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A Multi-faceted Approach to Collaborative Health Information Systems

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Abstract

Modern healthcare is confronted with increasing costs and complexity, progressive population ageing and pandemics triggered by new disease strains and population displacements fuelled by conflicts and climate change. In this context, effective cooperation and interoperability of the participants and their information systems in the healthcare effort becomes paramount. This brings about significant challenges, as healthcare institutions are typically hierarchical and heterogeneous owing to a complex administrative, geographical and historical context. At the same time, governments find it increasingly difficult to rely on 'silo' type information and organisational paradigms in order to manage population wellbeing. Thus, there is an increasing need for innovative, holistic and integrated models that take into account all essential aspects, elements and especially life cycles of all the healthcare effort participants. Building on previous research and applications, this paper proposes that the required modelling artefacts can be built using a life cycle-based holistic paradigm enabled by advances in Information Systems, Interoperability, Collaborative Networks and Enterprise Architecture. This multi-faceted approach holds the promise to a sound platform for sustainable solutions to both long and short-term challenges to population health and well-being.

Keywords

Health Informatics, Collaborative Networks, Interoperability, Enterprise Architecture

INTRODUCTION

Healthcare services worldwide are under pressure. Population ageing, increasing occurrence of exotic drug-resistant pandemics and escalating frequency and severity of natural and man-made disasters compounded by rising healthcare complexity and costs are important culprits. In this context, collaboration of all healthcare contributors and beneficiaries is a mandatory requirement that renders much of the legacy silo-type healthcare governance models irrelevant.

The complex regional, historical, organisational and political context surrounding the healthcare endeavour triggers significant challenges in managing the internal and external collaboration and interoperation of the rather heterogeneous set of participants involved in the healthcare endeavour. This constitutes a particularly critical issue in handling acute health incidents (e.g. pandemics) that require prompt response and claim resources and capabilities beyond those of any particular individual healthcare organisation. New innovative and *integrated* models, methods and tools are required in order to enable proper inter-professional and inter-organisational cooperation, so as to meet these serious long and short term healthcare challenges.

Previous research (Noran 2011; Noran and Bernus 2011) has investigated the use of Collaborative Networks (CN) (Camarinha-Matos and Afsarmanesh 2005) and Enterprise Architecture (EA) (Gartner Research 2012) concepts and methodologies in supporting a large variety of complex IS projects. This paper aims to build on the previous results by focusing this multidisciplinary approach on the healthcare-specific IS. It is hypothesised that this method will allow addressing the above-mentioned healthcare IS issues in a multifaceted life cycle-based, holistic and integrated manner. The resulting models are expected to enable a prompt and efficient response by agile and synergic teams to both acute and long-term challenges to population health and well-being.

CHALLENGES IN HEALTHCARE MANAGEMENT COLLABORATION

Healthcare has made significant advances in the last century, such as the development and wide use of vaccines, eradication of serious diseases and large reductions in communicable disease epidemics and chronic diseases (Fielding 1999; World Health Organization 1998). There is however a new set of challenges faced by the public and private healthcare infrastructure and organisations. Population growth and ageing triggered by increased longevity (World Health Organization 1998), while reflecting mankind progress and providing benefits (Healy 2004), also brings significant social security and healthcare challenges (International Labour Organisation 2009). Another major concern are the increasingly complex health incidents such as pandemics, owing to new strains of

diseases (Kilbourne 2006), population displacements fuelled by regional conflicts and climate change (Donohoe 2003). The magnitude of these challenges is beyond the capabilities of any single healthcare institution and demand effective collaboration of all parties involved regardless of their role.

Inter-professional and inter-organisational collaborative healthcare is encouraged in various medical and emergency response reports, conferences and journals (e.g. (Hughes 2008; Institute of Medicine 2000; Kapucu et al. 2010; Sansoni et al. 2012; Utah Department of Health 2007; Waugh and Streib 2006)) as well as in international projects. For example, the BRAID (BRAID 2011) project deliverables advocate the necessity for collaborative healthcare ecosystems (Holzman 1999) supported by integrated assistive services and infrastructure, as part of a 'healthy living and ageing' paradigm (Sansoni et al. 2012). Unfortunately however, the extent of actual cooperation in healthcare is still limited because unfortunately, collaboration between participants in the healthcare effort does not automatically occur. It must be "constructed, learned, and once established, protected" (Wilson et al. 2005); a true collaborative approach can neither be successfully forced on the participants nor achieved in a short time.

Whereas healthcare as a system has become somewhat more organised, it has also become more expensive, complex and difficult to manage. New technologies are making considerable progress towards supporting collaborative healthcare IS; however, the intricate nature of the host organisations involved presents significant impediments to successful technology transfer and diffusion (Southon et al. 1997) including interactional user resistance to the new systems (Markus 1983).

Research in the field has identified several aspects that can 'make or break' effective collaboration, all of which have to be considered if collaborative health information systems (HIS) are to be achieved. Thus, the main barriers to healthcare cooperation appear to be of organisational and cultural nature (Braude 1997; Krogstad et al. 2004; Ramanujam and Rousseau 2006; Wilson et al. 2005), with divergent perceptions and expectations of the parties involved (Krogstad et al. 2004), owing to a traditionally strong hierarchy and marked difference in status between partners (Ramanujam and Rousseau 2006). The higher ranking participants can deal with this issue by promoting collaboration and trust with a participatory and inclusive development approach (Baker et al. 2006; Nembhard and Edmondson 2006). This is particularly true of the disaster management setting, where the more powerful organisation(s) are tempted to override or disregard some participants and their IS, adopting a 'central command' approach rather than a cooperative one (Waugh 1993). This is not desirable as successful disaster management relies on a wide range of community, economic, social-psychological, and political resources.

A COMBINED APPROACH TO COLLABORATIVE HEALTHCARE INFORMATION SYSTEMS

Efficient healthcare collaboration requires that organisational cultures, processes and resources of the participants acquire suitable preparedness (Kapucu et al. 2010; U.S. Dept of Health and Human Services 2005; World Health Organisation 2011), with ethics playing a prominent role (NZ National Ethics Advisory Committee 2006; Thompson et al. 2006). This endeavour requires access to a plethora of interdisciplinary information and knowledge not always easily accessible to planners and disaster managers. Therefore, multidisciplinary and participatory analysis and design (Kristensen et al. 2006) represent essential collaborative healthcare enablers that help integrate all necessary scientific, administrative, social and political aspects into a whole-system approach (Moghadas et al. 2008; Utah Department of Health 2007; World Health Organisation 2011). The following sub-sections attempt to explain the potential contributions of the Interoperability, Collaborative Networks and Enterprise Architecture disciplines to the collaborative health IS challenges within the proposed combined approach.

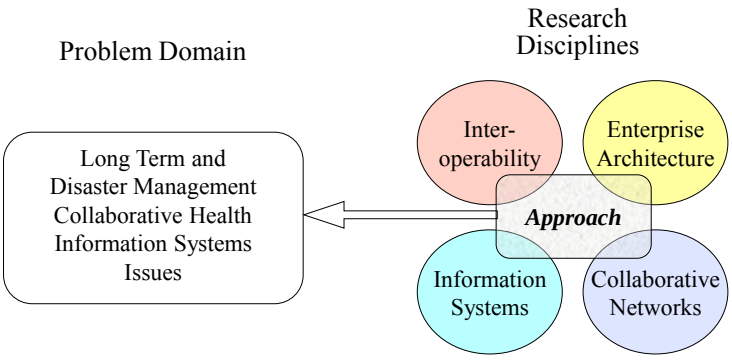


Figure 1: A multidisciplinary approach to Collaborative Health Information Systems

Interoperability as a Measure of Cooperation: Extent, Approach, Aspects

The concept of interoperability is often used as a measure of IS cooperation capability (see e.g. the Levels of Information System Interoperability taxonomy in the Department of Defence Architecture Framework (2004)) and it is therefore deemed to be useful in the analysis of HIS collaboration. The analysis of interoperability in the HIS domain must include some important aspects, such as extent, approach and aspects covered.

As shown in previous research (Noran and Bernus 2011), too high an interoperability degree (close to total integration) would be detrimental as it would mean a significant loss of autonomy, which is not desirable (especially in crisis situations). On the other extreme, minimal IS interoperability (compatibility) of the healthcare or health crisis management effort participants would be only valid as a starting point (often not met unfortunately). Thus, HIS 'desirable' interoperability lies between total (integration) and minimal (compatibility), depending on the agility and resilience required of the specific healthcare or health crisis management endeavour (see Figure 2).

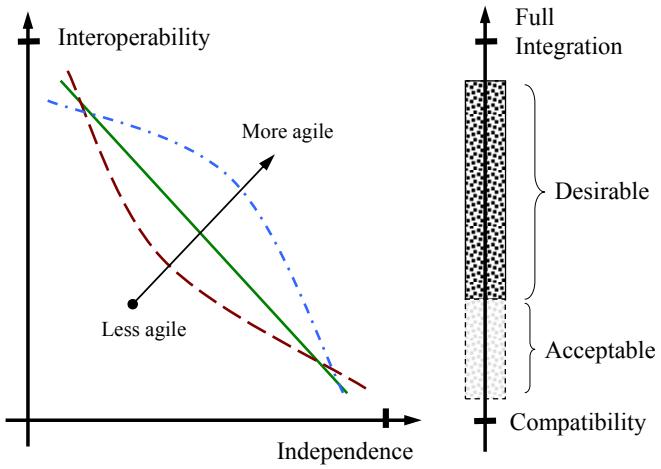


Figure 2 Interoperability issues in disaster management (based on (Noran 2011; Panetto 2007))

In relation to the interoperability approach, the 'full integration' and 'federalisation options' specified in ISO14258 (ISO/IEC 2005) did not seem to achieve the desired results in the past due to pronounced organisational heterogeneity and the impossibility to negotiate proper collaboration 'on the fly' in disaster events. A third (and apparently more suitable) 'unified approach' (ibid.) assumes that ontology is negotiated in advance. For this to happen however, previous experience shows that the organisations need to 'spend time together' in order to agree on the meanings associated with the concepts used to exchange knowledge.

Interoperability aspects are provided by various standards (ibid.) and frameworks (e.g. European Interoperability Framework (EIF)(2004), IDEAS project (2003), ATHENA Interoperability Framework (AIF)(2004), Chen's Interoperability Framework (2006)). As all these frameworks have overlapping and complementary areas, a combined model has been constructed and applied by Noran and Bernus (2011) for identifying the relevant aspects for generic disaster management. The results largely apply to HIS interoperability as well; thus, the data and process areas are the most urgent in a disaster situation as the ability to extract, filter and exchange information from heterogeneous sources providing high volume (and often 'noisy') data is paramount to being aware of the conditions on the ground and avoiding unknown and potentially life-threatening situations for emergency crews. Therefore, prior agreements on data format and especially on its *meaning* are essential.

The pragmatic interoperability aspect (Whitman and Panetto 2006) relates to the capacity but also *willingness* of the participants to interoperate, suggesting that the human component of the HIS needs attention prior to task force formation as to allow gaining trust and knowledge between the organisations.

Organisational interoperability is an important aspect in both long term and acute healthcare crises as task force participants may often exhibit significant organisational structure diversity that is reflected in their HIS. Issues identified by Chen (2006) based on the EIF (2004), such as responsibility and authority, imply that the roles and hierarchy within a (health or otherwise) disaster management task force must be clearly understood and properly reflected in their IS so focus is kept on managing the project at hand in an integrated manner.

Cultural interoperability (Whitman and Panetto 2006) appears to be one of the hardest problems that also affects HIS. Similar to obtaining pragmatic and semantic interoperability, the only current solution appears to be the regular immersion of the participant organisations in each other's cultures, which facilitates the transfer and conversion of tacit and explicit knowledge between the participants. This 'co-habitation', leading to optimally cooperating HIS, could be facilitated by the Collaborative Network concept explained in the next section.

Collaborative Networks for Healthcare

The concept of networks in disaster management and recovery as an alternative to a centralised command and control approach has been advocated, studied and applied to some extent for a number of years with mixed results (e.g. (Australian Psychological Society 2013; Bard et al. 2011; Cooper et al. 2007; Waugh 1993)). Substantial research has also gone into tackling the long term healthcare challenges in a collaborative approach (e.g. (Holzman 1999; Sansoni et al. 2012)).

While providing valuable data, such attempts appear to have two main shortcomings. Firstly, they appear to use untested models focusing on a specific aspect at a time, rather than employing a proven set of integrated models in a whole-system approach. Secondly, the *life cycle* aspect of the participant organisations, networks and other relevant entities (including the disaster event/s) appears to be less addressed. As all participants and their systems are evolving, it is essential that the interactions required for collaboration and interoperation be considered in an integrated life cycle context.

In attempting to tackle these issues, it has been observed that the healthcare challenges identified in the relevant literature describe a situation similar to that of commercial enterprises who, owing to a global business environment, find themselves compelled to tackle projects requiring resources beyond their own staff, knowledge and time capabilities. Their usual reaction to this problem is to set up or join so-called Collaborative Networks (CNs) that act as breeding environments for 'Virtual' Organisations (VOs) who are promptly created in order to bid for and manage projects requiring combined resources and know-how. The view of CNs as social systems composed of commitments, who absorb uncertainty and reduce complexity (Neumann et al. 2011) also supports their use in healthcare and health disaster management projects that typically display such features.

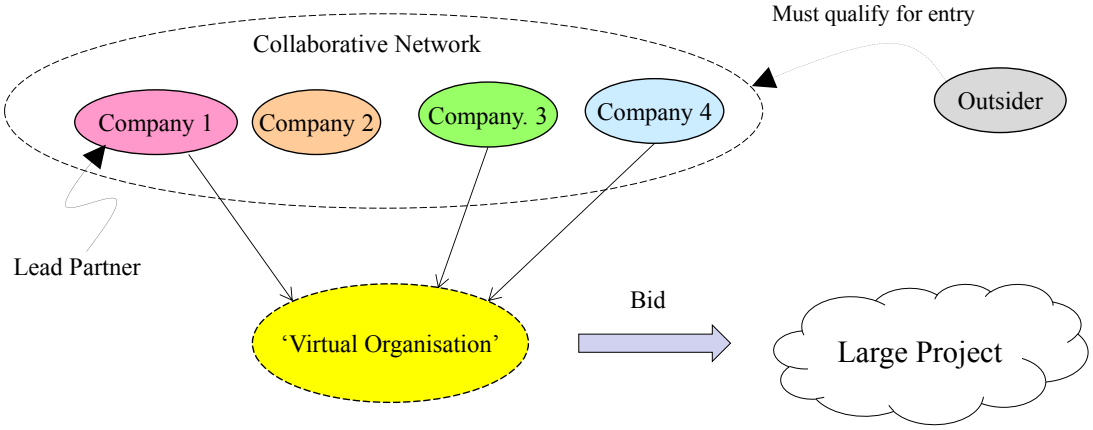


Figure 3: The Collaborative Network concept

CNs often have one or more 'lead partners', based on their size, influence (e.g. in the supply chain), etc. CN participants may participate in one or several VOs at the same time, with the VOs created typically having a life span limited to the project they are created to bid for, win and manage. Reference models (built by abstracting knowledge gathered from previous projects) are typically used to speed up VO creation.

The CNs and VOs set up for the healthcare domain would have specific features. For example, the competitive motivations of commercial CN participants that guide their decisions to create / join / remain / leave a network would transform into the need to cope with increasingly complex healthcare systems and urgent health challenges. The use of reference models, customary in commercial CNs, could be useful - albeit limited by the potential diversity in scale and type of healthcare incidents (Tierney and Quarantelli 1989). The 'Health Management' CN (HMCN) would create 'Health Management' VOs (HMVO) for long term projects (e.g. population ageing), or task forces (HMTF) for shorter term and more intense events (e.g. pandemics).

As previously shown, for a HMCN to be functional, the lead partner/s (here, government emergency management / healthcare agencies) need to take a participatory and inclusive approach. Thus, scientific, faith and community representatives and all relevant non-governmental and volunteer organisations must also be included in the setup and operation of the HMCN, in addition to the typical participants such as hospitals, allied healthcare (Queensland Health 2012), fire and rescue services, etc.

Adopting a CN approach for health disaster management provides benefits going beyond technical and syntactic-type interoperability. Thus, the participants in a HMCN have the time and suitable environment to overcome the previously described hierarchical, organisational and cultural interoperability barriers and achieve the required preparedness. This is essential in the prompt and successful setup of HMTFs for disasters and in the creation and operation of continuing HMVOs for long term healthcare challenges such as population ageing.

The Enterprise Architecture Perspective

As previously shown, HIS collaboration requirements are inherently linked to the current life cycle phase(s) of the host organisations. For example, many organisations undergo redesign, hence finding themselves in simultaneous Analysis, Design and Operation life cycles; others may be discontinuing certain areas, hence going through concurrent Operation and Decommissioning life cycles, etc. This would clearly affect their interoperability requirements and capabilities; it is therefore essential that the analysis of possible cooperation improvements is performed in a life cycle context. It is hereby argued that an optimal way to integrate the life cycle aspect in a collaborative HIS scenario is by using Enterprise Architecture (EA) approach.

While several EA definitions exist, here EA is considered a holistic change management paradigm that bridges management and engineering best-practice, providing the "[…] key requirements, principles and models that describe the enterprise's future state. […] EA comprises people, processes, information and technology of the enterprise, and their relationships to one another and to the external environment" (Gartner Research 2012). This EA definition reinforces the view of CNs as social systems composed of commitments (Neumann et al. 2011) and IS as socio-technical systems (Pava 1983) placing voluntaristic people (McGregor 1960) in a complex organisational, political and behavioural context (Iivari 1991; Keen and Scott Morton 1978; Markus 1983). As such, EA is potentially capable to provide a framework integrating all necessary aspects in a life cycle-based set of models ensuring the consistency and sustainability of complex projects.

To illustrate the way EA artefacts and methods can guide and enrich the analysis and improvement of health management collaborative network and task force interoperability we have selected a generic architecture framework (AF) subsuming and abstracting several other mainstream AFs. This AF is defined in Annex A of ISO15704 (ISO/IEC 2005) and it is called the 'Generalised Enterprise Architecture and Methodology' (GERAM). The modelling framework (MF) of GERAM's reference architecture component (called GERA) contains a rich repository of aspects (importantly, including human) that can all be represented in a life cycle context. GERA's MF has been used in enterprise modelling, management, manufacturing, environment and other areas (e.g. see (Mo 2007; Noran 2008; Noran 2009; Noran 2012a; Noran 2012b; Saha 2007; Vaniya et al. 2013)).

Subsets of the GERA MF can be used to build life cycle-based modelling constructs such as shown in Figure 4; these can be used as the building blocks of dynamic business models requiring a life cycle background and integration of several aspects in the same diagram, such as dynamic business models of the set up and operation of HMCNs, HMVOs and HMTFs. An example of such a diagram is shown in Figure 5.

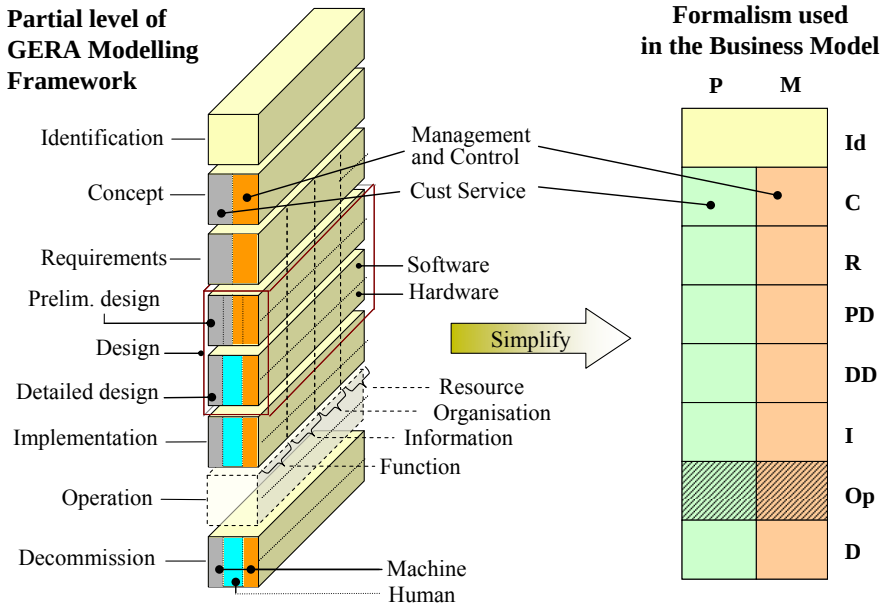


Figure 4 Creating a data and management-focused life cycle based modelling construct using GERA MF

Table 1 summarizes some of the main barriers in establishing collaborative health information systems and potential solutions offered by combining the knowledge offered by the CN, IS, EA and Interoperability disciplines.

Table 1: Barriers to collaborative HIS and solutions offered by CN, IS, EA and Interoperability disciplines

Healthcare and Health Informatics Issue	Applicability	Input from Collaborative Networks	Input from Information Systems	Input from Enterprise Architecture	Input from Interoperability
Divergent perceptions of the participants' roles	Long & Short Term	Clear, agreed roles for network and task force participants	Identify / address the root problems in divergent perceptions	Integrated modelling of all necessary aspects of collaboration	
Lack of trust between partiticipants	Long & Short Term	Trust building in time, within the network		Promote trust by common understanding of models	Methods to tackle cultural and organisational interoperability
Poor life cycle management of task forces / collaborative healthcare IS	Long & Short Term		Identified / addressed problems in healthcare management	Intrinsic life cycle context to the creation and operation of network and task forces	Interoperability reqs. and capabilities in respect to current life cycle phase/s
Difficulties setting up and operating Collaborative Healthcare (e.g. unclear rules, disagreement on the present and future situations)	Long / Short Term	Participatory design, inclusive approach by lead network partner. Agreed upon models of Networks as Collaborative Healthcare Ecosystems.	Participatory design methods and models	Integrated modelling of the creation and operation of complex projects	
Focus on a limited set of interoperability aspects	Long / Short Term		Cooperative IS requirements	A whole-system approach integrating all relevant aspects	Identify all relevant aspects based on interop. frameworks
Information sharing and cooperation impeded by traditional hierarchy	Long / Short Term	Information and process interoperability achieved at network level and carried on in task forces created	Methods to improve HI cooperation in hierarchical organisations		Methods to tackle cultural and organisational interoperability
Tendency to overrule rather than cooperate in task forces	Short Term	Cooperation previously agreed upon and built in the task forces created by the network			
Lack of preparedness to participate in a task force on short notice	Short Term	Participant preparedness built in advance within the network, ready for prompt taskforce / VO creation			Identify and address all required Interoperability aspects of network partners
Difficult discovery and assessment of suitable participants for an effective and agile task force	Short Term	Task forces created promptly using pre-qualified network partners implementing agreed upon processes.		Previous research results in 'methods to build methods' for creation and operation of complex projects	Interoperability and agility of task force inherited from the network

MODELLING COLLABORATIVE HEALTHCARE INFORMATION SYSTEMS

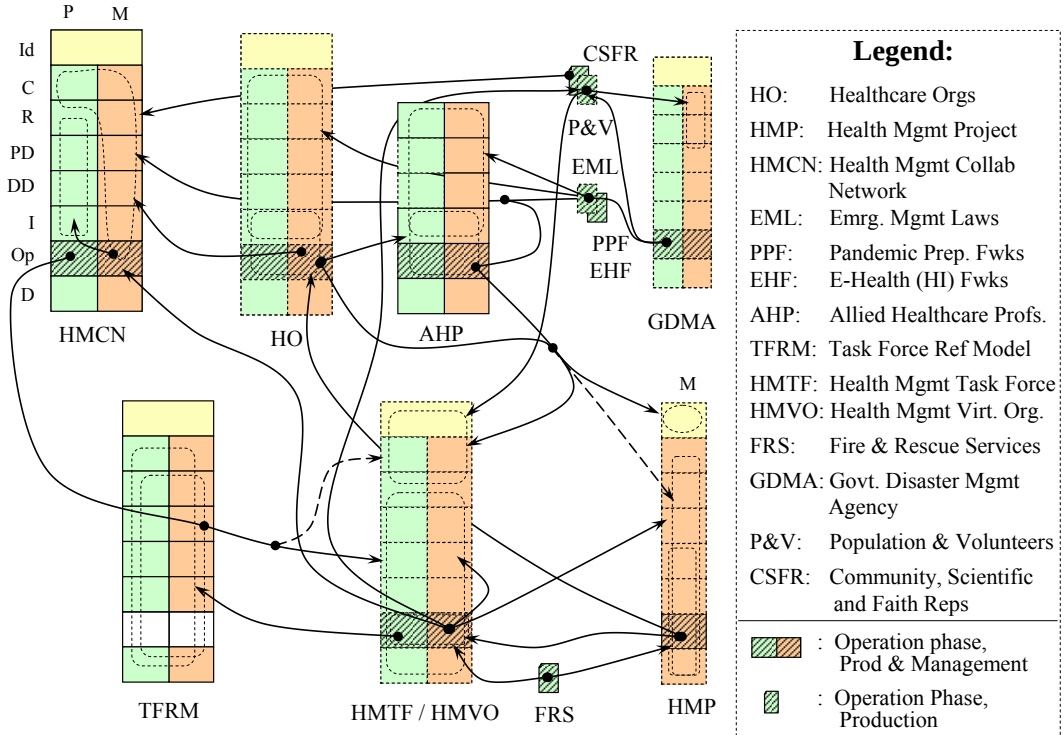
In the following we present a sample HIS dynamic business model integrating life cycle, management and information viewpoints in a possible health management collaborative network and task force scenario. This model can be used in order to identify the interactions that need to be considered in the (re)design of HIS in view of collaboration enhancement. The proposed approach supports an inclusive approach and audience diversity by using graphical models and complexity management. Thus, diagrams can be created for various combinations of aspects deemed to be relevant for the task at hand.

The model in Figure 5 shows how a collaborative network for health management can be set up by health organisations and allied healthcare professionals. The collaborative network then creates either virtual organisations for long term, or task forces for short term (e.g. disaster management) health management projects. The entities shown in the model in Figure 5 represent the main stakeholders in the proposed collaborative approach; however, as can be seen, some aspects deemed irrelevant to the purpose of the model are not shown for some entities. For example, only the Management aspect is shown for the health management project and only the Operation life cycle phases are shown for stakeholder such as laws, policies, other services and organisations. This is because no other life cycle phases of these stakeholders (except Operation) are deemed to be affected in this scenario. For example, no disaster management laws, preparedness frameworks or fire and rescue services are likely to be directly restructured as a result of the operation of the health management collaborative network or a task force (this may happen indirectly by action of the Government).

The arrows in Figure 5 show influences and contributions among the entities involved in the long and short term healthcare endeavour. Thus, healthcare organisations HO (e.g. hospitals), allied health professionals (AHP) and scientific, faith and other communities representatives (CSFR) all contribute to the design and operation of a HMCN in its various life cycle phases. These contributions may also extend directly to the design and operation of the HMTFs / HMVOs created by the HMCN, and to the health management projects (HMPs) created by the HTMFs / HMVOs. Influences and contributions also come from ‘non-physical’ artefacts such as emergency management laws (EML), pandemic preparedness (PPF), or e-health strategies / frameworks (EHF) (Council of

Australian Governments 2008). Access to properly aggregated, understandable information (Alpay et al. 2009) is provided by HTMFs / HMVOs. Population, organisations and community representatives' feedback flows to Government agencies (GDMAs) and the HMTFs/ HMVOs and may result in changes at various levels.

The arrow from HMTF/HMVO's Management side of the Operation life cycle phase to some of its upper phases represents a very important (if limited) 'self-redesign' capability, showing a need for the HMTF to be *agile* and adapt in real time in the face of rapidly changing conditions on the ground that are typical of some disaster events. However, any major HMTF / HMVO reconfiguration (e.g. involving Requirements or Architectural Design life cycles) must involve the HMCN participants and other entities as shown in Figure 5.



Life cycle phases: Id=Identification; C=concept; R=requirements, PD=preliminary design, DD=detailed design, I=implementation, Op=operation, D=decommissioning. **Other aspects:** P=Production / Service, M=management.

Figure 5: Sample HIS dynamic business model in a possible HMCN scenario

Note that a high-level model such as shown in Figure 5 does not aim to provide all the details necessary for actual HIS implementation. Rather, its main purpose is to facilitate stakeholder common understanding and consensus on the present state and support the selection of the optimal future state. Such models can provide checklists of the 'things' that need to be considered in the collaborative healthcare endeavour and spell out the interactions between them in the context of their life cycles. They can be used to build scenarios representing various degrees of autonomy and agility of the participants and their systems. Once consensus on present and future has been achieved, these models can be evolved into design and implementation blueprints. A complete analysis (not possible here due to space limitations) should include an integrated set of models depicting all required aspects, such as process, resource, organisation, decision, etc.

CONCLUSIONS AND FURTHER WORK

Healthcare needs to adopt a collaborative IS approach in order to cope with major contemporary challenges. Politics, hierarchy, diverging perceptions, lack of trust, dissimilar organisational cultures and limited life cycle-based perspective of the healthcare participants' roles and interactions are important IS collaboration barriers. This paper has argued and attempted to demonstrate that an optimal way to address these issues is to adopt a combined interdisciplinary approach that allows drawing upon a rich repository of Information Systems, Collaborative Networks, Enterprise Architecture and Interoperability research state-of-the-art results.

The paper makes a theoretical contribution by using four disciplines to advance collaborative healthcare IS research and also a practical contribution by providing an example of how CN concepts can be employed from an EA perspective in order to model a collaborative healthcare solution to health and well-being challenges.

The proposed approach will be further developed and tested in a variety of healthcare management and disaster management case studies in order to verify, validate and refine it.

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