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Systems integration of heterogeneous cultural heritage information systems in museums: a case study of the National Palace Museum

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Abstract This study addresses the process of information systems integration in museums. Research emphasis has concentrated on systems integration in the business community after restructuring of commercial enterprises. Museums fundamentally differ from commercial enterprises and thus cannot wholly rely on the business model for systems integration. A case study of the National Palace Museum in Taiwan was conducted to investigate its systems integration of five legacy systems into one information system for museum and public use. Participatory observation methods were used to collect data for inductive analysis. The results suggested that museums are motivated to integrate their systems by internal cultural and administrative operations, external cultural and creative industries, public expectations, and information technology attributes. Four factors related to the success of the systems integration project: (1) the unique attributes of a museum's artifacts, (2) the attributes and needs of a system's users, (3) the unique demands of museum work, and (4) the attributes of existing information technology resources within a museum. The results provide useful reference data for other museums when they carry out systems integration.

Keywords Systems integration · Legacy systems · Museum management · National Palace Museum

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1 Introduction

For decades, museums have used information technology to manage their huge amounts of data. In the past, information technology in museums mainly relied on Collection Management System (CMS). From the perspective of Jones-Garmil [18], as information technology has advanced across the decades, museums have increasingly acknowledged the importance of information technology, evidenced by their use of multimedia, the Internet, and other technologies as they became available [18]. Museums are now developing digital libraries (DLs) of their collections to provide a variety of users with access to their digital collections and other information services. However, few scholars have studied the relationship of DLs to their museums' original information systems. Even less research has been done on the systems integration (SI) that is needed when the lifespan of a museum's DL reaches its end or when changes occur in a museum's internal or external managerial environment.

Museums' CMSs are derived from the fundamentals of the management of museum collections. CMS is a system that is oriented toward procedures and management; its primary functions cover collection management and registration, transfer information, location history, conservation status, exhibition data, and publication records. Driven by factors such as evolving technological options and a growing number of digital collections, museums began to focus on digitizing their collections by building DLs and other management systems (not CMS). From the perspective of technology, these management systems and DLs function as information systems that play an essential part with respect to museums' overall collection management, exhibitions, education, and research.

Museums are now facing the need to integrate their existing information systems to improve their operational

performance in a climate of growing competition and increasing complexity in the operating environment. In addition, the lifespan of an information system tends to be 5–8 years [24], so the management systems and DLs built by museums in the 1990s and 2000s are reaching their endpoints. Museums need to review and reconstruct the functional capacities of their information systems and determine whether systems integration (SI) is a necessary step for them to take. However, although SI has become an important research topic in the field of information management, the studies mostly have focused on the integration of information systems in commercial enterprises, such as enterprise resource planning (ERP), product data management (PDM), or after a merger or acquisition. We know little about the SI of museums and cultural heritage institutions.

The museum environment is different from the commercial enterprise environment and its information processing, systems development, and integration requirements differ. Most software developers and information integrators have emphasized the business model and they lack experience in developing and integrating systems that meet museums' specific needs. As a result, it is challenging for a museum to find a systems integrator who speaks the museum "language" and there often is a learning curve.

This study addresses these issues using a case study approach to assess the National Palace Museum's (NPM) integration of its five legacy information systems. It employs the participant observation method to investigate (1) the museum's motivations for integrating its heterogeneous information systems and (2) the factors that influenced the execution of its SI. By investigating the motivations that drive the NPM's integration of its systems and analyzing the factors that influence its SI, this study aims to provide other museums and cultural heritage institutions with a specific reference model for planning and executing SI that will enhance the quality of their plans and improve their chances of success. The NPM began its "SI Project" in January of 2011 with the goal of integrating its original management system (the CMS) with its subsequent DLs to create one integrated comprehensive system.

The next section discusses the research literature that addresses the historical development and integration of museum information systems, their DLs, the attributes of museum information representations, and the SI in place. The methodology of the case study is explained in Sect. 3 with an introduction to the NPM and its status with respect to its SI. The results of the analysis of the data collected through participant observation are discussed in Sect. 4. Section 5 offers several suggestions regarding the use of SI based on general conclusions drawn from the study's results.

2 Development and integration of museum information systems

2.1 Development of museum information systems

Museum CMSs were developed to accommodate museum registration and collection management. Museums' DLs digitize artifactual information, including images, into databases to provide users with digital sources of artifactual data, multimedia data, and other information services. Although the development and functions of CMSs and DLs differ, advancements in information technology have made it possible to partially integrate them.

2.1.1 Collection Management System

In the 1960s, museums developed the CMS from their registration work [12,26]. This development was led by the National Museum of Natural History, a member of the American Smithsonian Institution. The first official CMS was the SELF-Generating Master (SELGEM), which used text and numerical data columns with number sequence tags to record basic data on the registration forms of collections [12,18]. In 1967, experts from the museum sector joined the effort and developed Generalized Retrieval and Information Processing for Humanities-Oriented Studies (GRIPHOS). This CMS recorded collections related to the humanities and the arts. SELGEM and GRIPHOS were similar in that they both were CMSs that had been developed from museum registration work, used large mainframe computers, relied on mainframe computing units located offsite from the museum, and were available to museums free of charge [18]. SELGEM and GRIPHOS have been used by museums for many years and they have had profound influences on the development of CMS.

The availability of minicomputers and personal computers since the 1970s and 1980s, the decreasing prices of computer software and hardware, and the enhancement of computer processing performance that accompanied the marketing of these tools meant that the CMS was freed from dependence on mainframe computers. Moreover, the CMS gained the ability to process images as well as text. During this period, CMS software packages for museums were developed and CMS functions were expanded from recording collection-related information to systematically integrating collection management to support other aspects of museum work. Museums began to establish specialized networks, such as the Museum Computer Network (MCN) and the Getty Research Institute, to exchange their views on the application of information technology and to study and stipulate museums' information representation standards [12,13,18].

Generally, because the CMS was developed from information that was produced in the processing of relevant

documents and activities related to registration work, it included the demands of other departments to which the information was relevant. The information contained in the CMS was mainly culled from collection catalogs, registration forms, inventory files, acquisition data logs, artifactual listing records, conservation files, and condition reports [31]. Thus, the CMS's primary contents consisted of collection registration forms and information associated with collection handling.

However, these data no longer satisfy collection management requirements. CMS must expand its functions to include all situations pertinent to museum affairs that could benefit from the application of collection data. According to an analysis by the Canadian Heritage Information Network (CHIN), a professional organization that enables museums and other heritage organizations to digitally interconnect, there are 40 CMS brands in the market. In addition, according to CHIN, today's CMSs should include the following: (1) basic collection registration management; (2) copyright; (3) exhibition management; (4) transportation, borrowing, and lending; (5) controlled vocabularies and authority control; (6) input/output control; (7) data search configuration; and (8) multimedia management [9]. Collecting all of the information relevant to museum affairs into a CMS is the only feasible way to properly manage a museum's collection information.

2.1.2 Development of other museum information systems

Museums have introduced a diverse array of information systems to promote museum business that have become a part of daily operations and work procedures [12]. Some examples of these systems are digital assets management (DAM), digital rights management (DRM), and in-house multimedia systems for exhibitions and educational displays. The CMS remained the primary information system to support these systems [13]. An additional important development in recent years is the use of a variety of information technologies to digitize large and small collections, provide search and application services, and build DLs. These technologies differ from the established CMS that was derived from the processing procedures of museum collections and from systems such as DAM and DRM that were built by museums to manage information or promote business.

The concept of digitizing cultural heritage data into a DL was introduced in the 1990s [29]. Some early examples are the Library of Congress' American Memory Pilot Program and the Digital Library Initiative. The efforts were collectively promoted by pioneering governmental agencies such as the United States' National Science Foundation. After nearly two decades of development, many museums are now planning to digitize their cultural heritage data. In 2002, the Taiwan e-Learning and Digital Archives Program (TELDAP) was founded to help museums and cultural heritage preservation institutions in Taiwan to digitize their collections [29]. The NPM used TELDAP to build numerous DLs for its collections. The NPM's DLs became the primary sources used by its curators and they were opened to the public as learning and research resources. The scope of a museum's DL is wide because DLs incorporate different data when they are created from different points of view. From the perspective of technology, a DL is an information services application software derived from a computer network, information technology that provides users with access to digital collections stored as multimedia, and a variety of information services related to collection information [5,15,28].

2.2 Attributes of museum information representation

When museums are establishing traditional CMSs and DLs, they tend to encounter organizational, storage, and presentation problems related to the data. Museum data have unique attributes that make them difficult to process. These attributes not only challenge the establishment of information systems [13], but also defy the integration of these systems. A large body of literature about the development of museum information systems and information representation suggests that museum data have numerous properties [4,6,18].

The first relevant attribute is that museum collections are diverse and museums are deeply influenced by the types of collections and the range of materials that each contains. The extent and nature of this diversity are the parameters by which museums tend to structure their departments. Different types of museums, even different collection departments within one museum, require different metadata and, consequently, different digitization technology. For example, an art museum and an anthropology museum are distinct with respect to metadata and their collection management procedures necessarily differ.

The second relevant attribute is that museums' information representation is multifaceted and academic. Precise and useful museum collection data do the following [4]:

1. include information on the sources of the collections;
2. communicate and preserves the meanings of the collections in their cultural or natural environments;
3. record the original environmental context of the collections that retains the underlying stories to effectively preserve collection-related information, such as other collections, persons, places, events, and actions; and
4. establish relationships.

The need to preserve variability is the third attribute relevant to the challenges to establishing a system. The representation of collection data must allow for variability because of the diversity of data across time and space, which makes it dif-

ficult to standardize the data. For example, large amounts of information on names of persons, names of places, and titles of eras must be processed. These terms not only differ among cultural systems; they may be represented in numerous ways according to factors such as religion, politics, and language [4,31]. The complexity of terms and their diverse meanings pose difficulties when information systems are attempting to process them. New titles and new content related to existing artifacts may need to be reorganized when discoveries are made that affect conceptual categorizations or when the artifacts are on exhibition. An example is art museums, which have internationally controlled vocabulary standards (e.g. Art and Architecture Thesaurus) and semantics' norms (e.g. Cataloging Cultural Objects) that were developed in the context of Western art history. Museums in other cultural systems or that host other types of collections need to develop specific and distinct processing methods that fit the attributes of their unique collections because the existing Westernized standards are not conceptually applicable.

2.3 Information SI and museums

2.3.1 Activities of SI

Information SI has always been important in the field of information management. SI, in the commercial enterprise context, usually refers to the amalgamation of an enterprise's information systems, databases, and/or functions aiming to enhance processing procedures or to provide better services [19,23]. Modern enterprises typically use numerous information systems, such as enterprise resource planning, supply chain management, electronic commerce, customer relationship management, and product data management. However, appropriate SI can improve procedural efficiency, standardize the way that information is presented, and increase the flexibility of processing methods. SI has the potential to help enterprises more easily achieve their operating and/or financial goals [27].

SI offers many benefits, but it is not as simple as combining numerous systems of software, hardware, and data. It must address the legacy system and its impact on the business and the systems' users. Thus, SI involves behavior integration as well as technological integration. The roles and responsibilities of systems' users must be adjusted to accomplish this and, given the difficulty of this endeavor, the overall success rate of SI Projects tends to be quite low. A considerable investment of time and funds is requires for success [19,23]. Moreover, SI must account for the lifespans of the relevant legacy systems. From the perspective of systems engineering, SI activities must holistically integrate hardware, software, products, services, commercial procedures, and personnel [17].

There are different levels of SI. The lowest level of integration involves the establishment of consistency within communications' frameworks and data transmission. SI on a slightly higher level is often termed "point-to-point integration", in which individual systems use an application programming interface or data synchronization tools to exchange information [23,27]. "Middleware" is an even more advanced level of SI. It standardizes and controls each system's data to facilitate data exchange, involving object-level integration and handling of semantic problems that are posed by an individual system's information contents. Process integration is perhaps the highest level of integration, which requires software, hardware, data, and semantics processing and forges connections among and adjustments to corporate procedures [23,27]. Generally, the SIs with relatively more stringent definitions are the SIs that are more likely to achieve process integration. Some SIs interact with external resources in the scope of their integrations [23,27].

The major information systems of museums include the CMS, digital asset management, and DLs; primary data are comprised of information related to artifactual management and conservation and the research metadata associated with the artifacts. Data about users or behavior is rarely present and situations common to the commercial sector, such as real-time data exchange between systems or integration with external resources, are seldom important to museums. Thus, the emphasis of a museum's SI should be on what is most important to museums: software and hardware integration, information integration, process integration, and interface integration.

2.3.2 Museum SI

The likelihood that problems among information systems, such as data content overlap, will occur has increased because of museums' growing reliance on these systems to handle artifact management, exhibitions, education, research, and publication. Museums need to integrate their related or repetitive information systems so that their efficiency can keep up with the changing social environment and the public's expectations. More than 15 years ago, Blackaby and Sandore [7] conducted the only thorough study of SI in museums. They analyzed numerous museums and their artifactual digitization plans and determined that museum SI generally takes one of four approaches:

1. an entrance frame is designed, in which users can choose which system to use (although this does not constitute a true integration).
2. A search engine is developed to perform cross-systems' data searches, although each system maintains independent operations.

3. A system or database is selected as the primary system and data are translated from the other systems to the designated primary system. The drawbacks of this approach are (a) the individual departments may not agree to use the same database (Take the Collection Department and Registration Department for an example, the former hopes that the database should focus more on the description of artifacts, while the latter hopes that database should record the movement locations of the artifacts in detail. Unless the database adjusts the functions for specific departments, different departments of the museum find it difficult to use the same database) and (b) there are potential semantic problems during translation.
4. Metadata of an adequate depth level are drawn from each system and built into a new system that stores and organizes the drawn metadata for public use.

Outside of the SI method proposed by Blackaby and Sandore [7], semantic webs for integrated searches of cultural data across museums have recently gained attention for integrating museum data. However, recently, some researchers have explored the use of the CIDOC Conceptual Reference Model (CIDOC CRM) as primary ontology for cultural heritage information and as a means to describe semantic cues for the concepts and relations within multi-sourced cultural heritage data. By pairing this approach with a semantic web technology, an inference mechanism for cultural heritage knowledge can be established and the aim of integrated searches across collections of cultural heritage data can be achieved. For example, Lin, Hong, and Doerr used the metadata and images of three art databases—the Louvre collection, Allposter, and Artcylopedia—and applied CIDOC CRM-based semantic webs as a mechanism for integrated searches [20]. The use of semantic webs for information integration at art galleries and museums has garnered increasing attention and many museums are testing or considering it for their data integration needs. The British Museum has reorganized the majority of its metadata using CIDOC CRM with a resource description framework (RDF) to describe it. The British Museum's information and examples are used as a reference by other museums.

The Europeana Project is a collaboration among European museums and cultural institutions that utilizes another important type of information integration for museum collections. The Europeana Project, generally believed to be the largest DL in Europe, integrated collection data from a variety of European nations. To achieve its goal, it devised sub-projects, such as ATHENA and LH, that integrate collection data, map the metadata of a variety of museums into shared metadata, and save the validated information in the Europeana Project's repository [30]. The process aggregates the data of the European collections to one location.

Many cultural heritage preservation institutions and museums have attempted to integrate their DLs by creating online exhibition systems and educational games. For example, Taiwan's National Museum of Natural Science and a team from the National Chi-Nan University plan to integrate two biological and national DLs and online exhibition systems to create the Digital Museum of Taiwanese Butterflies and the Lanyu Digital Museum [16]. Researchers in Taiwan have studied metadata integration to determine whether it is possible to integrate information from DLs and e-learning systems to design a model system [10]. The NPM installed a search engine in 2009 that provides a cross-database search service for curators within the museum. Taiwan's Ministry of Culture is planning to carry out, in 2015, the metadata integration of artifacts of the Dublin Core level in 187 Taiwanese museums' databases. Taiwan's Ministry of Culture plans to ask the museums for simple artifact metadata with which it will develop an integral query interface that can handle inquiries from a variety of fields. Although these efforts, whether they are the installation of a search engine for cross-database query, the accessing of simple metadata from databases for query services, or the integration of digital learning sources with DLs or multimedia exhibition systems, may achieve information integration, they do not constitute a thorough and complete SI of a museum's context.

3 Research methods

3.1 Research methods and data collection

Case study is a research method that investigates a single social unit as its research subject to address a real-world problem [3,32]. The case study method was used to address the investigation of SI in museums because little is known about the museum sector's use of SI and museum SI differs substantially from that of commercial enterprises (about which we know much more). Furthermore, SI varies depending on the properties of a given museum's collections and its other characteristics, such as organizational culture and work flow. Thus, to understand the ways that SI is implemented in the specialized environments and contexts of museums, detailed examination of specific cases is necessary, which points to the suitability of the case study approach for this study [11,14].

This study used participant observation to collect its data. The researchers were leaders of the NPM's SI Project management team who personally observed the implementation of the SI and recorded the details of the project. As participants in the museum's SI project, we had access to NPM's use of information systems and its perceptions of the SI. Furthermore, a thorough investigation of SI of the museum's organizational atmosphere, its members' behaviors, the work environment, and the expectations for the information system

Table 1 NPM's sources and scope of research data

Type of data	Period of data collection or generation
Participant observation notes	Jan 2011–Dec 2012
IT Department work files	Jan 2007–Jan 2011
Visitors' opinions of the DL	Jan 2007–Jan 2012
Internal users' opinions	Jan 2007–Mar 2012
SI Project management meeting minutes	Jan 2011–Dec 2012
SI Project system analysis requirement interviews	Jan 2011–Sept 2011
RFP and RFI of SI Project	Dec 2010–Jul 2011

was conducted [8,21,25]. In addition, meeting minutes, work files, requests for proposals (RFP), requests for information (RFI), project proposals, visitors' opinions, and recorded interviews on the systems' analyses were accessed and analyzed to construct a complete overview of the phenomena that occurred during the SI process, to induce NPM's possible motives for implementing SI, and to ascertain the factors influencing the SI. The sources and scope of the research data are shown in Table 1 below.

3.2 Case details

3.2.1 Development and the NPM's collections

The NPM is located in Taipei, Taiwan. It is one of the most important museums of Chinese art in the world. It possesses over 690,000 pieces of Chinese art that are recognized, both by their quality and quantity, as highly important to the history of the arts. The NPM may be deemed as the representative art museum of Taiwan and the Greater China Region. Founded in Beijing on October 10, 1925, it consists of an enormous treasure trove of objects from the Sung, Yuan, Ming, and Ching Dynasties. The NPM has been moved multiple times, and it moved to its present site in Taipei in 1965. The museum's collections are divided according to type of collection into three categories: antiquities, paintings and calligraphy, and rare books and documents. Several departments are tasked with the functions that are common to modern museums (e.g., Department of IT and Department of Registration and Conservation). Moreover, its organizational structure has been modified over time. The current organization at the NPM is generally as follows:

1. The Department of Antiquities manages, curates, researches, and publishes artifacts that are categorized as antiques and it designs and adds metadata content to the Digital Library for Antiquities. It is the authority for recording in the CMS the actual locations of antiques.
2. The Department of Painting and Calligraphy manages the warehouse curation, research, and publication of artifacts categorized as painting and calligraphy and it designs and adds metadata content to the Digital Library for Painting and Calligraphy. It is the authority for recording in the CMS the actual locations of paintings and calligraphy.
3. The Department of Rare Books and Historical Documents researches, curates, and manages documents, rare books, and ancient books. Its work attributes are more similar to libraries and archives than general art museums and it has information systems those are independent of the CMS.
4. The Department of Registration and Conservation registers and conserves artifacts. It is a primary user of the CMS.
5. The Department of Education, Exhibition, and Information Services is responsible for educational events and information management, which includes the maintenance and functional development of the CMS and the DLs.
6. The Department of Cultural Creativity and Marketing has licensing duties, develops the cultural creativity merchandise, and manages the museum shop.

The management of the NPM's SI Project is mainly the responsibility of the Department of Education, Exhibition, and Information Services. Its primary users are the Department of Registration and Conservation, the Department of Antiquities, the Department of Painting and Calligraphy, and the NPM's Southern Branch, which is currently under construction.

3.2.2 Establishment of the CMS and DLs

In the early phase of development of its information system, the NPM attempted to build a system that would enhance its management performance by establishing the CMS. In 1987, the NPM created the Information Center and built the Artifact Retrieval, Management, and Research System to store text data. The system was primarily intended to record background information about the collections and house data related to collection management. It was a common process and object-centered CMS. In 2002, the CMS underwent significant reconstruction that transformed it from a mainframe

single-operation apparatus to an in-house Intranet that provided users with browser-operated functionality. Its functions were further expanded in 2009 to include a module for managing artifact conservation data and enhanced records of artifacts' locations. The CMS consisted of basic, managerial, and registration data on collections, as well as recorded background information on collections. The primary NPM users and information maintenance personnel were the registrars in the Department of Registration and Conservation. Personnel from the Departments of (1) Antiquities, (2) Paintings and Calligraphies, and (3) Rare Books and Documents occasionally used the CMS to search for basic information on collections or to access records of the artifacts' movements across locations.

The NPM began to establish DLs of Chinese arts distinct from the CMS using advancements in information technology and the accompanying emergence of digital archives and DLs. Beginning in 2002, the NPM accepted subsidies from the National Science Council TELDAP and began digitizing massive amounts of data from a variety of collections and producing digital images of artifacts. It collaborated with expert scholars, referenced Categories for the Description of Works of Art standards, created metadata about Chinese artworks, developed DLs, and provided museum users a way to conduct detailed searches on antiquities, paintings and calligraphy, rare books and documents, and high-resolution images. The public was provided with partial access to the data in the DLs.

Currently, the NPM's primary DLs are the Digital Library for Antiquities, the Digital Library for Paintings and Calligraphy, 11 DLs on rare books and documents, the Image Management System for Paintings and Calligraphy, and the Authority Control System for Paintings and Calligraphy. The primary contents of the DLs are detailed data on the collections and images of artifacts, which are somewhat unrelated to the management process. However, the primary data maintenance and provision are the responsibility of the primary users of these DLs, which are the curators who specialize in art history in the Departments of (1) Antiquities, (2) Paintings and Calligraphy, and (3) Rare Books and Documents.

3.2.3 The NPM's SI Project

After about a decade of use, the CMS and the numerous DLs began to reach the ends of their lifespans. Maintenance was becoming a problem and the information systems were growing incapable of satisfying managerial needs and users' expectations. After a discreet assessment and numerous meetings of the Department of Information, the NPM decided in 2010 that the information system needed reconstruction and integration. It initiated the SI Project in January of 2011 to integrate the CMS with the primary DLs and to create a new information system that incorporated the functions and data of each system.

The contents of the 11 DLs covering rare books and documents were similar to the contents of libraries and archives yet different from the contents of art works, and these 11 DLs were, therefore, excluded from the integration. The primary subjects to be integrated by SI Project were the five legacy systems: (1) CMS, (2) Digital Library for Antiquities, (3) Digital Library for Paintings and Calligraphy, (4) Image Management System for Paintings and Calligraphy, and (5) Authority Control System for Paintings and Calligraphy. These five legacy systems were distinct in their developmental backgrounds, primary functions, primary users, and in their quantities of data, as shown in Table 2.

Prior to initiating its SI Project, the NPM considered whether it should continue using a relational databases management system for systems newly created after SI or to introduce an Extensible Markup Language (XML)-based system. XML is a relatively more structured and hierarchical method suitable for recording highly structured types of information. Owing to its relatively high processing efficiency, it works well for cross-platform exchanges of information. The alteration of fields in a relational database affects other schemas, making it unsuitable to alteration and, therefore, inconvenient for recording complex multi-variable exhibitions, conducting data maintenance, or conducting integrated searches for data across numerous cultural institutions.

The NPM had previously used XML to develop its highly structured DLs (e.g. rare books and documents). Using XML for the SI Project at the NPM would have combined it with the previously existing XML systems for rare books and documents. Subsequently, NPM determined that the management and properties of the XML systems were better suited to archival or library use than for systematizing an art museum. Therefore, the idea of using XML was discarded.

The primary goal of NPM's SI was to integrate its legacy systems. However, it was a method of data integration that could not span numerous institutions and would be, therefore, unable to meet the demands of cross-platform data exchange. The five legacy systems used relational databases with considerable design flexibility with respect to user applications that allowed them to meet the demands for new functions in the integrated system. Based on these factors, after the SI Project was evaluated, NPM decided to continue using its relational database management system.

When the decision-making process was completed, The Department of Information, assisted by the other six departments, headed the SI Project management and dealt with the problems related to information processing technology. The SI Project, expected to take 24 months for completion (January of 2011 until December of 2012), was divided into three phases.

Table 2 Systems integrated by the SI Project, dates of establishment, primary contents, primary users, and data quantity

	CMS	DL of antiquities	DL of paintings and calligraphy	Image management of paintings and calligraphy	Authority control system of paintings and calligraphy
Date of establishment	2002	2002 (also known as "antiquities archives data search system")	2003 (also known as "paintings and calligraphy archives data search system")	2006	2003
Main contents are data on:	Registration and conservation of collections	Metadata, research, and images of antique collections	Metadata, research, and images of paintings and calligraphy	Digital image files of paintings and calligraphy	Authority control related paintings and calligraphy
Users	Primary users are registrars; secondary users are researchers/curators	Primary users are researchers/curators in Department of Antiquities; partial contents open for search by the public	Primary users are researchers/curators from the Department of Paintings and Calligraphy; partial contents are open for search by the public	Primary users are researchers/curators from the Department of Paintings and Calligraphy	Primary users are researchers/curators from the Department of Paintings and Calligraphy
Approximate quantity of data	690,000 units	71,884 units	34,960 units	12,968 sets	2,081 units

Phase I

Phase I began in January of 2011 and ended in November of 2011. Its three primary steps took 11 months to complete, as follows:

1. plan the project management, stipulate a schedule for achieving each task, and determine the lateral communication methods among representatives of the departments;
2. conduct systems analyses and complete all interviews with users; and
3. normalize database (DB) schemas from the databases of the five legacy systems, create new DB schemas, and execute the first data migration.

Phase II

Phase II began in December 2011 and ended in September 2012. Its 10 months included two major steps, as follows:

1. complete a prototype to perform the core functions of the SI after integration and display system modules, confirm functions, and collect pilot opinions from users; and
2. complete adjustment of system functions, conduct a full establishment of system functions, and perform tests, debugging, and corrections based on users' feedback.

Phase III

Phase III lasted 3 months from October 2012 until December of 2012. Its primary tasks were to

1. review the accuracy of the data in the new SI,
2. execute parallel operations of each legacy system and the new system after integration,
3. conduct end-user training,
4. produce the technical documents and new source codes required to operate the new SI, and
5. prepare important documents such as system frameworks and DB schemas.

Upon completion of the three phases, the system was successfully launched for online use in January 2013, replacing the five legacy systems. All of the functions of the five legacy systems, and the data stored therein, were in the new system. The direction of the structural adjustments in the SI can be seen by comparing the diagram of the legacy systems (Fig. 1) to the diagram of the SI (Fig. 2).

3.2.4 Results of the NPM's SI Project

Although the five legacy systems became one system after SI, differences in functionality, data attributes, requirements of the legacy systems, and limitations of authority yielded

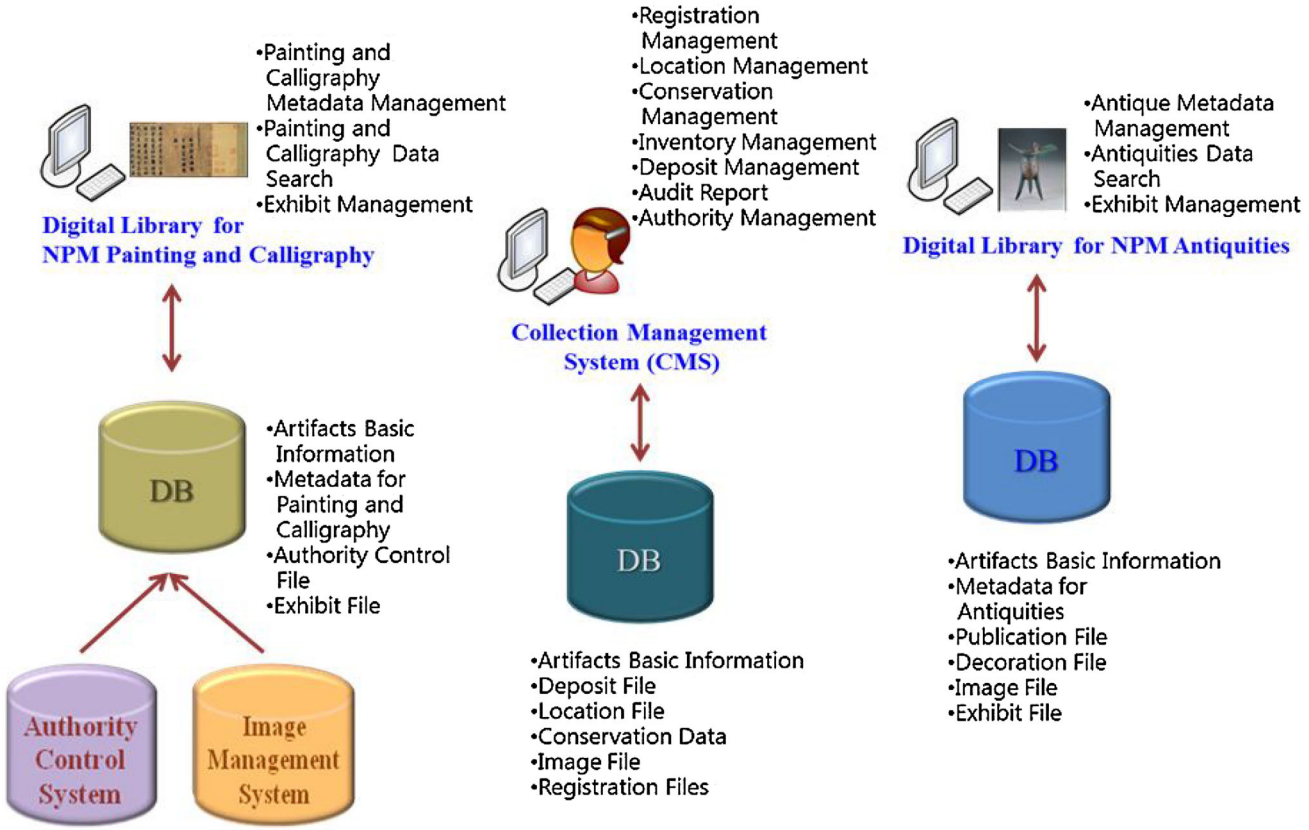

Fig. 1 NPM's legacy systems

inconsistent results with respect to the technical, informational, process, and user interface integrations.

Results of technical integration

The most thorough aspects of integration in the SI Project were the software and hardware integrations. The legacy systems had individual servers, operating systems (OS), programming languages, and database systems completed by different teams at different times. Through integration, these became one system with one server, one OS, and one programming language. The five legacy databases were combined into one database, which significantly reduced the time and funds spent by the Department of Information on maintaining the software and hardware and simplified the ability to control the statuses of the software and hardware in the information system.

Results of information integration

The databases of the five legacy systems were combined through normalizing and redesigning the DB schemas. The number of DB schemas was reduced from more than 300 (spread over the five databases) to fewer than 90 schemas. However, this efficiency only considers the data-level integration. The data integration of semantic problems consisted only of repetitive data or commonly used data because of the differences between the data structures of each unit. For example, the artifacts' basic information and exhibition data were originally scattered over at least three systems and, although most of the contents were repetitive, the SI Project successfully integrated them. The data involving special management requirements and artifact attributes that were managed by each unit were retained separately.

Results of process integration

The most difficult part of the SI Project was the process integration because it influenced the real-world work procedures and allocations of responsibilities. The process integration involved two major steps. The first step was to connect the process procedures that were originally scattered throughout the legacy systems. These procedures were linked according to the procedural concepts that professional museum work should possess (for example, the data processing procedure of artifact conservation originally included breakpoints, but the SI Project established a complete artifact conservation procedure). The second step was to redefine the information flow and the controlling authority. Although the data processing procedures applied by each unit were repetitive with respect to the five legacy systems, no conflicts occurred. Moreover, for the information processing

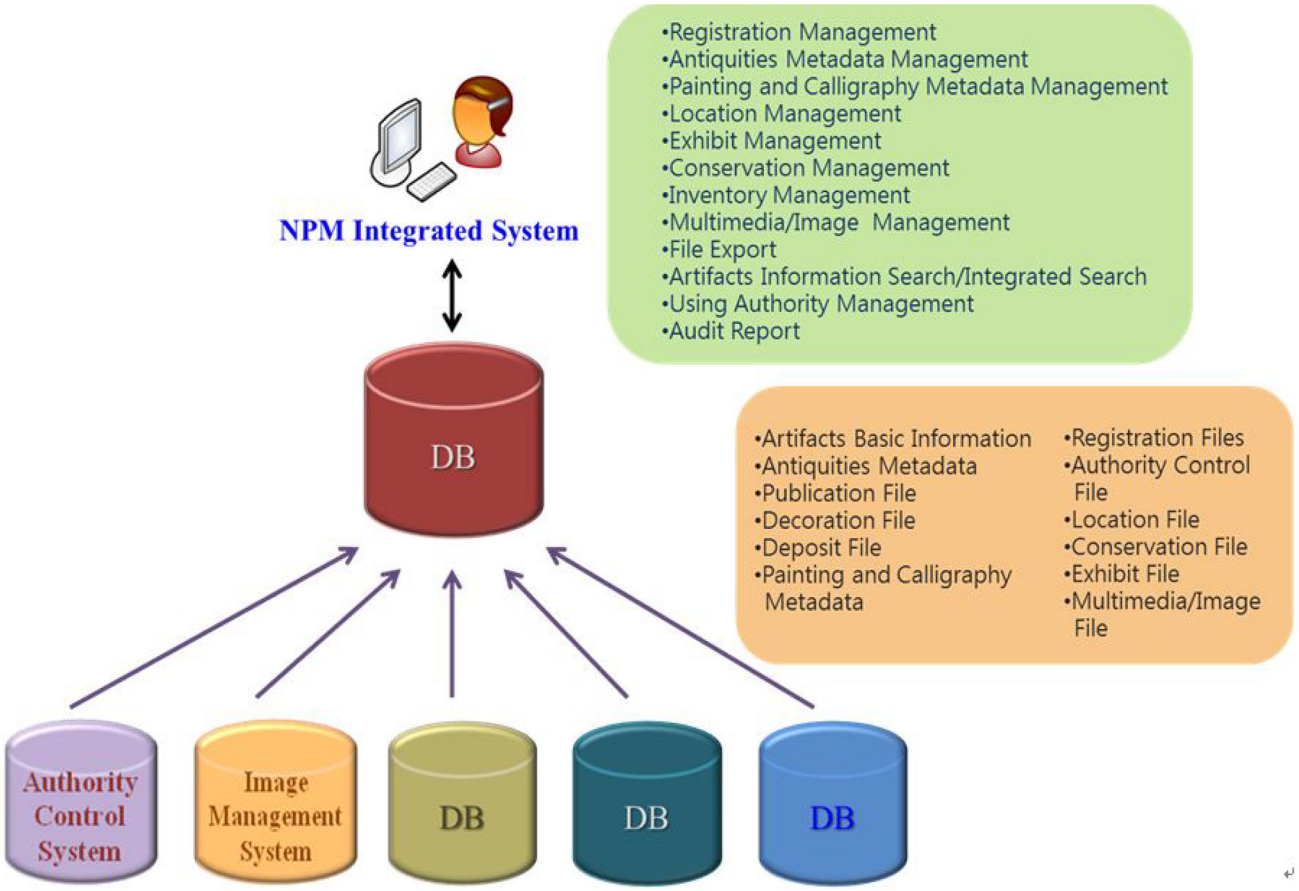

Fig. 2 NPM's new integrated system

procedures to be complete at the end of the integration, the limitations on the information flow and the controlling authority had to be defined. The NPM held numerous meetings on this issue and it ultimately defined regulations that limited the authority of each unit, which solved the problem of repetitive information processing procedures.

Results of user interface integration

The five legacy systems had originally been developed by separate teams, which resulted in different output/input designs, styles, and functionalities among the five user interfaces. The NPM's SI Project particularly valued the integration of the user interface and anticipated that similar output/input designs for the units could be achieved along with consistency in the aesthetics of the interface styles. The Project accounted for users' preferences when enhancing the usability of the system. For example, users in the Department of Antiquities valued entering data using Excel and uploading it in batches to the system's database rather than editing one datum at a time. Users in the Department of Paintings and Calligraphy highly regarded the ability to present special information generated from the calligraphy's and the paintings' frames. These user preferences regarding the interface were considered when it was designed. Each unit's user interface can be somewhat personalized with respect to output/input design and style without sacrificing usability. For comparison, Fig. 3 shows the user interface of the Digital Library for Antiques legacy system and Fig. 4 presents the user interface of the SI.

4 Analysis of the NPM's SI

For many years, CMS was the standard in museum information management. DLs increased museums' options because they digitized and stored detailed research, text information, images of artifacts, and provided a search engine for users inside and outside the museums. However, many problems emerged when the NPM introduced a wider variety of information systems, which necessitated the implementation of the SI Project. A number of related problems motivated the NPM to pursue the SI Project. The primary reasons why the NPM decided that the departments needed to collaborate in the SI Project were related to enhancing the internal collec-

Fig. 3 User interface of the legacy system for the Digital Library for Antiquities (Also known as "antiquities archives data search system")

tion management, users' expectations, and the burden posed by information system maintenance.

4.1 The NPM's internal collection management

The analysis used a process of generalization to identify the major reasons that NPM promoted SI. In general, the legacy systems were no longer able to meet the requirements of internal collection management, which led to recurring problems.

4.1.1 Repetition and inconsistencies of artifacts' basic information

Based on our observations and interviews with users, the artifactual information in the CMS, including the important managerial collection data, was primarily generated through a process of registration, whereas the data in the DLs were research-based for the purpose of identifying the artifacts. Because the CMS and the legacy DLs were built at different times by different teams, the information was not synchronized, which resulted in repeated entries of artifacts' basic information. This duplication wasted the curators' and registrars' time. More importantly, although the same basic information was entered into the five legacy systems, inconsistencies in a given artifact's basic information had occurred among the numerous systems over the years. Therefore, radical SI was necessary.

4.1.2 DL users' problems locating information

The Digital Library for Antiquities and the Digital Library for Paintings and Calligraphy contained detailed research data on artifacts that were important sources to the NPM's curators, who used them to search for background information on artifacts in their research, planning, and publishing. They also were available to the public. Based on our observations and the opinions of users voiced in meetings, users were able to find data only on artifacts and were unable to learn of the artifacts' locations or statuses. To find that information, users had to "log out" from the DL and "log in" to the CMS

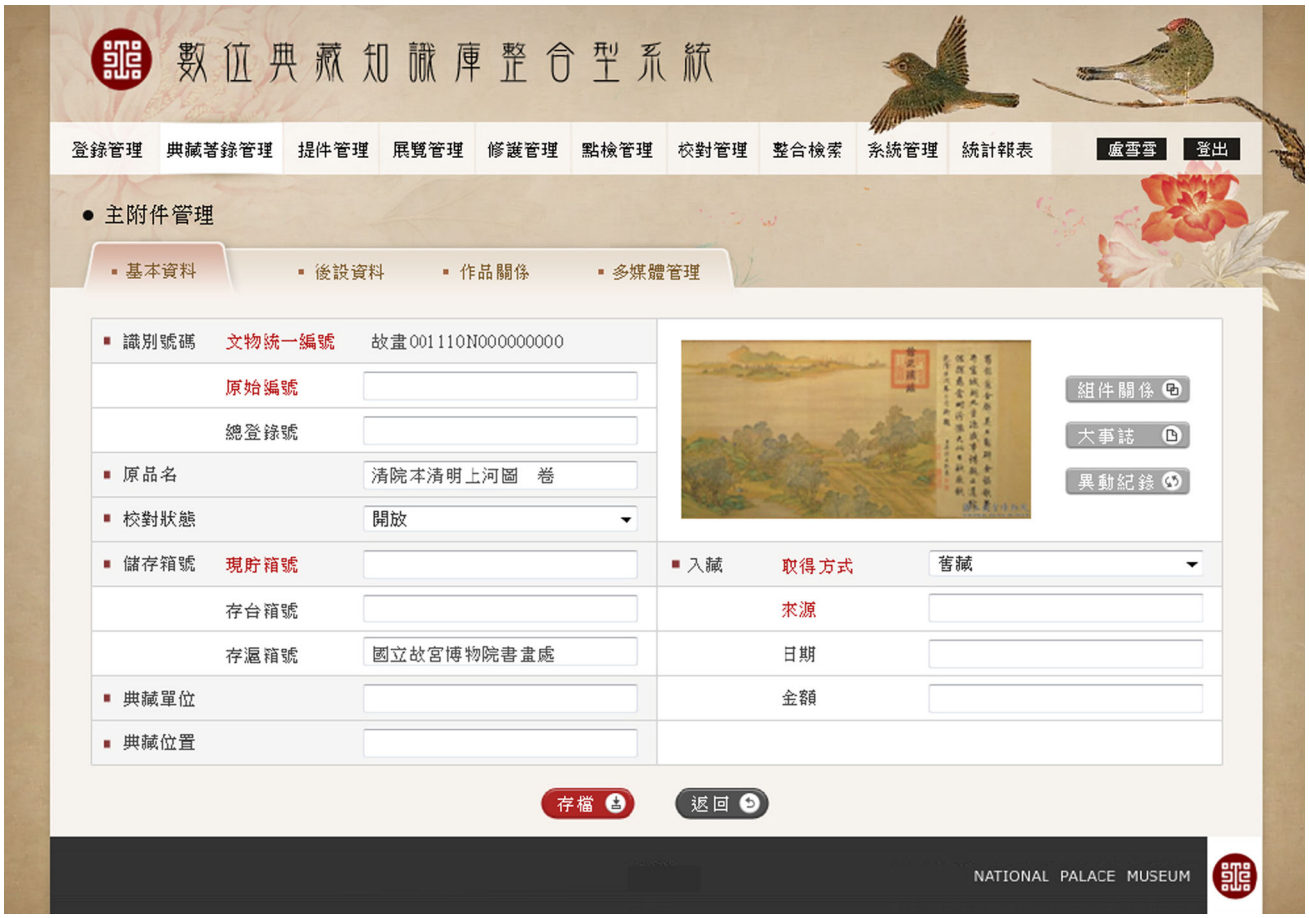

Fig. 4 User interface of the new integrated system

and search again. However, the CMS could not track artifacts that were undergoing conservation work. In other words, the NPM's numerous information systems did not have information about the museum's work procedures, which caused inefficiencies. SI was needed to conform the procedures that are associated with collection management to the collection information.

4.1.3 Establishment of the Southern Branch Museum

The NPM created the Department of the Southern Branch Museum Affairs to organize the establishment of the Southern Branch Museum. This new department was focused on collections of Asian artifacts rather than Chinese arts, per se, and its organization of artifactual data was different from the organization of most of the NPM's collections. The way that internal work was allocated in the Southern Branch Museum also was different from the NPM's other departments and the existing information systems could not handle its information in a complete or accurate way. Thus, it was necessary for SI to incorporate the new department's information and procedures.

4.2 Expectations of the public and the cultural creativity industry

A modern museum is an educational institution that often is a part of the formal learning activities of other educational institutions. Domestic and foreign Chinese arts researchers have historically relied on the NPM's artifactual data. In particular, the search flows of the Digital Library for Antiquities and the Digital Library for Paintings and Calligraphy have been quite high for this purpose. In addition, cultural creativity practitioners often use the style and image of the NPM when they design and manufacture products and they frequently search the NPM's DLs. Despite heavy use, visitors often indicated that the NPM's DL interfaces were out of date and that the style and display modes of the data were inconsistent. The public's comments were another motivator that propelled the NPM to undertake SI.

4.3 Information technology

Observations of the working conditions of the Information Department revealed that maintaining the legacy systems was

a complex and time-consuming task. The Digital Library of Antiquities and the Digital Library of Paintings and Calligraphy had been developed offsite for the NPM by other institutions that had relied on open-source software, without any documentation about system development. That condition ultimately led to substantial difficulties for maintenance. Thus, the NPM reasoned that integration of the five legacy systems would solve the problem of diversified software and hardware standards and would eliminate the problem of inconsistent frameworks between the systems, which would reduce the burden posed by information system maintenance. Table 3 lists the software and hardware specifications of each of the five legacy systems in the NPM.

The integrated system is equipped with all of the functions of the original five systems, but it uses one (instead of five) mainframe computer, OS, DB, and programming language, which greatly reduces the maintenance load. The software and hardware specifications of the integrated system are shown in Table 4.

4.4 Key factors influencing the execution of the NPM's SI Project

Through our observations of the NPM's SI Project, we identified key factors that influenced the functionality of the NPM's SI: (1) attributes of artifactual materials and forms, (2) needs of curators and other users, (3) unique museum needs, (4) organizational attributes, and (5) resource allocation.

4.4.1 Attributes of artifactual materials and forms

The extent to which information could be integrated in the SI Project was influenced by the nature of the materials and forms of the artifacts. Through numerous interviews conducted during the study period and from our personal observations, it was apparent that the information that was commonly used in management and application was the only information that was integrated by the SI Project. Information on the materials and the characteristics of the collections required large amounts of unique data, which was not suited to integration. The SI of commercial enterprises emphasizes the achievement of operational targets, but the attributes of products or merchandise rarely influence SI. In this respect, museums are different. Museum collections require long-term and even permanent preservation. The collections are the targets of museum management and the forms and characteristics of their materials are key factors to consider in information integration.

It was discovered during the course of the SI Project that the data that were available for information integration were mostly related to museum operations and management or to advanced promotional application. For example, the basic artifactual information that was generated by the Department of Registration and Conservation could be integrated with the basic artifactual information entered by the Department of Antiquities and by the Department of Paintings and Calligraphy. Moreover, the logistics of exhibition description data differed between the Digital Library for Antiquities and the Digital Library for Paintings and Calligraphy. This happened because the former was derived from information on artifacts and it recorded the exhibitions at which each artifact was displayed and the latter was from information on exhibitions and it recorded the artifacts that were included at each exhibition. In fact, all of the exhibition data in the new system were entered from information on exhibitions. Furthermore, the detailed record of any given artifact included information about that artifact in the NPM's publications. Thus, the methods of recording artifactual information in publications that were adopted by the Department of Antiquities and the Department of Paintings and Calligraphy were unified.

It was further discovered during the course of the SI Project that forcing the integration of data related to the materials and forms of artifacts resulted in the loss of important artifactual information because of differences among the types of artifacts. This loss of data was anticipated to be a problem for the museum's ability to use the artifacts for research, education, and conservation. To avoid this, each department's artifacts' metadata retained large amounts of unique and important information. For example, the metadata of the Department of Antiquities included information about the artifacts' purposes, materials, patterns, decorations, and organization in boxes and cabinets. The metadata of the Department of Paintings and Calligraphy recorded specific mounting forms, such as scrolls, leaves, and seals, along with data on signatures and inscriptions. The names and semantic controls of the two departments were different, which confirmed the hypotheses that museums' knowledge representations cannot be processed by one method and that knowledge representations necessarily differ by type of collections within and among museums.

4.4.2 Professional users with specialized data using habits

Art history is a common humanities course of study and art history scholars take a different approach to their scholarship and information processing than scholars in other academic fields. These scholars have unique behaviors and needs that influenced the SI. From our interviews and personal observations during the SI Project, it seemed apparent that the users of the NPM's internal information system were mostly curators who typically had art history backgrounds. The museum's artifacts have specific historical meanings and contexts, the interpretations of which are controlled by the curators, who ultimately decide the informational content that is stored in

Table 3 Software and hardware specifications of the NPM's legacy systems

System	Server	OS	Language	DB
Collection Management System (CMS)	HP DL360 G5	Red Hat Enterprise Server release 5.2	JDK 1.5.0	Oracle 9i
Digital Library for Antiquities	HP DL360 G5	Red Hat Enterprise Linux Server release 5	PHP 5.1.6	MySQL 5.0.22
Digital Library for Paintings and Calligraphy	HP DL360	Fedora Core release 3	JDK 1.4.2	Oracle 8i
Image Management System for Paintings and Calligraphies	IBM X335	Red Hat Linux release 9	JDK 1.4.2	MySQL 3.23
Authority Control Systems for Paintings and Calligraphy	HP DL360	Fedora Core release 3	JDK 1.4.2	Oracle 8i

Table 4 Software and hardware specifications of the NPM's integrated system

System	Mainframe computer	OS	Programming language	Database
New Integrated System	IBM 3650 M3	Microsoft Windows 2008	.NET	Microsoft SQL 2008

the system. Thus, the integrated system's data processing and interface designs and functions must accommodate the curators' work habits and perspectives. The SI used in commercial or other enterprises would not consider the academic backgrounds or work habits of employees.

It was observed that curators control more than the interpretation of the artifacts; they make decisions about the representations and structures of artifactual information, the sequencing and titling of items in columns, the designs of functions and interfaces, and they even control the methods used to search for artifactual data. Furthermore, curators control input when new academic research discoveries are made, new collection information is entered, original records are altered, and original collection titles are modified to accommodate the new discoveries. In short, collection data are dynamic, and the system's design needed to be flexible. Consequently, in the system's information integration, procedure integration, and user interface integration, respect was given to the curators' opinions regarding the types of data that should and should not be made available for integration to ensure that the new system would increase the curators' efficiency.

4.4.3 Process integration must reflect specific museum requirements

Process integration was influenced by not only collection materials and forms; it was influenced by the unique demands of museum work, which posed a challenge to radical SI. For example, because museum artifacts are unique items (meaning, they cannot be recovered once they are lost), there are management controls that limit the exhibition of particularly fragile collections, such as paintings and calligraphy, for their protection. When an artifact has been exhibited, it cannot be exhibited again for 18 months. However, these limitations do not exist with respect to antiquities. Differences in procedural rules across types of artifacts challenged the museum's ability to integrate its data.

However, as the SI Project progressed, it became apparent that artifactual attributes had no influence on some of the procedures related to professional museum management. Those procedures could be integrated because standard operation procedures tend to be similar across museums, even cross-nationally. The legacy systems did not account for the professional work procedures that museums must institute, so procedure integration was implemented. For example, the Department of Antiquities and the Department of Paintings and Calligraphy had different procedures for sending an artifact to the Department of Registration and Conservation for conservation work and the legacy systems did not carry out procedure controls in these cases. The SI Project unified the collection conservation procedures of the two departments and introduced procedural controls into the system.

4.4.4 Project management required support among museum executives, curators, and IT personnel

Historically, the materials and forms of collections are the criteria of the allocation of museum duties, particularly at large museums. The NPM is no exception. Each department in the

NPM has different work depending on its collections and the expertise of its curators. For the SI Project to succeed, each department's particular attributes needed to be considered for appropriate project management. The SI Project's managerial documents and our onsite observations made it clear that the NPM's executives supported the SI Project and, therefore, user resistance was a non-issue. The users participated in the SI Project by taking part in the required interviews during the system analysis phase and participating in data quality work after the data migration and user training.

Each department assigned a curator to represent it in the SI Project. Representatives conveyed their department's progress, informed their staff of the SI Project work that required the entire department's engagement, and handled communications and negotiations. Designating department representatives was more efficient than having the IT Department oversee all of the users because communications were carried out within departments among staff with similar academic backgrounds. The SI results showed that allocating responsibility among the departments facilitated the implementation of the SI Project.

In addition, it was found that the organization of the IT Department was different from commercial enterprises. Previously, it had generally been believed that museum employees in departments such as Information Technology and Registration were not as highly valued as curators [22]. IT personnel in museums are becoming more important as reliance on information technology grows in complexity and use, but curators are still considered the most crucial employees. As a result, it was difficult to adjust NPM's work processes to increase transmission speed, the quality of information flow, or to improve customer satisfaction unless those changes conformed to the needs of the curators. When carrying out a museum SI Project, IT personnel must remember that museum artifacts have unique, often priceless cultural value and historical meaning and they need to maintain cooperative attitudes with respect to the curators' perspectives. Reference to or reliance on SI experience in the business world is not helpful because success cannot be translated to the museum context. Attempting to do so can detract from the smooth implementation of a SI.

4.4.5 Technical integration must pay attention to IT resource allocation

Museum funds for the development of information systems are usually limited and much less than funds available to commercial enterprises [13]. A museum's IT resources allocation, selection of IT criteria, and planning of its information strategies influence the sustainability and cost of maintenance after the SI is complete. Basically, a museum's IT policies should include (1) the adoption of IT criteria, (2) authority limits to information processing, (3) control of access to information, (4) preservation of digital assets, (5) risk management, and (5) the role of users [33]. It was determined during the SI Project that the legacy systems' lack of IT policies had led to inconsistencies in the selection of technological criteria, insufficient maintenance resources for the IT Department, and unclear boundaries among information processing authority limits. The SI Project conducted software and hardware integration to solve the problem of the legacy systems' excessive technological criteria, designed a system framework that was relatively easier to maintain, and developed suitable standards for technology that were in line with the IT Department's resources. Numerous meetings were held to discuss modifications to over 60 fields and to resolve disputes regarding limits to information processing and data accessibility.

5 Conclusion

Modern museum SI has rarely been scientifically evaluated, particularly with respect to detailed comprehensive SI. With few relevant reference cases on which to rely, the NPM's SI Project underwent 6 months of planning and research. The project took 2 years to complete because it accounted for the museum's business traits and unique needs. Ultimately, it successfully integrated the information systems of five highly heterogeneous legacy systems, including CMS, DLs, and an image processing system for paintings and calligraphy. This study considered the factors related to the NPM's SI implementation as a case study. Its goal was to provide a reference for other museums to rely on when they plan or implement their own museum SI.

This study found that conducting a thorough SI Project in a museum, including the data processing, is a very challenging task. The NPM integrated its information systems using internal and external factors. The key factors that influenced the NPM's SI included work properties, the materials and forms of collections, user traits, project management approaches, and IT resource. An analysis of the reasons for and the factors influencing SI found that NPM's information systems integration differed substantially from the SI that is implemented by commercial enterprises after enterprise application integration (EAI) or mergers. A museum's SI can refer to EAI or business mergers for concepts or techniques, but a museum's information systems are unique in many respects, such as data content characteristics, flow, organizational atmosphere, user habits, functions, and requirements. Thus, the usefulness of a business approach in the museum context is limited. The results of this study suggest several particularities about museum SI that can serve as a reference for other museums when they carry out SI.

5.1 A museum's collections and the nature of its work influence the extent of its SI work

A thorough SI integrates hardware, software, data, interfaces, and procedures. The results of this study suggest that museums vary in their levels of integration of these elements. The extent of integration also likely varies among these elements within a given museum. Furthermore, the primary factors that influence the extent of integration are the attributes of the collections being integrated and the nature of a museum's work.

In the NPM's SI, the hardware and software had the highest levels of integration because they required knowledge and decision-making limited to IT. Interfaces had the next highest level of integration. This study found that the functional interfaces of the legacy systems differed by the work requirements of the individual departments. After the integration, it was found that, although some departmental interfaces could not be completely integrated and they retained some uniqueness based on the nature of their work, the style and the input/output designs of the interfaces could be integrated. The key was the use of thorough and accurate knowledge about user habits and preferences.

With respect to process integration, the SI Project successfully integrated processing problems such as registration and key-in authority limits of the basic artifactual data, operational procedures for artifactual conservation and maintenance, and descriptions of exhibition data. However, process integration was performed for a limited amount of the common data input operations within the museum and there was no dramatic SI of the operations of the departments. Even though process integration was limited, it was still useful for understanding the museum's management and administration operations. Information integration had the lowest level of integration in the SI Project. This was mainly because detailed artifactual information was reflected primarily in the artifacts' metadata, which required specialized knowledge about art history and involved description requirements for the diversity of art pieces. Different structures of metadata still needed to be used after the SI, suggesting that information integration had the lowest level of SI. Table 5 summarizes these aspects of the integration.

5.2 Background knowledge should be drawn from existing registration or description standards in the field of museology

Our assessment of the SI Project suggests that, although some aspects of the integration were challenging, SI resolved many overlapping processes that needed to be connected to improve museum management. Many standards for collection management and procedures have been generated over the years in the field of international museology to address such overlap, to provide norms for museum work processes, and to enhance managerial efficacy. We recommend that other museums refer to existing managerial procedure standards for museum collections when they implement SI. From these, museums can gain an initial understanding about the procedures that can be integrated and the procedures that must be connected for system functions. For example, the Standard Procedure for Collection Recording used in Museums (SPECTRUM), established by the UK's Museums Documentation Association, documents norms for recording important collection information and collection management. The "CIDOC Guidelines for Museum Object Information: The Information Groups and Categories" and the "CIDOC Fact Sheet", drawn up by the International Council of Museums' International Committee for Documentation, regulate the registration management of museum collection information. These standards for collection management are being adopted by some museums around the world and they can be important references for museum personnel in understanding procedures relevant to SI. These standards can be important indices for museum personnel when they discuss common procedures in museum operations and the scope of managerial processes.

5.3 Organizational culture, management, and familiarity with IT are crucial to SI success

A museum needs the support of its senior managers when carrying out SI and it is important to acknowledge and act on the fact that a museum's organizational atmosphere is different from commercial enterprises. Project management must take an approach that is suitable to museums. We found during SI Project that the museum's organizational culture and the relationship between IT personnel and curators deeply influenced SI implementation. The managers of each department in the SI Project had worked alongside the IT personnel for years, so they understood, to a certain extent, the nature of each other's jobs and responsibilities. The curators executed the TELDAP and were familiar with the importance of information systems as well as the drawbacks of the legacy systems, so they were able to reach a consensus and successfully complete the SI Project. We suggest that museums aiming to implement SI first address the following factors before drawing up a plan:

1. the extent to which a chosen approach to SI is likely to adapt to the organizational culture,
2. the extent to which there is consensus among the stakeholders,
3. the extent to which the department managers clearly understand the responsibilities and limits of managerial authority within each department, and
4. the extent of IT literacy among key personnel.

Table 5 The integration pattern, level, and required knowledge of different aspects of integration in the SI Project

Subject integrated	Integration pattern	Level of integration	Required knowledge
Hardware and software of each previous system	Hardware and software integration	Highest	IT knowledge
Operational interface of legacy systems	Interface integration	Second	Users' habits
Museum's common operational procedures	Process integration	Third	Museum management and administration
Metadata of artifacts from various categories	Information integration	Lowest	Art history

5.4 Scale and resources determine the approach to and extent of SI

The NPM spent 2 years completing its SI. The project required a massive investment of time and funds and involved integrations of hardware, software, information, processes, and interfaces. The operations and procedures of each department needed adjustments and users needed to adapt after the SI was completed. These conditions imply that the NPM's SI was a considerable undertaking. Yet, the museum was committed to this large project for internal and external reasons.

If other small and medium-sized museums face the choice of maintaining numerous legacy systems or committing to SI, they should not go into a project blindly. It is strongly suggested that they consider their human resources, available and accessible funds, IT support, organization, and managerial capability when deciding whether to carry out a thorough SI. Small to medium-sized museums that outsource their IT work to private companies may find that it is extremely challenging to obtain the personnel resources necessary to successfully complete an SI project. Moreover, the creation of DLs relies on special project funding and, without specialized technical planning, it is difficult for relatively small museums to achieve large-scale integration of their legacy systems.

Therefore, to establish SI or integrated searching of collection data, relatively small museums may alternatively decide to adopt a method that minimizes procedures, costs, and the difficulty of project management. A thorough SI requires high costs, direct and indirect, and a substantial investment of time and effort. Moreover, the ultimate result greatly impacts a museum's functioning. Museums that are small or that have limited resources may consider executing a translation of the metadata with adequate depth in each system before SI or implement a search engine to provide a cross-system query service to satisfy users' demands. Small steps may adequately alleviate some of the data problems, obviating the immediate need for a large-scale SI project.

In sum, the planning and implementation of SI at the NPM was based on intrinsic differences between the NPM and other museums. Over the course of 2 years, the NPM completed the work of technology, information, process, and interface integration, ultimately creating a unified, integrated system. During this period, several interesting cases of museum SI emerged. In 2013, the Cleveland Museum of Art in the US completed a 3-year process of integrating its existing systems related to its internal museum holdings and its business processes [2]. Their SI model was similar to the NPM model, although SI at the Cleveland Museum of Art included application programming interface (API) integration with the Getty vocabularies along with a library system for the museum's attached library. The NPM should follow suit in the future because integrated reference materials in libraries would likely support museum curators' searches of museums' collection data. Semantic web integration of museum data is a way to span the collections of different institutions and conduct integrated searches. For example, in cooperation with large museums, such as the Louvre, Victoria and Albert Museum, Uffizi Gallery, and the National Gallery in London, the EU-funded ARTISTE Project used RDF mapping to create shared semantics among the museums' heterogeneous DLs. It used the Open Archives Initiative and the Search/Retrieve Web service to establish standards for inter-system operability [1]. Unlike the NPM system, this type of integration method did not involve the integration of museum internal workflow and it differed in its integration goals, models, and technology. However, this method is deserving of future consideration for cross-institutional or cross-categorical integration of cultural data at the NPM and other museums.

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