# An Evaluation of Hospital Information Systems Integration Approaches

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**Abstract**
Healthcare organisations aim to provide high-quality, cost-effective healthcare delivery; to do this they must manage a large amounts of information. A fundamental concern in health management is the integration of health information across distributed, heterogeneous and disparate information systems. Various integration approaches have been attempted by healthcare organizations to solve the problems associated with this integration. However, the variety of approaches means that selecting the appropriate integration approach is problematic. This paper aims to analyse and evaluate current integration approaches in the healthcare domain. It attempts to clarify the issues surrounding the adoption of integration solutions in this domain for both healthcare decision-makers and system integrators.

**Categories and Subject Descriptors**

J.3 [LIFE AND MEDICAL SCIENCES]: Medical information systems.

**General Terms**
Performance and Theory

**Keywords**
Hospital Information System, Integration, Interoperability, Evaluation.

## 1. INTRODUCTION

A primary aim of healthcare organisations is to provide cost-effective, high-quality, shared and seamless healthcare delivery. They also aim to reduce medical errors, safeguard patients' data and streamline clinical and administrative tasks; aims which are more easily achieved through the integration of Hospital Information Systems (HIS) that manage healthcare data and processes [1, 2].
One of the major issues impacting on healthcare organizations' ability to achieve these aims is the large number of disparate and heterogeneous information systems that are characteristic of this domain. Many of these information systems have been designed and developed by different vendors to support specific processes in individual departments. This ad-hoc approach has resulted in the healthcare domain being left with islands of technologies and isolated independent information systems that are difficult to integrate [2].
These islands of information systems have a number of drawbacks that affect healthcare organizations. Because there is no sharing of data or process, each system stores and manages its own data. The resulting process and data redundancy leads to data integrity problems. In turn, this reduces the effectiveness of the data for decision-making and analysis [3]. This also leads to high operational costs caused by increased maintenance requirements [4].
Implementation of integrated HISs has provided significant benefits to healthcare organizations. Many complementary and overlapping integration approaches have been developed. However, selection of the most appropriate solution for each organisation is problematic as not all integration requirements can be addressed by a single solution [5, 6]. Healthcare stakeholders require an efficient method to realize and evaluate the abilities of each integration solution based on different integration requirements.
This paper attempts to aid integration of HISs by providing an evaluation and comparison of HIS integration approaches based on a categorization of integration solutions and integration requirements. The proposed integration requirements are derived from relevant case studies.
The remainder of this paper is organised as follows. Section 1 gives an overview of HIS and the issues associated with it. HIS integration is discussed in Section 3, including integration and interoperability paradigms and an overview of integration approaches. Categorization of HIS integration approaches are outlined in Section 4. Section 5 proposes a set of integration requirements. Finally, Section 6 presents some conclusions.

## 2. HOSPITAL INFORMATION SYSTEM (HIS)

The term Hospital Information System (HIS) refers to a federation of autonomous information systems which focuses on activities such as patient registration, transfer, admission, discharge, and other administrative, medical and financial functions [7]. This array of functions is illustrated in Figure 1. One of the prime requirements for providing continuity of care is the consistent and seamless sharing of medical information from multiple sub-domains in the healthcare domain. [1, 2, 8, 28]
The successful development of HIS depends upon an awareness of the need to deal with the integration of the information internal to the hospital and between hospitals' systems. This means that the focus is shifted from isolated processes in single healthcare institution to the patient-care oriented processes across institutional boundaries. Many of the problems associated with the

integration of healthcare information have resulted from the way in which HIS have developed.

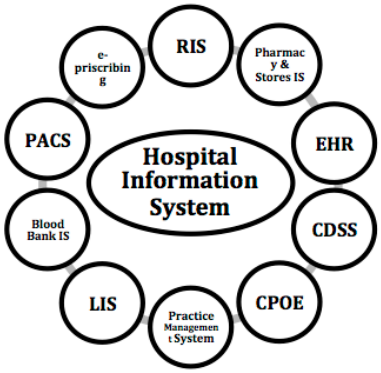


**Figure 1. Hospital Information System**

Early HIS were mainly batch applications in the financial and accounting domains. Later, limited online data entry for the purposes of patient transfers, admissions, discharges, reporting and scheduling was introduced. More recent approaches have included client/server architecture, graphical and web-based user interfaces, and the current state of play has shifted to middleware and service oriented solutions (See Figure 2) [3].

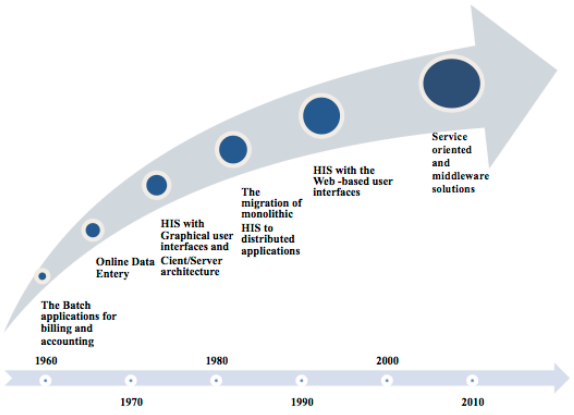


**Figure 2. The development of HIS**

The fundamental aim of each of these isolated systems is to deliver a single solution for each functional department in the healthcare domain. Even if each of these systems works as designed, none of them can supply the integrated information management needs of the entire healthcare enterprise [8]. In order to be able to do this, and improve the effectiveness of healthcare provision, individual HIS and their component systems need to be able to interact [9, 10].

Enabling HIS and their component parts to interact through integration of these systems is problematic because they have been implemented using different programming languages, communication protocols and architectural standards [8].

This has resulted in a high level of inconsistency in the management of healthcare information [5, 8, 9]. HIS are currently characterised by the individualization of activities, a highly heterogeneous and distributed environment and a lack of communication between information systems [10].

The next section will clarify these issues and outline the challenges for HIS integration.

## 3. INTEGRATION OF HISs

Information systems are essential for managing processes in hospital departments. To access information across hospital departments and between hospitals, integration of these information systems is necessary (See Figure 3).

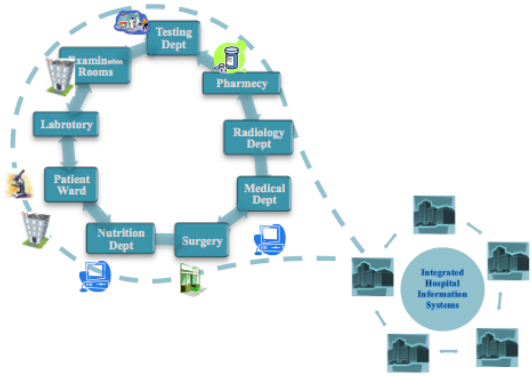


**Figure 3. Integrated HIS**

Combining data from multiple distributed heterogeneous information systems requires a great deal of effort. The differing functionality, data representation, user interface, semantic, presentation and terminology impose great challenges in terms of systems interoperability and integration [2].

Integration of HISs requires the interoperability of multiple independent systems. Interoperability is the ability of an information system to use services and data from another information system. This exchange allows these systems to achieve a specified task in a given context, and provides continuous exchange of information between collaborating HIS.

In achieving interoperability, as well as the obvious social and legislative issues, there are substantial technical issues to be considered. Interoperability is a necessary prerequisite and precondition fully integration solutions.

Integration refers to a moment in an interoperability time line where different information systems are interconnected physically and logically to achieve solution delivery [11].

The shift in the healthcare domain towards highly distributed and heterogeneous environments has created a need for these systems to support a consensus communication and interoperability on different levels as follows [12]:

- Technical interoperability refers to technical aspects of interconnecting computer systems. It covers key issues such as interconnection services, communications technologies, middleware, data exchange, security services, data presentation, technical architecture styles, technical infrastructures and accessibility services. This perspective should support the interoperable solutions at the technical layer.
- Syntactic interoperability is the ability of exchanging information between information systems. For achieving to this the compatibility at the transport and application layers of the communications protocols is necessary. The agreement with the messaging protocols and encoding data formats also require. It is a necessary precondition for further interoperability.
- Structural interoperability provides a common agreed model of clinical or other domain concepts. This model clinically is meaningful entity that can be shared by multiple independent information systems components.

This is resulted in enabling information to be shared between information systems.

- Semantic interoperability is the ability to provide meaningful exchanged of information in order to the content of the message be understood by the recipient system or process. It facilitates common reference models which recipient system must refer to it.
- Operational interoperability focuses on how administrative, clinical or statistical information should be represented and interpreted. To support interoperability administrative, clinical and management staff will require an understanding of the implications of having integrated data available.
- Organization interoperability is concerned with processes, policies, roles, management and frameworks around the integration of data from different administrative domains. It focuses on the understanding of the regulatory and legislative environment in order to improve healthcare delivery.

In order to be able to support these different perspectives, various approaches to interoperability and integration have been proposed. These include technical healthcare data exchange standards and protocols, domain specific standards, various types of middleware technologies, unified concept models and medical coding. Contemporary approaches include service-oriented architectures, semantic ontologies, knowledge level interoperability and model driven standardization. Despite distinct approaches, interoperability always relies on agreement between the participating information systems and components [3, 11].

There are two basic methods for HIS development and acquisition in healthcare organizations:

1. Acquisition of broad integrated systems that can provide majority of functional requirements for healthcare users.
2. Integration of component, application and systems from different vendors.

The systems could be integrated using automatic generator tools, specialized development of required extensions, or rapid prototyping. Healthcare systems are difficult to integrate because they have evolved gradually, with varying requirements from different users. This has led to a hospital ecosystem with technical infrastructure acquired over a long period of time from various sources. These legacy systems are often irreplaceable and vital to the functioning of the hospital [13]. With the increasing number of applications, an integrated system from one vendor is only possible for smaller organizations such as private clinics.

Because of this, unified architectures for HIS integration are rare. The needs of different healthcare users and traditionally strong healthcare users orientation in acquisitions led healthcare organization to integrate different systems from various sources.

Despite the development of new technologies such as data mining, automated knowledge management, clinical decision support, advanced machine learning; challenges to integrate systems and incompatibility of standards still exist [3].

Many health software vendors and research institutions have attempted to address the issues regarding HIS integration. Among these solutions, the introduction of healthcare data exchange standards, such as DICOM[1] and HL7[2], that specify interaction between separate systems have improved the way heterogeneous HIS sub-systems can share information [5,8].

[1] Digital Imaging and Communication in Medical

[2] Health Level 7

RSNA[3] and HIMSS[4] introduced the IHE[5] project to solve the integration issues in HIS through specifying the implementation of healthcare data exchange standards [8]. IHE introduced a detailed framework for establishing the relevant existing medical standards, and also bridges the gap between establishment of standards and implementation of integrated systems [14].

Data warehousing offers another solution for HIS integration; data from individual systems could be integrated and homogenized in the data warehouse, providing a single repository for disparate data extracted from multiple sources. This solution requires translation of data from multiple sources into one common database schema.

Another approach is Federated Database System Technology for the healthcare domain. This approach consists of an integrated set of fully featured distributed and autonomous databases, where the component administrators control their local systems, but they collaborate with the federation to achieve some degree of integration [15].

The IBHIS[6] project has been exploring the broker approach to resolving integration issues in the healthcare domain. The purpose of IBHIS is to build an IBS[7] that provides reliable integration of healthcare data owned and managed by distributed and autonomous information systems [16, 17, 18, 19].

The Synapses project, funded under the European Union's (EU) 4th Framework health telemetric Program in 1995, addressed the problem of sharing data between distributed information systems based on a common data model. This data model supplies a set of "building blocks" that are then used to create the shared healthcare data record [5, 9].

All other possible technical HIS integration solutions will be described in detail in the next section. The categorization of these solutions provides an appropriate perspective for evaluation of HIS integration approaches.

# 4. CATEGORIZATION OF HIS INTEGRATION APPROACHES AS A MULTI-DIMENTIONAL CONSEPT

The technical approaches to HIS integration are commonly characterised by very specific purposes that aim to unify information systems and databases. These approaches make disparate information systems interpretable by incorporating different technical artefacts into a coherent system that appears to function as a single system in order to integrate intra- and inter-organisational processes and data [20, 21, 22, 23].

The categorization of technical approaches is summarized below since the evaluation requirements which are proposed in Section 5 focuses to assess these approaches:

- Message-Oriented integration
- Application-Oriented integration
- Coordinated-Oriented integration
- Middleware-Oriented integration

**A- Message-Oriented integration** relies on a set of standard messages that allow various HIS subsystems to exchange messages carrying data. This approach uses databases, APIs and data exchange to produce information. The primary idea is to

[3] Radiological Society of North America

[4] Healthcare Information and Management Systems Society

[5] Integrating the Healthcare Enterprise

[6] Integration Broker for Heterogeneous Information Sources

[7] Information Broker Service

exchange structured electronic messages between different applications and also the use of already established standards [37].
It is considered a mechanism that supplies functional integration of HIS at regional level in order to automate the medical processes such as patient admission, transfer, prescriptions, ordering of laboratory and radiological examinations, for automatic or on demand receipt of results.
This approach provides an effective way to solve the basic integration problems between information systems; however they do not cover true interoperability and integration of information. The HIS still looks like "islands" of systems with a lack of interoperability and communication. The problem is with increasing the number of possible interactions between systems, the limitations of scalability become appear. Also, despite using medical standards, the implementation still varies and is vendor dependent. This solution cannot be considered as system integration but rather as inter-system communication [7, 8, 9].
Examples of Message-oriented integration approaches in healthcare is seen in the use of HL7, DICOM messages, EAI, XML DTD[8] and HL7 CDA documents [4].

**B- Application-Oriented integration** supplies a layer of defined and centrally managed applications on top of existing applications in order to support the flow and exchange of information and control logic between them by combining relevant applications and processes. This solution often consists of process engines, workflow or distributed objects and integration servers. It is essential to define and understand the application and processes in the organization to provide application-oriented solutions. Workflow-oriented IHE integration profiles are an example of an application-oriented integration approach [4, 24, 25].
IHE defines the Technical Framework to achieve system integration by describing implementation of already existing medical standards, integration profiles and detailed technical specification of actors and transactions.
Actors, in this technical framework, are information systems or component parts of information systems that provide, act, produce, manage, or operate on categories of information needed by operational activities in the enterprise. Transactions describe interactions between actors that transfer the needed information via standards-oriented messages. Integration profiles are identified as a set of IHE Actors which involved in a medical information process and interact through transactions to perform specific operations [8, 24].
The main goal is to ensure all information needed in decision making is available on time and is accurate for the users of medical software application and medical tasks.

**C- Coordinated-Oriented integration** provides a consistent view on the information held in several separate and disparate systems, applications and underlying services for user. This can be supplied by using a unified front-end system or by synchronizing and coordinating the various systems or applications on the user workstation. So when a user signs onto one system within the tied group of disparate systems by this approach, the same sign-on is simultaneously executed on all other systems within the group. This solution builds a combined view of the information at the desktop and/or portal level in a unified way.
This approach emphasises end-user aspects. The systems or applications are not necessarily directly integrated on a service or data level. The examples of this approach include the CCOW[9] context management standard from HL7, healthcare professional portals and IHE Patient Synchronized Applications (PSA) integration profile which includes more detailed specifications utilizing CCOW standard [24, 25, 26].
This division of integration approaches addresses the classification of specific integration needs (relating identified interoperability requirements to different integration approaches), and also identification of relevant standards and specifications. In many cases, the solution is the combination of features from different integration approaches, but it is useful to define the primary approach as one of the specified options.

**D- Middleware-Oriented integration** defines a set of services, interfaces or shared methods which support the entire system. This approach provides the infrastructure for sharing of functional services and information. Services are well defined and self-contained functions that do not rely on the context or state of other services. Services may be implemented using a wide range of technologies, including SOAP, DCOM, CORBA, Java or Web Services [27]. This approach reduces the need for replication of data and methods in several systems, and enables them to operate by providing infrastructure for Message and Application oriented integration [29].
Interconnection and integration of HIS can be provided by the generic middleware components. Healthcare organizations can be assumed to be a collection of disparate users that are performing diverse tasks. All require the sharing of a common data set and use of a common business services set. These must be accessible to applications by standard interfaces. This subject is addressed by the Middleware-oriented integration approach [9, 30, 31]. This solution may require changes in legacy systems such as adaptation into the common infrastructure.
The Object Management Group OMG Healthcare specifications (PIDS, TQS), DHI, HANSA, HISA, Synapess, CORBAmed and common services of the PICNIC project are examples of this approach [25, 26].
CORBA as an example of this solution introduces CORBAmed as a Healthcare Special division of CORBA. CORBAmed started providing standard interfaces for healthcare related objects by addressing a `request for information' that requested the healthcare organization and information technology industry to give the OMG[10] counselling in its standardization efforts for CORBAmed. Besides, the domain-independent services covered by the OMG, a collection of healthcare domain-specific services have been supplied, including Health care Resource Access Control, Person Identification Services, Clinical Observation Access Service, Clinical Image Access Service and Lexicon Query Services. The overall purpose of CORBAmed is "to improve the quality of care and reduce costs by applying the CORBA technologies for integration and interoperability in the global health care community" [9]. It can be assumed that the CORBAmed services within the CORBA framework could be an important standard for the integration of subsystems in healthcare domain. It is not currently clear to what extent CORBAmed will provide a solution to the challenge of HIS integration [7, 32, 33].
The CEN ENV 12967-1 standard HISA is constructed in three cooperative layers (bitways, middleware, and applications), each individually responsible for issuing specific design, function and operational aspects of the information system [9].
The middleware layer acts as the central component of the system, supplying an infrastructure where all applications can be connected. The DHE[11] is the representation of this middleware layer. The DHE middleware able information to be entered, stored, modified, and retrieved via a collection of common

[8] Document Type Definition
[9] Clinical Context Object Workgroup
[10] Online Marketing Group
[11] Distributed Healthcare Environment

services, that are approachable to the applications through stable and public APIs[12]. This layer, via its services, provides the management of the information through reliable and technology-independent interfaces for the whole organization [34, 35].

HISA provides an explicit conceptual framework for HIS. As a pathway to its establishment and implementation, the Synex project is an effective and efficient representation of the HISA model. It started in 1998, and attempts to provide a standard integration approach that allows both new and legacy HIS to exchange data. This project provides access to healthcare information services and remote sources of medical data through masking the distribution and heterogeneity aspects of HIS. The main purpose of the Synex project is a high level of portability of middleware and applications [2, 35].

Another representation of HISA model is the HANSA[13] project which was introduced under the EU Health Telematics Fourth Framework programme. The HANSA project attempts to identify common migration principles and instructions, and to demonstrate that the existing 'legacy' information systems can be constructed on top of a common, open middleware of healthcare-oriented functionalities [2].

EAI[14] is another new middleware approach that provides an integration framework to combines a set of technologies to integrate systems across the enterprise. The EAI techniques are similar to the three layers of HISA, but, the middleware layer of HISA is replaced by message-oriented communication structure. So, the problem associated with message based communication is also not solved in EAI approach [9, 30, 31].

In order to provide interoperability between HIS sub-systems, neither CORBAmed nor HISA could provide sufficient exchange of messages; therefore, these approaches lead to a loosely coupled interconnection between different sectors in the healthcare organization, without providing the requirements of the healthcare organization as a whole [9].

# 5. HIS INTEGRATION REQUIRMENTS

Identifying and comparing different aspects of various solutions is useful when selecting an integration solution.

Besides the technical requirements of each approach, there are integration requirements should be considered when information systems piecing together. The number of basic requirements based on literature reviews and published case studies on Enterprise Application Integration area have been identified. These set of requirements defines characteristics of overall integration approaches that can be used as evaluation criteria when assessing integration solutions, the integration requirements describe common functional and non-functional requirements which are needed when implementing integration approaches. These non – functional requirements include:

**Flexibility** refers to the capabilities of integration technologies toward rapid adjustments. For example modifications of software engineering, with minimum effort, operational and functional capabilities in various computing environments.

**Real time** describes the ability of integration technologies to support transactions which require up to the second data latency. Data latency describes how current information needs to be.

**Reliability** denotes the techniques and protocols which are practiced in integration technologies to ensure all transmitted data by sender to receive at end point and the order of packets that are sent is preserved.

**Reusability** refers to the ability to use existing information system components or software solutions to develop new applications in the specific domain. Reusability reduces the time and cost of implementation. It has a significant role in system integration and the results are more maintainable and flexible system.

**Performance** refers to the performance of the system. Some system integration approaches provide integration however the performance of overall integration solution may not be satisfactory.

**Complexity** refers to the implementation difficulty of integration technology from technical viewpoint. The complex integration approaches increase development and maintenance costs, so they may not be preferred.

**Maintainability** refers to the ability of information system components and software applications to allow changes without causing any problems in other systems. Integration technologies should aim for solutions which could be easily maintained.

**Maturity** refers to well tested, established, and mature integration technologies. The more mature technology is the better solution because the software developers, engineers and analysts can provide successful implementations.

**Portability** describes the software solution that is developed for one platform could be easily executed on different platforms. Portability is related to the concept of standards and provides an important role in the cost effectiveness of information systems [1, 2, 12, 36].

**Scalability** refers to the ability of integration technologies to supply high performance to accommodate a growing future loads and increasing demands.

**Heterogeneity** refers to capability of interoperating of legacy and new information system through the availability of proper programming language and operating system platforms.

Scalability and Heterogeneity are classified as functional requirements. Table 1 and 2 evaluate integration approaches based on the mentioned integration requirements.

This evaluation attempts to clarify the confusion surrounding integration solutions in order to support organizations when healthcare stockholders need to select appropriate integration approaches. The evaluation has focused on the set of criteria which efficiently describe the integration approaches area.

As observed in Section 4, integration approaches are supported by integration technologies that focus on integration of information, application, and infrastructure. Different integration approaches support different types of integration specifications.

The evaluation is provided based on the categorization of integration approaches. Such evaluation clarifies the differences between different integration solutions.

The Message-Oriented integration families address reliable, real time data integration. However, they not support all integration requirements. They rarely are compatible with each other. HL7 as an example of this category has a complexity of implementation that increases development and maintenance costs. DICOM, another member of Message-Oriented integration families, is a mature solution that provides low complexity and real time transactions. Neither HL7 nor DICOM satisfy the remaining criteria.

Application-Oriented integration solutions address real time issues more efficiently. They support reliable integration. CCOW, as an example of the Coordinated-Oriented integration solutions category, provides flexible and portable integration. The Middleware-Oriented integration solution families can be used to provide object and component integration.

[12] Application Programming Interfaces
[13] Health Advanced Network System
[14] Enterprise Application Integration

**Table1: Compression of some current integration solutions in the context of Non-Functional integration requirements.**

| Non- Functional Integration Requirements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Flexibility | Real-time | Reliability | Reusability | Performance | Complexity | Maintainability | Maturity | Portability |
| Message- OI | HL7 | × | ✓ | ✓ | × | × | ✓ | • | × | • |
| | DICOM | × | ✓ | ✓ | × | × | × | • | ✓ | • |
| Middleware-OI | CORBA med | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | × | • |
| | HANSA | ✓ | ✓ | ✓ | ✓ | × | × | ✓ | × | ✓ |
| | SYNEX | ✓ | ✓ | ✓ | ✓ | × | × | • | × | • |
| Application- OI | IHE | ✓ | ✓ | ✓ | × | × | • | ✓ | • | ✓ |
| Coordinated-OI | CCOW | ✓ | ✓ | ✓ | • | × | × | × | × | ✓ |

• : Unknown

**Table2: Compression integration solutions based on Functional Integration Requirements.**

| Functional Integration Requirements | | | |
|---|---|---|---|
| | | Scalability | Heterogeneity |
| Message- OI | HL7 | × | × |
| | DICOM | × | × |
| Middleware-OI | CORBA med | × | ✓ |
| | HANSA | ✓ | ✓ |
| | SYNEX | ✓ | ✓ |
| Application- OI | IHE | ✓ | • |
| Coordinated-OI | CCOW | × | × |

Nonetheless, they are not mature enough. CORBAmed, HANSA and SYNEX from this category satisfy reusability criterion. They can be used for development of flexible and maintainable solutions, and satisfy heterogeneity, real time and reliable criterions.

The results of the proposed evaluation show no single integration approaches satisfy all evaluation criteria and address all integration requirements. Each solution addresses a broad set of integration issues. Thus, this evaluation suggests a combination of integration approaches is needed to provide enterprise and cross enterprise integration. This work clarifies the differences between integration solutions and supports integrators to select most appropriate combination of integration approaches. It provides developers better understanding of capability of each approach.

The adoption of the proposed evaluation from healthcare organizations may leads to maintainable and flexible integrated enterprise solution. This solution could increases a performance of organization through eliminating the maintenance efforts and costs.

## 6. Conclusion

Information systems in the healthcare domain have been developed in different platforms, computer languages and data structures, they are not deployed as heterogeneous and autonomous systems and so the capability of healthcare organisation to provide quality and shared patient care delivery is impeded. Integration of these heterogeneous systems is seen as a solution to this, and many different integration approaches have been developed.

Different integration approaches provide different types of integration solutions. This paper has categorised integration approaches into four different categories based on their function, those being Message, Application, Coordinated and Middleware oriented integration. Some of current integration approaches in each category were evaluated based on set of defined integration requirement criteria. This analysis was based on different functional and non-functional integration factors such as Flexibility, Real time, Reliability, Reusability, Performance, Complexity, Maintainability, Maturity, Portability, Scalability, Heterogeneity. The results of this evaluation provided a clear vision that there is no single approach that satisfies all integration requirements. Identification and combination of integration solution is essential for Inter and intra-organizational integration to select the most suitable set of technologies, standards and approaches for a given set of integration requirements.

Efficient functioning of integrated HISs will help in reducing medical errors and Health delivery costs and save human lives. Moreover, healthcare organization can take advantage of improving processes between multiple hospital departments and organizations and multiple healthcare stakeholders.

This analysis attempted to clarify these issues by evaluating current solutions based on various integration requirements. The proposed evaluation had been provided a clear vision of benefits, barriers and specifications of each integration solution for healthcare service providers, healthcare decision-makers and system integrators and providers.

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