the term itself is being applied to so wide a range of issues that it can no longer retain only a single meaning" [9]. If this is the case, how do we know that we have achieved sustainability? In 2003, Maine brought attention to this lack of quantitative indicators of sustainability [9] and a decade earlier the International Institute for Environment and Development ([10], p.2) had already concluded that "*the need for sustainability analysis and particularly for indicators of sustainability is a key requirement to implement and monitor the development of national sustainable development plans [...]*".

To quantify sustainability, Maine suggests "*narrowing the use of the term strictly to physical processes, for this appears the only way to achieve the establishment of a secure and robust metric of sustainability [...]*" [9]. Consequently, he argues for a "*rigorous metric of sustainability derived from basic scientific principles, and avoiding the application of the term to sociological issues such as the longevity of an organization or society.*" He proposes the energy of reclamation of all outputs of anthropogenic (=derived from human activities) processes as a metric for sustainability. An important attribute any system requires to be sustainable would then be the minimal production of 'waste' or "*the amount of energy that is NOT used to reclaim waste*" [9].

A series of sustainability indicators is based on 'emergy synthesis' as introduced by Odum in [11]. Emergy (with 'm', not 'n') is an abbreviation of the term "embodied energy". Without going into complex mathematical definitions of emergy, it shall be said that emergy expresses the cost of a process or a product in solar energy equivalents, which is regarded as the ultimate energy source. Odum's innovation established a medium for environmental accounting that for the first time made it possible to express economic commodities, services, and environmental work of all kinds on a common basis as emergy [12]. In other words, by expressing the value of products in emergy units (*emjoule*), it becomes possible to compare 'apples and pears' [13].

Once the total number of input flows into a system has been identified and based on this the total emergy driving a process has been evaluated, a set of indicators can be calculated to illuminate different aspects of sustainability as the following important indicator developed by Brown and Ulgiati ([14]):

$$Sustainability\,Index = \frac{Emergy\,Yield\,Ratio}{Environmental\,Loading\,Ratio} = \frac{\frac{Y}{F}}{\frac{N+F}{R}} \qquad (1)$$

This index is also called the "Emergy Sustainability Index" (ESI). The *Emergy Yield Ratio* is defined as the ratio of the emergy of the output of the system (Y) and the emergy of purchased services and resources that are input to the system (F). *Emergy Loading Ratio* is defined as the sum of the emergy of local non-renewable sources (N) and purchased resources/services (F) divided by the emergy of the free environmental emergy available from local renewable sources (R).

More recently a joint initiative of Yale and Columbia University, in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission constructed an Environmental Sustainability Index (also called ESI, http://sedac.ciesin.columbia.edu/es/esi/index.html) and compared it to other sustainability indicators such as the Ecological Footprint Index measuring the area of productive land and water appropriated exclusively to produce the resource used and to assimilate the waste generated [15]. Zhao and colleagues further introduce a modified form of ecological footprint calculation by combining emergy analysis with conventional ecological footprint analysis [15].

Sustainability in Health and Health Information Systems

Given the long history of sustainability reaching back into the 18th century, it is astonishing that there are no agreed definitions for sustainability of health systems or health information systems – clearly the generic definitions are not sufficient for any measurement and the more specific definitions and indicators of sustainability are not applicable without restrictions to the area of health. Nonetheless we often argue that our health systems are not sustainable as for example Enrico Coiera in a recent paper: "*The health system at present is one that consumes enormous resource, and generates enormous waste, and **would not meet any criterion of sustainability**. Injecting new interventions from 'outside' the system, as we currently do in health informatics, is itself not a sustainable approach, as the capacity for external designers to meet all the evolving needs of those inside will just never be there*" [16]. Thus, intuitively we know that our health information system infrastructure as a whole is not sustainable – however we cannot measure it and thus are not able to take systematic corrective action.

In measuring sustainability of a health information infrastructure, we believe that in analogy to environmental sustainability, it is necessary to 'compare apples and pears' and thus have a common unit like emergy that achieves this for us. In essence, we need to consider what the inputs and outputs and storages of the system under investigation are. We then need to analyse - similar to environmental emergy analysis - which parts are renewable or non-renewable or used non-renewably. Where previously unknown (because no previous studies exist), we need to determine what factors we can use to convert these inputs and outputs into emergy units as detailed by Odum in [11]. Once we have achieved this, all the environmental sustainability indicators that are based on emergy can be applied to health information systems as well. For a given system, we need to identify and analyse the inputs, outputs and stored resources of the system according to Table 1. Other indicators like the ecological footprint seem to be less applicable for HIS.

Table 1: Analyis of items that are input or output of the system or are stored within the system.

Item	Input/output of the system and any items that stored within it. Some items are the same as typically used for environmental emergy analysis, but others differ.
Data	Raw data measured in joules, grams, dollars or any other appropriate unit.
Solar Emergy per Unit	Factor to transform the data into solar emergy.
Solar Emergy	Calculated: Data x Solar Emergy per Unit

In contrast to environmental sustainability, the differences between renewable and non-renewable sources however are not always that explicit - e.g. the labour of skilled workers are not always simply renewable – but can be very hard to come by. However, proper training/education programs can make a difference in the long run. For environmental sustainability these resources would be classified as 'used non-renewably' without further distinction [12]. For the analysis of HIS infrastructures, this may not be sufficient and we are currently investigating the use of a 'renewability factor' to rectify this.

Inputs, Outputs, Storages for Health Information Systems and Inhibitors for their Sustainability

In the following, we investigate these aspects – and especially the enablers and inhibitors for sustainable Health information systems in a high-level framework based on four pillars (each consisting of several high-level building blocks):

- clinical,
- technical,
- socio-technical,
- political & business.

These pillars are related to the structure of Interoperability Frameworks like [6]. Our framework is intended to 'get it right' on a high-level, not about providing all the details – as these details are (with a few exceptions mentioned in the following) relatively well researched.

Some of the inputs and outputs identified are similar to those investigated for environmental sustainability, however some are quite different. This is largely due to the fact that knowledge of various kinds can be seen as one of the most precious resources for us. Table 2 summarises some of the inputs, outputs, and stored items typical for a health information infrastructure, which are untypical from an environmental sustainability point of view and identifies typical inhibitors for sustainability with regard to each item.

PILLAR 1: Clinical Building Blocks

The clinically most important building block for a clinical system is the agreement on clinical content. This fosters semantic interoperability between systems and provides clear meaning – so that we can exchange and migrate data between different systems and support clinical decision making. This clinical domain knowledge needs to be managed and maintained – a complicated task that eventually has become feasible ([5]), although it will always remain difficult on a national or international scale to reach agreement. The separation of technical and clinical concern through *open*EHR's two-level-modelling paradigm seems to be well suited to enable this because it clearly separates clinical content definition from technical concerns.

We suggest the development and international use of a repository of clinical content models that are freely available so that 'flexible standardisation' of this content can occur[2]. For example, *open*EHR archetypes are particularly well suited to serve as a standard form for these clinical content models because archetypes are intuitive to clinicians, but also formal specifications of clinical content technicians can work with.

PILLAR 2: Technical Building Blocks

The technology chosen must be able to cope with the constant changes of health care and health care knowledge without having to change enormous amount of source code (and wait for the vendor to implement it). It must provide the technical basis for semantic interoperability and sustainability. This is not only important because of more and more specialised providers and more and more mobile patients, it also enables the

[2] See http://www.archetypes.com.au for the Archetype Finder, which is designed to support this task as well as the open source Java implementations of openEHR at http://www.openehr.org, developed by some of the authors of this paper.

migration of systems without losing considerable amounts of patient data, thus also avoiding vendor lock-in.

To achieve semantic interoperability, "*[y]ou need the ontology, the information model and services. [..] If you have one and don't have the others, it won't help*" [17]. It is the author's view that ontology and services are relatively well understood – the information model however is largely ignored. This is where an approach like the *open*EHR approach, which is based on a stable and generic information model is of major importance. This works similar to the Java programming language, which decouples itself from the operating system by translating the Java source code to Java bytecode. This code is then run on a native Java virtual machine – thus enabling portability. In a similar way, the *open*EHR two-levelling modelling decouples the technical knowledge (the information model of the software) from the clinical knowledge (expressed in archetypes) to achieve semantic interoperability.

Most importantly, technology needs to be designed to consist of largely independent components, so that replacement can occur without endangering the sustainability of the infrastructure as a whole. Open source implementations will help to validate, improve, evolve their specifications and educate the early implementers [18]. Moreover, if the initial code base is good enough for others to collaborate there is no need to reinvent wheels and thus open source components can serve as building blocks for high level HIS applications. Linux, Apache, OpenBSD, JBoss, Hibernate, Ant and many more are all part of the backbone of our current technical infrastructure and they contribute enormously to sustainability.

PILLAR 3: Socio-technical Building Blocks

While acknowledging the utmost importance of socio-technical issues ranging from comprehensive change management, proper localisation of clinical systems, sufficient training, etc., this has in theory been very well investigated (although not often enough implemented in practice), and "*[s]ocio-technical systems (STS) analysis has provided us with a powerful framework with which to analyse the reasons behind the poor acceptability, uptake and performance […]*" [19]. We therefore refrain here from elaborating on this topic.

PILLAR 4: Political/ Business Building Blocks

No matter how much sense this framework makes on a technical, clinical or socio-technical level – sustainability (as well as interoperability) needs to become a major business driver to become reality! We need to ensure that politics is informed and business drivers are 'right'. For this sustainability needs to be measured and a case made for public sector and regional healthcare information systems to be based on open source software to remove the risk associated with any given vendor.

In an era of constant change, political/business decisions do not often hold up long enough to see the rewards of a decision of e.g. implementing a nationwide EHR – as this commonly takes years from planning to roll-out. For this reason, we propose (independent) umbrella organisations on a national and eventually internationally level that render political decisions more predictable and sustainable. These organizations can provide leadership and stability for specific purposes.

Finally, while obviously appropriate funding is essential, it does not seem to be wise to provide more and more funding to a system that struggles - without identifying and addressing the fundamental problems within the 4 pillars.

Discussion and Conclusion

As shown in this paper, there are many problems to solve in achieving any state, which could be called sustainable. Some are technological, some are socio-political and some organizational. However, most importantly, the lack of a definition for

Table 2: Examples for inputs, outputs, and stored items in a health information infrastructure – and inhibitors that currently often prevent their sustainability.

Sustainability Items	Description	Examples for inhibitors to sustainability
Health Informatics Knowledge and Skills	Knowledge and Skills of Health Informatitions/ Health IT and IS Professionals. This is vital as we need to work with limited resources to fulfill the great demand.	• Starting similar initiatives from the beginning over and over again, thus losing knowledge inherent in unsustainable systems, which then needs to be recreated • Socio-technical issues, including localisation issues and insufficient change management • Political change and infrastructure not set up appropriately for political change. Independent umbrella organisations may be one solution. • Wrong infrastructure to cope with major changes (e.g. disaster management)
Clinical/Patient Information	The clinical information on a patient stored in a clinical system. If this information is lost, it has major consequence for patient life and money. We need to sustain clinical data for 100years and more.	• Migration of systems without loss of patient data not feasible (e.g. information model not sufficiently clear) • Vendor lock-in • Insufficient system ability to match clinical practice / workflow • Wrong business drivers • No open source or otherwise available and agreed (e.g. standardised) specifications for data that needs to be shared
Clinical knowledge	The clinical knowledge of Health Professionals – maintained, structured and evidence-based.	• Hard-coded clinical knowledge • Evolvement of clinical practice and general processes which causes systems to slowly become obsolete

sustainability and agreed and standardised metrics to measure sustainability in health is problematic because without we cannot quantify the status quo of sustainability at any given point of time - and as a consequence sustainability will be largely ignored by decision makers as an important business driver. Indicators generally simplify in order to make complex phenomena quantifiable so that information can be communicated efficiently to decision makers. We thus have to ensure that suitable indicators are applied to make the complex phenomenon sustainability quantifiable for decision makers. In this paper, we showed one possible way of developing such an indicator.

Shabo's Model for the Sustainability of Longitudinal EHRs [20] is one that tackles the concrete problem of sustaining EHRs. As such Shabo's model is more specific to this concrete problem, but also limited to it; his suggestions are in harmony with our results.

While Return on Investment (ROI) is an inherent part of this this paper, its quantification is not part of this paper. For a first estimate, a similar model as the model used by Walker and colleagues to quantify the value of health care information exchange and interoperability [2] could be employed. Also, the World Business Council for Sustainable Development, has formulated the business case for sustainable development and argues that "*sustainable development is good for business and business is good for sustainable development*". The same we believe is true is for the sustainable development of HIS. We need to develop such a business case for sustainability for our health information infrastructure and change business practices on every level. One important step for this is to develop, evaluate and use indicators for sustainability that can be used by decision makers to quantify sustainability to justify expenditures on fighting barriers to sustainability and take a systematic approach towards sustainability of HIS. This can be based on the analysis presented in this paper.

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