A technology ecosystem perspective on hospital management information systems: lessons from the health literature

Christopher A. Bain* and Craig Standing

School of Management,
Edith Cowan University,
Joondalup, WA 6027, Australia
Email: christopher.bain@wcmics.org
Email: c.standing@ecu.edu.au
*Corresponding author

Abstract: Hospital managers have a large range of information needs including quality metrics, financial reports, access information needs, educational, resourcing and decision support needs. Currently these needs involve interactions by managers with numerous disparate systems, both electronic such as SAP, Oracle Financials, PAS’ (patient administration systems) like HOMER, and relevant websites; and paper-based systems. Hospital management information systems (HMIS) can be thought of sitting within a Technology Ecosystem (TE). In addition, Hospital Management Information Systems (HMIS) could benefit from a broader and deeper TE model, and the HMIS environment may in fact represents its own TE (the HMTE). This research will examine lessons from the health literature in relation to some of these issues, and propose an extension to the base model of a TE.

Keywords: technology ecosystem; management; hospital; healthcare; healthcare management informatics and computing; health-mic; electronic healthcare.


Biographical notes: Christopher Bain is a medical practitioner and information technologist by training and works in the field of Health Informatics. He established the first international group dedicated to the area of healthcare management informatics and computing (health-mic). This group is now the health-mic SIG of HISA (the Health Informatics Society of Australia). He has published and spoken on related topics in a number of forums, and is currently completing a PhD on the topic of technology ecosystems in healthcare management.

Craig Standing is the Professor of Strategic Information Management in the School of Management at Edith Cowan University in Perth, Western Australia. He has published widely in information systems journals internationally and has presented at many international conferences. He has also published two books, and currently manages a number of funded research projects.
1 Introduction

Hospital managers have a large range of information needs, from quality, finance and access information needs to educational, resourcing and decision support needs. Currently, these needs are met by managers interacting with numerous disparate systems, including electronic systems such as SAP and Oracle Financials, PAS’ (Patient Administration Systems) like HOMER, and relevant websites, and paper-based systems. The management of this complex environment creates a significant burden for hospital managers because of the time required to train users, and the problems associated with providing accurate, comprehensive and timely information from typically disjointed information architectures.

A hospital management technology environment can be thought of a Technology Ecosystem (TE) (Adomavicius et al., 2006). High among the needs of hospital managers are newer, more advanced technologies that provide predictive and analytic capability not yet seen in this domain including technologies arising out of the field of ‘nosokinetics’ (Millard, 2006). Such systems will become critical elements of a Hospital Management Technology Ecosystem (HMTE) in the future. Nosokinetics is effectively the science of how patients move through hospitals, and is an evolving field. It has arisen out of the desperate need of hospital managers to better understand, document and control the way these movements occur.

There has been no work published to date on the application of the technology ecosystem concept to the specific organisational context of hospital management information systems. In addition, the information systems ecosystem literature does not have great breadth, and has not examined the relevance of additional biological ecosystem concepts to the field of information systems. For example, the work on ‘biomes’ (ThinkQuest.org, 2006) which represent a group of related ecosystems (e.g. all tropical rainforests are part of the tropical rainforest biome), has implications for the information technology ecosystem concept. It is possible that there may be structural commonalities among subsets of the various technology ecosystems.

The existing work regarding technology ecosystems is still highly conceptual and is largely undeveloped in terms of relating the key lessons of ecological science to the information system space. For instance there is a lack of published work in relation to the factors affecting technology ecosystem success and failure, or in relation to the key types of technology ecosystems and what distinguishes them and their ‘inhabitants’ from other ecosystems. There is also evolving work around the concept that biological ecosystems provide ‘services’ for ‘users’ such as humans (Unknown, 2006). There is potential to significantly improve our understanding of information architectures by using an ecosystem conceptual framework.

It is the fundamental contention of this research that addressing issues such as the ones raised above will provide an extension to, and improvement on, the technology ecosystem model for information systems in a way that will increase its usefulness and its practical applicability. The aim of this paper is to assess the contribution that the Technology Ecosystem Model (TEM) can make to the evolving area of Hospital Management Information Systems (HMIS). This is achieved through analysing and comparing the technology ecosystem literature and hospital information systems literature.
Background

There are many examples in the literature of references to ecosystem concepts to describe information architectures including those that emphasise technical aspects (Hoile et al., 2002) and the use of technology to study and monitor ecosystems (Baptista, 2003). Information ecosystems have been analysed in relation to security issues (Carlsson and Jacobsson, 2005), virtual ecosystems (Almada et al., 1996) and modelling ecosystems on computing grids (Wang, 2005). There is a lack of literature that relates many of the more detailed ecosystem concepts such as different types of ecosystems, biomes, and ‘services’ provided by ecosystems to information architectures.

Definitions of the concept of a biological ecosystem vary in the literature. Some authors, however, have defined some key elements of all ecosystems. For example, five descriptors of an ecosystem as identified by Capra (1996) are:

- Recycling
- Solar power
- Co-operation and competition
- Resilience
- Diversity

Further analysis of the literature reveals that one of the key issues overlooked by the existing TEM is the concept of a range of uniquely identifiable types of ecosystems or biomes (ThinkQuest.org). For example, a temperate forest is a biome that has an annual rainfall greater than 75 cm up to 90 cm and over and conditions are temperate but may vary with the season. It includes the presence of certain tree varieties (e.g. stringy bark, blue gum, karri, jarrah and mountain ash form a canopy blocking between 30% and 70% of the sky).

In addition, some of the issues that need to be faced in the context of this research include the fact that many natural ecosystems are in a state of decline because of a range of factors, including human activity (Thompson, 2006). The question here is do technology ecosystems really adopt this behaviour? That is to say what is the equivalent of degrading natural environments in the TEM?

There have also been a number of articles examining the concept of ecosystems in relation to specific technologies or business settings. For example, in relation to web technologies, Barros et al. (2005) have proposed the concept of a web service ecosystem in which web services are ‘deployed, published, discovered, delivered to different business channels through specialist intermediaries’. Quaadgras (2005), in examining RFID technology, outlines her interpretation of the term business ecosystem as: ‘a set of complex products and services made by multiple firms in which no firm is dominant’.

There have also been several definitions or descriptions put forward in the literature to describe the concept of a technology ecosystem (Iansiti and Richards, 2006). In addition, the term ‘ecosystem’ has been used in different ways even within the IS and IT literature. For example, Benkler (2001) refers to the ‘economic and technological ecosystem within which information is produced’ and Vuori (2006) uses the term in relation to a business ecosystem. As part of her examination of intellectual capital in the context of a business ecosystem, she refers to a business ecosystem as being ‘a dynamic structure which consists of an interconnected population of organisations’. An important point proposed
by Vuori is that one of the characteristics of a business ecosystem (which she relates to a ‘business network’) is that it ‘develops through self-organisation, emergence and co-evolution, which help it to acquire adaptability’. It is important to note that these usages of the term, with their implicit notions of relating the concept to business rather than IT specifically, are in contrast to what is being contemplated in this research, but provide important contextual information nonetheless.

Hsi (2004) defines a computing ecosystem as: ‘a set of use contexts that use computing to fulfil goals, contained within an environment of interest’. In turn, they define a use context as: ‘the external physical (or virtual) environment that contains the computing application and its users, the goals that the combined computing application/user system wishes to achieve, and the various nuances (business rules, customer demand, user and system capabilities) that govern the operation and performance of both environment and goal completion’.

Lin and Lin (2006) also use the term in very similar way to Adomavicius et al. (2006), but they also assert that the ecological perspective is useful if one is looking at the evolution of an entity since evolution also implies temporal change.

The definition proposed by Adomavicius et al. (2005) is ‘A system of interrelated technologies that influence each other’s evolution and development’. Furthermore, this definition includes the concept that ‘A specific technology ecosystem view is defined around a focal technology in a given context’. Although this definition has been put forward in the context of a proposed new model of technology evolution, it is highly appropriate in the context of developing effective hospital management information systems.

Importantly, these authors define some other key concepts which are complementary to their definition of a technology ecosystem, and which are also directly relevant to hospital management information systems. They are as follows:

- **Technology roles**: ‘The influential roles that a technology can play with respect to other technologies in a given technology ecosystem.’

- **Technology layers**: ‘In a specific ecosystem view, technologies playing the same role with respect to the focal technology are grouped in a technology layer.’

- **Technology-shaping forces**: ‘External environmental forces that can influence the development and evolution of a technology or technology ecosystem. These include social and governmental forces, technical forces and economic forces.’

For the purposes of this paper it is also important to specify what we mean by the term ‘manager’ and hence the term ‘management information system’. The fact that our focus of study is hospitals throws up a particularly important issue in relation to what a manager is.

In hospitals, many mangers also provide ‘service line operations’ for want of a better term (i.e. they provide care to individuals). As a result, in some of their information needs, and in terms of some of the systems with which they interact – that distinction (managerial versus care provision) is only made by the kind of information they seek – focused on individual patients as providers of care (service line), or conversely, focused on groups of patients, wards, business units or non-patient related information (e.g. finance, HR and throughput), with their managerial hats on. This is, therefore, the definition we will use of a hospital manager (some of whom also do not provide care), and of management information systems.
3 Methodology

The objective of this research is to access relevant health literature and analyse it in a fashion that will address the questions outlined below. These questions seek to address the broad issue of how the HMIS environment relates to a TEM approach and viewpoint.

- Does the TEM apply to a hospital management environment?
- If so then how does it apply – for instance, could it be conceptually related to the arid zone biome?
- How does it compare with other IT planning lenses?

Answering these questions will demonstrate ways in which the current TEM could be improved. The approach to the literature search is outlined in the section that follows:

In PubMed, the terms ‘hospital’, and ‘information system’ or ‘system’ were searched for in all text for the date of publication range back to 1 January 2002.

This strategy has been chosen on the basis that the combination terms ‘hospital’ and ‘information system’, or ‘hospital’ and ‘system’, are fairly specific and will go a long way to isolating the articles needed from the many hundreds of thousands of articles about hospitals in the health literature. These terms will assist on focusing on those articles about the functioning of hospitals as systems, and information systems more relevant to hospitals than patient specific applications, of which there are thousands, that will not be relevant to this research. In the health literature, more often than not, the term ‘management’ is focused on management interventions (e.g. drug therapies, surgeries) for patients and not on managerial and administrative issues in the health system, and hence this term was deliberately omitted.

While this is an initial detailed scan of the available literature, and not a systematic review of it, this is the first time such work has been performed and we believe that it will reveal some useful initial insights into the possible existence of a HTME.

4 Results

In this section of the paper we present an overview of the relevant literature identified under each of the key questions outlined previously:

4.1 Does the TEM apply to a hospital management environment?

We will consider this overarching question by assessing the literature in relation to each of the features of the original TEM.

4.1.1 Focal Technology (FT)

A focal technology is ‘A system of interrelated technologies that influence each other’s evolution and development’. Furthermore, this definition includes the concept that ‘A specific technology ecosystem view is defined around a focal technology in a given context’.

There is some evidence form the literature that the focal technology in this proposed ecosystem (HMTE) could be the Patient Administration System (PAS). Indeed it is arguably the core view (patient centred) that should be used in any analysis of technology and process in healthcare.
Table 1

<table>
<thead>
<tr>
<th>Possible evidence for a FT concept (e.g. PAS)</th>
<th>Author(s) and Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORIS (Operating Room Information System)</td>
<td>Dexter et al. (2005)</td>
<td>They highlight the importance of an Operating Room Information System (ORIS) in allowing an analysis of operating room turnaround time and delays. This system would receive its core patient-based information from the PAS.</td>
</tr>
<tr>
<td>AIMS (Anaesthesia Information Management System)</td>
<td>Reich et al. (2006)</td>
<td>An AIMS (Anaesthesia Information Management System) – that links to the PAS for the core patient-related information (versus clinical information).</td>
</tr>
<tr>
<td>LIS (Laboratory Information System)</td>
<td>Chien et al. (2007)</td>
<td>Paper regarding evaluation and improvement of turnaround time in a laboratory using LIS data. LIS will receive its core patient information from the PAS.</td>
</tr>
</tbody>
</table>

4.1.2 Technology Roles (TRs) and Technology Layers (TLS)

As outlined previously, the concept of technology roles means ‘The influential roles that a technology can play with respect to other technologies in a given technology ecosystem’. While the concept of technology layers refers to the technologies playing the same role with respect to the focal technology in a particular ecosystem view – these are grouped in a technology layer.

More specifically, they refer to three key roles in an ecosystem in this regard. They are:

- **the component role** – ‘describes technologies when they are used as components in more complex technologies’ (e.g. the hard disk drive).
- **the product and application role** – ‘describes technologies when they are built up from a set of components, and are designed to perform a specific set of functions or satisfy and specific set of needs’ (e.g. an MP3 player).
- **the support and infrastructure role** – ‘describes technologies when they work in conjunction or collaboration with (or as a peripheral to) other technologies’ e.g. a printer (Adomavicius et al., 2006).

Table 2

<table>
<thead>
<tr>
<th>Possible relationship to TLS and TRs concepts</th>
<th>Author(s) and Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORIS (Operating Room Information System)</td>
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</tr>
<tr>
<td>LIS (Laboratory Information System)</td>
<td>Chien et al. (2007)</td>
<td>Paper regarding evaluation and improvement of turnaround time in a laboratory using LIS data. LIS will receive its core patient information from the PAS. Acts as part of the same layer as the above systems.</td>
</tr>
</tbody>
</table>
4.1.3 Technology Shaping Forces (TSFs)

Table 3 highlights the range of candidate TSFs identified:

<table>
<thead>
<tr>
<th>Category of TSF</th>
<th>Specific type/example of TSF</th>
<th>Author(s) and Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government</td>
<td>Policy direction*</td>
<td>Demiris et al. (2007)</td>
<td>e.g. in Critical Access Hospitals (CAH) in USA – driving capacity reductions to take advantage of new funding/government support arrangements</td>
</tr>
<tr>
<td>Regulatory and funding requirements*</td>
<td>Millar et al. (2008), Pelletier et al. (2005)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Government initiatives and broader responsibilities *</td>
<td>Chiu et al. (2006)</td>
<td>Jossi (2006)</td>
<td>e.g. ‘need’ to comply with government computer system impositions – e.g. around quality indicators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Greenberg et al. (2005), Faguy et al. (2005)</td>
<td>e.g. participating in national demand management initiatives – in this case – capacity for burns beds. Notably same issue exists for critical care beds in Australia</td>
</tr>
<tr>
<td>Financial</td>
<td>Funding types and mechanisms</td>
<td>Pelletier et al. (2005)</td>
<td>e.g. capped payments for expected service levels, specific grants, research or commercial funding, patient billing (all even within a public facility)</td>
</tr>
<tr>
<td>Funding source</td>
<td></td>
<td>Oliva et al. (2004)</td>
<td>e.g. state funded versus private hospitals</td>
</tr>
<tr>
<td>Financial viability of organizations*</td>
<td></td>
<td>Demiris et al. (2007)</td>
<td></td>
</tr>
<tr>
<td>Interest rates*</td>
<td></td>
<td>Fang et al. (2006)</td>
<td></td>
</tr>
<tr>
<td>Need to improve economic management</td>
<td></td>
<td>Vicedo and Conde (2007)</td>
<td></td>
</tr>
<tr>
<td>Capital vs. recurrent expenditure and ROI</td>
<td></td>
<td>Reddy et al. (2006), Fang et al. (2006)</td>
<td>Example of PACS purchase</td>
</tr>
<tr>
<td>Complexities around costing healthcare investigations and treatments</td>
<td></td>
<td>Beinfeld and Gazelle (2005), Oliva et al. (2004), Alvarez et al. (2006)</td>
<td></td>
</tr>
<tr>
<td>Reducing expenditure</td>
<td></td>
<td>Fang et al. (2006)</td>
<td></td>
</tr>
</tbody>
</table>
Table 3  Literature evidence regarding the Technology Shaping Forces concept (continued)

<table>
<thead>
<tr>
<th>Category of TSF</th>
<th>Specific type/example of TSF</th>
<th>Author(s) and Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>IT Technical</td>
<td>Existing technical infrastructure</td>
<td>Millar et al. (2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Software and system innovations</td>
<td>Okoroh et al. (2007)</td>
<td>Artificial neural network as part of a management DSS</td>
</tr>
<tr>
<td></td>
<td>IT Technical competency</td>
<td>Dwivedi et al. (2007)</td>
<td>Workflow management systems</td>
</tr>
<tr>
<td>Personnel</td>
<td>CIO</td>
<td>Lapão et al. (2009)</td>
<td>'CIO is a critical contributor to organisational IT strategy'; the role is evolving</td>
</tr>
<tr>
<td></td>
<td>General staff – IT skills and comfort level</td>
<td>Demiris et al. (2007)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Workforce supply issues</td>
<td>Wideman and Gallet (2006)</td>
<td>e.g. in managing radiology department</td>
</tr>
<tr>
<td></td>
<td>In-house programming skill</td>
<td>Reich et al. (2006)</td>
<td>As a cost reduction mechanism</td>
</tr>
<tr>
<td></td>
<td>Workload and work pattern issues of key staff</td>
<td>Pelletier et al. (2005);</td>
<td>e.g. documentation burden on nurses in aged care</td>
</tr>
<tr>
<td></td>
<td>Productivity gains</td>
<td>Fang et al. (2006)</td>
<td>e.g. in radiology from PACS implementation</td>
</tr>
<tr>
<td></td>
<td>Training implications of technologies</td>
<td>Faguy et al. (2005)</td>
<td>e.g. training in new software linked infusion devices as part of organisational safety agenda</td>
</tr>
<tr>
<td>Patient Based</td>
<td>Patient case mix (2 dimensions to this – organisational and broader)</td>
<td>Greenberg et al. (2005)</td>
<td>Note – depending on specific organisational context – may be partially or completely controllable – or not at all controllable</td>
</tr>
<tr>
<td></td>
<td>Changes in patient severity of illness</td>
<td>Beinfeld and Gazelle (2005)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complexities of treatment imposed by interrelationships between patient illnesses</td>
<td>Oliva et al. (2004)</td>
<td>e.g. the effect of diabetes on patient recovery</td>
</tr>
<tr>
<td></td>
<td>Need for long-term mass surveillance</td>
<td>Thomas et al. (2004)</td>
<td>e.g. post-op orthopedic procedures – site infections</td>
</tr>
<tr>
<td>Category of TSF</td>
<td>Specific type/example of TSF</td>
<td>Author(s) and Year</td>
<td>Notes</td>
</tr>
<tr>
<td>----------------</td>
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<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Safety and Quality</td>
<td>A perceived need to improve safety and resource management as a management driver for CPOE (Computerised physician order entry)</td>
<td>Vicedo and Conde (2007)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Quality and safety monitoring*</td>
<td>Chiu et al. (2006), Mekhjian et al. (2004), Faguy et al. (2005)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety gains</td>
<td>Faguy et al. (2005)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety Culture</td>
<td>Grant et al. (2006)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Need for systematic large scale infection monitoring</td>
<td>Thomas et al. (2004)</td>
<td>e.g. post-op orthopedic procedures – site infections</td>
</tr>
<tr>
<td>Healthcare Technical</td>
<td>New treatment modalities and services*</td>
<td>Bandyopadhyay et al. (2005), Shieh et al. (2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changing patterns of imaging use</td>
<td>Beinfeld and Gazelle (2005)</td>
<td>e.g. in suspected appendicitis, in transient ischaemic attacks</td>
</tr>
<tr>
<td></td>
<td>Organizational context – rural/metro</td>
<td>Demiris et al. (2007)</td>
<td>Questionable whether is a separate factor or encompasses some of the other organisational factors</td>
</tr>
<tr>
<td></td>
<td>Level of IT support</td>
<td>Demiris et al. (2007)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clinical governance frameworks*</td>
<td>Millar et al. (2008)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Service levels</td>
<td>Reddy et al. (2006)</td>
<td>The example is of a radiology service – but applies to intensive care, emergency and pathology and is organisationally specific by definition</td>
</tr>
<tr>
<td></td>
<td>Performance management frameworks*</td>
<td>Chien et al. (2007), Dexter et al. (2005)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Safety Culture – the need to improve it</td>
<td>Grant et al. (2006)</td>
<td>The creation of a non-punitive adverse event performance environment</td>
</tr>
<tr>
<td>Public expectation</td>
<td>Accountability and transparency around performance</td>
<td>Greenberg et al. (2005)</td>
<td>e.g. of performance type data which is clearly in the scope of what HMIS should provide</td>
</tr>
<tr>
<td></td>
<td>Accountability and transparency around safety</td>
<td>Mekhjian et al. (2004)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Items marked with an asterix represent candidate ESF’s (Environment Shaping Forces).
4.2 How does it (the TEM) compare with other IT planning lenses?

Table 4 Literature evidence regarding the IT Planning Lenses

<table>
<thead>
<tr>
<th>Possible alternate planning lenses</th>
<th>Author(s) and Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial lens</td>
<td>Fang et al. (2006)</td>
<td>But is very much limited to the microsystem of radiology management (via PACS implementation)</td>
</tr>
<tr>
<td></td>
<td>Glaser (2003b)</td>
<td>Financial lens – specifically looking at ROI and with more of an investment by investment or project by project basis</td>
</tr>
<tr>
<td>3LGM2</td>
<td>Winter et al. (2007)</td>
<td>3LGM2 too provides a mechanism for modellers to create models of information systems of hospital – these in turn can be used by information managers (loose term)</td>
</tr>
<tr>
<td>Value-based lens</td>
<td>Glaser (2003a)</td>
<td>Assesses IT investment and development form a point of view of organisational return (value to the organisation) e.g. medical error reduction, reduced costs, increased revenue, service improvement</td>
</tr>
<tr>
<td></td>
<td>Khoumbati et al. (2007)</td>
<td>Traditional cost-benefit approach</td>
</tr>
<tr>
<td>Categorical analysis</td>
<td>Quinn (1994) – quoted in Glaser (2003a)</td>
<td>Quinn proposes six categories of IT investment – infrastructure, mandated, cost reduction, new products and services, quality improvement and major strategic initiatives</td>
</tr>
</tbody>
</table>

5 Discussion

One of the reasons this research is important is that some of the biggest problems facing hospitals, including for instance balancing access to care with demand for care, are primarily the responsibility of hospital managers, although clearly the solution to the problem can involve all parties in the care process. Technologies that can support hospital managers in this and other regards are ultimately important in improving the functioning of hospitals and the patient experience. Worryingly, as Van Der Meijden et al. (2003) stated ‘systems that support the process of healthcare without being directly relevant to patient care are less easily accepted (by healthcare professionals, as opposed to clinically relevant systems)’.

Another reason this research is important is the dynamic nature of the relationships between technologies and the environment in which they sit. Work by Mekhjian et al. (2004) illustrates how the need for web-based event reporting system then in turn led to system-enabled metrics that in turn allowed monitoring of processes around event reporting. The relationships between problems, and the technologies used to solve them, are indeed very dynamic. This research will allow a much greater understanding of the nature of those dynamics in relation to hospital management problems.
5.1 Does the TEM apply to a hospital management environment?

In this section of the paper we will seek to prove the assertion made above that the TEM can be applied to the hospital environment and in particular to the HMIS environment, which is the specific context of this work.

5.1.1 Focal Technology (FT)

There was a significant range of articles identified which, in various ways, support the concept of a focal technology if using the TEM lens in the HMIS environment. At the clear and simple end of the spectrum, is the case study of the implementation of a new Environmental Services Support System (Unknown, 2007) in Alabama in the USA. The focal technology pointed to in this case is the PAS. This is the most likely candidate for a focal technology in the HMIS environment.

Reich et al. (2006), in their article about an anaesthesia information system (AIMS), highlight how the PAS acts as a focal technology in a ‘micro-ecosystem’, for want of a better term. It acts as an information store that ‘loads’ patient related information into the AIMS.

5.1.2 Technology Roles (TRs)

The original work on this by Adomavicus et al. uses the concept of technology roles – particularly within the framework of a hierarchy. As outlined previously, they specifically refer to three key roles in an ecosystem in this regard. They are:

- **the component role** – ‘describes technologies when they are used as components in more complex technologies’ (e.g. the hard disk drive).
- **the product and application role** – ‘describes technologies when they are built up from a set of components, and are designed to perform a specific set of functions or satisfy a specific set of needs’ (e.g. an MP3 player).
- **the support and infrastructure role** – ‘describes technologies when they work in conjunction or collaboration with (or as a peripheral to) other technologies’ e.g. a printer (Adomavicius et al., 2006).

Drawing on these initial concepts, in relation to the component role, there is very little work in the literature addressing, or providing indirect insights into what technological entities fill this role in relation to the HMIS context (see Section 6 for a more in-depth discussion of this issue).

In regard to the products and application role it is arguable that the other technologies in the same technology layer as PAS systems [as described below in Technology Layers (TLs)] play a ‘product and application role’ in this setting.

5.1.3 Technology Layers (TLs)

The principle technology layer (TL) identified in the research is the patient layer – or in non-health terms – the transaction processing layer. So while an excellent candidate for the focal technology is the Patient Administration System (PAS) – of which there are numerous commercial incarnations, other technologies in this layer include:
Radiology Information Systems (RIS)
Laboratory Information Systems (LIS)
Emergency Department Information Systems (EDIS) and others.

The common thread here is that all provide Transaction Processing (TP) type functionality relevant to their local departments – and all will or should relate to the PAS in the hospital organisation.

The only notable flaw in this argument, and it is a minor one, is that EDIS may also contain clinically relevant information that extends beyond what is conceptually TP type information [i.e. in this case TP type information includes when the patient entered the Emergency Department (ED), what trolley are they on now, when were they discharged].

In the article by Reich et al. (2006) around their AIMS, it can be argued that the PAS and the AIMS are an example of two systems in the same TL – consistent with the principle outlined above.

Dexter et al. (2003) highlight the importance of an Operating Room Information System (ORIS) in allowing an analysis of operating room turnaround time and delays.

5.1.4 Technology Shaping Forces (TSFs)

It can be seen from the results presented above, that there are a significant number of references in the health literature (within the scope implied by the above stated methodology) that are supportive of the assertion that the TEM can be applied to the hospital environment. There are also references alluding to the way in which the TEM can be applied.

In relation to the identification of TSFs in the health literature – particularly in relation to the HMIS context – this was undoubtedly the most clearly supported dimension of the TEM that was found in this research. Many articles highlighted plausible TSFs in a range of contexts – from hospital supply and logistics collaboratives in Canada (Rosser, 2006) to small rural hospitals in the USA (Demiris et al., 2007).

There is also the opportunity to extend the existing TEM based on the evidence in the health literature. Just as in biological ecosystems, there are forces, especially global forces – outside of the ecosystem, such as global climate and the effect of a depleted ozone layer that are not specific to or contained within a given ecosystem – so too there appears to be what we may call ‘environment shaping forces’ (ESFs) – in the technology ecosystems world view.

In terms of the kinds of TSFs identified, they are categorised in Table 3 (see Section 4) and represent an interesting insight into the complexity of the business, policy and technical environment that is the HMIS environment. From a subset of references documented in Table 3, some candidate ESFs were marked with an asterix.

This dimension (TSFs) of the TEM has also offered an opportunity to extend the existing model by examining the ways TSFs themselves effect each other as well as their effect on technologies and the TE as a whole.

In order to more fully explore the concept of ESFs, let us consider the work of Oliva et al. (2004) in assessing the direct healthcare costs of diabetes in Spain. This analysis of the costs borne by the health system in Spain through the burden of diabetes is a fairly comprehensive example of such forces. Oliva et al. (2004) outline how the increasing
prevalence of diabetes has multiple ripple effects through the health industry – and specifically through hospitals in that country (somewhere around 35% of direct healthcare costs, billions of dollars annually, are from hospital incurred costs).

Now clearly such a burden has an effect on the practice of hospital management in its various dimensions – in turn this burden (and remembering that this is just one, albeit one very important, chronic disease) will therefore have an effect on information systems that can support that management practice. In referring back to the TEM world view however, it is not clear that this burden is in and of itself a TSF; just as climate change is not a direct effectors on the life expectancy of a species in its ecosystem – rather it is the intermediate effects of climate change such as lack of moisture and increased temperature that more directly effect a species. Hence we would argue that ESFs (Environment Shaping Forces) are a useful and essential extension to the core concepts of the TEM and that ESFs act on an ecosystem at a day to day or micro level through intermediaries (TSFs).

Painting a similar picture, although from quite a different angle, is the work by Bandyopadhyay et al. (2005) that describes the implementation and evaluation, although primarily from a customer (patient) satisfaction perspective of a direct access surgery service in the UK. In this case, a clearly identified driver for a redesigned service to patients (a direct access minor surgery service) was demand for service in the described institution. This demand pressure is recognised as a generic phenomenon in healthcare internationally (Hongsermeier, 1997; Erlen, 2002; Kalucy et al., 2005; Brogan et al., 2008; Massin et al., 2008) – it is not a unique factor operating on that service and hence in the technology that supports the management of that service or hospital – it is an ESF and not a specific TSF in that local context.

This proposed extension to the base TEM is quite consistent with the statements of Adomavicius et al. in describing their view of the TEM as a lens to be applies to a particular focal technology and context. In fact this view reinforces the need for an extension such that the effect of general external forces (ESFs) can be individually contextualised to the particular focal technology and context (in a specific ecosystem view) through the roles of the relevant local equivalents (TSFs).

5.2 If so then how does it (the TEM) apply (to the hospital management environment) – for instance, could it be conceptually related to the arid zone biome?

An initial analogy that adequately presents the HMTE may appear be that of the arid zone biome – as indicated by example earlier. This is on the basis that there are few species (truly integrated technologies) that operate in a dry and barren environment (arguably lacking in innovation and primarily concerned with basic organisational functioning) which has very little rainfall (poor funding dedicated to this area compared with say clinical systems or more ‘sexy’ applications like PACS).

It is worth reflecting on the findings of this initial review of the health literature in assessing in what way the TEM may apply to the hospital management environment.

An initially confronting feature is the complexity of the environment. It would appear clear from this initial scan of the health literature and subsequent analysis that the perhaps the core of this is that the HMTE has many, many species in it, and forces operating on it, possibly reflecting a range of climates – but without extremes that minimise the number of species that can survive.
The role of government in terms of policy, compliance and funding is critical in this ecosystem, even in private hospitals, as the state usually has overarching responsibility for the quality and outcomes of care irrespective of the nature of the institutions in which it is delivered.

Earlier in this research we alluded to a concept from the biological space – namely that of ecosystems services. It is easy to see an application of this concept to this problem space. There are several ‘users’ or ‘receivers of service’ from the proposed HMTE, and the most important group by far are patients. In this ecosystem, patients as ‘receivers of services’ from the ecosystems are critical to the description of this ecosystem. An examination of how ‘users’ of ecosystems interrelate with those ecosystems could provide an insight into how the TEM may apply to this setting.

Put simply, perhaps the biological ecosystem that is the best analogy for the HMTE is one that

- has many, varied species
- endures a wide variety of climatic conditions
- provides services to a large key ‘user group’ and
- exists in a very constrained (arguably geographic) location

Clearly this assessment represents an initial postulation at this stage in the evolution of this area of knowledge. Further work in the context of the aforementioned programme of PhD research will seek to validate this initial proposal in a more objective fashion. In particular, further validation of this postulation against known biological ecosystems will be carried out.

5.3 How does it (the TEM) compare with other IT planning lenses?

Disappointingly, there is not a lot of research described in the health literature that allows a comparison of how the TEM compare with other IT planning lenses. This is not surprising, however, given the base literature examined in this research (itself part of a broader PhD research effort) is health literature rather than IT, IS and IM literature.

There is an argument that says that many organisations do not have a robust and established mechanism for planning their IT and IS developments and investments (Hosseini, 2005). Albeit this article comes from the non-health literature, it is a useful counterpoint to the limited literature in this area in the health domain.

‘Despite advances in the development of new applications, many organisations are not able to embrace these new technologies mainly due to not having devised an appropriate plan to position themselves technologically and organisationally to incorporate these technologies. In many instances, organisations are even crippled to take advantage of the new competitive systems, because they lack the right standards and or suffering from old, mismatched and antiquated systems that they can not get rid of easily. The roadmap will provide organisations with specific technical requirements for the immediate needs as well as a migration path to “plug in” the component and the products the business is moving towards.’

In support of this argument, Demiris et al. (2007), in their survey of US Critical Access Hospitals, found that half of their respondents (total $n = 27$ hospitals) did not have an IT plan. It is important to note however, that this survey was focused on small hospitals by definition.
As a counterbalance to this view however there are many organisations, including some hospitals, which have not only established roadmaps or other planning frameworks, but have also published them publicly. In fact, a 1999 article by Gottschalk (1999) even analysed the strategic IT plans of 190 companies. Again, this is not a health specific piece of research, but it goes to indicate that IT strategic planning is not such an unusual concept and perhaps suggests that there is a gross lack of evidence of the existence, or at least the published evaluation, of such plans in the health IT context.

6 Considerations and limitations

There are several important points to note in analysing the results obtained and in considering the review process:

- The management of patients (out of scope), and the management of hospitals in their entirety or wards or business units, are at the ends of a spectrum. As mentioned in the statement around definitions, there are hospital staff who do both – where search results may provide an insight into this middle ground they have been included.

- Equally, where results provide insights into the hospital environment (e.g. – infrastructure or biomedical engineering issues), definitely in scope in this work, they have been included.

- This work is heavily focused on the software and business aspects of the HMIS environment – whereas the original work devotes significant conceptual space to the role of hardware, components and end user devices through its concept of ‘component’ roles for technologies in particular. This is a reflection of the scope of the literature review in this particular piece of work – namely it includes health-based literature only. The complementary work being completed as part of the broader PhD research also examines the IT, IM and IS literature.

7 Conclusions

This work is some of the first of its kind and represents an opportunity to reassess the existing TEM of Adomavicius et al. (2005) in light of the evidence in the health literature. We conclude that the TEM is very applicable to the HMIS context, although its fit is stronger in some dimensions than others.

In addition, the evidence in the health literature – especially when cross referenced with the original TEM and the biological principles in which it has its roots – suggest a viable extension to the core concepts of the TEM. Specifically, that is, an additional dimension of ESFs (Environment Shaping Forces) that act at a more global level, potentially on multiple technological ecosystems, but in a way specific to each through the intermediaries of TSFs – technology-shaping forces.

Finally, the nature of the proposed HTME, in terms of biological correlates, has been further clarified and will act as a focus for further analysis as part of a broader program of PhD research.
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References


