PLANNING OF A STORAGE SPACE IN RUAM SAMAI MUSEUM, CHIANGMAI, THAILAND CONCEPT FOR FURNISHING A SUITABLE STORAGE TO PROTECT AND PRESERVE WORKS OF ART

By

MISS Pornganok SADAKORN

An Independent Study Submitted in Partial Fulfillment of the Requirements for Master of Arts CULTURAL HERITAGE CONSERVATION AND MANAGEMENT

Silpakorn University

Academic Year 2023

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การอนุรักษ์และการจัดการมรดกทางวัฒนธรรม (หลักสูตรนานาชาติ)
แผน ข ระดับปริญญามหาบัณฑิต
มหาวิทยาลัยศิลปากร
ปีการศึกษา 2566

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By	MISS Pornganok SADAKORN
Field of Study	CULTURAL HERITAGE CONSERVATION AND MANAGEMENT
Advisor	Thanya Lunchaprasith, Ph.D.

Faculty of International College, Silpakorn University in Partial Fulfillment of the Requirements for the Master of Arts

.....Dean of Faculty of
(Assistant Professor Sompid KHATTIYAPIKUL, Ph.D.)International College

Approved by

.....Chair person
(TATJANA BAYEROVA, Ph.D.)

.....Advisor
(Thanya Lunchaprasith, Ph.D.)

.....Committee
(Nethchanok Riddhagni, Ph.D.)

.....External Examiner
(Professor Gabriela Krist, Ph.D.)

649020005 : Major CULTURAL HERITAGE CONSERVATION AND MANAGEMENT
Keyword : Preventive conservation, condition assessment, museum storage space, collection analysis, storage furniture

MISS Pornganok SADAKORN : PLANNING OF A STORAGE SPACE IN RUAM SAMAI MUSEUM, CHIANGMAI, THAILANDConcept for furnishing a suitable storage to protect and preserve works of art Thesis advisor : Thanya Lunchaprasith, Ph.D.

Planning of A Storage Space in Ruam Samai Museum, Chiang Mai, Thailand

Concept for furnishing a suitable storage to protect and preserve works of art

The Ruam Samai Museum, an upcoming museum project scheduled for 2026, emerges from the privately owned collection of the Angsuvarnsiri family in Chiang Mai, Thailand. The Angsuvarnsiri family's extensive collection of antiques, artworks, and their burgeoning interest in contemporary art have motivated them to exhibit their private collection to the public. The collection primarily focuses on antique Buddha statues originating from Southeast Asia and China, accompanied by modern Thai paintings and international contemporary art. With a vast assemblage of over 6,000 objects, the collection encompasses a diverse range of materials, including ceramics, wood, paper, textiles, ivory, metal, plastic, and media art. Currently, the collection is housed in a temporary storage in Bangkok, with plans to relocate to a new storage building in Chiang Mai by 2024.

This thesis recommends an appropriate guideline for the new storage facility. It is critical to categorize the artifacts and identify the volume of the collection based on collection analysis and collection survey to establish the necessary storage space, construction as well as furniture requirements. The materials to be used for the storage furniture must be considered since they might contribute to the deterioration of the artifacts, and it is critical to evaluate the possible chemical reactions with sensitive objects before selecting the materials to use. Metal and wood are currently the primary materials for furniture in Thailand, and there are no companies in the country that specialize in museum furniture production. Large format artworks storage provides a difficulty in terms of space and proper depository, so the focus of this thesis will be on the right planning of furniture and systems for storing these artworks.

ACKNOWLEDGEMENTS

I would like to express my heartfelt appreciation to my thesis advisor, Univ.-Prof. Mag. Dr. Gabriela Krist and Dr. Thanya Lunchaprasith, for her unwavering guidance, support, and patience throughout the entire research process. Her valuable insights and dedication to my academic growth have been instrumental in shaping this thesis.

I am also grateful to my thesis committee members, Mag. Paul Schubert, Univ.-Ass. Mag. David Zeno Kastlunger, Univ.-Ass. Mag. Elias Campidell, Univ.-Ass. Mag. Franziska Marinovic, and Univ.-Ass. Dr. Tanushree Gupta from University of Applied Arts, Vienna, for their constructive feedback and expertise, which significantly enhanced the quality of this work.

I extend my gratitude to Ajarn Jiraporn Aranyanark and Mr. Atthasit Sukkam for their knowledge, guidance, and assistance in completing this thesis.

My heartfelt thanks go to my family, my best friends, and my colleague at SAC Gallery for their unwavering encouragement, understanding, and belief in my abilities. Without their love and support, this achievement would not have been possible.

I am profoundly grateful to the Angsuvarnsiri family for their generous assistance in providing valuable information of Ruam Samai Museum project. Their support played a crucial role in making this research project not only possible but also successful.

Special thanks to my gratitude to all my fellow students, both at Silpakorn University International College and the University of Applied Arts, Vienna, including Muenkaew Charutula Wachiratienchai, Kawinthip Kittiphong, Nuchada Pianprasankit, Khakhanang Jongaurak, Khanh Nguyen Quang, Prerana Kaushik, Abolghasem Tabrizian, Prathamesh Laxman Pawar, Tahmida Afroze, Aurelia Berger and Martina Klinkert. Your encouragement and mutual support throughout our academic journey have been invaluable.

Finally, I wish to acknowledge the exceptional resources and facilities provided by Silpakorn University International College and the University of Applied Arts, Vienna. These institutions played a pivotal role in the successful completion of this thesis.

Pornganok SADAKORN

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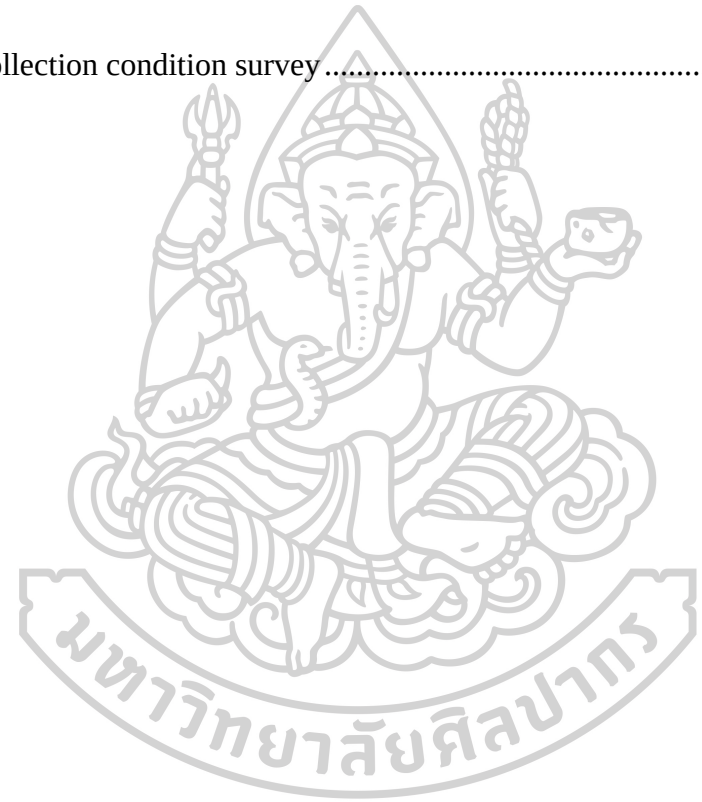

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Introduction

The Angsuvarnsiri family has been a passionate collector of antiques and artworks from the reign of their parents for several decades. Over the years, their interest in collecting antiquities and artworks has persisted, resulting in the continuous acquisition and accumulation of pieces. Additionally, their appreciation for contemporary art and art from various countries has grown significantly. Full by their love and enthusiasm for these treasures, the family has conceived a compelling idea to showcase their private collection, which has been amassed over many years, to the public. The exhibition aims to illuminate the origins of their collection and demonstrate their commitment to supporting valuable works of art within the capacity of a museum.

The Ruam Samai Museum project was initiated in 2018, starting with the planning phase of establishing the museum's vision and mission. Extensive research has been conducted on antique collections, including the formulation of strategies for acquiring artworks and conducting art research. Prior to commencing the architectural design phase, careful consideration was given to the exhibition methodologies in collaboration with the curator team.

The collection predominantly focuses on Buddha statues and antiques made of various materials from Southeast Asia and China. In addition to these historical pieces, the museum also features modern Thai paintings and contemporary art from international artists. The owner has been collecting Thai contemporary art since the 1990s, making the future museum a unique blend of traditional and modern artworks. With such a varied collection, it is crucial to have a new and storage system in place to ensure the preservation and maintenance of the museums' treasures. The estimated finalization year of the museum will be by 2026.

All objects are presentingly at temporary storage in Bangkok and it is planned to move them to the future storage building at Chiang Mai in 2024. The collection is composed of more than 6,000 objects made from a range of materials such as ceramic, wood, paper, painting, leather, textile, ivory, metal, and plastic, among others.

The planning of a storage space is crucial before transferring the objects from Bangkok to the future storage in Chiang Mai, to guarantee proper preservation and accessibility of the collections.

Effective museum storage planning requires careful consideration of several factors related to the collection being stored. It will be referred to "RE-ORG", a method developed by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and the International Committee for the Conservation of Cultural Heritage (ICC) under the auspices of UNESCO.

The thesis explores the planning of the museum's storage space in Ruam Samai Museum, Chiang Mai, Thailand and focuses on the concept of furnishing a suitable storage space to protect and preserve works of art. Once the storage requirements have been determined, the next step is to design the space and layout of the storage facility. This involves determining the appropriate amount of space needed for the collections and designing a layout that maximizes storage capacity while ensuring ease of access. The layout should take into consideration participation of staff, researchers, and visitors to ensure that collections can be accessed easily and safely. Furthermore, the availability of suitable storage space enables museums to organize and inventorize their collections effectively. Objects can be stored in a logical and structured manner, making retrieval and documentation more efficient. This systematic approach promotes better inventory control and facilitates research, exhibition planning, and loan requests.

In the first chapter, the detailed planning and location of the Ruam Samai Museum's establishment, collection focus, and condition survey, artwork's exhibition and temporary storage facilities in Bangkok are discussed. The focus of this chapter is to provide a comprehensive understanding of the museum storage project and to offers a detailed overview of the collection.

In the second chapter, the research focuses lays on requirements for the future storage building. This section focuses on various considerations pertaining to storage space for the museum, encompassing factors such as the location of the storage building, construction aspects of storage rooms, building services, climate regulation, facility requirements, space allocation, and the importance of flexibility. Furthermore, it explores essential considerations for storage rooms, including the storage system,

access, furniture and equipment, selection of packing materials, and the necessary inventory and housekeeping requirements. By examining these factors, this section aims to provide a comprehensive understanding of the critical elements involved in designing and maintaining an efficient and effective storage space for the museum and preservation of the collection.

The third chapter concentrates on the collection analysis of Ruam Samai Museum’s collection analysis. The primary objective of this chapter is to provide a comprehensive examination of the methodology employed to categorize the collection based on various factors such as material composition, type, size, condition, and the growth of the collection over time. By employing this analytical framework, the chapter aims to determine the specific storage space requirements necessary to accommodate the collection adequately. Furthermore, this chapter includes a case study that presents the architectural team’s design and estimation of storage space for the future storage of Ruam Samai Museum. This chapter seeks to enhance the understanding of the collection's characteristics, composition, and overall significance within the context of the museum. Through this analysis, valuable insights are gained into the organization and management of the museum's collection, facilitating effective decision-making processes related to storage space and preservation.

The fourth chapter presents the planning of storage space framework of the Ruam Samai Museum, with a particular emphasis on the future storage facilities. The chapter encompasses various aspects, including the architectural structure and spatial considerations for the storage building. It also involves the determination of storage requirements through the quantification of necessary space, inventory management practices involving grouping and the utilization of accession numbers for collection organization. Furthermore, the chapter explores the implementation of a collection management system utilizing database. Significantly, the chapter provides recommendations for the storage system, with a specific focus on determining the appropriate materials, shelving and furniture. It further addresses the arrangement of an adjustable shelving and furniture system within the storage space, considering aspects of accessibility and preservation of collection.

1. Ruam Samai Museum project, Chiang Mai, Thailand

The Ruam Samai Museum project was initiated in 2018, emerging from the privately owned collection of the Angsuvarnsiri family, led by Subhashok and Jonsuwat. Subhachok and Jongsuwat, the father and son, have always been deeply interested in amassing antiquities and artworks, reflecting their profound appreciation for the arts. The collection comprises a diverse array of artifacts from different historical periods, representing a wide range of cultures and artistic styles. For many years, the family has been actively engaged in acquiring and preserving these valuable pieces, which serve as a testament to their enduring passion and commitment to art.

In addition to their dedication to historical artifacts, the Angsuvarnsiri family has broadened their horizons and developed an increasing interest in contemporary art and artworks from abroad. This expanded focus has allowed them to explore diverse artistic expressions, pushing the boundaries of their collection. By incorporating contemporary and international artworks, the family seeks to create a dynamic and culturally rich environment within their private collection.

Motivated by their love for art and a desire to share their collection with the public, the Angsuvarnsiri family has embarked on a remarkable endeavor. Their aim is to curate an exhibition that not only highlights the origins and historical significance of the collection but also emphasizes the importance of supporting valuable works of art. Through this exhibition, the family hopes to provide a glimpse into their private collection, offering a unique opportunity for the public to appreciate and engage with these remarkable pieces. Hence, the family has proposed the establishment of a private museum under the name "Ruam Samai Museum (RSM)" in Chiang Mai, Thailand. This selection is driven by the recognition that Chiang Mai possesses a rich amalgamation of cultural and artistic elements, making it an ideal location for the museum. The diverse cultural heritage and artistic traditions found in Chiang Mai provide an enriching environment that aligns with the museum's objectives and vision. By situating the museum in Chiang Mai, the proponents aim to create a cultural hub that celebrates and showcases the region's unique blend of cultural diversity and artistic expressions.

Most of the collection consist of buddha statues, antiques in various materials from SEA regional and China. Besides from the antiques collection there are also

modern Thai paintings and international contemporary art, the owner was also collecting Thai contemporary art since 1990's.

Ruam Samai Museum will be constructed in an approximate covered area of around 11,200 sqM in the heart of Chiang Mai. The area is located next to the canal (connected to the In-Doi Village which is around 2.3 KM further from Nimman Soi 1). It is an empty space now. The estimated finalization year will be 2026.

Ruam Samai means 'contemporary', particularly reflecting the multiplicities of the 'now', highlighting how fragments of the past are always in our present, via curated exhibitions, educational programs, and a publicly accessible research library. Working with a unique collection of over 6,000 objects, from the 1500's to the present day - deemed art, craft, and design, used in rituals and the everyday life. The Ruam Samai reflects on the lens of human migration, trade, faith, and politics, seeking to transmit an understanding of the role of artefacts in writing histories and their symbolic materialities.

The collection consists of various materials such as ceramic, wood, paper, textile, ivory, metal, plastic, media art, etc. All objects are now located at a temporary storage in Bangkok and it is planned to move to the new storage building in Chiang Mai in 2024.

The forthcoming storage building in Chiang Mai is designated to be situated at Yu Yen Soi 3 in the Chang Phueak district, approximately one kilometer away from the museum building. Currently, the site is vacant and undergoing the process of space allocation for the construction of the storage building. The architecture team is actively involved in estimating the required usage area for the facility, ensuring that the space is effectively utilized for the storage of the museum's collection.

During the planning process for the storage building, it is essential to accurately determine the volume of the collection and categorize the objects accordingly. The team can determine the specific storage requirements and plan the necessary furniture and storage systems.

Planning for the storage building necessitates careful consideration of the objects within the museum's collection. Categorizing the objects allows a systematic approach in determining the storage space needed, considering the size, fragility, and other characteristics of the objects. Additionally, understanding the volume of the

collections is essential to ensure that the storage space is adequate to accommodate the entire collection.

Furthermore, the planning process entails identifying the furniture requirements for the storage building. This includes selecting appropriate materials, shelving, cabinets, and other storage units to ensure optimal organization and accessibility of the objects.

1.1 Materials and collection focus

The private collection comprises 6,686 pieces, which can be classified into two main categories: antiques and artworks. Antiques are objects that have a distinctive aesthetic value (due to their age) and historical significance.[1] They are often cherished for their association with famous people, important historical moments, or skilled craftsmanship.[2] In general, they indicate a specific age or period, antiques can encompass a wide range of items, such as furniture, ceramics, textiles, coins, tools, and household items. The value of antique objects is primarily derived from their age and historical context rather than their artistic expression. Artworks encompass a diverse range of forms, including paintings, sculptures, drawings, prints, photographs, installations, and multimedia creations. Artworks are typically created by skilled artists who employ various techniques, materials, and concepts to convey their artistic vision, emotions, ideas, or social commentary. They are primarily valued for their artistic qualities, creativity, conceptual significance, and the artist's individual expression.[3]

The antique objects within the collection comprise a diverse range of items, with a predominant focus on artifacts originating from Southeast Asia and China. This emphasis is primarily due to Subhashok's expertise and interest in Chinese art and

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[1] Laura Felleman Fattal, n.d. “Antiques Roadshow: The Object of Learning,” VCU Scholars Compass, accessed April 21, 2023, https://scholarscompass.vcu.edu/jstae/vol22/iss1/6/.

[2] Benjamin L.Curtis, Darrin Baines, “What Is an Antique?,” *The Journal of Aesthetics and Art Criticism* 74 no. 1 (2014): 1, https://doi.org/10.1111/jaac.12237.

[3] Gary Iseminger, “Aestheticized Institutionalism and Wollheim’s Dilemma,” *The Journal of Aesthetics and Art Criticism* 73, no. 4 (2015): 385–90, http://www.jstor.org/stable/44510186.

history. Consequently, the collection features a significant number of objects that reflect Chinese artistic traditions (Fig.1-4). Most of these works encompass various categories, including furniture, accessories, ceramics, Buddha statues, and iconographic objects[4]. Moreover, the collection exhibits a wide variety of materials, such as wood, ceramics, metal, glass, and textiles, among others.

Fig. 1. Antique Chinese folding chair from Qing Dynasty circa 1800. Copyright 2018 by Subhashok ‘s collection.

Fig. 2. Antique Chinese incense burner from Qing Dynasty circa 1900. Copyright 2018 by Subhashok ‘s collection

Fig. 3. 25 Ore Denmark coin circa 1972. Copyright 2018 by Subhashok ‘s collection.

Fig. 4. Tibetan vessel style circa 1900. Copyright 2018 by Subhashok ‘s collection.

[4] Iconographies refer to artifacts or items that hold symbolic or representational meaning within a particular cultural or religious context. Such as buddha statue, Thangka painting.

In addition to that, Subhashok also has an interest in collecting artworks from renowned Thai artists during the period of Thai Modern Art (19th -20th c.).[5] This period encompasses the works of various prominent Thai artists, including Tawan Dachanee, Chalermchai Kositpipat, and Fua Haripitak, among others. Subhashok's collection includes pieces created by these acclaimed Thai artists, showcasing their significant contributions to the art scene in Thailand.

This focus on Thai Modern Art reflects Subhashok's appreciation for the artistic development and achievements within his own cultural context. By collecting and preserving the works of these renowned Thai artists, Subhashok contributes to the recognition and preservation of Thai art history, as well as the promotion of Thai artists both locally and internationally.

The inclusion of Thai Modern Art within Subhashok's collection further enriches the diversity and breadth of the overall collection, showcasing the cultural significance and artistic excellence of Thai artists during this transformative period. This emphasis on Thai Modern Art also highlights the importance of supporting and preserving contemporary art movements within a local context, while fostering a deeper understanding and appreciation of the artistic heritage of Thailand.

[5] Modern art in Thailand emerged during the late 19th and early 20th centuries when the country underwent significant political, social, and cultural changes due to its engagement with the global art world and exposure to Western artistic influences. It has its own genealogy and serves as an expression of an ethical need to embody moral experience. The development of Thai art can be traced back to the early Ratanakosin period, where artisans were inspired by Buddhist beliefs and literature. See list of reference.

Fig. 5. Thawan Dachanee. *Unknown*. (Chinese ink on paper). Copyright 2018 by Subhashok ‘s collection.

Fig. 6. Chalermchai Kositpipat. *Unknown*. (Watercolor on paper). Copyright 2018 by Subhashok ‘s collection.

Over time, Subhashok and Jongsuwat have increasingly recognized the importance of supporting contemporary artists, both from Thailand and abroad. Within their collection, they have acquired renowned works from esteemed contemporary artists, exemplifying their dedication to fostering contemporary art.

The collection features works from highly acclaimed contemporary Thai artists such as Apichatpong Weerasethakul, known for his influential independent films, and Montien Boonma, a conceptual artist (Fig.7 and 8). Additionally, the collection also includes works from internationally acclaimed artists such as Jeff Koons, Ai Weiwei, Anish Kapoor, Yves Klein and many other globally renowned contemporary artists (Fig.9 and 10).

Fig. 7. Apichatpong Weerasethakul. *Memoria (Diptych).* (2022). (Two Giclée prints on Awagami Fine Arts Paper). Copyright 2018 by Ruam Samai Museum, Bangkok, Thailand.

Fig. 8. Montien Boonma. *Room 1994,* (Reconstructed 2020). (Timber, hand-woven cotton, silkscreen). Copyright 2018 by Ruam Samai Museum, Bangkok, Thailand.

By incorporating these celebrated contemporary artists into their collection, Subhashok and Jongsuwat demonstrate their commitment to promote and preserve contemporary art movements on both a local and global scale.

Fig. 9. Yves Klein. *La Victoire de Samothrace* . (2000). (Dry pigment and synthetic on plaster with metal rod on stone base). Copyright 2018 by Subhashok ‘s collection.

Fig. 10. Ai Weiwei. (2017). *Stacked Porcelain Vases as a pillar.* [Porcelain]. Copyright 2018 by Subhashok ‘s collection.

1.2. Exhibitions

The Museum's three exhibition spaces will serve as the main component in achieving the Museum's mission. These spaces will be designated for showcasing works of art or art projects and are divided into three categories based on different curatorial approaches: 1) Private Collection, 2) Thai Contemporary Art Collection, and 3) Temporary Exhibition and Special Projects. The first and second will be permanent exhibitions, which adhere to Museum Standards and are intended to be exhibited for a longer period, with the goal of rehanging every 5 years. The third exhibition space is more experimental in nature and aims to host both cutting-edge contemporary art exhibitions and international traveling exhibitions.

1.2.1. Permanent exhibition

1.2.1.1. Private collection

The private exhibition space in the museum will showcase a selection of up to 200 high-quality works of art, historical objects and archives loaned from the founder's collection. Guest curators are invited to create the exhibition, with the support of the curatorial department for research and insights. The selection of loaned items is subject to rigorous academic and aesthetic study before being displayed, and external loans require aboard review. The exhibition must adhere to a guideline for rotating items on display every 5 years. The guest curator also contributes to catalogs, other publications, publicity, and educational programs. The curatorial department works with conservators and exhibition designers to ensure that each item is displayed according to museum standards.

1.2.1.2. Thai Contemporary Art

The Thai Contemporary Art exhibition space will display a growing collection of contemporary art in Thailand, dated from the 1990s onward, with some exceptions. The collection has acquired using art-historical research, and the chief curator is responsible for researching, proposing acquisitions, curating the exhibition, and putting items on display. The exhibition content and selection of items are regularly refined to reflect the evolving nature of contemporary art in Thailand. The curatorial department works with conservators and exhibition designers to ensure that

each item is displayed to meet museum standards. New acquisitions will be displayed in the exhibition when possible.

1.2.2. Temporary Exhibition

The temporary exhibition space will be a platform for contemporary art exhibitions and special projects, which may be initiated by the Museum or external parties overseen by the Curatorial Department. The Museum intends to host two to three themed exhibitions per year in this space, following certain guidelines. These exhibitions must align with the Museum's mission and vision and contribute to the development of contemporary art in Chiang Mai and Thailand. Furthermore, they should provide opportunities for collaboration between Thailand and the international community. The Curatorial Department oversees the exhibitions in this space, ensuring that they adhere to the highest possible academic and aesthetic standards.

1.3. Storage

The temporary collection storage facility is a building located at Soi Sukhumvit 49, Bangkok. Most of the stored artworks consist of paintings, sculptures, and mixed media pieces by both Thai and international artists. The storage area is structured as a two-story warehouse with high ceilings, occupying an approximate area of 1,600 square meters (Fig.11 and 12).

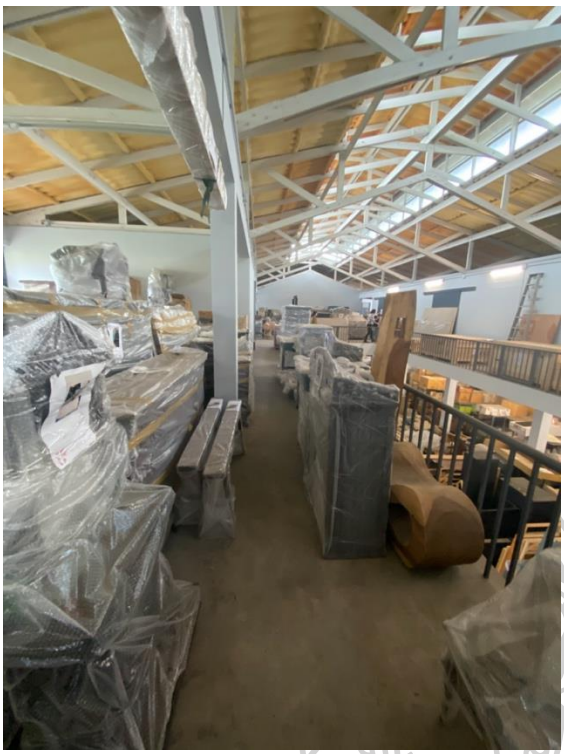

Fig. 11. Temporary storage in Bangkok.
Source: Pornganok Sadakorn (9 December 2022)

The art storage facility is divided into two main sections. The lower level houses the storage of antique wooden furniture, while the upper level is further divided into three rooms: Room A, Room B, and Room C (Fig. 13). These rooms house the storage of various types of artworks, including paintings, sculptures, and mixed media pieces. The rooms are equipped with an internal air conditioning system, which is programmed to operate during daytime hours and automatically switch off during nighttime hours based on pre-set settings. This leads to increased fluctuations in temperature and relative humidity throughout the day. Upon inspecting the storage area and assessing the condition of the artworks, it was observed that artworks of different types and materials were stored together in the same space to optimize storage capacity. However, this has resulted in high density and inconvenience during the process of movement and storage, leading to increased risk of damage to the artworks.

To facilitate future transportation and exhibition preparations at the Ruam Samai Museum, it has become necessary to plan for the relocation of artworks to a new storage facility in Chiang Mai. Additionally, the design and planning of the new storage building must adhere to conservation standards. This strategic move aims to alleviate the challenges associated with the current storage space, such as overcrowding and difficulties in handling and storing the artworks, ultimately minimizing the risk of damage to the collection.

Fig. 12. Temporary storage in Bangkok.
Source: Pornganok Sadakorn (9 December 2022)

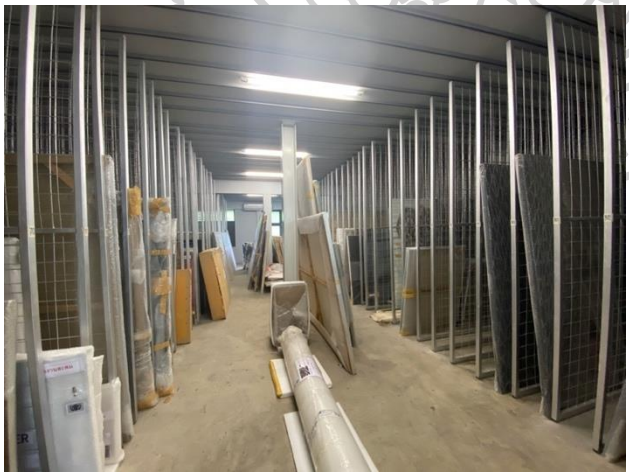

Fig. 13. Painting room (Room B).
Source: Pornganok Sadakorn (9 December 2022)

2. Requirements for the future storage building

2.1. Storage space consideration

Storage space is a multilayered structure that protects museum collections. The outer layer of the facility is the protective shell of the building or other structure, which can be unconventional, such as a disused coal mine, underground bunker or a new building. There are segregated storage areas or rooms that provide additional protection to the collections. These storage areas have additional protective layers in the form of shelving, racking, cabinets, boxes, trays, and packing media (Fig.14). Each of these layers are carefully planned to provide optimal conditions for each object or collection in storage. The additional physical protection and buffering of environmental conditions provided by each layer ensures that the collections remain safe and well-preserved. The careful planning of each layer ensures that the collections are protected from damage caused by physical contact, environmental factors such as temperature and humidity, and other potential hazards. The collection storage facility is an essential component of any museum, as it ensures that the collections are preserved for future generations to enjoy and learn from.[6]

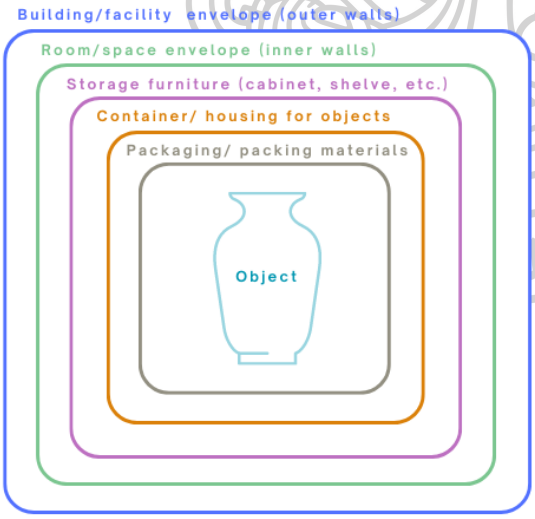

Fig. 14. Multilayered structure of museum storage.
Source: Pornganok Sadakorn (11 June 2023)

[6] NPS Museum,“Chapter 7: Museum Collection Storage.” In *NPS Museum Handbook Part 1*, (np., 2012), 2.

2.1.1. Storage building

2.1.1.1. Building location

Selecting the location for a museum is one of the first planning decisions, with the needs of the collections as the first priority. A site might seem great for visitors, but it could also have problems such as regular flooding, unstable soil, earthquakes, termites, or other costly issues. These challenges can be lessened with proper engineering and construction, but future potential problems should be carefully considered. It's easier and cheaper to find the right site than to constantly fix subpar conditions. Sometimes, the best place for storing collections can be found in a separate non-public facility, which is becoming more popular due to rising land costs in city centers.

These are the factors that should be considered for storage building location. Firstly, collection storage sites should be situated away from flood plains or areas with a high water table.[7] This is important because flooding can cause significant damage to collections, leading to irreparable loss of cultural heritage.

Secondly, the storage site should have good drainage and soil stability.[8] This is necessary to prevent waterlogging and soil erosion, which can also damage collections. A stable soil foundation is also important to ensure the structural integrity of the storage facility.

Thirdly, the site should allow ease of access for full-size delivery vehicles.[9] This is important because collections are often transported to and from the storage facility, and it is essential to have easy access for large vehicles (to avoid any damage to the collections during transportation).

Fourthly, the storage site should have a reliable utilities supply, including emergency supply.[10] This is necessary to ensure that the collections are stored in a controlled environment with proper temperature and humidity levels. In

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[7] Barry Lord, Gail Dexter Lord, and Lindsay Martin, eds., *Manual of Museum Planning: Sustainable Space, Facilities, and Operations*, 3rd ed. (United States of America: AltaMira Press, 2016), 252.

[8] Ibid.

[9] Ibid.

[10] Ibid.

case of any power outage or other emergencies, it is important to have a backup power supply to maintain the environmental conditions. The site should be close to fire station, police station, and other emergency services. This is important to ensure the safety of the collections in case of any emergency, such as fire or theft. Also, having emergency services nearby can help in quick response and minimize any potential damage to the collections.

Additionally, it’s crucial to avoid having plants or forest nearby. These can contribute moisture that could impact the groundwater and attract pests.

Certainly, many museums have their storage room located within the museum building or have the building nearby museum building. These can allow for more efficient management and movement of items between storage and exhibition spaces. Curators and staff can easily access objects, reducing the time and effort required for preparation and curation. As well as can lead to cost savings in various aspects. Maintenance and operation costs are streamlined since there's no need for a separate storage facility. This also simplifies building services maintenance, security systems, and climate control, as they can be centralized.

Additionally, some museums have "visible storage" areas where visitors can see behind-the-scenes operations, providing a more immersive and educational experience. For example, Silpakorn Art Centre in Thailand (Fig.15). Due to limited exhibition space in the gallery and insufficient space for constructing a storage facility, a strategy for creating visible storage has been developed. This approach allows for the simultaneous storage and display of artworks within the gallery area that can help interactive learning experiences, enriching the museum's educational offerings.

Fig. 15. Visible storage gallery at Silpakorn Art Centre, Nakhon Pathom, Thailand. Source: Silpakorn Art Centre, Thailand.

However, the Ruam Samai Museum project is planning to separate the storage building from the main museum building. This decision involves careful consideration of both advantages and disadvantages, as it significantly impacts the museum's storage facilities. Due to insufficient space for constructing storage rooms.

On the positive side, the separation offers several benefits. Separate storage buildings can be purposefully designed with specialized environmental controls to optimize artifact preservation, ensuring consistent conditions for temperature, humidity, and lighting. Enhanced security measures, such as advanced surveillance systems and access controls, can be implemented to safeguard valuable collections. Dedicated storage structures allow efficient use of space, accommodating various storage needs with high-density shelving and compact solutions. These buildings facilitate organized artifact retrieval and cataloging, minimizing the risk of damage during handling. Additionally, it can provide room for collection expansion without encroaching on exhibition spaces, thus allowing the acquisition and storage of more items. The separation also grants greater flexibility in designing the exhibition building, focusing on immersive visitor experiences and thematic displays while

minimizing noise and disturbances that can affect sensitive collections during setup or renovations.

However, there are also challenges to consider. The disadvantages include logistical complexities that may arise from transporting artifacts between separate storage and exhibition locations, potentially impacting efficiency. As well as, in the event of heavy rain or flooding during transportation, besides the transportation difficulties and time loss, there's a risk of artworks getting damaged during transit. Therefore, vigilance is essential, and protective measures to prevent damage should be in place.

Visitor engagement might be constrained by having storage off-site, limiting opportunities for educational programming and behind-the-scenes access. Rapid access to artifacts for curatorial decisions and research could be compromised due to physical separation. Operating two distinct buildings may result in increased costs related to maintenance, utilities, security, and staffing. Coordination complexity could arise as staff members in different locations need to collaborate closely.

Additionally, inefficiencies in managing artifacts might occur, given the need for staff to commute between storage and exhibition sites. Some argue that separating storage and exhibitions may lead to a loss of synergy, as having them in the same building fosters stronger connections between curators, conservators, and exhibition designers, enhancing collaboration and creativity.

Overall, the advantages and disadvantages must be carefully weight, aligning with the museum's mission and goals, and considering innovative solutions, the decision to separate storage from the main museum exhibition facility can be made in a way that maximizes both artifact preservation and visitor engagement. If visitor engagement is a crucial aspect of your museum's mission, explore alternative ways to engage visitors despite the separation. This could involve designing interactive storage displays, virtual tours, or scheduled behind-the-scenes access.

2.1.1.2. Building construction

The characteristics of an old building, with thick walls, architectural details, and structural integrity, can provide unique opportunities and challenges when considering it for museum storage. Museums often use existing buildings, such as

attics or basements of historic building. The basement has some advantages such as being underground, that gives it stronger floors that can hold more weight. It also stays at a more stable temperature and protects against outside temperature changes. Since it doesn't have windows, pests, too much moisture, and extra sunlight can't get in. Additionally, using the basement doesn't get in the way of public areas. However, basements also have disadvantages, the risk of flooding and ground water infiltration is significant due to the basement's location.[11] This can be dangerous for the space and collection.

To address these issues, it's essential to establish effective drainage systems incorporating well-designed floor drains and implement additional foundation work. These measures prevent water from flooding in during heavy rainfall or rising from the ground.

As a choice building located at a distance from the museum, as storage space for their collections. These storage rooms are usually chosen because of their low rent, but they have several drawbacks, such as difficult access, unsuitable climate, and difficulty in keeping them clean. It is important to convince decision-makers that using cheap storage in the short term can be very expensive in the long term, as collections can be damaged by handling, mold growth, and degradation, and cleaning and conservation can be time-consuming and expensive. Adequate storage from the beginning can protect objects better and more cheaply.[12]

The new building principle suggested that a lighter construction of the building and high demands on its airtightness would yield an improvement in energy consumption, making the building cheaper and improving its preservation quality. A new building can be designed from scratch to perfectly meet storage requirements, incorporating advanced climate control, security systems, pest prevention and storage

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[11] Lord, Lord, and Martin, *Museum Planning,* 253.

[12] Lise Ræder Knudsen and Rosenvinge S. Lundbye, "Performance of Danish low-energy museum storage buildings," *ICOM-CC 18th Triennial Conference Preprints, Copenhagen, 4–8 September 2017,* (2017),: 2, https://www.icom-cc-publications-online.org/1601/Performance-of-Danish-low-energy-museum-storage-buildings.

solutions. A new building can accommodate future growth and changing collection needs without constraints from existing structures.[13]

Especially in Thailand located in tropical climate zone[14], the challenges of high temperatures and humidity impact buildings, including archives, with risks like insect pests and poor maintenance. Biodeterioration from mold due to flooding and poor air circulation is a concern. Temperature range and humidity fluctuations throughout the year, along with rain distribution, are important for preserving cultural property. The significant variations in temperature and humidity in the tropics pose difficulties for protecting cultural items. Human comfort and construction in these areas are affected by factors such as temperature, humidity, precipitation, radiation by the sun, sky condition, air movement.[15]

When planning a building for collections' protection, the climate's suitability is crucial. This means designing to consider outdoor conditions, especially in hot climate. For tropical regions, using passive techniques for climate control involves experiments, simulations, and data. A climate-responsive design aims to minimize heat gain and loss, internal heat, and use a suitable site, structure, sunlight control, and air circulation.

Passive climate control is a concept that is aligned with the idea of sustainable building, which aims to reduce the environmental impact of buildings. It is an alternative to mechanical air-conditioning systems, which consume a lot of energy and contribute to greenhouse gas emissions. Passive climate control involves designing and arranging the repository in a way that utilizes the thermal and hygroscopic properties of the building and its contents to create a stable indoor

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[13] Ibid.

[14] Shin Maekawa, Beltran Vincent, and Henry C. Michael, "Appendix 3 Climate Calculations for Bangkok and Istanbul: Alternative Conservation Strategies for Hot and Humid Climates." In *Environmental Management for Collections*, (United States of America: Getty Conservation Institute, 2015), 390.

[15] René Teygeler et al, "Chapter 4: Building: Problems and Solutions," In *Preservation of Archives in Tropical Climates*, 1st ed., (Paris, France: ICA/ARA/ANRI, 2001), 28. https://doi.org/10.13140/2.1.2285.9849.

climate.[16] This method is all about using the building's structure to control the temperature and humidity. For engineers, passive climate control means designing the building, so it keeps a steady indoor climate, based on how it'll be used. People who use the storage area should also know about things they might do that could accidentally change the indoor climate, like adding extra heat or moisture. The key is that if they want to avoid temperature and humidity fluctuation, they need to consider about sensitive objects and have a specific storage room for stable control system in place.

Load reduction in hot climates pertains to mitigating heat and humidity within buildings to establish a more pleasant indoor atmosphere, achieved through adept shading and ventilation strategies.[17] Well-conceived architectural designs can also mitigate the impacts of daily temperature and humidity fluctuations, necessitating a contextual understanding of the local climate to ensure optimal interior comfort.

Views on the desirability of windows in storage building areas are varied. While open windows can aid in reducing heat and humidity, potentially preserving materials, the presence of windows can also elevate indoor temperatures when exposed to sunlight, undermining preservation endeavors. Even if there's air conditioning, windows that can slide open are better than ones that can't, so they can let air in if there's no power.

In warmer place, where sunlight can be intense, it's recommended to have about 1-5% of the sides of the building that face the sun covered with glass. This measured approach allows for controlled sunlight to enter the building without overheating the interior. On the other sides of the building that doesn't directly face the sun, having about 1-10% of the surface as glass is a good balance. This glass is accompanied by protective elements like sunshades and screens. These components help manage the amount of sunlight and heat that enters the building, ensuring a comfortable indoor environment.

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[16] Ibid, 31.

[17] Ibid, 35.

Many strategies such as blinds, shutters, and curtains can counter sunlight, though Venetian blinds may hinder air and natural light, necessitating artificial lighting. Effective insect exclusion involves fine wire mesh screens, while hurricane-prone areas warrant sturdy windows equipped with cyclone shutters to prevent glass breakage and thwart water and debris infiltration.

In Japan, they've innovative approach to use special window panels that have different layers, including filters, to keep out tiny particles, germs, and mold spores. This could even stop volcanic gases from damaging metals. And in Vietnam, planting trees around buildings helps control how hot it gets and how much sun comes in. But cutting down tree can help prevent pests. Nonetheless, having trees or plants around might also make it easier for people to get to windows and roofs and moisture problems, which might not be safe.

The building should use high quality materials and the right techniques for its purpose. It should be built strong enough to handle things like earthquakes. Keeping the inside airtight helps keep the right air conditions for the collections. Also, the building needs to be well-sealed to keep out things like rain, dust, sand, and pollution that can be harmful for the collections.[18]

After engaging in discussions and consultations regarding the design of Ruam Samai Museum storage building in Chiang Mai with senior conservator and owners of the collection, a consensus was reached regarding the need to enhance energy efficiency in the building's design. This consensus inspires from the desire to reduce various electricity-related costs within the building. As a result, an idea has emerged, which is suggested by the senior conservator, for the architectural team to incorporate the concept of "Stack effect ventilation" into the museum storage building's design.

Normally, to optimize the utilization of natural airflow and ventilation through openings, it is crucial to investigate wind direction, wind speed, and frequency to tailor their integration with building designs in various locations. A comprehensive understanding of natural wind patterns is necessary. When designing

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[18] Ibid, 36.

openings to harness wind flow, a combination of both inlet and outlet openings (cross ventilation) is essential for effective air circulation. Conversely, a single-direction opening (single ventilation) can lead to inadequate air exchange, limiting the efficiency of air movement into the interior (Fig.16).

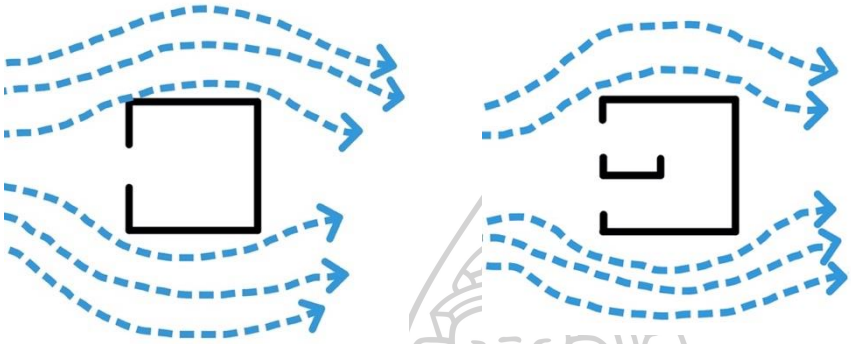

Fig. 16. Natural airflow pattern of single ventilation, while one opening and multiple openings on the single wall.
Source: Pornganok Sadakorn (3 August 2023)

Air ventilation theory encompasses two primary types: Cross ventilation and Stack effect ventilation. Cross ventilation involves directing air movement between spaces through multiple openings, creating differential pressures that facilitates airflow within a structure (Fig.17). This method is commonly adopted in naturally ventilated buildings, though its efficacy is confined to horizontal air circulation. On the other hand, Stack effect ventilation is a method used to improve airflow and thermal comfort in buildings (Fig.18). It utilizes the natural buoyancy of warm air to create a pressure difference that drives air movement. Naturally, higher temperature (hot) air rises and is replaced by lower temperature air (Fig.19). The main variable that causes air circulation in the building is the height of the chimney. Chimney cross-sectional area outside air temperature and inside the building and wind speed levels, etc. This method can be used for more higher vertical buildings.[19]

[19] Nutthapong Tongkam, "An Application of Stack Effect Design in Multi-Store House Project." Bachelor thesis, Sri Pathum University, 2017.

Fig. 17. Show the natural airflow patterns of cross ventilation.

Source: Pornganok Sadakorn (3 August 2023)

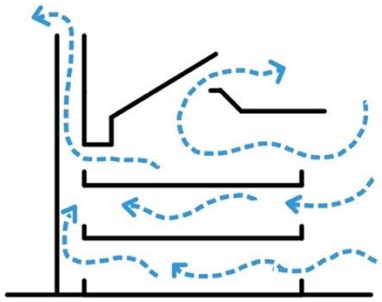

Fig. 18. Show the natural airflow characteristic of stack effect ventilation.

Source: Pornganok Sadakorn (3 August 2023)

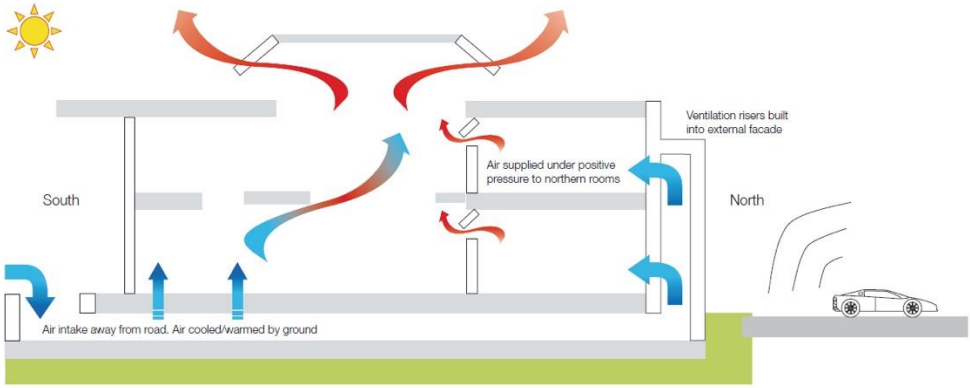

Fig. 19. Air circulation of differences indoor and outdoor air temperatures and densities.

Source: https://www.designingbuildings.co.uk/wiki/Natural_ventilation_of_buildings (15 March 2023)

Optimal positioning of building openings should align with prevailing wind while accounting for odor and smoke dispersion. Avoid openings on one side of a wall due to air pressure hindrance. Proximity to neighboring structures should be avoided to maintain efficient airflow. Openings should be placed in relation to body zones; entrances at body level and exits above facilitate circulation, drawing away elevated heat.

Consider additional factors such as awning type and size, internal partition walls, furniture arrangement, and the characteristics of openings, including building shape.[20] Structures with more inlet and outlet openings encourage improved air circulation and opening size influences airflow speed and strength. A smaller entrance with a larger outlet yields faster and stronger airflow compared to a large entrance and small outlet. However, when the opening is larger at the entrance and smaller at the exit, the airflow will cover a larger area. This design leads to a reduction in wind speed at the outlet's opening.[21]

Collectively, the style, size, number, and placement of openings significantly impact airflow within a building. These aspects must be considered for optimal utilization, as well as their alignment with local wind direction. When building orientation is restricted, wind deflectors like tree lines or walls can modify wind flow.[22]

A notable example of research into stack effect ventilation can be found in regions with a thermal climate zone, similar to Thailand. This is exemplified in the article titled *"Interaction Between Wind and Buoyancy Effects in Natural Ventilation of Buildings"* conducted in a house called Kebun Angin, Batu Pahat, Johor, Malaysia.

The article has implications for the design of an atrium house building utilizing natural ventilation. In examining the interplay of wind forces and the upward and downward movement of warm air, the article places particular emphasis on the

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[20] Chumnan Boonyaputthipong and Elnimeiri M. Mahjoub, "Stack Effect Ventilation in Different Climates." *Journal of Building Energy & Environment* 1, 1(2018): 24–25, https://bee.kku.ac.th/wp-content/uploads/2018/06/bee-full-1-2018-Stack-Effect-Ventilation-in-Different-Climates.pdf.

[21] Tongkam, "Stack Effect Design", 24.

[22] Ibid, 24.

interaction between wind speed and thermal buoyancy. The article recognizes that external wind conditions can influence the effectiveness of natural ventilation within the atrium building.

Depending on the building's configuration and the velocity of the external wind, it can either enhance or counteract the internally generated buoyancy-driven airflow. This insight directly relates to the consideration of building orientation, openings, and other design elements in optimizing natural ventilation strategies.

Furthermore, the article suggests that the effects of external wind and internal thermal buoyancy interact to shape the internal airflow patterns and temperature distributions. This dynamic interaction becomes more intricate when both external wind and internal buoyancy-driven effects are considered (Fig. 20).[23]

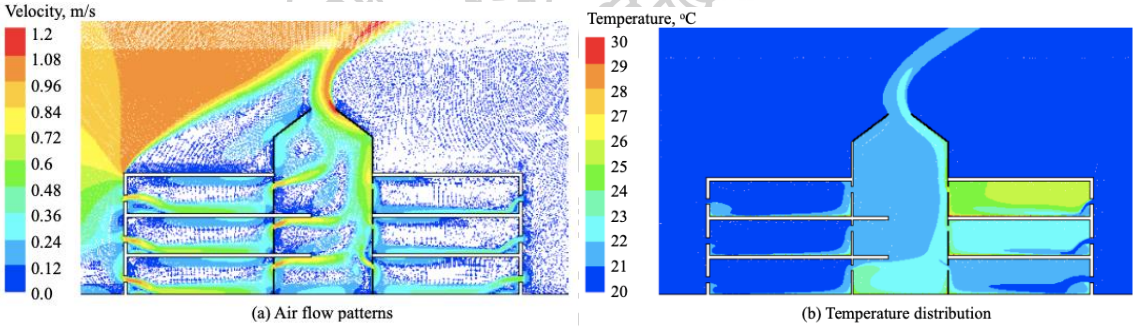

Fig. 20. The wind effect has a major influence on the indoor environment of the naturally ventilated atrium building.
Source: https://doi.org/ 10.2174/1874836801004010134. (2010)

Understanding and incorporating these interactions empowers designers and engineers to formulate strategies that ensure ideal airflow, temperature regulation, and preservation conditions for valuable museum storage within such facilities.

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[23] Guohui Gan, "Interaction between Wind and Buoyancy Effects in Natural Ventilation of Buildings." *The Open Construction and Building Technology Journal* 4 (1)(2010): 134–145, https://doi.org/ 10.2174/1874836801004010134.

Due to this, the senior conservator suggests that, in Thailand, storage building designs need not invariably encompass comprehensive air conditioning systems. Instead, harnessing stack effect ventilation can conserve energy and expenses, particularly for less sensitive items like stone or ceramics. However, air conditioning and humidity control are selectively used for sensitive items.

Especially considering the prevailing misconception about temperature control through air conditioning in Thailand, operational issues arise in several storage facilities due to intermittent air conditioning usage to economize on electricity costs. This causes temperature and humidity fluctuations, deviating from recognized international control standards that mandate consistent conditions. Consequently, mold growth concerns have arisen in numerous Thai museums' storage facilities, underscoring the need to optimize temperature and humidity control in alignment with international standards.

Hence, the design principle for Ruam Samai Museum's collection storage building underscores the implementation of stack effect ventilation. The senior conservator, the owner, and collection manager all agree on its use. The subsequent step involves collaborative design with the architectural team to align the building with this principle.

2.1.1.3. Storage room construction

Storage rooms for collections require structurally sturdy, easy to clean and maintain floors, walls, and ceilings made of materials that do not contribute to environmental or pest problems, inert and must resist vibration, leaking, flooding, pest, and pollution hazards, fire-resistant or fireproof materials. For instance, unsealed concrete can shed gritty, abrasive dust that can be highly damaging to collections, so it must always be sealed.

Additionally, the structure needs to be resistant to leaking or flooding risk, plumbing hazards, pest and pollution hazards, fire, and intrusion hazards. Therefore, it is crucial to consider all these factors while designing and constructing storage rooms for collections to ensure the safety and preservation of the stored items.

The floor in storage rooms should be stiff, even, and fire-resistant with a minimum load capacity based on the type of storage equipment and collections to be

accommodated. Floor drains with backflow preventers should be installed, and tracks for mobile storage rails should be cut before bringing in any storage equipment or collections. Floors should be of solid construction, such as polished concrete, finished with sheet vinyl or commercial grade linoleum, and non-slip to support the weight of objects or storage furniture.[24] Wooden boards or carpets should be avoided as they may harbor dust and pests and are likely to be uneven.

The outer walls need to be nicely finished and include insulation, materials that prevent moisture, and necessary utilities. These walls should have a fire resistance rating of at least two hours for both the materials and the structure. Doors and pathways leading outside should also be well-insulated, sealed against weather, and fitted with strong security hardware and alarm systems.[25] When planning a building, we can make choices to keep it safe from fires. Using materials that resist fires can slow down the fire's spread. Another way is to divide storage rooms into smaller sections using walls that resist fire. Also, can keep rooms with important objects separate from other areas to be more safety.[26]

As well as the interior or partition walls in storage areas should be sturdy, pest-resistant, and fire-resistant with a minimum of two hours of fire resistance for partition wall materials and structure and should be cleanly finished and sealed or painted. All concrete parts and the walls of the storage area should also be smoothed, sealed with epoxy or water-based polyurethane and painted with latex paint.[27] This will make it easier to clean the walls and prevent dust from settling on them. Additionally, they suggest painting the walls and ceiling with paint containing

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[24] Lord, Lord, and Martin, *Museum Planning*, 254.

[25] Ibid.

[26] Teygeler et al., *Building*, 36.

[27] Martijn de Ruijter and ICCROM, *Cultural Heritage Protection Handbook: Handling of Collections in Storage*. Edited by Nao Hayashi Denis. (Paris, France: Cloitre Imprimeurs, 2010), 13, https://unesdoc.unesco.org/ark:/48223/pf0000187931.

titanium dioxide pigment. Because it will absorb ultraviolet radiation emitted by ambient or artificial lighting.[28]

Exterior doors should be strong, made of solid hardwood or hardcore materials. For higher security, steel doors with insulation and a thermal break can be used to prevent heat and cold from passing through.[29] When choosing the size of storage room doorways, consider the largest object that will be stored inside. The standard option is to have a regular double door, but if there are big objects, it's better to think about using customized double doors or doors that roll up. The doors inside the storage rooms should be strong and made of metal. And they should have windows, so that it’s possible to see the collection on the other side.[30]

The doors can be made of metal with a hollow center or wood that's very solid and can handle fire well. It's also a good idea to have door closers, which are devices that make sure the doors close on their own after they're opened.[31] This is important for safety in case of a fire, and it also helps to keep secure and prevents wear and tear on the doors. If a door is meant for people to use in case of a fire, it needs special so-called panic hardware called hardware. This hardware makes it easy for people to open the door quickly and easily in an emergency.[32]

Windows should be fitted with blinds or screens to control natural light according to the requirements of the stored objects, or even eliminated completely if the objects are light-sensitive.[33] However, when a system like the stack effect ventilation is in place, which uses natural air movement to reduce indoor temperatures and save electricity, windows are necessary to allow wind to enter. This means that apart from having windows on the exterior walls of the building, there also needs to

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[28] U.S. Department of the Interior, “*Chapter 9: Museum Property Storage”,* In *Museum Property Handbook.* (np.: U.S. Department of the Interior, 2018), 7.

[29] The Council for Museums, *Archives and Libraries, Security,* (np., 2003), 8.

[30] Lord, Lord, and Martin, *Museum Planning,* 255.

[31] NPS Museum*, “Chapter 7,”* 8.

[32] Lord, Lord, and Martin, *Museum Planning,* 255.

[33] Freda Matassa, *Museum Collections Management*, (London, United States of America: Facet Publishing, 2011), 127, https://doi.org/10.29085/9781856048699.

be a design for windows on the interior walls of each room. These windows help air flow in and out.

Architects, conservator, and engineers need to work together to figure out the right techniques and methods for designing these windows. They need to decide on the type and size of windows both inside and outside the building. Additionally, they have to plan ways to prevent dust and insects from entering the building.

Ceilings in storage areas should be open to the underside of the roof for easy access in case of problems, and all elements should be finished, sealed, and painted in a light color. Care should be taken to coordinate beams, service runs, ducts, and lighting to avoid losing storage height, a minimum clear ceiling height below services would be 3 meters, allowing 0.6 meters for air circulation below structure and services, and above storage equipment[34] to accommodate raised and stacked cabinets without interfering with lighting and protection systems.[35]

Proper lighting layout in storage areas is crucial for safety and avoiding overlighting. Lighting should be placed strategically, with fluorescent utility lighting fitted with UV sleeves, and motion sensors used to turn off lights when not in use.[36] Lights should preferably be of the light-emitting diode (LED) type, which uses long-lasting lamps that emit very little heat to protect objects from light and reduce the carbon usage of the building.[37] And should not exceed 200 lux or 200 footcandles.[38]

Overhead lighting is necessary at the entry and staging area, as well as along all fixed circulation aisles. Lighting should not be placed above pull-out picture racking, but rather in the aisle area where individual racks can be viewed. For compacted sliding picture racks or high-density mobile shelving, lighting should run perpendicular to the racks to ensure that the racks can be viewed at any open position.

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[34] Lord, Lord, and Martin, *Museum Planning,* 256.

[35] NPS Museum*, "Chapter 7,"* 5.

[36] Matassa, Museum Collections, 127.

[37] Ibid.

[38] NPS Museum*, "Chapter 7,"* 10.

Fluorescent utility lighting is appropriate in collection storage, fitted with UV sleeves to reduce ultraviolet light to less than 10 μWatts/lumen.[39]

The appropriate ambient light levels would provide for safety of operations, such as safe operation of a forklift truck, and depend on whether objects are further protected from light by row covers, boxes, or drawers. Lighting in a storage room should only be on when the room is being accessed, and a motion sensor can be used to automatically turn off lights when people have exited. Lighting can also be zoned so that areas requiring access can be switched on and off separately.[40] At night, only safety or exit lights should be on to ensure the safety of the storage area. For the control centers of electrical and energy systems should be located well away from storage areas and regularly maintained. All maintenance work should be recorded, and the maintenance schedule should be circulated to staff.[41]

2.1.1.4. Building services

Museum storage building services refers to the infrastructure facilities and functions provided within a museum storage building to ensure the proper preservation, organization, and management of collections.

Building services such as plumbing, security control, climate control and monitoring system, and electronical service are necessary for the proper functioning of the building but can pose hazards to the collection storage area. These building infrastructural elements should never be located within the storage area to avoid any potential damage to the collection.

The plumbing system in a collection storage room needs to be designed in a way that minimizes the risk of flooding by water or sewage. The only water or waste-bearing lines that are allowed in the storage room are those that are associated with a fire suppression sprinkler system. If the building already has water or waste-bearing lines present in the storage room, a separation and containment system can be designed and implemented to minimize the effects of a leak. In case the storage area

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[39] Lord, Lord, and Martin, *Museum Planning*, 256.

[40] NPS Museum, *"Chapter 7,"* 10.

[41] Matassa, Museum Collections, 126.

is located below grade, moisture sensors can be installed as a precautionary measure to warn of flooding incidents.[42] It is important to ensure that the storage room is protected from any potential water damage as it can cause irreparable damage to the collections stored within. Water and drain pipes should not run through the storage rooms as they can cause water damage if they burst or leak. This can be detrimental to the collections stored in the area.[43] Therefore, proper planning and implementation of plumbing systems is crucial for the preservation of collections.

Climate control system also known as HVAC systems (Heating, Ventilation, and Air Conditioning), are considered a required feature for museum collections, as they help maintain stable environmental conditions and reduce mechanical damage to sensitive materials that can occur due to fluctuation in environment conditions.[44] By controlling the indoor climate, climate control systems help prevent deterioration, mold growth, and other damage that can be caused by fluctuations in temperature and humidity.

This system is designed to maintain specific temperature and humidity levels. It's including sensors that continuously monitor the conditions inside the storage areas. If the temperature or humidity starts to deviate from the desired range, the system automatically adjusts the heating, cooling, and ventilation to bring the conditions back to the optimal levels.

For instance, during hot and humid weather, the HVAC system might activate the air conditioning to cool down the storage areas and reduce humidity. In colder seasons, it could provide heating to maintain a consistent temperature. The system might have dehumidifiers to remove excess moisture from the air and humidifiers to add moisture if the air becomes too dry. However, full climate control

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[42] Lord, Lord, and Martin, *Museum Planning*, 256-257.

[43] Ruijter and ICCROM, Handling of Collections, 15.

[44] Bart Ankersmit, and Marc H. L. Stappers, *Managing Indoor Climate Risks in Museums*, Edited by Naomi Luxford, (Switzerland: Springer International Publishing Switzerland, 2017), 167-168, https://doi.org/10.1007/978-3-319-34241-2.

by HVAC and/or a (central) heating system greatly affects the indoor climate, but the final climate class that can be maintained depends on the building physics.[45]

The storage area needs electricity for tasks like lighting, security, and monitoring. Outlets along the walls are important for things like computers and vacuum cleaners. Good power supply is vital to prevent problems and damage to stored items. Safe wiring and installation are essential, and the system must handle equipment without overloading. Regular checks are needed to catch problems early.

Using computers and devices is becoming more common for managing storage. This helps avoid paper records and makes work faster and more accurate. Staff can upload data directly to a database. This is better than using paper records. Sometimes, staff need to work in storage areas. For this, there should be data outlets available. These outlets are important for efficient work. Without them, staff might have trouble accessing and uploading data, causing delays and mistakes. So, it's important to plan for data needs when designing storage areas and provide the right infrastructure.[46] However, loose electrical wiring should not be present in the storage area as it can pose a risk of fire due to short circuiting.[47] All electrical equipment and wiring should be insulated and kept in good condition to eliminate this danger.

The security controls systems are including fire and smoke detection, room surveillance systems, access system, and control panel. The storage area should be constructed and made of materials that meet or exceed code requirements and have low fire spread numbers to minimize the risk of fire.

A smoke detection system should cover the entire space to detect any smoke or fire, and a sprinkler system should also cover the entire space to suppress the fire.[48] Hand-held fire extinguishers should be easily accessible at the door and at the far end of the room to provide quick access to extinguish any small fires in case of an emergency. This includes portable fire extinguishers, which should contain

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[45] Ankersmit and Stappers, Managing Indoor Climate, 143.

[46] Matassa, Museum Collections, 126.

[47] Martijn and ICCROM, *Handling of collection*, 15.

[48] Matassa, Museum Collections, 57.

pressurized water or carbon dioxide (CO_2) instead of powder.[49] Powder can stick to the surface of objects and cause damage. Gaseous systems are also used to protect specific areas where water isn't suitable for fire suppression. They reduce oxygen levels to extinguish fires and are used in places like computer rooms and to safeguard delicate artifacts. Halon, the main gas, is being phased out due to environmental concerns. Alternatives like carbon dioxide and safer gases such as FM200 and Inergen are available. Halocarbons and inert gases each have pros and cons.[50] Choosing a system depends on factors like environmental impact, storage space, and effectiveness. Considerations include system installation's impact on historic structures and associated costs. For new buildings, protecting valuable collections outweighs expenses.

A water hose reel should be available in the adjacent circulation space to provide additional fire suppression capabilities.[51] Fire exiting provisions should be coordinated with door security provisions to ensure that the contents of the collection storage are protected while allowing for safe evacuation in the event of a fire. Access/exit can also be made easier through emergency escape routes, if they are not secured internally during closed hours or sufficiently protected during open hours.[52]

Room surveillance systems, such as CCTV[53], are also necessary for the collection storage area. The CCTV should be of the best quality affordable, monitored 24 hours a day, and have continuous digital recording. The cameras should have low-light capability (< 5 lux) and color charge-coupled device (CCD) cameras positioned at all room exits facing the exiting person. This ensures that any suspicious activity can be detected and recorded.[54]

For the door lock of building and storage room, choosing a secure locking system is crucial for doors, with advice from a locksmith for high-risk

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[49] Martijn and ICCROM, *Handling of collection,* 14.

[50] The Council for Museums, Archives and Libraries, Security, 8.

[51] Lord, Lord, and Martin, *Museum Planning,* 257.

[52] The Council for Museums, Archives and Libraries, Security, 6.

[53] Closed-Circuit TV (CCTV) systems are used for detection and monitoring in surveillance.

[54] Lord, Lord, and Martin, *Museum Planning,* 257.

premises. There are different types of locks are available, and consideration should be given to finding a suitable system. An example of door lock system and access are card keys, more advanced electronic technology, such as fingerprint, eye retina and voice identification are available where unattended high levels of control are desired.[55]

In addition, along with the implementation of CCTV systems to monitor movements within the storage room, the incorporation of an alarm system is equally essential. This system enhances the efficiency of tracking in instances of internal theft or break-ins within the storage building or its rooms.

A dependable intruder alarm system should prevent criminals from entering and leaving before the police arrive. Strong physical security is essential for this purpose. The alarm can also be employed to notify the police of a burglary attempt. The best chance of receiving a swift police response is achieved by combining robust security measures with a reliable alarm system.

Relying solely on loud external alarms is insufficient to deter thieves. It is more effective to connect monitored phones to an automated system. This method alerts a central monitoring center, which subsequently informs the police. To safeguard valuable items in the event of system malfunction, human oversight is necessary.

Most alarm systems comprise two components: perimeter security for the exterior and trap security for the interior. Perimeter security covers doors, windows, and other entry points. Prompt alerts for perimeter breaches are critical. Trap detection devices activate when someone is inside, detecting both movement and body heat. Although more expensive, newer systems are significantly more dependable.[56]

The security of a museum is crucial, and a centralized and coordinated security strategy is necessary for the entire museum, including the collection storage area. The collection storage area requires specific security measures, such as secure

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[55] The Council for Museums, *Archives and Libraries, Security*, 25.

[56] Ibid, 9-10.

exiting and entry provisions with hardware, electronic locking, checking, and monitoring systems, and lockdown provisions for closed periods. These measures ensure that only authorized personnel can access the storage area. However, security measures should be part of new building designs. Architects should get clear instructions about security early on. This can prevent extra measures later that could affect how the building looks and avoid more costs after it's occupied. Incorporating security features from the start also makes it simpler to manage different parts of the building's security and reduces features that might aid intruders.[57]

2.1.2. Facility and space requirement

In the context of the proposal to construct a distinct museum storage building apart from the main museum structure, it is of utmost importance to meticulously strategize the spatial utilization for Ruam Samai Museum's storage. This entails creating specialized sectors that cater exclusively to the efficient storage of collections, completely detached from the exhibition area. This holistic concept encompasses various sectors that collectively constitute the comprehensive collection storage facility, to be approached as a cohesive unit during the planning phase.

This approach is drawn from the guidance presented in the book titled "Museum Collection Storage,"[58] specifically in the section concerning 'Planning relationships between the collection storage support areas and other museum facilities.' It serves as a fitting framework for the meticulous planning of Ruam Samai Museum's storage project, ensuring alignment with best practices. The incorporated components within this collection storage facility unit encompass the following:

1. Service Yard: A designated area for the loading and unloading of artifacts, supplies, and equipment, ensuring secure delivery and transportation.

2. Loading Dock: An elevated platform that facilitates efficient loading and unloading of artifacts and materials from trucks and vehicles.

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[57] Ibid, 5.

[58] E. Verner Johnson and Joanne C. Horgan, *Museum Collection Storage: Protection of the Cultural Heritage: Technical Handbooks for Museums and Monuments*. (Paris, France: United Nations Educational, Scientific and Cultural Organization, 1979), 12-15.

3. Receiving Area: A space intended for inspecting, documenting, and preparing incoming artifacts for storage, furnished with examination tables, workstations, and equipment for condition assessment.

4. Fumigation or Specimen Washing Area: Should the need arise, this area serves for fumigating artifacts to counteract pest infestations or washing specimens before storage.

5. Crating Area: A dedicated zone for assembling crates or containers used in artifact transportation, providing a controlled environment for secure packing.

6. Crate Storage Area: Space allocated for storing empty crates and containers post unpacking, ensuring organized storage and convenient access for future repacking.

7. Registration and Holding Area: A central hub for initial documentation, labeling, and registration of incoming artifacts before their transfer to designated storage zones.

8. Photo Area: A controlled environment equipped for capturing high-quality images of artifacts for documentation, research, and publication purposes.

9. Conservation Lab: A dedicated room outfitted with tools and equipment for conservators to undertake restoration and preservation work on artifacts.

10. Collection Storage Areas: Principal spaces reserved for storing artifacts, further subdivided into zones based on attributes such as material type, size, and preservation requisites. Utilizing shelving, cabinets, and specialized storage solutions, these areas house artifacts securely and efficiently.

Moreover, the crucial connectivity prerequisites between the collection storage facility unit and other pertinent areas must be meticulously considered, encompassing:

11. Outside Night Entrance: An entrance thoughtfully designed to allow access during non-operating hours, ensuring secure admission for authorized personnel.

12. Security Control Station: A central control room or station where security personnel monitor surveillance cameras, alarms, and access controls to uphold the safety of stored artifacts.

13. Public and Staff Entrances: Entrances designated exclusively for museum staff and authorized personnel, granting regulated access to the storage building.

When a new object arrives at the museum storage area, must be considered followed: The process begins at the designated service yard where the artifact, along with supplies and equipment, is safely unloaded from trucks or vehicles. The artifact is then moved onto the elevated loading dock, streamlining the transition from the delivery vehicle to the storage facility. The artifact is taken to the receiving area, a designated space designed for inspecting, documenting, and preparing incoming objects. Here, it undergoes thorough examination by museum staff, who assess its condition and record relevant details. If required, the artifact is directed to the fumigation or specimen washing area. This space is used for procedures like fumigation to prevent pest infestations or washing specimens before storage, ensuring their cleanliness and preservation.

After inspection and, if necessary, treatment, the artifact is prepared for storage. This involves the assembly of crates or containers in the dedicated crating area, guaranteeing secure packing for transportation to the designated storage location. Once the artifact has been removed from the crate, the empty crates are stored in the designated area for future use, ensuring organization and accessibility. In the central registration and holding area, the artifact's documentation and labeling process takes place. This stage involves recording essential information about the object and labeling it for identification. Before moving the artifact to its designated storage space, high-quality images are captured in the controlled environment of the photo area. These images serve as documentation for research, publication, and reference purposes. For artifacts requiring restoration or preservation work, the conservation lab provides a space equipped with tools and equipment for conservators to undertake necessary procedures. Following the preparation process, the artifact is finally moved to its storage area. These areas are organized based on material type,

size, and preservation requirements, ensuring the artifact's safety and proper storage conditions.[59]

2.2. Storage rooms

2.2.1. Inventory management

An inventory is an itemized list of objects that the museum has accessioned or received via loan(s) and must be physically located by an examiner.[60] The inventory is generally done by cross-checking each object with the information contained in the museum accession book or catalogue. The objective of the inventory is to ensure that all the objects in the collection are present and in the correct location. A proper inventory management helps in identifying any missing or misplaced objects, which can be crucial for the security and preservation of the collection.[61] It also helps in keeping track of the condition of the objects and identifying any damage or deterioration that may have occurred.

It is imperative that all collection objects are assigned a registration or acquisition number, with an effort to visibly mark the items with these numbers when feasible. Additionally, a comprehensive index encompassing all collection materials should be upheld, detailing registration or acquisition numbers alongside thorough written descriptions for each object such as type of object, materials and techniques, size, title, condition, date, year, artist, etc. Furthermore, photographs of every collection item need to be taken, and each photograph should be appropriately labeled with the corresponding registration or acquisition number of the objects.

Effective inventory management encompasses several practices such as the location register that is a record detailing where each item is permanently stored in the museum, including the room, gallery, shelf, or cupboard. Any movement of objects should be noted, and removal cards placed in their original location. When objects are taken for examination or loan, removal cards must be used. They should be left in

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[59] Ibid, 12.

[60] "Inventory (Museum)." In *Encyclopedia.Pub*, 2022, accessed August 24, 2023. https://encyclopedia.pub/entry/3248.

[61] Matassa, *Museum Collections*, 90-91.

place of the removed item and destroyed when the item is returned to its proper position. And each room or area has a dedicated file that lists the items stored or displayed within. This assists in conducting daily checks and monitoring any additions or removals. The collection index offers a means to always locate any item within the collection. Consistent spot checks and audits are performed to uphold the precision of the system.

Collection manager should do the regular collection inventory that should occur every one, two, or three years, depending on collection size, and include loaned items. Especially, high-value and theft-susceptible items should be checked more frequently, with staff responsible for monitoring certain objects daily, weekly, and during regular inventories. And they must recognize internal theft as a significant threat and safeguard inventory records from manipulation. Occasional checks by external agencies can enhance the system's integrity.[62]

All information of the inventory should be recorded and updated in the museum's database or catalogue for future reference. The collection database system allows for searching on details such as inventory number, location, classification, or donor. It can also facilitate functions such as movement control or keeping conservation records. The system must fit the requirements of the museum and its collection and not only hold information but also be an information reporting system.[63]

2.2.2. Access

Access to storage locations refers to the ability to locate and identify objects within a museum's facilities. It is important to have a system for finding objects at any time, wherever they are located within the storage space.

Location identifiers for every object should be in place to ensure proper management of collection assets. Planning for intellectual access to storage locations should be an integral part of the design process, and custom labels or barcodes are

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[62] The Council for Museums, *Archives and Libraries, Security,* 167-168.

[63] Matassa, Museum Collections, 74.

important cost elements. Location information on the object is usually linked to its accession number in the museum's documentation system, which tracks movements in and out of storage and on and off display.

Additionally, the object container should be labeled with specific accession and site numbers, as well as descriptors like site name or object name; object can have a photograph affixed to the box for easy identification in storage; institutions are using technologies like bar coding and RFID tags[64] to record locations and manage storage.[65]

2.2.3. Storage system, furniture, and equipment

Storage systems are divided into two groups such as open-storage and close storage system. The decision to use either open or closed storage systems depends on the environmental quality of the storage area and the size or value of the objects to be stored. Open storage systems are suitable for items that are in sound condition. These objects can be stored in an open area without any additional protection. Closed storage systems, on the other hand, are recommended for objects that require additional protection. These objects include small and precious items, structurally sensitive, dust-sensitive, and light-sensitive objects.[66]

Small and precious objects are vulnerable to damage and theft, and hence, require additional protection. Closed storage systems provide this protection by keeping these objects in a secure and enclosed space.

Structurally sensitive objects, such as those with complex constructions of feathers or dense fibers, are prone to damage from external factors such as humidity and temperature. Closed storage systems can help regulate these factors and protect the objects from damage.

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[64] RFID tags are devices used for identification, tracking, and sensing applications.

[65] Lord, Lord, and Martin, *Museum Planning*, 272.

[66] Barbara Moore, et al., "Storage Furniture." In *Preventive Conservation: Collection Storage*. (United States of America: American Institute for Conservation, 2019), 616.

Dust-sensitive objects, such as those with loose pigments or uneven surfaces, can accumulate dust and dirt over time, which can cause damage. Closed storage systems can prevent dust from settling on these objects and keep them clean.
Light-sensitive objects, such as rubber, paper, textiles, and some pigments, can fade or discolor when exposed to light. Closed storage systems can provide protection from light and prevent damage to these objects.[67]

The first step in determining the appropriate storage system is to assess the size, weight, shape, value, number of objects in the collection and collection growth in the future. This information will help determine the amount of space needed and the type of storage furniture required. The storage furniture must be large enough to accommodate the collection and sturdy enough to support its weight.[68] This is important to prevent damage to the objects and ensure their longevity. The configuration of the storage furniture is also important. It must be designed to provide physical support for the objects, whether they require a flat surface or a form-fitted mount. This is critical to prevent damage to the objects over time. Inadequate physical support can lead to significant damage over time.[69] This can include warping, cracking, or other forms of damage that can compromise the integrity of the objects.
Storage furniture refers to the cabinets, shelves, and other structures used to store objects in a collection. When selecting storage furniture, factors such as organizational requirements, object sensitivity, storage space, and available funds need to be considered.[70] It is important to consider the preservation requirements of different materials and considering furniture that will provide protection against the agents of deterioration that pose the greatest threats to a given collection in a particular space.

Collections in spaces without environmental controls, prone to dust, soot, or leaks, require cabinets for additional protection. If cabinets aren't suitable for some items, they should have waterproof and dust-resistant covers. In controlled

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[67] Martijn and ICCROM, *Handling of collection*, 22.

[68] Lord, Lord, and Martin, *Museum Planning*, 205.

[69] Moore et al., “Storage furniture”, 616.

[70] Ibid, 615.

environments without leaks, sturdy items may be stored on open shelving without covers. However, vulnerable objects susceptible to deterioration from pollutants, light, or pests should not be stored openly, even under optimal conditions.

Including the quality and stability of the building environment, the nature and condition of the collections, and the level of access and use required need to be considered. The building environment plays a crucial role in determining the type of storage furniture that should be used. For instance, if the building is prone to moisture or temperature fluctuations, furniture that can withstand such conditions should be chosen. The nature and condition of the collections are also important considerations. For example, if the collections are fragile or require special handling, furniture that provides adequate protection and support should be selected.

The level of access and use required is another factor to consider. If the collections need to be frequently accessed or moved, furniture that is easy to handle and transport should be chosen. It is important to avoid false economies when selecting storage furniture. While cheaper options may seem attractive in the short term, they may not provide adequate protection or support for the collections, leading to damage or deterioration over time. Quality is critical when it comes to storage furniture because it is a long-term investment. Good quality furniture can provide appropriate housing for specimens or objects for decades with minimal maintenance.

Additionally, for selecting stable, nonreactive materials for storage units to prevent volatile organic acids, peroxides, sulfur, and other chemicals emitted by common furniture materials from reacting with collection materials, especially in well-sealed cabinets is important. It is recommended that storage units are constructed of stable materials and finished with nonreactive neoprene or silicone elastomer door gaskets.

Custom made storage systems can be expensive and may not be feasible for many institutions. Powder coated metal storage furniture is a good option as it is inert and does not react with materials in the collection. Wooden furniture can release harmful chemicals like formaldehyde, which can damage materials in the collection.

If wooden furniture is the only option, it should be sealed with an aluminum foil laminate or a water-based polyurethane to prevent harmful reactions.[71]

For an open-storage system including furniture can be open-shelving system, metal adjustable shelving, compartmentalized storage system, pallets, and dollies, sliding rack, steel cantilever shelving, wire mesh shelving, vertical panels.

Open steel shelving systems are cost-effective and can be easily adjusted to accommodate objects of different sizes (Fig.21). Deeper shelves are used for larger objects, while narrower shelves are used for smaller objects to prevent overcrowding and potential damage. It is recommended to place objects in boxes or cover them to protect them from dust and environmental factors (Fig.22). Metal shelving should be lined with protective padding to minimize vibrations.[72]

Fig. 21. Open steel shelving system.
Source: https://www.rom.on.ca/en/collections-research/magazine/rom-away-from-rom

Fig. 22. Tyvek® shelve cover.
Source: http://insidetheconservatorsstudio.blogspot.com/2014/11/dust-covers-so-many-designs-so-many.html

[71] Ibid, 621.

[72] Olpin Group. n.d., "Art Racks | Art Storage | Olpin Group," accessed July 12, 2023. https://www.olpingroup.com/products/shelving/art-storage?hsCtaTracking=d4eb78e8-f96b%20420%209-bcad-9f260f9e3daa|f966701b-83e3-45e6-8c0e-3b8c5b639003.

Compartmentalized storage system for framed prints, drawings, or paintings are mostly made in the form of vertical wood posts and plywood shelving (Fig.23). The slots are relatively narrow in order to minimize the number of items that can be stored in each compartment. Storing only a few items in each slot reduces the possibility of the works of art rubbing against each other or against the structure of the storage system itself. The slot height should be varied so that different sizes of paintings can be accommodated without wasting space. This system is easier to build and costs less than the sliding rack storage system, making it a good option for museums with limited budgets.[73]

Fig. 23. Compartmentalized storage system.
Source: https://www.artisticstorage.com

Fig. 24. Metal adjustable shelving.
Source: https://spacefile.com

Metal adjustable shelving are appropriate for open-shelf storage (Fig. 24). By placing the shelving units back-to-back, and leaving access space on both sides, the depth of the shelving unit is doubled. Metal shelving is durable and can support heavy objects, making it a popular choice for museum collections.

[73] Johnson and Horgan, Museum Collection Storage, 52.

Pallets and dollies are custom-made platforms used for storing bulky and heavy items such as boats, furniture, sculptures, and large fossils. Pallets are designed to be safely moved and lifted onto sturdy shelving with a forklift (Fig. 25), while dollies are wheeled platforms that can be easily moved around (Fig.26). Both pallets and dollies help in facilitating access to the stored items and minimize the risk of physical damage during handling.[74]

Fig. 25. Pallet racking.
Source: https://www.bhdstorage.com.au

Fig. 26. Dolly base for support heavy object.
Source: https://pattersonpope.com/industries/museum-storage/

Sliding racks are commonly used for storing framed works of art, providing adjustable distance between racks, and keeping the works upright to prevent damage. These sliding rack systems can be open or closed units, with closed units being used for textile display or visible storage systems. Mobile racks can be used for hanging textiles, while mounted racks on walls are suitable for framed objects that should not be moved often (Fig. 27).[75]

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[74] Moore et al., “Storage furniture”, 620.

[75] Johnson and Horgan, *Museum Collection Storage,* 46-48.

Fig. 27. Sliding racks for painting.
Source: https://www.montel.com/en/products/modulart-art-racks-freestanding-pull-out-screens-kits

Steel cantilever shelving is a type of open shelving that is supported by brackets attached to a vertical support. The brackets extend out from the vertical support and support the shelf from below, without any additional support from below.[76] This type of shelving is useful for storing long, flat objects, such as textiles or carpets, because it allows the objects to be stored horizontally without any support from below (Fig. 28 and 29).

Fig. 28. Steel cantilever shelving for textile.
Source: https://www.spacesaver.com/products/rolled-textile-racks/

Fig. 29. Steel cantilever shelving for long object.
Source: https://donnegan.com/storage-shelving-solutions/gallery-storage-

[76] Christina Schaaf Fundneider and Tanja Kimmel, "Relocation of the Collections of the Kunsthistorisches Museum Vienna to the New Central Storage Facility Preparation, Planning, and Implementation" In Technological Studies Kunsthistorisches Museum Vienna, Translated by Aimée Ducey-Gessne, (np., Special volume), 50.

An open-drawer system is a type of storage system that consists of shallow drawers that are open to the air, rather than being enclosed in a cabinet or other type of storage unit. open-drawer systems are flexible and economical and can be built by museum staff. They are useful for storing small objects, such as unframed prints and drawing, small flat textile, jewelry, or coins, and can be divided into compartments using plastic or wood dividers (Fig. 30 and 31). However, paster drawing should not be stored in this system because the kind of movement they would be subjected to is extremely destructive to this medium.[77] And open-drawer systems can be subject to dust and other environmental factors, which can damage the objects being stored. Therefore, it is important to carefully consider the advantages and disadvantages of open-drawer systems before implementing them in a museum collection.

Fig.30. Open drawer cabinet for small object.
Source: https://spacesaverinteriors.com /museum-cabinets/

Fig. 31. Open drawer cabinet.
Source: https://spacesaverintermountain.com/ products/museum-storage-cabinets/

Plastic wire mesh is recommended for supporting lightweight objects when air circulation is important, as contact with copper or other types of metal screening may be damaging to the objects. Plastic wire mesh shelving is an economical option compared to metal or wood and can be supported by metal or wood vertical supports (Fig. 32). This type of shelving is suitable for storing straw artifacts such as baskets.

[77] Johnson and Horgan, Museum Collection Storage, 39.

Additionally, the framed wire mesh racks that can be mounted on walls (Fig. 33), which is useful for storing a variety of objects such as mirrors, frames, paintings, drawings, masks, swords, and tools.[78]

Fig. 32. Steel wire mesh shelving. Source: https://gw-textile-museum.tumblr.com

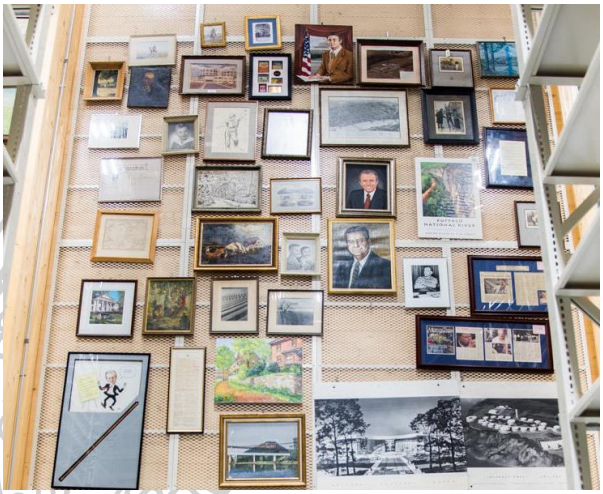

Fig. 33. Wire mesh on wall. Source: https://www.montel.com/en/products/wall-mounted-art-racks-screens

Close-storage system in term use for storage furniture refer to cabinet, that has a solidly constructed metal case with gasket seal.[79] It can accommodate a wide variety of objects with adjustable shelving and drawers. They can close the objects off to avoid damage from insect dust and light. Cabinets can create an interior microenvironment that buffers temperature and relative humidity fluctuations even if the objects are not in boxes or otherwise covered. It is necessary for cabinets to be stabilized by being bolted to the floor or walls, and for shelves to have restraining bars, to avoid tipping, especially in earthquake-prone areas.[80]

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[78] Ibid, 36.

[79] Moore et al., “Storage furniture”, 624.

[80] U.S. Department of the Interior, “Chapter 9”, 24.

Museum cabinets should not be stacked more than two cabinets, and cabinet drawers should not be loaded beyond the manufacturer's recommended weight capacity to prevent damage to the objects and the equipment.[81]

Cabinet storage can be adapted to store film cassettes or small objects, with options for shallow drawers and dividers. Plastic or wood dividers can create compartments for small artifacts, and shallow plastic boxes can be used for additional storage.[82] The advantage of this approach is that entire boxes can be removed during retrieval, and drawers can be equipped with locks for added security.

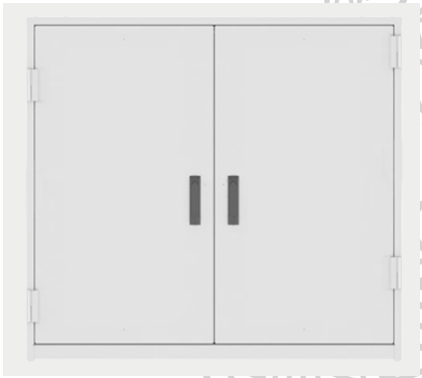

Fig. 34. Counter-height cabinet, securely stacked if more cabinets are purchased in the future
Source: https://motusspacesolutions.com/how-to-choose-the-best-museum-cabinets-for-collections-storage/

Fig. 35. Full-height cabinet.
Source: https://motusspacesolutions.com/how-to-choose-the-best-museum-cabinets-for-collections-

Cabinet storage can come in different types, such as those with doors or removable panels, and can be stacked for space efficiency (Fig.34-36). Flat files shallow cabinets with multiple drawers commonly used to store artworks, maps,

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[81] NPS Museum,"Chapter 7," 12.

[82] Johnson and Horgan, Museum Collection Storage, 21.

prints, drawings, flat textile, and oversized documents flat to prevent creasing or damage (Fig.37). They can be made from various materials, with steel being desirable for heavy loads and to prevent warping due to humidity changes. Manufactured systems with interior drawers are available in different sizes and materials, such as steel, which provides dust-tight protection. Wood systems can be custom-made but may not be as airtight, which is important for certain types of collections.

Fig. 36. Visible storage cabinet.
Source: https://motusspacesolutions.com/markets/museum-collections-storage-and-archival-storage/

Fig 37. Flat file cabinet.
Source: https://pattersonpope.com/products/cabinets/flat-file-cabinets/

The type of cabinet chosen for storage depends on the specific needs of the user, including the type of objects being stored, the frequency of access required, and the available space. For the cabinets that directly on floor or shelving unit bottom shelf is not adequately raised off the floor. They can raise on platforms, appliance rollers, or caster bases so that they are 4"–6" off the floor. Adjust shelving unit bottom shelf to be at least six inches off the floor (Fig. 38).[83]

[83] NPS Museum,"Chapter 7," 39.

Fig. 38. Archival flat drawer cabinet with casters.
Source: https://www.emmeitalia.com/en/archival-flat-drawer-cabinets/

For the storage of small three-dimensional objects in a museum, it suggests that a standard museum storage cabinet with 16 drawers can be used. The cabinet can accommodate 2,000-4,000 small objects stored in specimen trays.[84] However, all shelving rows and all cabinets should be clearly numbered and labelled. There should be a list of contents on the inside of each cabinet or on the end of each shelving unit.[85] The height of the drawer is mentioned to be around 5 cm, which is a standard measurement used in the museum industry.[86]

Museum collections often encompass three-dimensional artifacts that are not only valuable but also possess intricate details or materials that can be easily damaged. These objects might range from sculptures and intricate models to delicate artifacts of historical importance. Due to their size and characteristics, they can be more susceptible to mechanical stress, temperature fluctuations, humidity changes, and even exposure to pollutants.

To safeguard these valuable objects, museums invest in specialized storage equipment designed to address their specific requirements. This equipment might

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[84] National Park Service Museum Management Program, and Donald R. Cumberland Jr, "Determining Museum Storage Equipment Needs." *Conserve O Gram*, no. 4/10 (June, 1997): 1.

[85] Matassa, Museum Collections, 31.

[86] NPS and Cumberland, *Equipment Needs*, 1.

include custom-designed display cases or oversized cabinets with controlled environmental conditions, padding and cushioning to prevent physical damage, and sophisticated monitoring systems that track temperature, humidity, and other environmental factors. (Fig. 39).

Fig. 39. The colossal 395 Model cabinet for oversized object from Spacesaver®.
Source: https://www.spacesaver.com/products/museum-storage-cabinets/

The standard museum cabinet is recommended for storing such objects, as it provides proper containment and basic preservation. However, larger objects may reduce the number of objects that can fit into a cabinet, and fewer objects may fit in a drawer, which in turn reduces the number of drawers that can fit into the cabinet. It is important to allow enough distance between drawers to prevent the object from scraping against the bottom of the drawer above, which can cause damage to the object. Caution should be exercised when opening drawers to prevent any accidental damage to the objects stored inside.[87]

[87] Ibid.

Fig. 40. Costume hanging storage over drawer units.
Source: https://www.cincinnatimagazine.com/citywiseblog/cincy-obscura-the-cincinnati-art-museum-textile-archives/

Fig 41. Hats storage (compact system).
Source: https://www.spacesaver.com/portfolio-posts/fashion-storage-museum-at-fashion-institute-of-technology/

The storage furniture for costumes wl is the best choice for the collection. The upper unit in of this furniture is a cabinet with doors and adjustable shelves for storing hats and other similar costume items (Fig. 40). The hats are mounted on support cones to make them more visible and easier to access (Fig. 41). The doors of the cabinet can be double folding to minimize unnecessary protrusion into the aisle space. The drawer units below the cabinet can be used to store shoes and other accessories. And small accessories such as jewelry and hair ornaments can be placed in special plastic trays that are stacked inside the drawers. The units can be made of wood and covered with an inert plastic to protect the costumes and accessories from damage.[88]

[88] Johnson and Horgan, Museum Collection Storage, 41.

Compact storage systems or High-density mobile shelving system can be open or close system that also call compact storage system or movable storage.[89] Compact storage systems are mobile shelving systems that slide back and forth on floor tracks, allowing for double the storage capacity in the same footprint. These systems can accommodate various types of museum shelving and cabinets, including specialized options for records, textiles, books, photographs, and more.

Compact storage systems can protect collections from damage by offering customizable security features, such as stabilizing accessories, anti-tip rails, sealed cabinets, and locks. They save space by eliminating wasted aisle space and can double storage capacity or reduce storage space requirements by half.

Compact storage systems improve organization by centralizing the entire collection in one location and providing customizable storage for each item. They are cost-effective, often eliminating the need for new construction and allowing for future growth within existing space.

Compact storage systems are versatile and designed to preserve and protect all types of artifacts and specimens. They have safety features to prevent damage and can guard against threats like insects, rodents, and mold. Compact shelving utilizes vertical height and provides efficient storage with various storage solutions like drawers, trays, racks, and shelving.[90]

These are examples of Compact storage systems such as Electric Powered Mobile Shelving (Fig. 42) presents an advanced solution that enables aisle opening through a button press. Suited for larger, dynamic setups, it prioritizes safety for users and stored items, alongside ample storage capacity. With versatile safety features and customizable functions, it excels in open-access settings where reliability, security, and material protection are vital.

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[89] Pope Patterson, “Mobile High Density Storage System: Compact Storage”, Patterson Pope, August 15, 2023, https://pattersonpope.com/products/high-density-storage-systems/.

[90] Moore et al., *Preventive Conservation*, 632-634.

Fig 42. Electric Powered Mobile Shelving.
Source: https://pattersonpope.com/products/high-density-storage-systems/electrical-powered-mobile-shelving-eclipse/

Secondly, Mechanical Assist Mobile Shelving involves users in aisle opening via ergonomic drive handle rotation (Fig. 43). These systems offer fundamental safety features and are well-suited for medium-sized storage demands with increased activity, heavier materials, longer carriage spans, and multiple system sections.

Fig. 43. Mechanical Assist Mobile Shelving.
Source: https://www.montel.com/en/products/mobilex-mechanical-assist-mobile-storage-system

Thirdly, Manual Mobile Shelving adopts a manual-assist approach, where users access aisles by pushing handles left or right (Fig. 44). Designed for smaller storage spaces with limited activity and access, it provides a straightforward and cost-effective solution when compared to more complex automated systems. This is ideal for scenarios where storage needs are modest, and frequent access is not a primary requirement.[91]

Fig. 44. Manual Mobile Shelving.
Source: https://www.hydestor.co.nz/mobile -shelving

Fig. 45. Mobile Art Racks.
Source: https://pattersonpope.com/products/high-density-storage-systems/mobile-art-rack-systems/

Lastly, Mobile Art Racks are specialized storage solutions meticulously designed to securely house framed and flat artworks (Fig 45). Utilizing wire construction, they feature diverse hook attachments to safely accommodate various art pieces. Reinforced with steel, these wire panels can be positioned as freestanding units or ceiling-hung, guided along the floor. Engineered to manage maximum art load per panel, these racks ensure optimal load management. Their mobility is effortless, vibration-free, and supported by steel structures for stability. Fixed screens, usable as freestanding units or wall-mounted art displays, and linked panels, creating

[91] Jeremiah Brooks, “Mobile Shelving | MobilStor Rolling High Density Storage | GSA.” Systec Group Website, April 11, 2023, https://www.systecgroup.com/mobile-shelving/.

extended horizontal screens for larger art collections, further enhance art management and preservation while optimizing storage space.[92]

Drawers are a type of storage equipment that can be enclosed or open and are designed to support objects. They are typically constructed from materials such as wood, wood composites, sheet metal, or various plastics. Drawers are often lined with cushioning materials to provide extra support and protection for the objects stored inside. They are usually enclosed at the sides but lack a top and can slide or glide out from the runner (Fig. 46).

Fig. 46. Rolled textile drawers.
Source: https://www.spacesaver.com/blog/rolled-textile-drawers/

Fig. 47. Drawer and tray cabinet.
Source: https://blog.dar.org/exploring-new-museum-study-gallery-storage

Trays are shallow containers that provide horizontal support for collection items and can be moved without direct handling (Fig. 47). They are structurally independent of any storage furniture and are used to provide local support for items that reside on shelves or in drawers. Trays can be constructed from materials such as cardstock, matboard, corrugated board, or inert plastic and can be individually constructed or premanufactured in a set of sizes that fit a particular storage drawer or shelf. Trays are made from wood or wood composites can emit VOCs that may damage collection items.[93] Additionally, the essential equipment required for handling collections in storage includes tray. It must possess smooth surfaces devoid of sharp

[92] "Fine Art Museum Storage -Donnegan Systems Inc," Donnegan Systems Inc, September 29, 2015, https://donnegan.com/fine-art-museum-storage/.

[93] Johnson and Horgan, Museum Collection Storage, 21.

edges or corners to avert any potential damage to the objects during handling or movement.

Fig. 48. Custom-made tray for transporting objects on a cart.
Source: http://managingcollections.blogspot.com

Museum quality storage furniture is typically made of steel that is coated with an epoxy, acrylic, or polyester finish to protect it from damage and corrosion. Testing has shown that the most durable coating for this type of equipment is the epoxy powder coating. Anodized or powder-coated aluminum can also be used for storage equipment, although it is less common.[94] Wooden storage cabinets, shelving units, and other equipment pose a high risk to sensitive collections because they can off-gas harmful organic acids and peroxides even after many years. It is recommended to replace wooden equipment with newer steel equipment to protect sensitive collections from damage.[95]

Inert and non-reactive materials are also used to construct these furniture and equipment as well as materials use for housing objects. These materials do not emit any substances that can accelerate, or cause deterioration of the objects stored inside them. The term "pH neutral" is often used to describe museum quality materials (Fig. 49). This means that the material has a pH level that is neither acidic nor alkaline, which can be harmful to objects. Another term used to describe museum

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[94] NPS Museum,"Chapter 7," 13.

[95] Simon J. Lambert, "Resource 4 - Products and materials for storage," *RE-ORG: A Methodology for Reorganizing Museum Storage Developed,* n.p.: ICCROM and UNESCO, (2017): 17, https://doi.org/10.4000/ceroart.2112.

quality materials is "alkaline buffered". This means that the material has a buffer that can neutralize acidic substances that may meet it.[96] Such as some acid free tissue paper contain buffering alkaline compounds (e.g. Calcium carbonate) that can help prevent migration of harmful acidic products onto paper objects, but they can be harmful to some other items and should never be used for photographic and textiles.[97]

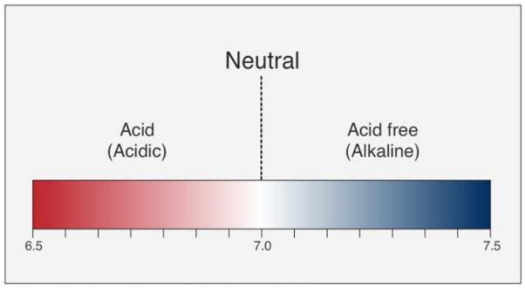

Fig. 49. The pH scale.
Source: https://www.strathmoreartist.com/faq-full/what-is-the-difference-between-acid-free-archival

Additionally, these standards and requirements should not only address the appropriate design construction and materilas, but also ensure that the quantity and arrangement of storage furniture are managed effectively to prevent overcrowding issues.

The storage equipment should be raised off the floor at least 4 inches, preferably 6 inches, on metal risers to prevent potential flooding and facilitate cleaning of floors and inspection for pest problems.[98] The storage furniture should be arranged in a way that allows safe access and inspection and cleaning of the objects and interior spaces without impeding access.

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[96] NPS Museum,“Chapter 7,” 13.

[97] “Introduction to Storage and Display Materials,” Museums Galleries Scotland, access August 24, 2023, https://www.museumsgalleriesscotland.org.uk/advice-article/introduction-to-storage-and-display-materials/#:~:text=Some%20storage%20and%20display%20materials,humidity%20can%20accelerate%20this%20damage.

[98] NPS Museum,“Chapter 7,” 25.

For accessing items stored at elevated heights, stable ladders capable of supporting both the storage worker and the objects' combined weight are necessary to prevent accidents or object damage (Fig. 50). Transport carts employed for moving objects need to be equipped with smooth-running mechanisms and hard rubber tires (Fig. 51). This feature ensures that the objects remain stable and unimpeded during transportation, mitigating the risk of damage.

Furthermore, tables designated for sorting or arranging objects should exhibit high quality and the capacity to accommodate multiple items concurrently. Ensuring these tables are situated on even flooring prevents any wobbling or instability. Ensuring the tables should be easily maneuverable, facilitating flexibility within the storage space.[99]

Fig. 50. Mobile ladder with platform.
Source: https://transtak.co.nz/product/tank-access-platform/

Fig. 51. Platform truck use for transporting object.
Source: https://www.amazon.com/Platform-Foldable-Storage-Capacity-35-8x24x34-3in/dp/B09BZDZS48

However, open shelving should be stabilized by bolting it to the floor, wall, or adjacent equipment to prevent tipping over. Restraint bars or cords should be installed on the edges of shelves to prevent objects from falling. Objects in museum cabinets,

[99] Martijn and ICCROM, *Handling of collection*, 26.

shelving, or other storage furniture should be properly cushioned, mounted, or stored in trays using museum quality materials to prevent damage during handling or storage.

Even if items stored in cabinets or on shelves, collections may require additional housing such as open pallets, trays, and closed, cover boxes or other enclosers by appropriate materials and mounts to prevent damage during handling or storage[100]. Proper housing in specialized storage equipment and container also helps in organizing, accessing, and securing the collection. This means that the objects can be easily located, retrieved, and protected from damage or theft. And the size and quantity of the objects, as well as their specific storage requirements, must be considered when planning the storage space.

Storage containers are used to store various items, including museum artifacts, and can be made of different materials such as corrugated paper-based boards or plastics.

They effectively guard against physical forces and, depending on their construction, can also shield against pests, pollutants, and significant fluctuations in room humidity. The ideal storage containers should possess the following qualities: airtightness to safeguard against external contaminants, insects, and substantial humidity fluctuations; waterproofing, unless stored in a waterproof cabinet or covered with a plastic sheet; non-emissive materials; long-term stability; sufficient strength to support the weight of objects and potential additional loads; clear labeling for easy identification; convenient handling with sturdy handles and reasonable weight. Insulation may be considered if the containers are exposed to fluctuating temperatures, but overall temperature control should be achieved through room and building features. Fire-resistant containers are advisable, although caution must be exercised regarding the use of flame retardants, as they may pose risks to objects in enclosed environments.

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[100] Rachael Perkins Arenstein, Lisa Goldberg, and Eugene Milroy, "*Support and Rehousing for Collection Storage*," In *Preventive Conservation: Collections Storage (*New York: American Institute for Conservation, 2019), 649.

Clear small containers are made from acrylic, polystyrene, polypropylene, polyethylene (like Tupperware and Lock & Lock containers) (Fig. 52), and poly(ethylene terephthalate) (PET) (Fig. 53). While polyethylene containers may become slightly yellow over time, transparent plastics offer the advantage of allowing object visibility without direct handling (although the wrapping or padding covering the object is typically not transparent).[101] It's important to considered of cleanliness and the use of a soft, non-slip surface for containers and materials.[102] This is crucial because any dirt or debris on the surface can damage the objects stored inside, and a non-slip surface ensures that the containers do not move or slide around, which can also cause damage.

The second point stresses the need to separate objects from each other using cushioning material.[103] This is important because objects can rub against each other during storage, causing scratches, abrasions, or other forms of damage. Cushioning material such as foam, bubble wrap, or acid free tissue paper can help prevent this by providing a protective barrier between objects.

Fig. 52. Polypropylene container.
Source: https://www.ikea.com/my/en/p/ikea-365-food-container-with-lid-rectangular-plastic-50507964/

Fig. 53. Small polyethylene container.
Source: https://kaooriginal.com/product/square-pe-plastic-box-3-8-cm-x-3-8-cm-x-1-8-cm-sku-7064/

[101] Canadian Conservation Institute, "Products Used in Preventive Conservation - Technical Bulletin 32," Canada.Ca, February 19, 2021, accessed August 15, 2023, https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/products-used-preventive-conservation.html#a3g2.

[102] Martijn and ICCROM, *Handling of collection*, 35.

[103] Ibid.

Corrugated plastic is another material used for making museum box, and it is usually made of polyethylene or polypropylene plastics (Fig.55). These plastics are stable and do not release any harmful gases[104], making them suitable for storing sensitive items.

Fig. 54. Corrugated plastic box.
Source: https://www.uline.com/Product/Detail/S-18329/Special-Use-Boxes/Corrugated-Plastic-Boxes-16-x-12-x-12

Fig. 55. Documents box.
Source: https://www.archivalmethods.com/product/document-boxes

Museum quality boxes come in a variety of types, shapes, and sizes. Most are made of acid-free, corrugated paper board. They are available in pH neutral (unbuffered) or slightly alkaline (buffered) varieties. [105] Boxes can be used to store flat paper and textile items as well as three-dimensional objects, and their design and construction can be infinitely variable.

Custom made box can crafted to accommodate categories of collection. In instances where object unique dimension or specialized oversize box not readily available in ready-made box market, corrugated paperboard can be utilized to individually customize box sizes. They can employ features such as drop-down sides that open to allow an object to slide forward or out, adjustable sides that can distribute safe pressure on the sides of an object, or flaps that allow for full and close coverage of the item (Fig.56 and 57).

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[104] NPS Museum,"Chapter 7," 13.

[105] Ibid, 27.

Fig. 56. Custom-made storage box by using archival material.
Source: https://stashc.com/the-publication/containers-2/boxes/objects-secured-directly-to-a-box/

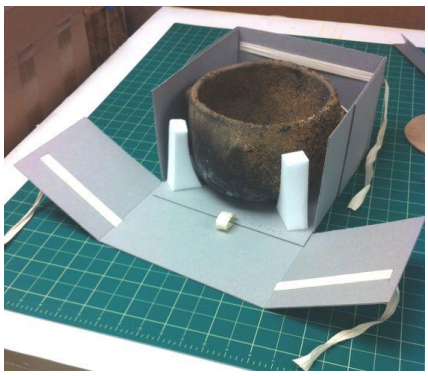

Fig. 57. Custom-made artifact box.
Source: https://ellencarrlee.wordpress.com

Nonetheless, ready-made boxes from the market can offer efficiency and cost savings, especially when used for housing large groups of similarly sized items. Standardized sizes allow boxes to be fitted together efficiently in larger boxes or drawers.[106] Furthermore, they offer various type of boxes such as triangular roll storage box for roll items, clamshell box for old book, archival box, slipcase for book, folded boxes for film reel storage, or the simple two pieces box (Fig.58-61).[107] There are various companies that produce ready-made museum boxes, such as Klug-conservation company from German, which offers a range of box sizes and formats suitable for conservation purposes. Additionally, they provide a box configurator service, allowing users to select box formats, sizes, types, colors, and paper thickness according to their specific needs (Fig. 62).[108]

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[106] Arenstein, Goldberg , and Milroy, “Rehousing”, 653.

[107] “Boxes,” KLUG-CONSERVATION, n.d. accessed August 25, 2023, https://www.klug-conservation.com/Boxes.

[108] “Box Configurator,” KLUG-CONSERVATION.” n.d. August 25, 2023, https://www.klug-conservation.com/Box-configurator.

Fig. 58. Triangular rolls storage box.
Source: https://www.archivalmethods.com/product/triangular-roll-storage-box

Fig. 59. Gaylord Archival® Blue E-flute Clamshell box.
Source: https://www.gaylord.com/Preservation/Book-%26-Pamphlet-Preservation/Book-Boxes-%26-Covers/Storage-Boxes/Gaylord-Archival%26%23174%3B-Blue-E-flute-Clamshell-Box/p/HYB02289

Fig. 60. Folded boxes for film reel storage.
Source: https://www.klug-conservation.com/Folded-boxes-for-film-reel-storage

Fig. 61. Two-pieces box for large textile.
Source: https://www.klug-conservation.com/New-in-our-product-range-of-boxes-Two-piece-boxes-for-textiles-

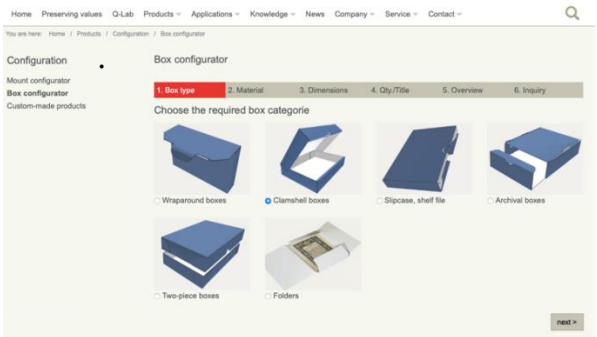

Fig. 62. "Box Configurator" services by Klug-conservation, Germany.

Source: https://www.klug-conservation.com/Box-configurator

Enclosures are the support allowing the object safely to rest on or within a particular containers or housing in the box.[109] Enclosures encase objects and are used for densely packed configurations and separation between objects. Different types of enclosures include folders, window mats, envelopes, sleeves, and bags are used for flat items such as archival paper document and photographs (Fig. 63-66). Enclosures are made from various materials such as polyester film, acid-free papers, and plastics.

Enclosures can provide external support, easy access, and specific environmental conditions for collection items, including oxygen-sensitive materials. Additionally, there are innovative ideas for organizing and arranging multiple items within secondary containers.

Paper to be used for storage enclosures should be acid-free. Acid-free paper have a pH of 7.0 or higher, which means they are not acidic when produced. However, they can become acidic over time due to internal or external impurities. An alkaline reserve or buffer, usually 2-3% calcium or magnesium carbonate, is added to paper or board during manufacture to neutralize acids that may be produced over time. Most paper collections require buffered enclosures. However, some collections, such as blueprints and diazo reproductions, works of art with pigments that react to high pH, albums and collages with wool or silk components, and other items that contain animal proteins, are sensitive to alkaline materials and should be stored in pH-neutral enclosures.[110]

Fig. 63. Flap envelops.
Source: https://www.archivalmethods.com/product/flap-envelopes

Fig. 64. Pamphlet binders.
Source: https://www.universityproducts.com/perma-dur-document-preservation-binders.html

[109] Arenstein, Goldberg , and Milroy, “Rehousing”, 649.

[110] “Guide to Collections Care | Section 1: Archival Storage of Paper,” Gaylord Archival, n.d. accessed July 15, 2023, https://www.gaylord.com/resources/guide-to-collections-care/section-1.

Fig. 65. Window mats.
Source: https://www.archivalmethods.com/product/pre-cut-exhibition-mats-100-cotton-board

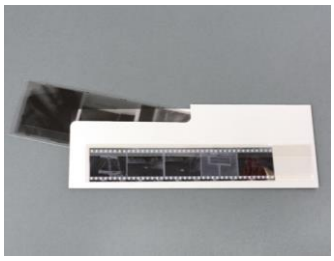

Fig. 66. Paper sleeve for negative film.
Source: https://www.archivalmethods.com/product/negative-file-folders

Clear plastic enclosures are useful for objects that require frequent handling or are too brittle to be handled without protection. However, artwork with friable media like charcoal or pastel should not be placed in plastic enclosures because static electricity can lift the image from its support. It is important to note that plastic enclosures do not provide any protection from light, and all items in clear plastic enclosures should be placed in boxes for long-term storage. Plastics are safe for collection following polyester, polypropylene, and polyethylene (Fig. 67 and 68).[111]

Fig. 67. Polyester interleaving folder.
Source: https://www.archivalmethods.com/product/film-interleaving-folder

Fig. 68. Polypropylene presentation pocket.
Source: https://www.gaylord.com/Preservation/Photo%2C-Print-%26-Art Preservation/Envelopes%2C-Sleeves-%26-Protectors/6-mil-Polypropylene-Presentation-Pocket-Variety-Pack-%2840-Pack%29/p/067-VP40

[111] Arenstein, Goldberg , and Milroy, “Rehousing”, 656.

2.2.4. Storage materials

Storage materials for paper used in storage should also be lignin-free. Lignin is a natural component of the cell walls of plants and trees. If not removed during manufacture, it can react with light and heat to produce acids and darken paper. Lignin-free materials usually have a maximum of 1% lignin. Cotton fiber makes the most chemically stable paper and board, while groundwood pulp is always of poor quality and cannot be used to make suitable enclosures. Adhesives used in enclosures must not discolor, deteriorate, or fail, and they should not discolor or damage adjacent materials.[112]

Acid free tissue paper and cardboard are recommended packing and padding materials to prevent damage to museum objects (Fig 69-71). As well as buffered tissue paper with an alkaline composition can be used for storing synthetic materials and objects with a plant origin, while unbuffered tissue with a neutral composition is suitable for objects made from proteins with an animal origin.

Fig. 69. Acid free tissue paper. Source: https://www.caraselle.com/products/jumbo-size-acid-free-tissue-paper .

Fig. 70. Acid free-tissue paper for padding. Source: www.sciencemuseumgroup.org.uk/

[112] Gaylord Archival n.d., Archival storage.

Fig. 71. Acid free corrugated board.
Source: https://www.talasonline.com/Heritage-Corrugated

Glassine paper is a thin, shiny, semitransparent paper that is both strong and flexible. It is made from bleached sulfite wood pulp that undergoes extensive beating, hydration, and supercalendering processes. Glassine is resistant to oils and greases, and when waxed or laminated, it becomes nearly impermeable to air and water. It is commonly used for packaging breakfast cereals and as a facing for wax-lined paintings due to its non-adhesive properties with wax. While it was previously used for storing photographic negatives, this practice is now deemed inappropriate due to the risk of gelatin attachment under humid conditions. Acid-free and buffered glassine tissues are available from archival suppliers, but even pH-neutral glassine may contain lignin and degrade over time, limiting its shelf life to 3-5 years (Fig. 72).[113]

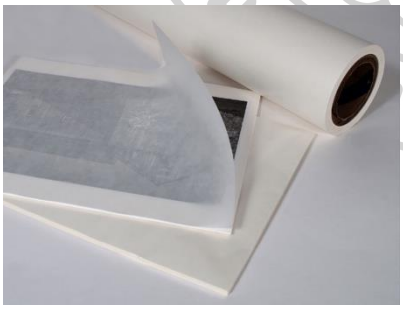

Fig. 72. Glassine paper.
Source: https://www.archivalmethods.com/product/rolls-glassine-interleaving

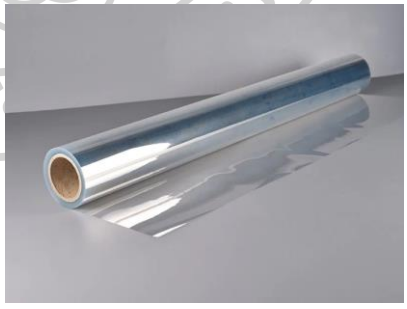

Fig. 73. DuPont™ Melinex® & Mylar® polyester film.
Source: https://www.archivalsurvival.com.au/collections/dupont™melinex®-mylar®polyester

[113] "Glassine," CAMEO, n.d., accessed July 15, 2023, https://cameo.mfa.org/wiki/Glassine.

Polyester is a versatile material used for making various envelopes, sleeves, and folders. It comes in different thicknesses, ranging from 0.1 to 0.5 mil. Polyester is also known as Poly(ethylene terephthalate) or PET and trade name for PET are Melinex® and Mylar®(Fig. 73). While Mylar D, which was previously recommended for long-term archival use, is no longer being made, Melinex 516® is now the suggested replacement. Generally, other types of Mylar and Melinex® are likely suitable for regular indoor use, as there haven't been any reports of damage. PET films are commonly used in museums for things like interleaving, encapsulation, and as window materials for mats and boxes.[114] Mylar® and Melinex® sleeves are very useful for the storage of photographic material (prints, negatives, slides, plates) and work on paper (prints, drawing, letters, documents, posters, and pamphlets).[115]

However, current research indicates that acidic paper deteriorates more rapidly if sealed in polyester, so it is advisable to place sheets of buffered paper behind the documents before putting them in polyester or to consult a conservator about having them deacidified.[116]

Polypropylene is commonly used for containers, while polyethylene is highly flexible but not as clear and is used for sleeves and bags.

Polyethylene (PE), or polythene, is a cost-effective option compared to PET or polypropylene. It is less transparent and reliable. PE sheets are available in high density (HDPE) and low density (LDPE). HDPE generally lasts longer than LDPE (LDPE for short-term use 5-10 years, after which becomes yellow and brittle but will not stain objects).[117] Both densities are recyclable and commonly used to cover objects or shelving for dust protection and to prevent water leakage. PE film is often used as a waterproof wrap for shipping boxes. PE bags are popular for storing small items like archaeological metals or organic fragments (Fig. 74). Polythene bags

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[114] "Products Used in Preventive Conservation - Technical Bulletin 32," Canada.Ca., February 19, 2021, accessed July 17, 2023, https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/products-used-preventive-conservation.html#a3g2a.

[115] Museums Galleries Scotland, "Storage and Display materials", 3.

[116] Gaylord Archival n.d., "Archival storage."

[117] Lambert, *RE-ORG*, 20.

should be food grade to avoid contamination and should not be sealed unless necessary for pest control or maintaining a controlled microclimate; however, caution should be exercised as polythene can trap moisture and may contain oils and contaminants that can damage objects.

Fig. 74. Polyethylene bags.
Source: https://www.archivalmethods.com/product/polyethylene-bags

Polyvinyl chloride (PVC) enclosures, also known as vinyl, are unsuitable for use due to high instability that risk of becoming sticky and of corroding acid-sensitive objects caused by benzoic acid (after 5 years).[118]Plasticizer degradation leads to yellowing, deformation, brittleness, and staining of objects. Potential hydrochloric acid off-gassing remains unconfirmed in museums storage.[119] Especially, objects made of rubber and modern plastics can be very unstable and easily affected by plasticizers released by some wrapping materials.[120]

Tyvek®,[121] a lightweight and water repellent material, that made from spin-bonded, non-woven, high-density polyethylene fibers (Fig.75). Material resembles a cross between fabric and paper and contains Teflon®. Tyvek sheet can bock water in one direction (outside to inside) but allows two-way air flow. This is

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[118] Ibid.

[119] "Products Used in Preventive."

[120] Museums Galleries Scotland, "Storage and Display materials," 2.

[121] Tyvek® is the trade name for a spun-bonded polyolefin and can be bought in a number of different grades.

the ideal materials for dust covers for costumes, furniture, objects, rolled textiles, and museum labels.[122]

Unbleached and undyed cotton fabrics are commonly used for making padded hangers and dust covers for objects and can be washed and reused (Fig. 76). Avoid using wool, fabrics treated with fire retardants or finishes, and foam or adhesive-backed fabrics, as they release harmful vapors.[123]

Fig. 75. DuPont™archival Tyvek®. Source: https://www.talasonline.com/Dupont-Tyvek

Fig. 76. Unbleached cotton cloth. Source: https://www.gaylord.com/Preservation/Conservation-Supplies/Wrapping,-Lining-&-Support-Materials/Unbleached-Cotton-Flannel-(10-Meters)/p/FLANNEL10

Inert foams are a type of foam material that is commonly used in the Europe for various purposes, including cushioning and lining of shelves. These foams are available under different trade names such as Plastazote®, Ethafoam® (Fig. 77 and 78), or Jiffy foam. These are made of polyethylene and available in different colors, densities, and thicknesses. These stable polyethylene foams are made using nitrogen and can be cut easily to create mounts for 3D shapes. Stick to black and white options

[122] Museums Galleries Scotland, "Storage and Display materials," 3.

[123] Ibid, 4.

among the various colors available, as the colorants in others could stain or damage objects.[124] These foams are known for their shock-absorbing properties, and the higher densities and thicknesses can provide better cushioning for heavier objects.[125]

Inert and of archival quality materials are recommended for tubes or rods used to support objects in packaging.[126] Acrylic rods, stainless steel rods covered with silicon tubing, and acid-free cardboard tubes are suitable for supporting materials like textiles or paper (Fig. 79), which can be rolled around them. Additionally, these tubes can serve as external protection for rolled items stored within them.[127]

However, along with the safe packaging materials for long-term storage, there are certain materials that can still be used but should not be used for an extended period. These materials are suitable for short-term packaging and storage purposes only such as bubble wrap, polythene or polyethylene and polystyrene. Polystyrene is a type of plastic that is commonly used in packaging materials. However, it is not recommended as a packing material because it is not a good shock absorber. This means that it may not be able to protect the contents of a package from damage during transportation or handling (Fig. 80 and 81).

Additionally, polystyrene is static, which means that it can attract dust and other particles. Despite these drawbacks, white polystyrene peanuts can be used as void filling materials inside sealed polythene bags. This means that they can be used to fill empty spaces in a package to prevent the contents from shifting during transportation.

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[124] Ibid, 3.

[125] Norfolk Museums and Archaeology Service, *Packing Museum Objects: A Collections Care How To Guide*." Press release. Edited by Alex Dawson and Natasha Hutcheson, 2012, 6-7, https://www.sharemuseumseast.org.uk/wp-content/uploads/2013/08/How-To-Guides-Packing-Museum-Objects.pdf.

[126] S. Anstey, M, Myers and I. M. Godfrey, "*Handling, packing and storage*," Western Aystralian Museum (n.d.), access August 15, 2023, https://manual.museum.wa.gov.au/book/export/html/143.

[127] Ibid.

Fig. 77. Ethafoam® sheet.
Source: https://www.insituconservation .com/en/products/packaging_foams/ethafoam

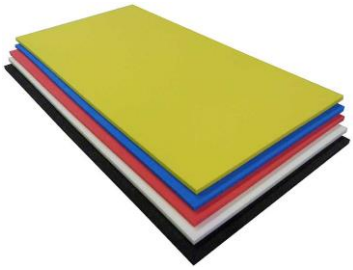

Fig. 78. Plastazote® foam sheet.
Source: https://www.efoam.co.uk/ zotefoam-plastazote.php

Fig. 79. Archival textile rolling and storage tube.
Source: https://www.talasonline.com/ Textile-Rolling-and-Storage-Tubes

Fig. 80. Polystyrene foam sheet.
Source: https://www.constguide.com/ en/product/INSUTECH-EPS-Foam

Bubble Wrap, introduced in 1960 by Sealed Air Corporation, consists of a double layer of plastic film with sealed air pockets (Fig. 82). It provides cushioning and shock isolation. The term is now used generically for similar low-density Polyethylene cellular cushioning sheets. Over time, the film's permeability may cause bubble deflation. Direct contact with objects should be avoided to prevent surface marks.[128] Especially, it should not be used in damp conditions as it can trap moisture against the surface of the objects, causing damage. To reduce the risk of causing a "dimpling" effect in softer surfaces, the bubbles should face away from the object's surface.[129]

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[128] "Products Used in Preventive."

[129] Alex and Natacha, *Packing Museum Objects*, 7.

Fig. 81. Polystyrene peanuts.
Source: https://www.recycling.com/packing-peanuts-and-styrofoam-alternative/

Fig. 82. Bubble Wrap.
Source: https://www.dcgpac.com/catalogsearch/result/?q=Air+Bubble+Wrap

Materials such as non-acid free tissue or cardboard, newspaper, and dyed textiles are not recommended for preservation as they can become acidic, etch surfaces, and irreversibly stain objects.

Biodegradable packing peanuts, PVC Poly, and polyurethane foam should also be avoided as they can dissolve in water, become sticky and brittle, and attract dust.

Cotton wool, wooden fruit crates, and pressure sensitive adhesive tapes are not suitable for preservation due to their acidic nature, potential gas emissions, and adhesive bleeding.[130]

2.2.5. Sustainability

Sustainability becomes more prominent also in collections care; the professionals seek to minimize their impact on the environment while still maintaining best practices for preserving collections. Sustainable alternatives may include materials made from recycled or renewable resources, or products that are designed to minimize energy or resource consumption during use. These alternatives may be more expensive or require more effort to use than traditional products, but they offer the benefit of reducing the environmental impact of collections care practices. The availability of sustainable alternatives is a positive development for the

[130] Ibid, 8.

field of collection care, as it allows professionals to make more environmentally responsible choices without sacrificing the quality of their work.[131]

Sustainability in materials usage for museum storage involves a range of considerations and practices aimed at minimizing environmental impact while ensuring the preservation of artifacts. Several strategies can be employed to achieve this goal:

Reduce Material Quantities: Whenever possible, minimize the quantity of materials used, as lighter materials contribute to reduced environmental impact.

Material Inventory and Reuse: Create a "material inventory" of the museum to identify reusable resources. Establish closed material loops with local suppliers to borrow materials non-destructively and return them post-exhibition.

Low-Impact Construction Materials: for construction materials that have low environmental impact and can either be reused or biodegrade harmlessly.

Appropriate Material Selection: Choose materials based on their intended use. Use materials appropriate for short-term or long-term purposes.

Local Sourcing: Prioritize materials that are sourced and produced locally to reduce transportation-related emissions.

Recycled Materials: Whenever feasible, use recycled materials instead of new resources. Recycled materials often have significantly lower carbon emissions during production.

Carbon Tracking: Monitor carbon data during the design phase to ensure environmentally sound decisions are made and avoid late-stage corrections.

FSC-Certified Wood: Choose wooden materials that are FSC-certified, ensuring responsible forest management.

Cradle to Cradle Certification: Look for materials and products that carry Cradle to Cradle certification, indicating safety, circularity, and responsible production.

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[131] Christian Hernandez, “The Green Challenge: Incorporating Sustainable Practices and Materials into Collections Care,” MA Thesis, (n.p. , 2013). https://www.academia.edu/5376921/The_Green_Challenge_Incorporating_Sustainable_Practices_and_Materials_into_Collections_Care_Condensed_Version_by_Christian_Hernandez.

Substitution Consideration: When substituting materials, consider local and carbon emissions factors. Hidden sources of CO_2 emissions, such as fixtures, should also be evaluated.

Non-Toxic Paints: Opt for non-toxic, water-based paints with low levels of volatile organic compounds (VOCs).

Examples of Low CO_2 Footprint Construction Materials include Green Cast (recycled and recyclable acrylic sheets), Lemix clayboards (composed of clay, wood fiber, etc.), Woodcrete wall units (cement-bonded wood fiber), and more.

Materials to avoid include tropical hardwood, virgin steel, MDF, and hard-to-recycle materials such as composite plastics, polystyrene, and PVC. Harmful chemicals and environmentally detrimental detergents should also be avoided.[132]

In essence, sustainability in museum storage materials involves conscious material selection, reuse, and avoidance of harmful substances to minimize ecological impact while maintaining effective preservation practices.

For example, certain synthetic waste materials like plastics and foam can be recycled or repurposed. These materials include Tyvek®, Polyethylene foam (Ethafoam®, Plastazote®), polystyrene foam, Mylar®/Melinex®, and bubble wrap.

Tyvek® can be cleaned and used again by handwashing it with mild soap. Bleach should be avoided, and it's not a good idea to iron or dry clean Tyvek®. Even Tyvek® scraps can have a second life by being used as padding, like making bean bags out of them. Although Tyvek® isn't typically recyclable, DuPont® offers a recycling pouch for it, though there might be a cost for shipping.

Ethafoam® and Plastazote® can be reused. However, Ethafoam®, being made from petroleum, usually isn't recycled. They can cut and stick Ethafoam® scraps together using hot glue for reuse. These foams can be reused by covering their dirty surfaces with scrap Tyvek®, Mylar®, or even reusable textiles for supporting.

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[132] "Sustainable Cultural Production: Museums." n.d. accessed August 8, 2023, https://sustainable-toolkit.czk.si/.

Polystyrene foam can also be reused and recycled. It's useful for supporting and transporting items to prevent vibrations. But it shouldn't touch the item's surface directly. Some companies, like FedEx®, collect this foam for reuse and recycling.

Natural materials like cotton cloth, they can be reused after washing. Additionally, materials like acid-free paper and cardboard are among the easiest to repurpose and recycle.[133]

2.2.6. Planning storage space for collection growth

The first step of estimating storage space is calculating of the volume required for storing collections in a museum storage. The space occupied by the collections is measure in cubic meters (m^3). This measurement should only include the filled storage areas and not the empty shelves or aisle ways. The figures obtained from the measurement should be adjusted to account for any objects that are crowded or stacked in a way that makes access unsafe. This adjustment ensures that the storage space is safe and accessible for staff and visitors. Growth figures should also be added to the calculation. These figures can be obtained from previous records or curatorial expectations. They should be adjusted to account for the expected life of the new storage space. In cases where the collections are mixed, the total volume required may be subdivided based on environmental requirements.[134] This ensures that collections with different environmental needs are stored appropriately.

Planning storage space to accommodate collection growth involves several key steps. After completing quantitative and qualitative analyses of the collection, projections must be developed to estimate the collection's expansion by category and

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[133] Gillian Gibson et al., "Waste & Materials Ki Book : Collections Care: Packing, Storage & Transport, A Step-By-Step Guide for Sustainable Action Volume I". Edited by Caitlin Southwick. Vol, 20-41, https://kibooks.s3.us-east-2.amazonaws.com/2021/january/Waste+and+Materials+Ki+Book++KiCulture.pdf?utm_source=Ki+Culture&utm_campaign=c2ce693f89-AUTOMATION_Welcome_Message_1&utm_medium=email&utm_term=0_b66c79af28-c2ce693f89-603823990&ct=t()&mc_cid=c2ce693f89&mc_eid=125fcce1bf.

[134] "Journal Article | Natural Sciences Collections Association." n.d., 34-35, http://www.natsca.org/article/709.

type up to an exhibition plan and acquisition plan in each year. This involves estimating how the collection will grow across different categories and types of objects by a year. These projections help determine the required storage space. When planning new facilities for existing institutions, historical patterns of collection growth based on categories and types are used as a basis to forecast future growth. Historical growth rates provide a foundation for projecting changes due to upcoming developments, even if the future differs from the past. It's crucial to measure historical growth in terms of actual object numbers acquired each year rather than percentages, as percentages can lead to misleading projections due to compounding effects as the collection base increases.[135] However, the storage space must be large enough to accommodate the existing collection as well as the projected growth of the collection over the next 10-20 years.[136]

To calculate the collection growth rate, compare the number of acquisitions with the size of the existing collection at the beginning of the chosen time period. The growth rate can be calculated using the following formula: Growth Rate = (Number of New Acquisitions / Size of Existing Collection at the Beginning) x 100. For example, if there were 100 new acquisitions and the existing collection size at the beginning was 1,000, the growth rate would be (100 / 1,000) x 100 = 10%.

Estimating annual collection growth, categorized by type, is a complex process. A typical planning horizon is around ten years, but longer spans can be considered based on specific circumstances. This task becomes challenging, especially if the museum lacks a strict collection policy or has experienced inconsistent growth. In such cases, curators or external experts need to provide educated estimates for expected growth by category. This estimate combines factors like art market trends, acquisition budgets, and object availability. While not an exact prediction, it's an educated guess informed by available information and expert opinions. Despite its imprecision, this estimate is vital for decisions about storage space, conservation resources, and exhibition planning.[137]

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[135] Lord, Lord, and Martin, *Museum Planning,* 205-207.

[136] U.S. Department of the Interior, *Museum Property Storage*, 4.

[137] Lord, Lord, and Martin, *Museum Planning,* 210.

In terms of storage space planning, options include future exterior expansion to increase capacity, requiring careful integration with initial facilities and site considerations. Alternatively, repurposing existing museum spaces can boost storage, but only if those spaces are no longer needed for their original purposes. High-density mobile storage systems can also be adopted to increase capacity and eliminate aisles, but the building structure must support the added weight. Manufactured compaction systems offer benefits but they come with costs, so the pros and cons of both approaches should be carefully evaluated. Developing the museum's own compaction systems can reduce capital investment, though not all object categories may be suitable for mobile systems.

2.2.7. Housekeeping requirement

In museums, "housekeeping" involves regular care for objects, records, and archives. This includes planning, monitoring, and hands-on collection care, combining thoughtful attention and practical actions.[138]

Housekeeping of storage room is crucial knowing the appropriate methods and times for cleaning. This encompasses various responsibilities such as tending to the museum's premises and structure, assessing the efficiency of environmental management systems, and keeping track of factors like light, temperature, and humidity levels. Vigilance against pests, maintenance of air handling unit filters, and consistent evaluation of the condition of museum items are all part of this endeavor. Basic cleaning activities such as dusting and vacuuming, along with the application of protective waxes, also fall within the realm of museum housekeeping's objectives.[139] For cleaning agents that containing bleach or ammonia should be avoided near objects to prevent damage or discoloration. A comprehensive cleaning regime is advised, including daily vacuuming with special filters to capture dust. The waste should be collected in dustbins with lids to prevent the spread of dust and disposed of properly, Weekly cleaning involves wiping the floors with a damp cloth, which helps to remove

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[138] National Park Services Museum, “Chapter 13: Museum Housekeeping,” In *NPS Museum Handbook, Part I*. (n.p. 1998), 3.

[139] Ibid, 3-4.

any dirt or stains that may have accumulated. Mats outside the storage area should also be vacuumed to prevent the transfer of dirt and dust into the storage room. And monthly cleaning involves vacuuming underneath chests and cupboards, which are often overlooked areas that can accumulate dust and debris over time. And yearly cleaning involves a thorough vacuuming of the entire storage room to remove any accumulated dust and debris that may have been missed during regular cleaning. [140]

It is important to note that the cleaning regime may vary depending on the type of items stored in the room and the level of traffic in the area. Therefore, it is recommended to consult with a professional or follow manufacturer's guidelines for specific cleaning instructions.

Additionally, safety measures including proper ventilation, are essential during inspections to ensure the preservation of objects. Overall, regular inspection and vigilant housekeeping contribute to the early identification and mitigation of risks, safeguarding the collection's integrity.

2.2.8. Museum objects and their storage requirements

The importance of understanding the materials that museum objects are made of when managing their preservation professionals. This can make informed decisions about how to best store and care for them to ensure their longevity. The properties of the museum objects can divide into three main type categories such as organic, inorganic, and composite materials, one can better predict how the objects will react to their environment.

2.2.8.1. Organic materials

Organic materials are materials that were once living, such as plants or animals. These materials are used to create various objects, including wood, paper, textiles, leather, ivory, bone, feather, and more. Organic materials have several common characteristics, including the presence of the element carbon, which is a key component of all living things. They are also combustible, meaning they can catch

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[140] Martijn and ICCROM, *Handling of collection*, 42.

fire and burn. Organic materials are sensitive to light, which can cause them to fade or deteriorate over time. They are also a source of food for mold, insects, and vermin, which can cause damage and decay. The molecular structures of organic materials are complicated and susceptible to deterioration from extremes and changes in relative humidity and temperature. This means that they can be damaged by exposure to heat, cold, moisture, or dryness.

Organic materials are also hygroscopic, which means they absorb water from and emit water to the surrounding air in an ongoing attempt to reach an equilibrium. This can cause them to expand or contract, which can lead to warping or cracking.

Organic materials with a surface rich in soluble protein, starch, or sugar are highly vulnerable to ongoing deterioration cause by mold. These materials include leather, skin, parchment, starched, sized, or dirty textiles and paper. Mold development increases rapidly when the relative humidity (RH) is 75% or above. The time frames for mold development at different levels of RH are as follows:

100 days at 70% RH

10 days at 80% RH

2 days at 90-100% RH[141]

For organic materials, maintaining an appropriate relative humidity (RH) in the environment is crucial. Ideally, a stable RH between 50-55% is recommended as the optimal balance and widely recognized standard. In cases where there is no climate control system or limited control available, an RH range of 45-60% is deemed acceptable. However, it is important to steer clear of abrupt and substantial RH fluctuation whenever feasible. Minor, gradual changes or seasonal variations in RH can be accommodated within this recommended range.

Temperature and humidity are closely linked and can impact collections similarly. Higher temperatures can lower relative humidity (RH), while lower temperatures can increase it. For optimal preservation, having separate temperature ranges—one for collections (15-18 °C) and another for staff comfort (20-22 °C)—

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[141] Lambert, *RE-ORG*, 27.

would be ideal, but this is costly and complex. As a practical compromise, both collections and human comfort are best maintained within 18-22 °C. Temperature changes should be gradual and controlled to prevent damage.[142]

Chemical, biological, and mechanical deterioration accelerates with extreme temperature and humidity levels—either too high (above 60-70% RH) or too low (below 40-45% RH)—or fluctuations. Mixed collections fare best at temperatures between 65-70°F.

Temperature changes further affect relative humidity (RH); as cold air warms, RH decreases, and vice versa, impacting objects in various ways. For instance, excessive humidity can lead to paper cockling or desiccation (Fig. 83), affecting adhesives, sizing, wood, ivory, and leather properties. These effects manifest as softer or stickier adhesives, sweating in wood and ivory, and cracking or tear in leather (Fig. 84). Photographic emulsion and leather respond with shrinkage or fading under low humidity, while high humidity induces discoloration and silver mirroring on photos. Notable signs of improper temperature and RH include condensation on windows then mold can growth (Fig. 85) and the presence of insects like book lice and silverfish (Fig. 86).[143]

Fig. 83. Paper extreme clocking because of high humidity.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/paper-objects.html

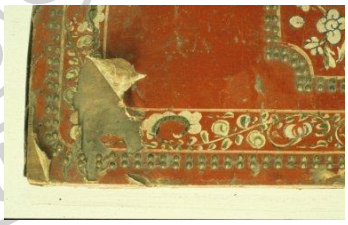

Fig. 84. Splits and tear in the leather cause by low RH.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/caring-leather-skin-fur.html

[142] Museum of New Zealand Te Papa Tongarewa, "Preventive Conservation: Collection Care." *Te Papa National Services Resource Guides*, no. 5, June 2001,) 4.

[143] Tennile Jackson, Carolyn Wavrin, and Ohio Historical Society, *Collections Care Management: Guidelines & Procedures*, (n.p., 2013,) 4.

Fig. 85. Mould colonies on the back of a poorly framed print cause of large RH. Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/paper-objects.html

Fig. 86. Silverfish insect enemies of paper.
Source: https://www.canada.ca/en/Conservation-institute/services/preventive-conservation/guidelines-collections/paper-objects.html

The suggested upper limits for light exposure align with museum standards, which advise maintaining light levels at or below 50 lux for delicate materials like textiles and paper. As for ultraviolet radiation, the specified threshold should not exceed 75 microwatts per lumen.[144]

The storage method for organic objects depends on factors such as the material, size, characteristics, condition, and environmental risks within the storage facility and specific requirements and vulnerabilities of each object and the storage environment.

For smaller items, they can be placed horizontally inside a cabinet or drawer, supported by acid-free paper tray or foam to prevent shifting. Preserve artifacts made from ivory by storing them in sealed display cases or drawers to shield against temperature fluctuations, dust, and dirt. Darkness is ideal for safeguarding light-sensitive surfaces. Regularly inspect for insects and mold growth—infestations demand prompt action. Line drawers and shelves with stable cushioning materials like

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[144] Sarah Staniforth, "*Light and Environmental Measurement and Control in National Trust Houses*. Edited by Simon Knell," In *Care of Collections*. (New York, United States of America: Taylor & Francis e-Library, (1994) 2005), 130-131.

polyethylene or polypropylene sheeting (Ethafoam®) to prevent damage. And avoid using rubber-based materials to prevent ivory discoloration (Fig. 87).[145]

For flat textile, roll with a tube 10cm longer, 5cm diameter. Opt for acid-free cardboard tubes, add Dacron/cotton for larger sizes. Larger tubes from stores or PVC drainpipes are usable, cover with Mylar/polyethylene, wrap with acid-free tissue/cotton. On clean surface, place longer acid-free tissue or washed cotton. Lay textile flat, face up/down by texture. Put tube on tissue edge, parallel to textile's weave. Roll firmly, maybe two people, maintain tension, smooth creases. Cover roll with acid-free tissue, cotton, or Tyvek, secure ends gently. Support sides with dowels, steel pipes, or Ethafoam®/wood blocks.[146] Items can be stored in a textile rolled cabinet, a custom box, or hung using steel cantilever shelving (Fig. 88-90).

Fig. 87. Box made of non-acidic corrugated board and Ethafoam®, holding many smaller boxes in drawer cabinet.
Source: https://ellencarrlee.wordpress.com

Fig. 88. Rolled textiles for housing collection.
Source: https://vimeo.com/203863910

[145] Canadian Conservation Institute, "Care of Ivory, Bone, Horn and Antler – Canadian Conservation Institute (CCI) Notes 6/1." Canada.Ca., January 27, 2020, accessed on August 28, 2023, https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/care-ivory-bone-horn-antler.html.

[146] "Textile Storage | Development Services." n.d. accessed on August 29, 2023, https://manual.museum.wa.gov.au/textile-storage/index.html.

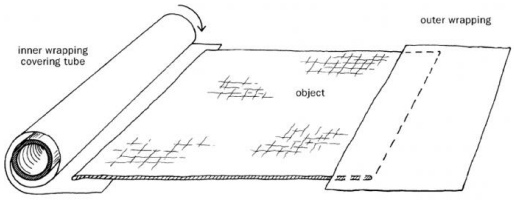

Fig. 89. Set-up for rolling textile or large paper object.
Source: https://stashc.com/the-publication/supports/tubes/method-for-rolling-flat-flexible-objects/

Fig. 90: Rolled textile are hung on steel cantilever shelving.
Source: https://i.pinimg.com/originals/41/f4/a9/41f4a93c1ffe3ecae7b37dd653427f9c.jpg

Textiles that possess curves, protrusions, thinness, or damage require specialized storage. It's recommended to store them separately from other items in a horizontal position within a closed cabinet (Fig. 91). This method prevents potential deformations that could arise from stacking. Alternatively, sturdy textiles can be hung on padded hangers for protection (Fig. 93). Use a smaller, padded hanger that matches the costume's shape, filling it with polyester wadding (e.g., Dacron) for structure. Padding spreads the costume's weight, easing stress on the shoulders. Cover the padded hanger with pre-washed cotton fabric. To safeguard against dust and pests, they can be covered with unbleached cotton fabric (Fig. 92).[147]

[147] "Storage Systems | Development Services." n.d. accessed August 29, 2023. https://manual.museum.wa.gov.au/conservation-and-care-collections-2017/textiles/storage-systems/index.html.

Fig. 91. Women's clothing stored flat in a box.
Source: http://www.museumtextiles.com/vac--pack.html

Fig. 92. Dust covered for costume.
Source: https://blog.nms.ac.uk/2015/10/14/helping-hands-the-volunteers-making-a-difference-to-textile-storage-at-the-museum/

Fig. 93. Padded hanger.
Source: https://www.universityproducts.com/padded-hangers.html

Textile object within the wooden frames can got damage due to the frame's natural expansion and contraction, leading to warping or tearing. To preserve these items, it's crucial to provide a stable environment with consistent temperature and humidity. Moreover, direct sunlight exposure should be avoided. To offer added protection, wrapping the item with unbleached cotton or Tyvek® that can prevent dust

accumulation and sunlight damage. Before hanging, placing the item on a metal rack or shelf provides an extra layer of safeguarding.

When storing paper collections, must be housed in protective enclosure for all paper objects and don't put directly on the floor. Enclosures can be folders, sleeves, mat window, or other protective covers that shield the paper from dust, light, and physical damage. And then stored in either document or record storage boxes. Loose items should be protected in folders, and a few similar objects can be placed in one folder. But acidic paper objects including the old book, should be separate or isolated from adjacent object (Fig. 96).[148]

Fig. 94. Storing paper items in a drawer paper cabinet with protective mat windows and acid-free tissue paper.
Source: https://aurorastorage.com/markets /museums/

Fig. 95. Using plastic sleeves to protect object.
Source: https://pattersonpope.com/ industries/museum-storage/

[148] "Caring for Paper Objects - Preventive Conservation Guidelines for Collections." Canada.Ca., July 15, 2020, accessed August 29, 2023, https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/paper-objects.html.

Fig. 96. Acidic paper can keep seperate in acid-free box.
Source: https://www.containerstore.com/s/office/paper-storage/university-products-archival-document-storage-boxes/12d?productId=10001336

Fig. 97. Book cradles help to prevent damage to spines of books when stored, displayed and viewed.
Source: https://www.preservation equipment.com/Catalogue/Display-Products/Display-Supports/Book-cradles-for-boxes-archival-board

For choosing appropriate storage equipment is essential, map cabinets also known as flat files are designed to hold larger items such as large paper, documents, map, and more that cannot fit into traditional boxes. Additionally, shelving units can be used for various paper collections (Fig. 94 and 95). To ensure proper organization and preservation, the enclosures should be used for all paper objects.

Map cabinets with shallow drawers are more efficient because they allow for easier access and organization of the materials. Moreover, using folders that match the drawer size helps keep items neatly stored. Polyethylene foam blocks can be placed in empty spaces within the drawer to prevent shifting and ensure stability. The different groups of items or rolled papers within a drawer, archival cardboard dividers can be used to separate and categorize them, reducing the risk of damage during storage.[149]

Additionally, artworks created with delicate media on paper need specific matting and framing methods. This involves using anti-static glazing and

[149] National Park Museum Services, “Appendix J: Curatorial Care of Paper Objects,” In NPS Museum Handbook Part I, n.p., 2003, 22.

adding a window mat or spacer. These steps safeguard the artwork by preventing its fragile surface from getting scratched, smudged, or coming into direct contact with the glazing (Fig. 98).[150]

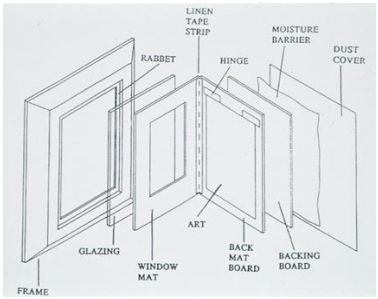

Fig. 98. Components of a preservation mat and frame package.
Source: https://www.loc.gov/preservation/care/mat.html

Photographic collections are mainly stored in museum storage, where proper conditions protect them. However, unfavorable conditions can trigger chemical deterioration processes, causing slow but irreversible damage. This can result in issues like fading, discoloration, color changes, embrittlement, silver mirroring, and mold growth (Fig. 99 and 100).

Fig. 99. Fading damage of photography.
Source*:* https://restoreoldphotosnow.com /fading-happens-how-to-protect-and-save-faded-photos/

Fig. 100. Effect of silver mirroring on surface.
Source: https://icatchshadows.com/an-example-of-silver-mirroring-deterioration-in-an-old-gelatin-silver-print/

[150] Canada.Ca, “Caring for Paper Objects”.

To ensuring that they the Museum Galleries Scotland has recommended storage environment for storing photographs is as in Table 1.[151]

Table 1. Recommendation for storage environment of photography.

Storage environment	**Recommended**
Relative Humidity	Stable, between 30-40%
Temperature	Stable, below 16°C
Light	No light, except for access
Air quality	Reduced particulate and gaseous pollution
Storage enclosure	Only use specified chemically inert materials such as Unbuffered acid-free tissue, unbuffered museum board, Melinex or Mylar, Polypropylene, Cellulose triacetate,
Format and furniture	Well organized and accessible

They also recommend storage methods for the photography collection. Such as framed photos should be mounted on unbuffered cardboard, sealed in quality frames, and stored vertically on frame racks cover with acid-free paper to protect from dust and lighting. Fine art photos can be mounted on buffered cardboard and placed in acid-free boxes, stored horizontally on shelves or cabinet. As well as, fragile photo albums can be wrapped in acid-free tissue paper and kept in shallow acid-free boxes, which can then be stored horizontally on shelves (Fig. 101 and 102).[152]

[151] Museums Galleries Scotland, "Caring for Photographic Collections in Museums." In *Advise Sheet*, n.p. 2001, 2,4.

[152] Ibid, 5.

Fig. 101. Photo storage envelope.
Source: https://www.preservationequipment.com/Catalogue/Photographic-Products/Photographic-Envelopes/Photo-Storage-Envelopes-PermaDur-Buffered

Fig. 102. Photography stored in plastic sleeve with card paperboard in the box.
Source:://www.archivalmethods.com/blog/3-inch-drop-front-box/

Fig. 103. Box storage keep on the shelve.
Source: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/occupational-health-safety/whmis-quick-facts-storage-requirements-health-canada-2008.html

Fig. 104. Small photo collections in drawer cabinet.
Source: https://www.theodi.org/article/collection-trust-tapping-the-potential-of-museum-collection-data/

Objects made from bone, animal skin, or feathers are often delicate and sensitive to environmental conditions. To ensure their preservation and protection, these items should be stored in containers that provide a snug fit, such as boxes and cabinets (Fig. 108-110). This minimizes exposure to dust, light, and fluctuations in temperature and humidity, all of which can contribute to deterioration (Fig. 105-107).

The tightly fitting storage also prevents unnecessary movement and potential damage to these delicate materials.

Fig. 105. 19th century Chinese ivory screen and stand showing cracking.
Source: https://manual.museum.wa.gov.au/conservation-and-care-collections-2017/ivory-bone-and-related-materials/deterioration/index.html

Fig. 106. Damage caused by worms on leather.
Source: https://www.leather-dictionary.com/index.php/Vermin_damage_on_leather

Fig. 107. The brown shading and blotches on the feathers are dust, soiling and oily deposits.
Source: https://www.canada.ca/en/Conservation-institute/services/preventive-conservation/guidelines-collections/feathers-quills-horn-keratinous-materials.html

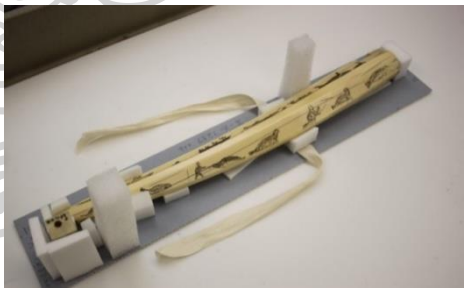

Fig. 108. Ivory cribbage boards sit in custom storage mounts.
Source: https://alaskapublic.org/2013/10/04/ak-museum-moving/

Fig. 109. A storage mount and dust protection box for an eagle feather headdress.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/feathers-quills-horn-keratinous-materials.html

Fig. 110. Leather gloves stored in cabinet.
Source: https://www.mfa.org/collections/conservation/feature_costumeaccessories_glovesandwristlets

Artifacts made from plant-based martial and basketry commonly damage from careless handling. Furthermore, basketry crafted from plant-based materials is particularly susceptible to light-induced fading and embrittlement. High humidity can lead to water absorption, resulting in swelling, warping, and mold growth, especially in older and delicate pieces. Conversely, low humidity and elevated temperatures can cause moisture loss, contributing to embrittlement. Additionally, dirt, dust, and pollutants can become embedded in fibers, hastening degradation, and masking surface details. Baskets can also suffer from exposure to nicotine and soot in smoking areas, cooking spaces, and near fireplaces. Rodents and insects pose threats by nesting in or consuming the plant-based materials. Notably, powder post beetles can create small boreholes and leave behind frass and larvae casings as signs of infestation.[153]

[153] Marlene Gray,"The Care and Preservation of BASKETRY." *Benson Ford Research Center*, n.d., 1.

Fig. 111. Fading damage on basketry.
Source: https://lam.alaska.gov/condition-reporting/basketry

Fig. 112. Pest damage.
Source: https://lam.alaska.gov/condition-reporting/basketry

Small two-dimensional pieces artifacts can be stored similarly to animal products. They can be placed in folders designed for small objects and then stored in cabinets. These cabinets offer protection against dust, abrasion, and pressure, while also providing a convenient way to support the artifact during storage and examination, including the ability to easily turn it upside down for inspection (Fig. 113 and 114).

Fig. 113. The trays with foam for storage of small objects made of plant material.
Source: https://www.researchgate.net/publication/311243924_Woven_Wonders_and_Saving_Basketry_at_the_Arizona_State_Museum

Fig. 114. A storage cabinet solution for basketry and plant materials.
Source: https://www.researchgate.net/publication/311243924_Woven_Wonders_and_Saving_Basketry_at_the_Arizona_State_Museum

Different artifacts require specific types of storage and support. Some can be stored on flat, cushioned surfaces or secured to padded vertical ones (3D objects). Others are best stored rolled and displayed hanging or on standard mounts. Complex artifacts may need custom-designed mounts for complete support during storage and display. These mounts not only support the artifacts but also enable safe handling. While crafting contoured supports can be time-consuming and costly, it's often beneficial to create storage mounts that can also serve for future display. When selecting the storage and support should consider the significant variation in artifact characteristics, including size, weight, shape, construction technique, and material. Examples of support types encompass pillows, coiled cushions, and contour forms that are either cut or cast. Additionally, certain packing techniques, like tying and sewing onto backings, have proven useful not only for storage and display but also for providing support during the handling of artifacts (Fig. 115 and 116).[154]

Fig. 115. Custom carved blocks of ethafoam for support.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/basketry-plant-materials.html

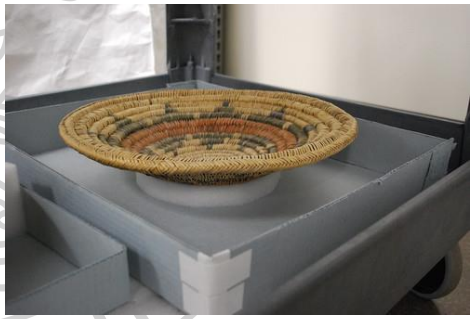

Fig. 116. Ring-base for prevent basket.
Source: http://managingcollections.blogspot.com

[154] Mary-Lou E. Florian, Dale Paul Kronkright, and Ruth E. Norton, *The Conservation of Artifacts Made from Plants Materials*. (n.p., Princeton University Press, 1996,) 202-203.

Wood, a widely known material, possesses a hidden complexity despite its familiar attributes. Comprising numerous cells, it holds water, polysaccharides, polyphenolics (lignin), and extractives, which can impact its color and scent. Damage to wood and wood objects may be caused by poor handling, inadequate packaging, temperature and humidity fluctuation, light, biological agents, and chemicals. In addition, wood often forms a component of various museum artifacts. The example of the degradation process could be an antique wooden furniture piece stored in a damp environment with fluctuating temperatures. Over time, poor handling during movement, coupled with humidity changes, might lead to visible cracks and warping on the wood's surface. Simultaneously, exposure to heat and light could cause the wood's color to fade and its structure to weaken, contributing to its overall deterioration. If not properly addressed, the combination of physical and chemical damage could eventually render the furniture unusable and beyond repair (Fig. 117-120).[155]

Fig. 117. Fading damage of wooden furniture. Source: https://careforwood.wordpress.com/chemical-degradation/

Fig. 118. The woven cane seat had been damaged by pressure from above.
Source: https://www.nbm-mnb.ca/agents-of-deterioration-with-nbm-conservator-dee-stubbs-lee/

[155] Garcia, Godfrey, and Lussier. n.d. “Wood.” Manual.Museum.Wa.Gov.Au, accessed August 30, 2023, https://manual.museum.wa.gov.au/book/export/html/121/#:~: text=Poor%20handling%20and%20packing%2C%20exposure,complete%20destruction%20of%20the%20wood.

Fig. 119. Prolonged exposure to moisture has led to the top of this chest experiencing finish blooming and deterioration.
Source: https://www.nbm-mnb.ca/agents-of-deterioration-with-nbm-conservator-dee-stubbs-lee/

Fig. 120. Insect damaged.
Source: https://www.nbm-mnb.ca/agents-of-deterioration-with-nbm-conservator-dee-stubbs-lee/

For optimal preservation of wooden objects, recommended environmental conditions include maintaining relative humidity levels between 40 – 60%, with a maximum 5% variation in 24 hours, a temperature range of 15 – 25 °C with a maximum 4 °C variation in 24 hours, and controlling light levels to 50 lux for dyed/painted wood, up to 200 lux for untreated wood, and a maximum of 300 lux for outdoor-exposed or faded wooden items, while limiting UV radiation to 75 µwatts/lumen. Avoid direct contact with exterior walls, extreme temperature/humidity fluctuations, fireplaces, heaters, vents, and sunlight exposure. For mixed metal-wood objects, prioritize wood's sensitivity to moisture changes. Direct sunlight exposure can lead to photochemical harm and affect veneers and glues, causing issues like lifting, shrinkage, warping, and cracking.[156]

When storing wooden objects, it's crucial to follow these guidelines to ensure their preservation: Firstly, select storage methods based on the size of the objects, such as utilizing drawers, shelves, cupboards, or padded surfaces. Selected

[156] National Park Museum Services, “Appendix N: Curatorial Care of Wooden Objects,” In NPS Museum Handbook, Part I. n.p, 2022, 20-21.

for enameled metal drawers or shelving to prevent potential damage. Flat objects should be placed on level surfaces and provide specialized supports or padding for items with irregular shapes to maintain stability (Fig. 121 and 122). When positioning large flat-bottomed objects on the floor, never store wooden furniture directly on concrete, stone, or brick floors. Elevate them using padded blocks to enhance air circulation and prevent moisture accumulation or can stored on the pallet shelving and high-density mobile shelving to be more effective space (Fig. 123 and 124). Employ dust covers on shelves to shield objects from dust accumulation, while also maintaining the cleanliness of furniture surfaces (Fig. 125 and 126). Avoid sitting on historic pieces to prevent wear and stress on the wood. Be cautious with items placed on furniture to avoid surface scratches, and protect against potential harm from heat, condensation, or spills. Prioritize lower storage levels for heavier objects, using suitable padding to prevent strain, and store wooden frames without stacking to minimize potential damage. Lastly, avoid using drawers in period furniture for object storage, as this could compromise both the furniture and the objects within.[157]

Fig. 121. Wooden spoon with rattle support.
Source: https://ellencarrlee.wordpress.com/2013/12/16/artifact-storage-pallet-solutions/

Fig. 122. Wooden collection storage within acid free box.
Source: https://www.flickr.com/photos/porkynz/34420086052/in/datedposted-public/

[157] Garcia, "Wood."

Fig. 123. High density mobile shelving houses wooden furniture.
Source: https://pattersonpope.com/products/commercial-grade-static-shelving/wide-span-shelving/

Fig. 124. Pallet shelving designed for storing oversized objects.
Source: https://pattersonpope.com/industries/museum-storage/

Fig. 125. Cotton dust cover furniture.
Source: https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/products-used-preventive-conservation.html

Fig. 126. Employ dust covers on shelve.
Source: https://www.nps.gov/orgs/1565/volume-1-no-4.htm

2.2.8.2. Inorganic materials

Inorganic materials, on the other hand, are not derived from living organisms and include things like metals, ceramics, glass, stone, mineral and plastic. These materials are generally more durable and resistant to environmental factors. Inorganic materials also have a presence in paper-based collections. Photographs contain minute metallic elements, and certain pigments and inks incorporate minerals

or metallic oxides. Metal particles can even be present within the composition of the paper[158]. So, certain types may necessitate specialized conditions.

Metals and glass can easily deteriorate in high humidity conditions. Corrosion of metal is encouraged by both high humidity and salts. (Fig. 127).[159] Elevated levels of moisture are associated with the occurrence of crizzling in glass, resulting in the formation of minute cracks on the surface that give the appearance of a hazy finish (Fig. 128)[160]. It's important to maintain humidity levels around 35-50%. In the absence of humidity control equipment, keeping the temperature between 22-24°C is advisable. Without air conditioning, always ensure good airflow and store problematic items in well-sealed containers to use moisture-absorbing agents such as silica gel.

Fig. 127. Metal corrodes.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

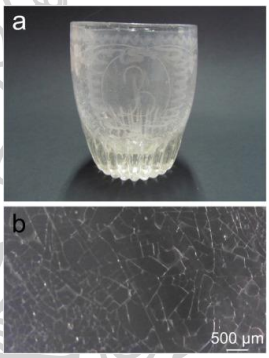

Fig. 128. Crizzling on glass surface.
Source: https://www.sciencedirect.com/science/article/pii/S036013232100456X

[158] "Session 3: Caring for Collections," n.d. Northeast Document Conservation Center, accessed August 30, 2023, https://www.nedcc.org/preservation101/session-3/2basic-concepts.

[159] "Metal Collections Care - Museums Galleries Scotland," Museum Galleries Scotland, accessed August 30, 2023, https://www.museumsgalleriesscotland.org.uk/advice-article/metal-collections-care/.

[160] "Preventive Conservation | Development Services." n.d. accessed August 30, 2023, https://manual.museum.wa.gov.au/conservation-and-care-collections-2017/glass/preventive-conservation/index.html.

Materials that have a natural salt content, they may suffer from efflorescence. Efflorescence is a phenomenon that occurs when materials with a natural salt content experience a reaction with moisture, leading to the salts migrating to the surface of the material. This process is particularly noticeable when the surrounding air is dry. Certain materials, such as deteriorated glass, porous ceramics, and specific geological substances, naturally contain salts within their structure. These salts might have been present since the material's formation or could have been absorbed from the surrounding environment over time. When there's a change in humidity levels, particularly from higher humidity to lower humidity, the moisture that has been absorbed by the material starts to evaporate.

As the moisture evaporates, it carries the dissolved salts from within the material towards the surface. Once the moisture reaches the surface and evaporates, the salts are left behind, forming visible crystalline deposits. These deposits can appear as whitish or colored streaks, powdery coatings, or even crusty formations on the material's surface (Fig 129).[161]

Fig. 129. White efflorescence on vessel. Source: https://www.sciencedirect.com/science/article/abs/pii/S0010938X17311915

Fig. 130. Support cushion for object. Source: https://psap.library.illinois.edu/collection-id-guide/museumobjects

[161] Canadian Conservation Institute. 2018. “Caring for Ceramic and Glass Objects - Preventive Conservation Guidelines for Collections.” Canada.Ca. December 14, 2018, accessed August 30, 2023, https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/ceramics-glass-preventive-conservation.html.

Small objects can be problem-free by placing them in cabinets or on shelves, covered with cloth or plastic sheets to prevent dust accumulation. This also aids in maintaining a controlled level of humidity. For smaller ceramic, they can be stored together in drawers using plastic box and Ethafoam® sheet as cushioning to prevent impact and minimize movement when the drawers are opened (Fig. 130 and 131).

Delicate small or flat items should be stored in specially designed foam-lined boxes with custom cutouts that closely match the item's size and shape. This helps prevent movement. Alternatively, place them on trays with supportive materials to minimize internal motion. Before storing them in a tightly sealed cabinet, ensure they are well-protected (Fig. 132 and 133).

Fig. 131. Drawer cabinet for small object.
Source: https://www.southwestsolutions.com/divisions/museums/museum-storage-cabinets/museum-drawer-cabinets/

Fig. 132. Storage solution for small objects within the drawer cabinet.
Source: https://blog.dar.org/exploring-new-museum-study-gallery-storage

Fig. 133. Storage solution for small objects within the drawer cabinet.
Source: https://www.montel.com/en/markets/museum-fine-art-storage

Fig. 134. Ring supports for pottery.
Source: https://psap.library.illinois.edu/advanced-help/advhelp-glass

Three-dimensional objects can be placed on shelves with care to prevent them from falling off by using raised edges on the shelves and cabinets. Additionally, use supports and cushions to protect and prevent items from moving or tipping in storage (Fig. 134-137).

Fig. 135. Circular Tyvek pillows for objects in storage.
Source: https://stashc.com/the-publication/supports/malleable/circular-tyvek-pillows-for-art-objects-in-storage/

Fig. 136. Visual storage cabinet of ceramic collection.
Source: https://blog.dar.org/exploring-new-museum-study-gallery-storage

For larger or heavier objects such as Buddha statues or sculptures, it's advisable to use supportive cushions to distribute weight, focusing on areas like the waist, neck, back, knees, and ankles. Place them on sturdy shelves or pedestals capable of securely bearing the weight. For particularly tall or large objects, if placed on the floor, be cautious of toppling or movement due to vibrations (Fig. 138). Therefore, consider using pallets or supportive materials and securing them with soft cords attached to walls, posts, pedestals, or shelves. Large, fragile items that are prone to breaking should be placed in cabinets lined with soft materials to prevent impacts.

Fig. 137. Storage solution for pottery collection.
Source: https://motusspacesolutions.com/visible-museum-collection-storage/

Fig. 138. Solution for storing oversized object.
Source: https://news.yale.edu/2021/04/12/west-campus-new-and-improved-access-peabody-museums-collections

Objects made of iron, brass, bronze, and bronze alloys, they are susceptible to corrosion, especially in the presence of moist air. High humidity levels accelerate corrosion that gradually damages the metal surfaces. When humidity exceeds 50%, corrosion becomes more severe. Therefore, it's advisable to store these items separately from others. Place them in tightly sealed plastic containers with silica gel packets inside that can helps absorb moisture (Fig. 139 and 140). Regularly check and replace the silica gel within the container. Silver items should not encounter other metals such as pins or paperclips, especially in high humidity conditions. Moisture can cause these metals to corrode, leading to rust deposits adhering to the surface of the silver (Fig. 141-144).[162]

Specially shaped elongated items should be placed horizontally on shelves lined with plastic or secured onto boards or metal grids. Covering them with silk or Tyvek® is recommended to prevent dust accumulation. Alternatively, storing them on custom-designed shelves or within cabinets with specialized compartments, such as platforms with tailored slots, is advisable (Fig. 145).

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[162] "Caring for Metal Objects - Preventive Conservation Guidelines for Collections." Canada.Ca. March 16, 2021, accessed August 30, 2023. https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html.

Fig. 139. Simple zip-lock bags for reducing corrosion risks caused by external sources of pollutants.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

Fig. 140. Wrap silver in tissue paper before sealing inside a polyethylene bag.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

Fig. 141. Silver objects wrapped in PET (Melinex®, formerly called Mylar®).
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

Fig. 142. Plastic box container with silica gel and an RH monitor card.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

Fig. 143. Metal objects are bagged to prevent contact, which could cause galvanic corrosion.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/metal-objects.html

Fig. 144: A storage cabinet at the Bavarian National Museum in Munich displays silver items.
Source: https://www.nytimes.com/2023/04/10/arts/germany-museums-silver.html

For objects composed of multiple materials, particularly with special decorative components such as silver or brass accents, it's advisable to wrap the metal parts with plastic to minimize reactions between the metal and gases in the atmosphere. Storing these items should maintain a moderate environment with temperature and humidity levels around 50-55%. If any material in the collection has specific vulnerabilities, like iron susceptibility to rust, humidity should not fall below 50% to prevent corrosion (Fig. 145). However, excessively low humidity might cause other materials such as paper or fabric to become brittle and fragile. Addressing and preventing rust, followed by surface coating to guard against moisture, is recommended.

Fig. 145. Storage cabinet with platforms with tailored slots.
Source: https://pattersonpope.com/products/cabinets/museum-cabinets/

Small gemological specimens like gemstones and minerals can be stored in sturdy paper boxes with divided compartments, further cushioned with polyethylene foam sheets at the base (Fig. 146). Afterwards, these can be placed within drawers for safekeeping.

Fig. 146. Small stone and gemstone stored in box divided compartment.

Source: https://www.spacesaverva.com/museum-storage-products/

Caring for plastic items in collections is complex. Plastics are relatively new materials with often unknown vulnerabilities. Conventional display and storage practices can speed up their decay, causing unfixable damage that's unsightly and corrosive. Plastics, being diverse and versatile, have been widely used in everyday items since the 19th century.[163]

Aging is a concern, especially for early plastics due to unstable additives used in the late 19th and early 20th centuries. Composition matters, as many plastics are chemically unstable with plasticizers and fillers. Over time, plasticizers move to the surface, causing brittleness and warping (Fig. 147 and 148). Environmental factors like pollutants, gases, excessive light, and changing temperature/humidity speed up degradation. Careful handling and proper cleaning are crucial to avoid harm and quicken deterioration.

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[163] "Caring for Plastics and Rubbers - Preventive Conservation Guidelines for Collections." Canada.Ca. July 16, 2020, accessed August 30, 2023, https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/caring-plastics-rubbers.html.

Fig. 147. Plastic degradation: brittleness and yellowed. Source: https://www.getty.edu/conservation/our_projects/science/plastics/cellulose.html

Fig. 148. Degraded plastic (cellulose nitrate). Source: https://www.getty.edu/conservation/our_projects/science/plastics/cellulose.html

For storing the plastic materials should ensure proper ventilation. Choose acid-free unbuffered tissue unless the item is tacky and could stick to the tissue. And exercise caution with buffered tissue paper, as alkaline buffers can expedite degradation in specific plastics. Utilize inert and acid-free materials for storage and display, including wooden or fiberboard cases.

Store plastics in a cool, dry, dark, and well-ventilated environment; consider using absorbents in sealed containers for certain plastics. Most plastics can be stored in sealed bags, boxes, or well-wrapped packages. Categorize plastics by type and store similar ones together while preventing contact. Avoid co-storing plastics with other materials, especially metals and organics. Use inert materials like Ethafoam® or Mylar® for support and careful with materials prone to off-gassing or changing shape over time, like bubble wrap. Regularly monitor and document plastic

condition, removing deteriorating objects and storing them separately from those in good condition.[164]

Fig. 149. Storing plastic objects in Ziplock bags.
Source: https://americanhistory.si.edu/blog/2012/01/preserving-plastics.html

Fig. 150. Storing plastic objects in Ziplock bags.
Source: https://www.getty.edu/conservation/publications_resources/newsletters/29_1/storage.html

Due to the absence of international standards for plastic storage conditions, museums often adopt preservation practices designed for delicate organic materials like artworks on paper. This includes maintaining stable relative humidity at approximately 50%, temperature between 18°C and 20°C, low light levels of 50–100 lux, and the exclusion of ultraviolet radiation.[165]

2.2.8.3. Composite materials

Composite materials are made up of a combination of organic and inorganic materials, such as a painting on a canvas, a sculpture made of metal and wood or a bone-handled knife and more. These materials can have unique preservation challenges as they may react differently to environmental factors than

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[164] National Park Services. 2010. Care and Identification of Objects Made from Plastic Number 8/4. Conserve O Gram, 1-2.

[165] "A Safe Place: Storage Strategies for Plastics (Article)." n.d. accessed August 30, 2023, https://www.getty.edu/conservation/publications_resources/newsletters/29_1/storage.html#:~:text=Since%20there%20are%20no%20international,light%20levels%20that%20are%20often.

their individual components would. So, need to decide to favour one constituent material over another.

Paintings are intricate compositions consisting of different elements. When the artists create paintings, they start by preparing a first layer, called the support, and then paint an image on the support. These two main parts are known as the support and image layers. Usually, both layers are made up of multiple components (Fig. 151). However, these components can react inconsistently to external factors such as temperature and humidity, which can stress the painting.[166] This complexity makes paintings vulnerable, and they need specific attention to maintain their best condition. This involves careful management of environmental conditions to prevent damage and ensure the painting's longevity.

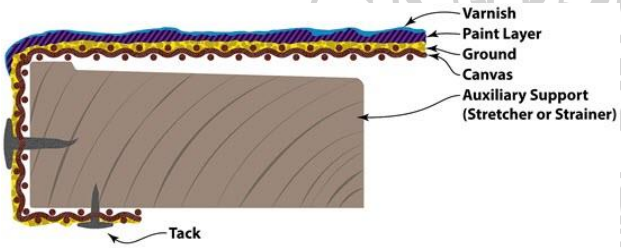

Fig. 151. Cross-section of a stretched painting on canvas.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/paintings.html

There are primarily two types of paintings: canvas paintings and panel paintings. Canvas paintings involve a piece of fabric, often linen, cotton, hemp, polyester, or silk, stretched over and fastened to a wooden frame like a strainer or stretcher. The fabric is the base for the image layer, while the wooden stretcher or strainer provides additional support. A strainer is a wooden frame with fixed corners, while a stretcher is designed to expand and tighten the canvas.

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[166] Jessica S. Johnson, and Karen Bennett, “APPENDIX L: CURATORIAL CARE OF EASEL PAINTINGS”. Edited by Tom Carter. The Museum Handbook Part I: Museum Collections. n.p., 1990, L:2-3.

Some acrylic paintings are not varnished, and folk artists may paint directly onto wood without sizing or ground. Modern artists may also incorporate materials like glass, textiles, paper, and plants. Specialized techniques like encaustic use paints with beeswax and resin that are fixed with heat after application.

Panel paintings on wooden supports can be prone to warping, and sometimes auxiliary supports called cradles can cause warping or cracking by restraining the natural movement of the panel due to changes in humidity.

Deterioration of a painting can occur due to various factors, which can be natural or external. Natural factors may include aging, while external factors may include environmental conditions, mishandling, or accidents. Fire and water are other agents of deterioration that can cause irreparable damage to a painting. Fire can destroy the artwork, while water can cause warping, swelling, or mold growth. Pests, such as insects, vermin, or mold, can also harm a painting by feeding on the materials or causing discoloration and decay. Contaminants, such as air pollution or dust, can also accumulate on the surface of the painting and cause damage over time. UV light can also cause fading or discoloration of the pigments in a painting. High, low, or fluctuating temperatures and relative humidity can also cause the materials to expand or contract, leading to cracking, flaking, or warping of the artwork. Over time, all layers in a painting deteriorate, with paint becoming brittle, varnish discoloring, and supports warping (Fig.152-154).

To preserve paintings, store them at temperatures between 18º to 24º C and maintain a relative humidity of 40% to 55%, as sudden temperature changes can harm the artwork and low or high RH levels can cause damage. Changes in temperature and humidity affect older paintings more, as their materials become less resilient with age. And it is recommended to limit visible light levels to 50-200 lux and filter all UV light, and to consider using automatic dimmer switches or turning off lights when visitors are not present to further limit light exposure[167].

[167] Ibid, 4-7.

Fig. 152. Cracked oil painting.
Source: https://fineart-restoration.co.uk/news/a-clear-view-british-landscape-painting-restoration/

Fig. 153. Tear damage by physical forces.
Source: https://www.canada.ca/en/conservation-institute/services/preventive-conservation/guidelines-collections/paintings.html

Fig. 154. Water damage of painting.
Source: https://fineart-restoration.co.uk/our-services/oil-painting-restoration/water-moisture-damaged-painting-restoration/

There are three main ways to store paintings: hanging them from storage screens, placing them on storage shelves, or stacking them vertically against an interior wall or side of a cabinet. Storage screens are a useful method for storing paintings, especially in earthquake-prone areas, and instructions for constructing them (Fig. 155). Also use Tyvek® or cotton cloth to protect painting when storing on the art racking. However, should consider that storage screen system isn't properly for damage painting or not in the good condition. Storing such paintings in a vertical position can cause further damage to the paint layer as gravity can pull the flakes down, causing them to detach from the surface. Therefore, it is recommended to lay damaged paintings flat on shelves to prevent any further damage to the paint layer (Fig. 156).

Fig. 155. Art screen racking for painting with framed.
Source: https://bruynzeel.co.uk/applications/museum/art

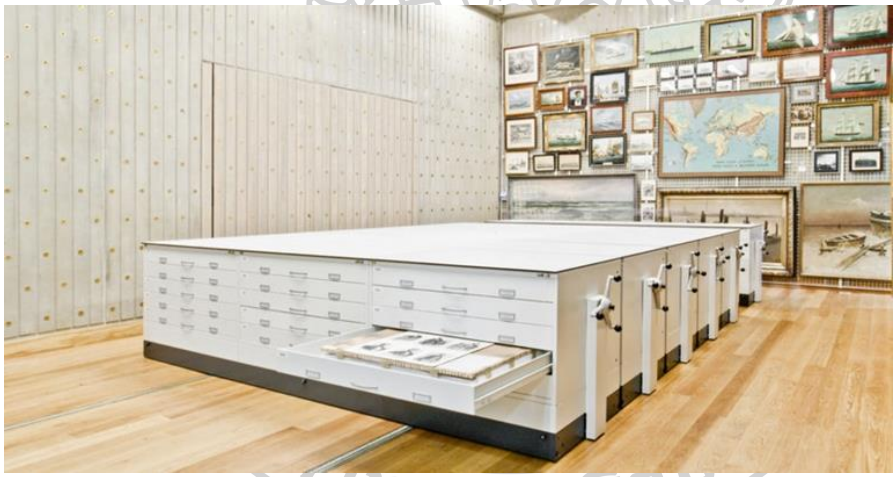

Fig. 156. Art screen racking on wall.
Source: https://www.tsaoussoglou.com/en/products/museum-255

Storage shelves are useful for housing smaller painting collections. These shelves can be made of coated wood or metal and oriented either horizontally or vertically. Horizontal shelves are better for larger paintings, while vertical ones (storage bins) suit smaller collections (Fig. 157). When using vertical compartments, it's vital to store just one painting per section to prevent harm. If storing multiple paintings in one compartment is necessary, placing heavy-duty, acid-free cardboard between them safeguards against damage. The cardboard should be larger than the

biggest painting in each section for proper protection. It's crucial to avoid stacking paintings horizontally, as this can harm the artwork.

Fig. 157. Storage shelves for storing the small painting or damage painting.
Source: https://www.southwestsolutions.com/divisions/museums/museum-painting-storage/art-storage-racks/

When temporarily storing paintings against a wall, arrange them in a vertical stack with the assistance of skid-proof and padded blocks to prevent slipping. Place acid-free cardboard between paintings to avoid contact and protect their surfaces. Group paintings of similar sizes together. It's important to maintain a near-vertical angle while stacking to prevent the paintings from falling forward or leaning onto each other, which could cause damage. For unframed paintings, use temporary frames to provide support. Adding dust covers offers extra safeguarding against dust and environmental elements. This method is effective for short-term storage but ensure long-term preservation by adopting proper storage solutions.[168]

[168] Ibid, 11-12.

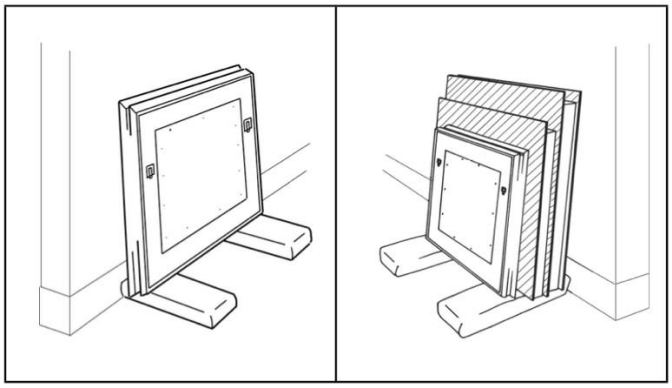

Fig. 158. Temporary storing painting.
Source: https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/canadian-conservation-institute-notes/storage-display-guidelines-paintings.html

2.3. Condition survey and risk assessment

2.3.1. Condition survey methodology

Condition surveys are a common practice in museums for conservation planning. These surveys are conducted to assess the overall condition of the collections in the museum. The main benefit of conducting a condition survey is that it provides baseline information that can be used to make definitive, quantifiable statements about the condition of the collections.

One of the advantages of conducting a condition survey is that it allows for the comparison of the condition of different parts of the collection or collections in different locations. This information can be used to identify areas that require more attention and resources for conservation.

Another benefit of conducting a condition survey is that it can provide evidence about the damage that has occurred to the collection and link it with the conditions in the museum. This information can be used to identify the causes of damage and develop strategies to prevent further damage.

Condition surveys can also help in prioritizing actions to improve the condition of the collection. By identifying areas that require immediate attention, museums can allocate resources more effectively and efficiently.

Condition surveys can help estimate the cost and time required to achieve the necessary improvements. This information can be used to develop a conservation plan that is both realistic and achievable within the available resources.

Survey work may seem like a straightforward process, but it requires a deep understanding of materials and their decay processes. Experienced conservators have the ability to judge the severity of damage and its implications, which is crucial in determining the appropriate conservation treatment.

Inexperienced conservators or non-conservators may focus on trivial surface details when assessing damage, which can lead to incorrect conclusions and ineffective conservation treatments.[169]

Therefore, it is essential to have trained and experienced conservators conduct survey work to ensure accurate assessments and effective conservation treatments.

Additionally, it is important to agree on a methodology before conducting a survey on the condition of objects in a collection. This involves identifying the key questions that need to be asked and designing an effective survey form. To ensure that the survey is efficient, it is recommended to keep the number of questions to a minimum, as unnecessary questions can increase the time and cost of the survey.

The categories of questions that are likely to be included in the survey form are administrative data, such as the location of the objects, identification, and description. Another important category of questions is descriptions of damage, which can be classified into typical categories such as major or minor structural damage, surface damage, disfigurement, chemical deterioration, biological attack, harmful old repairs, and accretions.

In "Managing Conservation in Museums" by Suzanne Keene, the author emphasizes the importance of understanding and categorizing various types of damages in museum collections. Standardized terminology enables effective communication among conservation professionals. The book identifies eight broad terms of damage, including structural, physical, surface, disfigurement, chemical

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[169] Jane Henderson, "*Collection condition surveys*," In *Working with Independent Conservators*. (London: Arts Council England, 2000), 1.

deterioration, biological attack, bad repairs, and accretions (table 2). The condition of objects is evaluated using four grades: good, fair, poor, and unacceptable (table 3). By understanding the condition and specific conservation needs of objects, museums can develop effective storage strategies that prioritize preservation and ensure the continued safeguarding of their collections.[170]

The purpose of the table 2, is to provide a standardized way of categorizing and describing damage to museum objects, which can help museum professionals assess the condition of their collections and plan for conservation and storage needs.
In understanding the damage factors, eight key terms are significant:

- Major structural damage refers to damage that affects the overall structure of an object or collection, such as loose cracks or breaks that compromise its stability.

- Minor physical damage refers to small-scale damage that may not affect the overall structure of an object or collection but can still impact its appearance or function.

- Surface damage refers to damage that occurs on the surface of an object or collection, such as scratches or abrasions.

- Disfigurement refers to damage that alters the appearance of an object or collection, such as discoloration or cockled.

- Chemical/ internal deterioration occurs when the chemical composition of an object or collection changes over time, leading to degradation and potential loss of original properties.

- Biological attack can occur when living organisms, such as insects or fungi, damage an object or collection through feeding or other activities.

- Accretion refers to the accumulation of foreign materials on an object or collection, such as dust or dirt, which can obscure its original appearance or function.

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[170] Suzanne Keene, *Managing Conservation in Museums*. 2nd ed. Oxford. (United States of America: Butterworth-Heinemann, 2002), 144-148.

- Bad old repairs refer to previous attempts at repairing an object or collection that were not done properly and may have caused further damage.

Table 2. The table displays the terms under which types of damage.

Damage		Type of objects							
		General	**Furniture**	**Paper**	**Book**	**Textile fibre**	**Pictures**	**Ceramic/ glass**	**Metals**
Structural	**Major (MAJ)**	- Separate part - Loose crack - Large tear - Large holes - Major splits - Parts missing - Mechanical disorder	- Very loose joint - Separated attachment	- Very badly crumpled with split - Very badly creased with split - Very badly distorted/rolled	- Separated or nearly separated spine/ cover	- Split seam - Badly creased with split - Seriously crumpled - Crushed			
	Minor (MIN)	-Crack - Small tear - Puncture - Small holes - Small splits - Obviously weak - Loose attachment - Bent -Warped - Creased - Distorted elements		- Cockled - Crumpled - Folded		- Shrunken - Detached fibres		- Chipped - Small crack	
	Surface (SUR)	- Flaking/lifted - Peeling - Paint/surface losses - Bruised - Cupped - Delaminated - Crazed - Denited	- Lifted veneer				- Cupped paint - Losses - Flaking paint - Lifted paint		
	Disfigurement (DIS)	- Scratched - Stained - Abraded - Discolored - Faded - Tarnished - Color bled						- Salt damage - Crizzled	
	Chemical/ internal (CHE)	- Crumbling - Friable - Desiccated - Exudations - Grease - Salts		- Acid - Yellowed - Chemically changed edges - Matt burn - Redox spots - Metal impurity	- Acid paper - Red rot	- Deteriorated silk - Acid dyes	- Blanched - Deteriorated canvas	- Encrustations	- Corroded - Rusted
	Biological (BIO)	- Insect attack - Moth - Woodworm - Foxed - Rodent damage - Mould - Mildew							
	Accretions (ACC)	- Dirty - Encrusted - Surface salts - Deposits - Greasy							
	Bad old repair (OLD)	- Adhesive - Misalignment - Staples - Sellotape - Patches		- Tape - Sellotape		- Clumsy stitching - Alterations			- Soider

Note. Adapted from *Managing Conservation in Museums* (second edition, p.143-146) by Suzanne Keene, 2002, London, England: Butterworth-Heinemann. Copyright 2002 by Suzanne Keene.

Table 3 displays the condition grade that is a measure of the severity of damage in the context of a collection. It is used in surveys to assess the condition of the collection and prioritize conservation efforts. Most surveys use a four-level condition-scoring scheme, which ranges from fair to unacceptable.

The four levels of the condition-scoring scheme are defined as follows:

1. Fair: The item is in generally good condition, with minor wear and tear that does not affect its overall appearance or function.

2. Good: The item is in good condition, with some signs of wear and tear that may affect its appearance or function, but not significantly.

3. Poor: The item is in poor condition, with significant wear and tear that affects its appearance or function and may require conservation treatment.

4. Unacceptable: The item is in very poor condition, with severe damage that makes it unusable or irreparable, and requires immediate conservation treatment.[171]

The condition grade is an important tool for collection management and conservation, as it helps to identify items that are at risk of deterioration and prioritize conservation efforts accordingly.

Another type of useful data that can be collected is the suitability of the object's store location. This means recording whether the location where the object is stored is appropriate for its preservation and protection.

For collecting this additional data, museums and preservation professionals can gain a better understanding of the condition and needs of their objects. This can help with prioritizing preservation efforts and ensuring that objects are properly cared.

[171] Ibid.

Table 3. The table displays the terms under which condition grade.

Condition grade	Description
GOOD	Object in the context of its collection is in good conservation condition, or is stable.
FAIR	Fair condition, disfigured or damaged but stable, needs no immediate action.
POOR	Poor condition, and/or restricted use, and/or probably unstable, action desirable.
UNACCEPTABLE	Completely unacceptable condition, and/or severely weakened, and/ or highly unstable and actively deteriorating, and/or affecting other objects: immediate action should be taken.

Note. Adapted from *Managing Conservation in Museums* (second edition, p.146) by Suzanne Keene, 2002, London, England: Butterworth-Heinemann. Copyright 2002 by Suzanne Keene.

In Table 4, there is a form utilized for conducting a condition survey, which contains information concerning the location, collection, and the date of the object assessment within the storage facility. This form requires specific details about the items, coupled with condition grades and types of damage as discussed in Tables 2 and 3. This form approach significantly streamlines and speeds up conducting a condition survey, facilitating the subsequent evaluation and analysis of data. The design of Table 4 draws inspiration from the methodology developed by Keene[172], similarly enhancing the overall efficiency of the condition survey procedure.

[172]Ibid, 164.

Table 4. Collection condition survey

Collection Condition Survey

Condition grades:

1. GOOD:	Good conservation condition, stable
2. FAIR:	Disfigured or damage, no immediate action
3. POOR:	Probably unstable, needs remedial work
4. UNACCEPTABLE:	Actively deteriorating

Damage categories

MAJor	Structural damage
MINor	Structural-cracked, bent, loose
SURFace	Flakes, crazing, lifting
DISFigurement	Stains, scratches
CHEMical	Acid paper, corrosion, rubber breakdown
BIOlogical	Mould, insect, rodent
OLD	Sub-standard repairs
ACCretions	Dirt, grease, deposited

Survey code: **Initials :** **Date:**

Collection:

Sub-collection:

Store:

Location

			Damage									
Inventory no.	**Object name**	**Materials**	**MAJ**	**MIN**	**SUR**	**DIS**	**CHE**	**BIO**	**OLD**	**ACC**	**CON-DITION**	**Remarks**
	Totals for damage categories										CON:	1 2 3 4

Note. Adapted from *Managing Conservation in Museums* (second edition, p.146) by Suzanne Keene, 2002, London, England: Butterworth-Heinemann. Copyright 2002 by Suzanne Keene.

The approach to conducting a collection condition survey using random sampling will adhere to the pilot survey methodology, employing the condition survey form developed by Keene.[173] A pilot survey is a small-scale survey conducted before a large-scale survey to test the methodology and ensure that it will provide the desired information. The purpose of a pilot survey is to fine-tune the methodology and make any necessary changes to ensure that the work can be completed on schedule.

A pilot survey and analysis of the results typically occupy about 20% of the total available survey time.[174] This approach is well-suited for conducting a condition survey at the storage planning for Ruam Samai Museum project due to the diverse

[173] Ibid.

[174] Henderson, "*Collection condition surveys,*" 4.

range of materials within the extensive collection and the team's limited time to inspect items before their transfer to Chiang Mai. Therefore, the random sampling for the condition survey will be based on statistical data of artifacts brought in for conservation at the conservation lab in 2023. This information will specify the types of artifacts that were brought in for restoration, aiding in a more straightforward selection of samples. The process of sample selection and the survey results will be elaborated further in Chapter 3, relating to collection analysis.

2.3.2. Risk assessment

The International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) has developed a guide to risk management of cultural heritage, which focuses on ten agents of deterioration that can harm cultural heritage. The ICCROM guide offers practical strategies and techniques for identifying, assessing, and managing the risks associated with each of these agents of deterioration. By implementing effective risk management practices, cultural heritage institutions can help to safeguard their collections and ensure their longevity for future generations.

Understanding the ten agents of deterioration outlined in the ICCROM guide is crucial for the effective management and preservation of cultural heritage. By identifying and assessing the risks associated with physical forces, theft and vandalism, fire, water, pests, pollutants, radiation, incorrect temperature, incorrect relative humidity, and dissociation. Cultural heritage institutions can implement strategies and techniques to mitigate these risks and safeguard their collections.[175] By doing so, they can ensure the longevity of cultural heritage objects and structures, as well as their cultural and historical significance, for future generations to appreciate and learn from. Ultimately, a thorough understanding of the agents of deterioration and effective risk management practices are essential for the preservation and continued appreciation of our shared cultural heritage.

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[175] José Luiz Pedersoli et al., *A Guide to Risk Management of Cultural Heritage*, (n.p., 2016), 26-27.

2.3.2.1. Physical forces

Museum storage is designed to protect and preserve objects over long periods of time, and one of the factors that can contribute to their deterioration is physical forces. Physical forces can be broadly defined as any mechanical stress, strain or pressure exerted on an object, and can include things like vibration, shock, compression, tension, torsion, or even the weight of the object itself. There are three main types of physical forces that can impact objects in storage: catastrophic forces, working forces and cumulative forces.

Catastrophic forces can cause significant damage to the artifacts and objects stored within them. Catastrophic forces can arise from a variety of sources, including natural disasters such as earthquakes, floods, hurricanes, and fires, as well as human-made disasters such as theft, vandalism, or accidental damage.

To mitigate the risk of catastrophic forces in museum storage, several measures can be implemented. Firstly, regular inspections and maintenance of storage facilities and equipment must be conducted to identify and address potential hazards or weaknesses. Secondly, proper handling and packaging of artifacts during transport and storage should be ensured to prevent any damage caused by jostling, impact, or vibration. Thirdly, appropriate shelving, cabinets, and support structures must be used to store artifacts securely and safely. Fourthly, implementing fire suppression systems, such as sprinklers or fire extinguishers, is crucial to prevent or minimize damage in a fire. Lastly, emergency response plans that outline clear procedures for evacuating staff and visitors, securing the collection, and coordinating with local authorities should be in place to deal with any unexpected emergencies. Working forces in museum storage refer to the stress and strain that artifacts are exposed to because of the way they are stored, handled, or displayed. This can include the weight of other artifacts or storage materials placed on top of them that can affect the integrity of the artifacts over time.[176]

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[176] “Physical Forces,” Canada.Ca., May 17, 2018, access April 21, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/physical-forces.html.

Working forces that can affect artifacts in museum storage are numerous and can cause significant damage if not appropriately managed. Examples of these forces include mishandling during transportation or installation, transit (in-house) movement, shipment, gravitational loads, construction vibration, and excavation near museum storage. During transit or in-house movement, artifacts are exposed to various forces, including vibrations, impacts, changes in temperature and humidity, which can cause direct or indirect damage such as chipping, cracking, or weakening of materials, leading to further damage over time (Fig. 85). Similarly, shipment poses significant risks to the safety and preservation of objects due to handling, temperature, humidity, vibration, and impact, which can cause mechanical damage, such as chipping or cracking, or indirect damage, such as loosening of joints or weakening of materials. Gravitational loads, particularly on large and heavy artifacts, can cause sagging, warping, or deformation if not properly supported. Nearby construction activity, such as demolition, excavation, or pile driving, can also cause damaging vibrations if proper precautions are not taken. Finally, excavation near museum storage can cause damage due to factors such as vibration and dust, which can be detrimental to the preservation of museum collections.[177] Therefore, proper management and mitigation of these forces are crucial to ensure the long-term preservation of artifacts in museum storage.

Cumulative forces refer to the gradual and ongoing impact of low-intensity forces that may not be immediately noticeable but can cause significant damage over time. High incidence refers to the frequency with which these forces occur, while low intensity refers to their relative strength. Handling of objects over time can cause wear and tear, especially if the objects are made of poorly adhered, weak, or fragile materials. When objects are handled, they can be subject to various forms of stress, including bending, twisting, rubbing, and impact, which can lead to physical damage and deterioration. Shipping of objects can subject them to various low-level forces such as vibration, shock, and impact. These forces can cause damage to object parts or surfaces, particularly if the objects are fragile or poorly secured

[177] Ibid.

within their packaging. Gravity can be a significant force that can cause damage to objects over time, especially if they are not properly supported or stored. Improperly designed supports can concentrate static loads on objects or their parts, leading to distortion or breakage over a long time.[178]

2.3.2.2. Fire

The risk of fire in museum storage areas can be high due to several factors. Museums often store valuable and historically significant objects, some of which may be flammable or susceptible to fire damage. Additionally, many museums are housed in older buildings that may not have up-to-date fire suppression systems or other safety features.

There are several potential sources of fire in museum storage facilities that can lead to catastrophic losses of the collections. These include electrical systems, heating and cooling systems, combustible materials, smoking, arson, and natural disasters. Faulty wiring, overloaded circuits, and malfunctioning electrical equipment can generate heat, sparks, and electrical arcs, which can ignite flammable materials. HVAC[179] systems can malfunction, causing overheating or sparking, and improper maintenance or installation of heating equipment can also lead to fires. Storage materials such as cardboard boxes, wooden crates, and other combustible materials can ignite and spread the fire rapidly. Smoking should never be allowed inside museum storage facilities as a lit cigarette or cigar can easily ignite materials. Intentional acts of arson are rare but pose a serious threat to museum collections. Natural disasters such as lightning strikes or earthquakes can also cause fires in museum storage facilities.[180] By identifying and addressing these potential sources of

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[178] Ibid.

[179] 'Heating, Ventilation, and Air Conditioning' These systems are designed to constantly move a stream of air through the space as a means of conveying heat and/or humidity into or out of the space as required. A fraction of this air stream typically consists of fresh outdoor air and the remainder is recirculated (*IPI's Guide to Sustainable Preservation Practices for Managing Storage Environments*, (n.p., 2012), 26.

[180] Lord, Lord, and Martin, *Museum Planning,* 312.

fire, museums can take effective measures to protect their collections and prevent the loss of irreplaceable artifacts.

To minimize the risk of fire in museum storage facilities, several precise measures can be taken to protect and preserve their collections. Regular inspections of storage space and equipment should be conducted to detect potential fire threats, such as poor wiring or overloaded electrical outlets. To ensure adequate fire extinguishing systems, sprinklers, fire alarms, and smoke detectors should be installed. In case of a fire, the use of fire-resistant materials such as coatings and insulators can help restrict the spread of flames and reduce damage. Proper storage methods, such as securely storing all objects and keeping combustible goods apart from other items, can also help reduce the risk of fire. Proper training in fire safety procedures should be provided to all personnel to ensure they understand how to use a fire extinguisher and how to exit the building in case of a fire. Regular checks and proper fire prevention measures should be employed to significantly lower the risk of fire in museum storage areas and safeguard their collections from significant loss.[181]

2.3.2.3. Water

Museum storage areas are susceptible to water damage from various sources, which can pose a significant risk to collections. These sources include flooding due to heavy rain, natural disasters, or burst pipes, which can lead to substantial water damage and even the destruction of collections. Additionally, a damaged or poorly maintained roof can allow water to seep into the building and cause damage. Leaking pipes, faulty valves, and other plumbing issues can also lead to water damage in storage areas. Moreover, heating, ventilation, and air conditioning (HVAC) systems can sometimes leak or malfunction, leading to water damage. Finally, if the temperature and humidity levels in the storage area are not properly

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[181] Wisconsin Historical Records Advisory Board Registers in Probate Association and National Historical Publications and Records Commission. 1998. *Everything You Wanted to Know About Storage Environmentk: ...But Were Afraid to Ask*.p.7

regulated, condensation can form on windows or walls, causing water damage over time.[182]

To mitigate the risk of water damage in museum storage areas, there are several steps that museums can take. These include conducting regular inspections of storage areas and equipment to identify any potential water damage risks, such as leaking pipes or roofs. Proper storage is also essential, and all stored objects should be properly stored and secured, kept away from potential water sources such as windows or pipes. Maintaining appropriate temperature and humidity levels is critical in preventing condensation and moisture buildup. Additionally, developing an emergency response plan in the event of a flood or water leak is essential. This plan should include procedures for evacuating staff and collections, shutting off water sources, and contacting emergency services. Regular maintenance of plumbing and HVAC systems is also necessary to prevent leaks and other malfunctions that could lead to water damage.[183]

2.3.2.4. Theft

Theft is a significant risk in museum storage areas, as they often contain valuable and historically significant objects that may be targeted by thieves. The consequences of a theft can be severe, both in terms of the loss of irreplaceable objects and the potential damage to the museum's reputation and public trust.

Museum storage areas are vulnerable to theft, which can be caused by both internal and external factors. Internal factors include employee theft, where museum staff may be tempted to steal valuable objects from storage areas for financial gain or personal possession. Security breaches can also occur when museum staff members fail to properly secure storage areas, such as by leaving doors unlocked or failing to activate alarms. Additionally, staff members who have insider knowledge of the museum's security protocols and procedures may be able to circumvent security measures to steal objects. External factors include professional thieves who may

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[182] "Water." Canada.Ca. May 17, 2018, accessed 18 April, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/water.html.

[183] Wisconsin, Storage Environment, 7.

target museums due to the high value and rarity of the objects stored there, using methods such as breaking in through windows or using hacking techniques to bypass security measures. Organized crime groups may also be involved in museum thefts, using their resources and networks to plan and carry out the thefts. Finally, once stolen, museum objects may be transported through unsecured channels, such as illegal art markets, to be sold or traded.

To mitigate the risk of theft in museum storage areas, there are several steps that museums can take. These include limiting access to storage areas to authorized personnel only, using key card systems or other access control measures to monitor and restrict access. Installing security cameras to monitor storage areas and deter potential thieves is also essential. Implementing a system for tracking inventory, including regular audits to identify any missing or misplaced objects, is crucial. Ensuring that all stored objects are safely stored and secured, and that high-value items are kept in locked cases or cabinets is also necessary. Providing staff with proper training on security protocols, including how to identify and respond to potential security threats, is important. Finally, collaborative efforts with law enforcement agencies, other museums, and private security firms to share information and resources and develop best practices for security can be highly effective in preventing theft.[184]

2.3.2.5. Pests

Pests in museum storage areas can pose a serious threat to museum collections. Pests such as insects, rodents, and fungi can damage or destroy objects, and can also pose health risks to museum staff members and visitors.

Museum storage rooms are prone to pests that can harm the collection. Insects such as beetles, moths, and cockroaches can consume organic materials in museum collections such as textiles, paper, and wood, causing harm. Insects and rodents eat cellulose (a common ingredient in paper), starch, glue, and gelatin.

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[184] "Thieves and Vandals." Canada.Ca. January 27, 2020, accessed April 21, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/thieves-vandals.html.

Cockroaches will eat electronic components. Rats, mice, and squirrels can literally eat records, and their droppings will leave permanent stains. Pests also create health risks in the work environment. Live plants, flowers, food waste and water can encourage all types of pests.[185] Leaving excrements on items and making holes and tunnels in them. Rodents like rats and mice can potentially cause damage to museum items by chewing on them. Urinate on them and leave the manure behind.

Other pests, such as fleas and mites, might be introduced by rodents and cause damage to an object. Due to the dirt and excrements from pests mold growth can be induced in museum display and storage facilities. Especially if the thing is kept in a moist or humid environment. These pests can discolor, weaken, and degrade items. It could potentially endanger the health of museum employees and visitors.

Several efforts can be taken by museums to limit the risk of pest infestations in their storage rooms. Regular cleaning and maintenance of storage rooms is one of these steps to prevent pests from entering and establishing themselves. Remove food waste from adjacent "people areas" every day.[186] Maintaining adequate temperature and humidity levels in the storage room can also aid in the prevention of pest growth, such as mold, insects, and rodents.

Pest control measures such as traps, bait, and insecticides can aid in pest population control in storage facilities. Quarantine measures can also be used to isolate suspected pest objects from the rest of the collection, preventing them from spreading. Museums may protect their important collections from pests by taking the actions outlined above.[187]

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[185] Wisconsin Historical Records Advisory Board Registers in Probate Association and National Historical Publications and Records Commission. 1998. *Everything You Wanted to Know About Storage Environmentk: ...But Were Afraid to Ask*.p.5.

[186] Ibid, 17.

[187] "Pests." Canada.Ca. March 7, 2022. https://www.canada.ca/en/conservation-institute/services/agents- deterioration/pests.html.

2.3.2.6. Contaminants

Contaminants in museum storage areas can also pose a serious threat to museum collections. Contaminants can come from a variety of sources, such as pollutants in the air, water, or soil, and can cause damage or deterioration to objects in the collection.

Contaminants can be categorized into several types, such as gaseous pollutants that include sulfur dioxide, nitrogen oxides, and ozone, which can enter museums and archives from outdoor sources such as traffic and industrial emissions. Gaseous pollutants can cause discoloration, fading, and embrittlement of cultural heritage objects. Volatile organic compounds (VOCs) are emitted by various sources, such as adhesives, paints, and cleaning products, and can damage cultural heritage objects. Some examples of VOCs include formaldehyde, acetic acid, and benzene. Particulate matter can come from both indoor and outdoor sources, such as dust, dirt, and pollen. These particles can accumulate on cultural heritage objects, causing discoloration, staining, and abrasion.

To protect museum collections from contaminants, it is important for museums to take the following measures such as air filtration. Installing air filtration systems can help reduce the amount of dust and particulate matter in museum storage areas, improving the overall air quality and reducing the risk of damage to objects. Regular maintenance of heating, ventilation, and air conditioning (HVAC) systems can help prevent the buildup of air pollutants in museum storage areas. Proper management of chemicals used in the museum or in neighboring areas can help prevent contamination of museum storage areas. This can include storing chemicals in separate areas, using them in well-ventilated areas, and disposing of them properly. Using appropriate storage materials such as acid-free boxes, folders, and sleeves can help prevent contaminants from damaging objects in museum storage areas.

filtration system, and implementing proper inventory management and storage protocols. Regular cleaning and maintenance can prevent the buildup of dust and particles, while maintaining proper temperature and humidity levels can prevent mold

and mildew growth. Installing a filtration system can remove airborne pollutants and dust from the air, reducing the risk of contamination.[188]

2.3.2.7. Radiation

Radiation in museum storage areas can come in several forms, including ultraviolet (UV), visible (VIS), and infrared (IR) radiation. Each of these types of radiation can cause damage to museum objects in diverse ways. Of all the different types of light, UV rays are most active in causing fading and physical deterioration of records. Infrared light damages records by the heat it generates.[189]

a. Ultraviolet (UV) radiation: UV radiation can cause fading, discoloration, and other forms of damage to objects in museum storage areas, particularly those made of organic materials such as paper, textiles, and leather. UV radiation can also cause damage to some types of plastics, organic and synthetic materials.

b. Visible (VIS) radiation: Visible light can cause fading and discoloration of objects in museum storage areas over time, particularly those that are sensitive to light. However, visible light is typically less damaging than UV radiation.

c. Infrared (IR) radiation: IR radiation can cause heating and drying of objects in museum storage areas, particularly those made of organic materials. This can lead to cracking, warping, and other forms of damage.[190]

To mitigate the risk of radiation damage in museum storage areas, museums can implement a range of measures, such as limiting the amount of time that objects are exposed to radiation, particularly UV radiation, can help prevent damage. Installing UV filters on windows and lights in storage areas can help block harmful UV radiation. Keep curtains and/or shades drawn as often possible. Store objects in

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[188] "Control of Pollutants in Museums and Archives – Technical Bulletin 37." Canada.Ca. June 7, 2021 accessed April 21, 2023, https://www.canada.ca/en/conservation-institute/services/conservation-preservation-publications/technical-bulletins/pollutants-museums-archives.html.

[189] Wisconsin, Storage Environment, 5.

[190] Canadian Conservation Institute. 2018a. "Light, Ultraviolet and Infrared." Canada.Ca. May 17, 2018. https://www.canada.ca/en/conservation-institute/services/agents-deterioration/light.html.

boxes with lid or in closed drawers when feasible. Maintaining appropriate temperature and humidity levels in storage areas can help prevent the growth of mold and fungi, which can be particularly sensitive to radiation. And using protective covers or display cases can help shield objects from radiation.[191]

2.3.2.8. Incorrect temperature

Temperature is the measure of the motion of molecules in a material. As temperature increases the molecules move faster and collide with greater force, increasing the chances for a chemical reaction to occur. At higher temperatures, biological activity also increases as insects eat more and breed faster, and mold growth increases.[192]

The Canadian Conservation Institute (CCI) identifies three practical categories of incorrect temperatures that can adversely affect cultural heritage objects.

a. High temperature can cause physical and chemical damage to cultural assets. For example, can hasten chemical processes that make different materials wear out faster High temperature can also produce physical changes including warping, breaking, and melting.

b. Low temperatures can cause both physical and chemical damage to heritage objects. Low temperatures can make materials more brittle and susceptible to damage due to decreased flexibility. Additionally, low temperatures can cause condensation to form on objects, which can lead to staining and corrosion over time.

c. Temperature fluctuations can cause physical stress on heritage objects, especially those made from materials with different coefficients of thermal expansion. Rapid changes in temperature can cause materials to expand and contract at different rates, leading to cracking and other forms of physical damage. Additionally, temperature fluctuations can cause changes in humidity levels, which

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[191] Wisconsin, Storage Environment, 15.

[192] Ford, Patricia, Peter Herzog, Jeremy Linden, James Reilly, Kristin Smith, and National Endowment for the Humanities, Division of Preservation and Access, Education & Training Grant Program. 2012. *IPI's Guide to Sustainable Preservation Practices for Managing Storage Environments*. 2nd ed.p.8.

can affect the moisture content of cultural heritage objects and lead to deterioration over time.[193]

Incorrect temperatures can be caused by weather and climate change, as well as malfunctioning or neglected HVAC equipment. Poorly built or constructed museum storage space, as well as human activities in and around storage, are substantial contributors to temperature and humidity changes to damage objects. Weather and climate changes can produce large fluctuations in temperature and humidity levels, causing damage to a variety of objects.

HVAC systems that are malfunctioning or poorly maintained can cause temperature and humidity levels to vary or remain too high or too low. As a result, objects can be damaged. Poorly built or constructed museum storage areas can be subject to temperature and humidity variations, resulting in object deterioration. Furthermore, human activity in and around storage areas, such as opening doors or moving goods, may create temperature and humidity variations, resulting in object damage.

To reduce the risk of temperature-related damage in museum storage areas, museums can implement specific measures such as climate control and maintaining suitable temperature and humidity levels in storage areas is critical. The ideal temperature range for most museum objects is between 20-22°C (68-72°F), with a relative humidity of 50%. Regular monitoring of temperature and humidity levels in storage areas can detect potential issues and allow for corrective action to be taken promptly. Proper insulation of storage areas can maintain stable temperature levels and prevent fluctuations. And separating objects based on their temperature requirements can prevent damage from objects with conflicting temperature needs. It is essential to group similar objects with similar preservation needs.[194]

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[193] Canadian Conservation Institute. 2018a. “Incorrect Temperature.” Canada.Ca. May 17, 2018, accessed April 21, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/temperature.html.

[194] Wiki. 2021. “Temperature and Relative Humidity for Exhibits - Wiki.” Wiki. January 8, 2021, accessed April 21, 2023, https://www.conservation-wiki.com/wiki/Temperature_and_Relative_Humidity_for_Exhibits.

2.3.2.9. Incorrect relative humidity

Incorrect humidity levels in museum storage can pose significant risks to the collections. The risks vary depending on whether the humidity is too high or too low.

High relative humidity levels can lead to the growth of mold and other microorganisms, which can damage or even destroy organic materials in the collections such as textiles, paper, and wood. High humidity can also cause corrosion of metal objects and swelling or warping of wooden objects, which can lead to cracking and other forms of physical damage.

Low relative humidity levels can cause desiccation and cracking of organic materials such as leather, parchment, and ivory. Low relative humidity can also cause wooden objects to shrink, crack and can lead to the embrittlement of some types of plastics.

Relative fluctuation poses a risk to the collection in museums and archives because it can cause cumulative and long-term damage to cultural heritage objects. Even small and consistent fluctuations in temperature or humidity levels can cause physical and chemical changes to the materials, leading to their deterioration. For example, relative humidity fluctuations can cause hygroscopic materials such as paper, leather, and textiles to expand and contract, leading to distortion, warping, and cracking. Similarly, temperature fluctuations can cause differential expansion and contraction of different materials, leading to mechanical stress and structural damage.

There are several sources that can result in inappropriate relative humidity levels in museum storage. These include malfunctioning or inaccurately calibrated HVAC systems that regulate temperature and humidity levels, as well as moisture intrusion from roof, wall, window, or door leakage, or insufficient sealing. Human activity, such as breathing, sweating, and other storage activities, can introduce moisture into the air, contributing to excessive humidity levels and collection damage. Inadequate ventilation can also prevent extra moisture from being removed from the air, leading to excessive humidity levels. Weather variables, such as rain, snow, and humidity, can also impact humidity levels in storage, especially if the building structure is in a high-humidity environment. Additionally, the materials

used to keep collectibles, such as wood and cardboard, can absorb and release moisture into the air, increasing humidity levels.

It is important to identify sources of incorrect humidity levels in the museum storage area to develop a comprehensive plan to address them and maintain proper environmental conditions for the collections. Maintaining proper humidity levels in museum storage is crucial for the preservation of collections.

To maintain proper humidity levels in museum storage areas, several measures can be taken by identify the ideal humidity range. The ideal humidity range varies depending on the types of collections being stored. The ideal range for museum storage is between 40-60% relative humidity (RH). However, certain materials may require more specific ranges. Regular monitoring of the humidity levels is essential to maintaining proper environmental conditions. Humidity sensors should be placed throughout the storage area and calibrated regularly to ensure accurate readings. If humidity levels are outside the ideal range, adjustments should be made to the environment. This may include adjusting the HVAC system, using dehumidifiers or humidifiers, or making repairs to the building envelope to prevent moisture intrusion. Human activity in the storage area can contribute to increased humidity levels. Limiting the number of people entering the storage area and restricting activities that generate moisture can help maintain proper humidity levels. Choosing appropriate storage materials can also help maintain proper humidity levels. For example, using sealed containers or barrier materials can prevent moisture from entering storage spaces. Moisture can enter the storage area through leaks in the roof, walls, or windows, or through improperly sealed doors. Identifying and repairing these sources of moisture intrusion is essential for maintaining proper humidity levels.[195]

2.3.2.10. Dissociation

Dissociation in a museum storage refers to the separation of an object from its original context, meaning, or significance. When an object is removed from

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[195] "Incorrect Relative Humidity." Canada.Ca. February 5, 2021, accessed April 21, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html.

its original environment, it can lose important contextual information, such as its historical, cultural, or social significance. This can happen in museum storage when objects are separated from their original locations, groupings, or accompanying materials, such as labels, photographs, or documents.

Dissociation can occur for several reasons, such as conservation, research, or exhibition purposes. For example, an object may be removed from a site for preservation, but the site's context is lost. Or, an object may be studied or displayed without its original context, leading to a partial or distorted understanding of its meaning.

Museums often strive to minimize dissociation by documenting and preserving as much information about the object as possible, including its provenance, history, and cultural context. This information can help to reconstruct the object's original context and meaning, even if it is physically separated from its original environment. Additionally, some museums prioritize keeping objects in their original context whenever possible, such as displaying them in situ or creating immersive exhibits that replicate the object's original environment.[196]

[196] “Dissociation.” Canada.Ca. February 19, 2019, accessed April 21, 2023, https://www.canada.ca/en/conservation-institute/services/agents-deterioration/dissociation.html.

3. Collection analysis

'*RE-ORG: A Method to Reorganize Museum Storage*' is a book published by the International Center for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in 2011. This book provides guidance on collection analysis, object categories, and object size as key elements of a comprehensive collection management plan. Before starting to plan the museum storage, it is essential to analyze the collection thoroughly to understand its scope, nature, and significance.

The collection analysis aims to determine the type(s) and volume of the museum's collection through surveys and analysis. It involves assessing the scope, significance, and condition of the collection to identify conservation needs and develop preservation strategies. This includes condition surveys, significance assessments, and risk assessments to prioritize objects for storage. Categorizing objects is crucial for storage planning, considering variations in material types, physical properties, analyzing the collection's growth rate provides insights into future space requirements, enabling proactive planning to accommodate new acquisitions.
, and cultural or historical significance that require specific handling and environmental conditions. Additionally, object size is a critical factor, as larger or heavier objects may necessitate specialized storage equipment and conservation treatments for safety and longevity.

Categorizing objects is crucial for storage planning, considering variations in material types, physical properties, and cultural or historical significance that require specific handling and environmental conditions. Additionally, object size is a critical factor, as larger or heavier objects may necessitate specialized storage equipment and conservation treatments for safety and longevity.[197]

Categorizing the collections by object types allows for a systematic understanding of the diverse range of artifacts present in the Ruam Samai Museum. This categorization enables the identification of different groups of objects, such as Buddha statues, antiques, modern Thai paintings, and international contemporary art.

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[197] Lambert, *RE-ORG*, 11.

By organizing the collections in this manner, it becomes easier to assess their storage needs and plan for appropriate storage solutions.

Materiality plays a significant role in collection analysis as different materials require specific preservation and storage conditions. By categorizing the collections based on material types, such as ceramics, wood, paper, textiles, ivory, metal, plastic, and electronics, it becomes possible to determine the storage requirements specific to each material. For instance, fragile ceramics may need padded compartments, while delicate textiles may require controlled humidity levels.

Condition assessment is essential for understanding the state of the objects in the collection. This assessment involves evaluating factors such as physical damage, deterioration, and conservation needs. By incorporating the condition assessment into the collection analysis, it becomes possible to prioritize objects for conservation and allocate appropriate storage space based on their condition.

This thesis focus on planning the storage space at Ruam Samai Museum in Chiang Mai, Thailand. It utilizes quantitative analysis techniques to categorize collections by considering factors such as object types, materiality, size, growth rate, and condition assessment. The primary aim is to accurately estimate the museum's storage space requirements and formulate a customized storage plan. The study emphasizes the design of suitable storage solutions that optimize capacity, facilitate easy access, and meet furniture requirements. Subsequently, the focus shifts to designing the layout of the storage facility, ensuring efficient space utilization and optimal preservation of the collections. Importantly, the study's outcomes can serve as a guideline for the Museum's storage practices and contribute to the development of a comprehensive collections management plan that addresses the specific preservation needs of their objects, ensuring their long-term preservation.

3.1. Methodology for collection analysis of Ruam Samai Museum

The importance of analyzing existing collections to forecast future space needs. This includes both qualitative and quantitative analysis of the collection, e.g., review of collection policies, categorize collections and calculate the growth rate and storage ratio. The chapter emphasizes the importance of using this information to

develop a collection development strategy and plan for the resulting changes in staffing, space and facility requirements.[198]

Quantitative analysis involve gathering detailed information about each items in a collection, including details of each item, such as size, weight, material, and condition. Through this procedure, data is acquired that can be used to classify and further categorize objects, such as by size or material. This data can be used to estimate future growth rates for each category and determine how much space is required to store each type of object.[199]

Collection storage by materials, medium, or objects type refers to organizing objects based on the materials they are composed of. This is important because each material has its own optimal requirements for care, such as specific humidity, temperature, and light restrictions. For example, all paper-based artifacts and artworks should be kept in similar conditions to ensure their preservation. It is usually more cost-effective and efficient to store objects of the same material in one location rather than spreading them across various departments and storage rooms.

The antique objects contain 4,892 pieces, while the artworks comprise 1,794 pieces as (08 May 2023). The artworks are further divided into three categories, namely Thai modern art, Thai contemporary art and international art (Fig. 159). This classification system allows for a more detailed understanding of the composition and diversity of the collection, providing valuable insights into the different genres and styles represented within the artworks category.

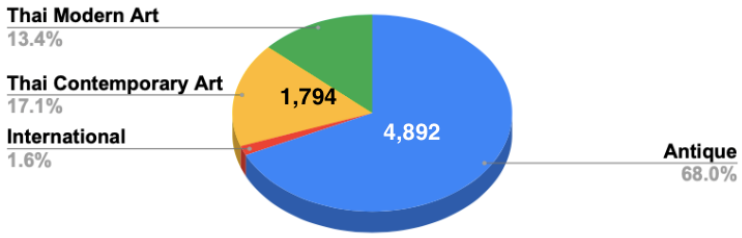

Fig. 159. Pie chart of displaying four different categories of art objects in the private collection.

Source: Miss.Pornganok Sadakorn (12 May 2023)

[199] Lord, Lord, and Martin, *Museum Planning*, 202-207.

3.1.1. Objects categorized by materiality and type

The significant quantity of collectibles and the diverse range of materials found within a collection necessitate the implementation of efficient techniques for object classification and inventory management to facilitate their organization and storage within museums.

A recommended strategy involves categorizing objects based on their material composition and type, thereby simplifying the classification process, and optimizing storage procedures. By adopting this classification methodology, museums can enhance their inventory management practices, ensuring systematic arrangement and effortless retrieval of objects.

3.1.1.1. Objects categorized by materiality

Objects categorized by materiality are systematically organized based on the specific types of materials they are composed of. This classification method enables a comprehensive understanding of the diverse range of materials present within a collection, allowing for more efficient management, preservation, and storage of the objects. By categorizing objects according to their materiality, museums can effectively address the unique conservation needs associated with different materials, implement appropriate handling and storage techniques, and ensure the long-term integrity and accessibility of the collection.[200]

For Ruam Samai Museum's collection, the objects are sorted into eleven primary categories based on their material composition, specifically animal products (e.g., ivory, leather, skin, bone, and animal hair), ceramic, electronics, glass, metal, paper, painting, plastic, stone, textile, and wood. These categories are then further divided into subcategories based on the type of function of each object. This approach facilitates the storage and accessibility of the objects for researchers and staff, with the subcategories including accessories, ceremonial, coin, furniture, iconography, instruments, kitchenware, manuscript cabinet, miniatures, miscellaneous, painting,

[200] Ibid, 206.

sculpture, vessels, and weapon. The classification of objects also affects identification through assigned registration numbers.

The total of 4,892 antique objects that are available for classification based on their material type, which can be categorized into nine categories (Fig. 160). The most common type of object in the collection is ceramic with 1,963 pieces (40.1%), followed by metal with 1,774 pieces (36.3%), wood 763 pieces (15.6%), animal products 185 pieces (3.8%), stone 65 pieces (1.3%), glass 63 pieces (1.3%), paper 38 pieces (0.8%), 32 pieces of textiles (0.7%) and 9 pieces of plastics (0.18%) (fig.8,9).

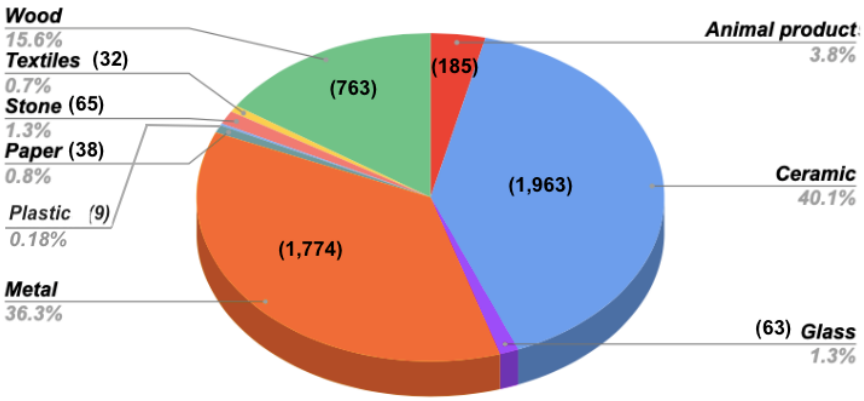

Fig. 160. Pie chart illustrating the classification of antique objects.
Source: Miss.Pornganok Sadakorn (12 May 2023)

The 1,794 pieces of artworks in the collection are classified into three main categories, namely Thai contemporary art, Thai modern art, and international art, to facilitate storage in the storage area. Artworks are available for classification based on their material type, which can be categorized into ten categories. Figure 9 displays the number of artworks categorized by materiality. The most common type of material is canvas with 839 pieces (46.8%), followed by paper with 812 pieces (45.2%), metal 82 pieces (4.56%), electronics 20 pieces (1.12%), plastic 14 pieces (0.8%), wood 9 pieces (0.5%), textile 8 pieces (0.45%), glass 6 pieces (0.34%), ceramic 3 pieces (0.17%) and stone 1 piece (0.06%).

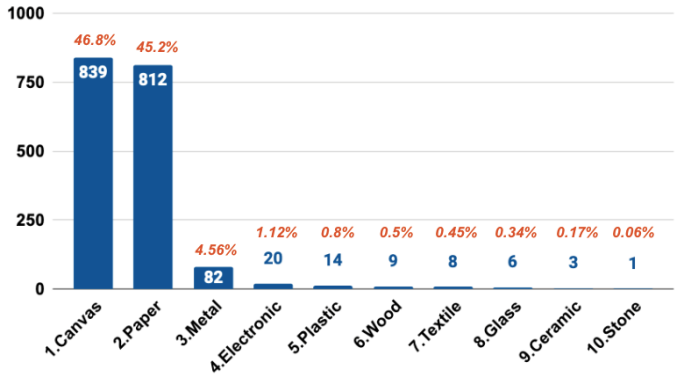

Fig. 161. Chart illustrating the materials of artworks.
Source: Miss.Pornganok Sadakorn (12 May 2023)

In summary, the collection includes antiques and artworks intotal 6,686 objects. Ceramics dominate with 1,986 pieces (29.4%), closely followed by metals with 1,856 pieces (27.76%). Paper and canvas account for 850 (12.71%) and 839 (12.55%) pieces, respectively. Wood totals 772 pieces (11.55%), while animal products, glass, stone, and textiles have smaller proportions. Plastic and electronic materials are represented by 23 (0.34%) and 20 (0.3%) pieces, respectively (Fig. 162). Overall, ceramics and metals are the most common materials, followed by paper and canvas. Categorizing objects by material aids in storage planning, as different materials require specific storage conditions. Organic materials like paper, textiles, and canvas are particularly vulnerable to environmental factors and necessitate careful management to mitigate damage risks.

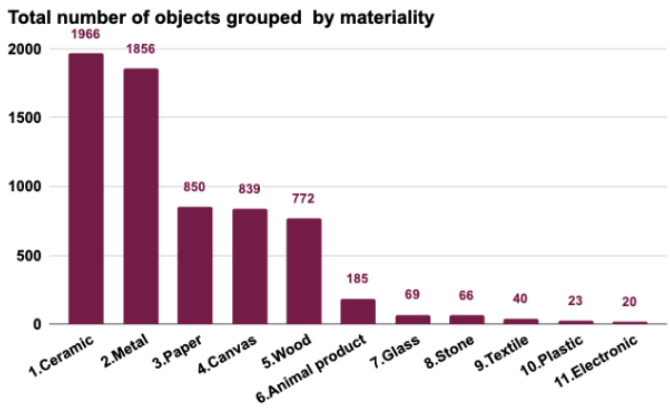

Fig. 162. Chart illustrating the material groups of collection.
Source: Miss.Pornganok Sadakorn (12 May 2023)

3.1.1.2. Objects categorized by types

The museum objects have been systematically categorized based on their type of functionality. This classification allows for a comprehensive understanding of the various functional purposes served by the objects within the collection. By categorizing objects according to their functionality, museums can effectively organize and present the objects in a way that highlights their intended use and significance. This classification methodology enhances the overall interpretation and exhibition of the collection, providing curator or researcher with a deeper understanding of the objects' functional roles and historical context.

The antique objects are categorized into 14 subcategories by their functionality. The most common types of objects are 1,109 miscellaneous items (22.7%), followed by kitchenware 939 pieces (19.2%), accessories 651 pieces (13.3%), coins 593 pieces (12.1%), furniture 368 pieces (7.5%), sculptures 349 pieces (7.1%), iconography[201] 261 pieces (5.3%), ceremonial 171 pieces (3.5%), vessels 124 (2.5%), weapons 113 pieces (2.3%), miniatures 106 pieces (2.2%), paintings 69 pieces (1.4%), manuscript cabinets 29 pieces (0.6%) and instruments 10 pieces (0.2%) (Fig. 163).

The artworks in the collection have been meticulously classified into three primary categories to facilitate their storage in the designated storage area. These categories include Thai contemporary art, Thai modern art, and international art. Furthermore, the artworks are further classified based on their specific type, resulting in a total of nine subcategories. According to the provided chart, the collection comprises a total of 1,794 artworks. The largest number of works belongs to the paintings category, accounting for 56.6% of the collection with a total of 1,015 pieces. Sculptures rank second, representing 27.8% of the collection with 498 pieces. Photography follows with 100 pieces (5.6%), drawing with 60 pieces (3.3%), archive with 46 pieces (2.6%), printmaking with 46 pieces (2.6%), media with 17 pieces

[201] Iconography refer to artifacts or items that hold symbolic or representational meaning within a particular cultural or religious context. Such as buddha statue, Thangka painting.

(0.9%), installation with 9 pieces (0.5%), and finally embroidery with 2 pieces (0.1%) (Fig. 164).

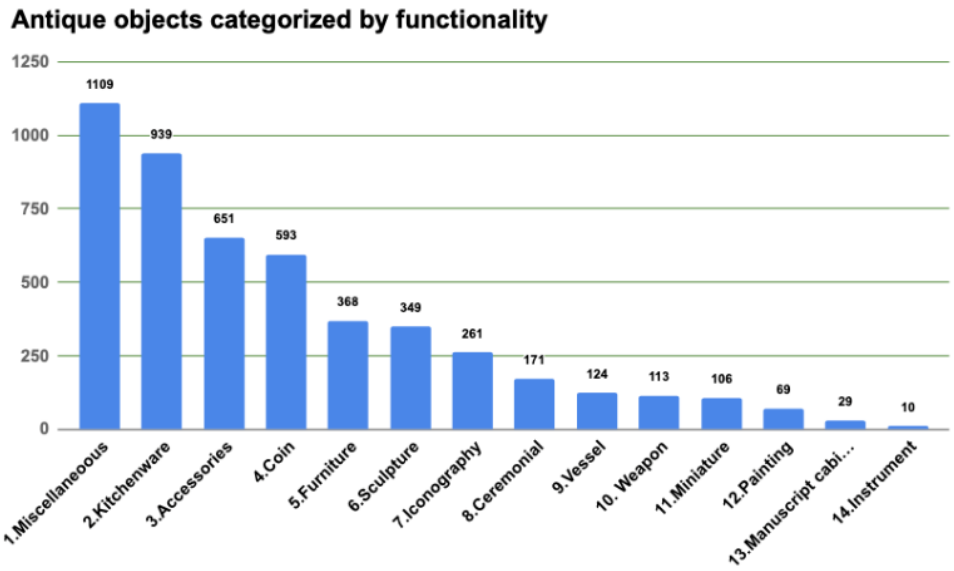

Fig. 163. Chart illustrating the categorization.
Source: Miss.Pornganok Sadakorn (12 May 2023)

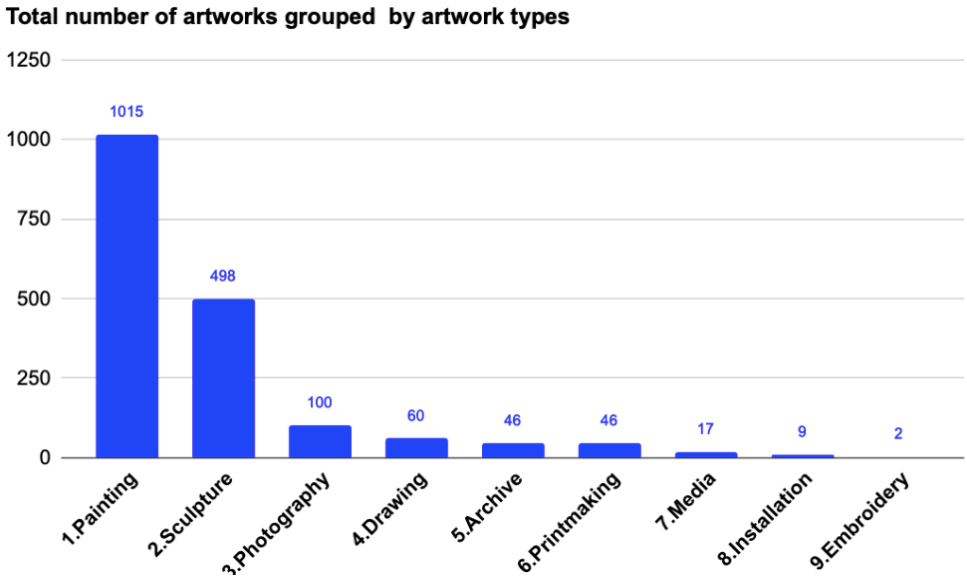

Fig. 164. Chart illustrating the artwork groups.
Source: Miss.Pornganok Sadakorn (12 May 2023)

3.2. Collection space requirement

Estimating the required storage space is a crucial aspect of collection analysis, particularly through the assessment of object sizes measured in cubic meters (m^3). By determining the cubic meter size of each object, an estimation of the volume necessary to accommodate the entire collection can be obtained. This information serves as a foundation for designing storage areas that optimize space utilization while ensuring the objects' proper preservation and accessibility.

In the case of this collection, the analysis reveals that wood objects occupy the largest proportion of storage space, amounting to over 995 m^3, accounting for 67% of the total. Metal objects follow, utilizing 210.4 m^3 (14%), while paper occupies 173.6 m^3 (11.5%). The storage space allocation continues with canvas requiring 28.32 m^3 (1.82%), ceramic occupying 26 m^3 (1.7%), electronic materials utilizing 23.5 m^3 (1.5%), glass objects requiring 14.6 m^3 (1%), textile artifacts taking up 12.2 m^3 (0.8%), stone objects occupying 8.3 m^3 (0.55%), plastic materials requiring 1.82 m^3 (0.15%), and animal products utilizing 0.2 m^3 (0.01%). Totally, the collection occupies approximately 1,162.4 m^3 of space (Fig. 165).

In order to collaborate effectively with the architect team for the design and calculation of storage space, it is essential to obtain the dimensions of the works in 3D format (m^3). These measurements are necessary to accurately determine the size requirements for the storage area. Moreover, it is crucial to allocate a storage room with a minimum height of 5 meters, considering the presence of objects that reach a maximum height of approximately 4 meters. By obtaining precise 3D measurements and adhering to the minimum height requirement, the storage space can be designed and planned appropriately to accommodate the collection.

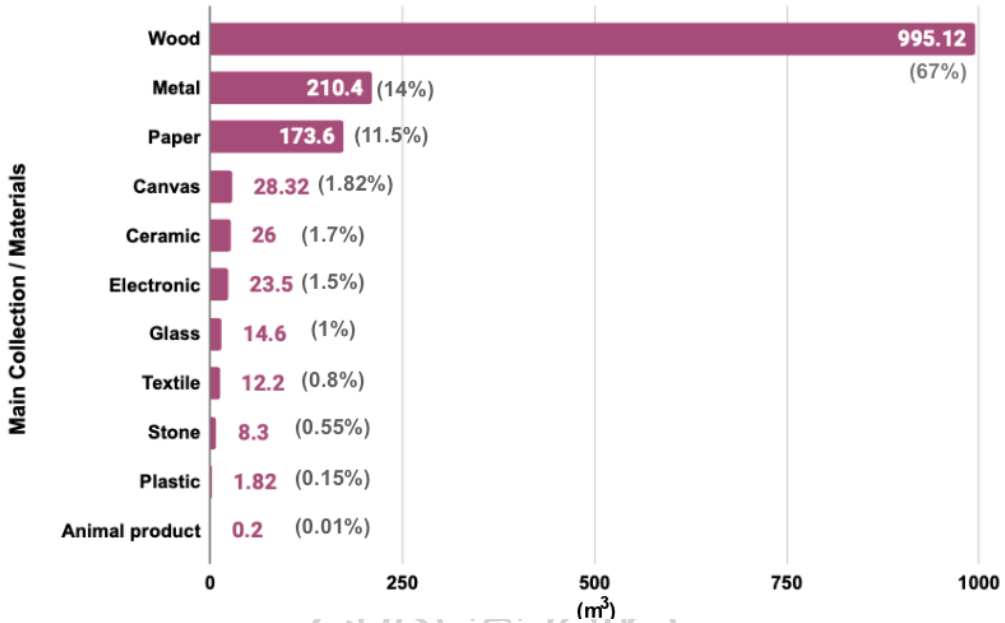

Fig. 165. Chart illustrating the collection space requirement.
Source: Miss.Pornganok Sadakorn (12 May 2023)

This information provides insight into the space requirements when storing objects classified by their material type. However, it is important to note that this estimation only considers the object measurement and does not account for their storage in boxes or cabinets. Once this information is obtained, the next step involves planning for collection growth and conducting a comprehensive collection assessment.

3.3. Condition survey

In Chapter 2, which covers the condition assessment, the researcher employed the condition survey form and the principles of a pilot survey to evaluate the items within our collection. In this section, the pilot survey methodology will involve random sampling, using data from artifacts and artworks brought in for conservation lab in 2023.

Based on the inventory data obtained from a comprehensive condition survey of private collection, it has been determined that most the museum's collection objects are in good condition, accounting for approximately 97.8% of total. This indicates that a significant portion of the collection is well-preserved and does not require immediate conservation intervention.

However, a small percentage of the collection objects have been categorized as fair (0.5%), poor (1.05%), or unacceptable (0.65%) in terms of their condition (Fig. 66). These objects exhibit various levels of deterioration or damage, warranting attention and further conservation planning to prevent further degradation.

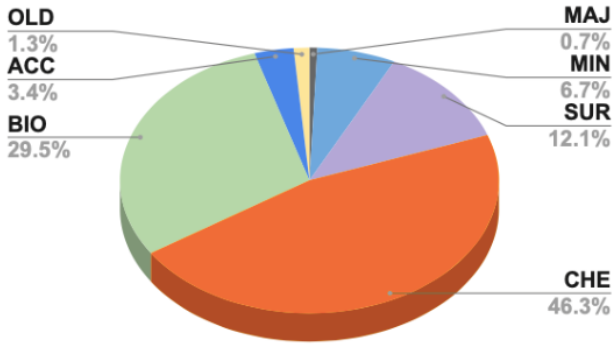

Fig. 166. Pie chart illustrating the type of damage.
Source: Miss.Pornganok Sadakorn (12 May 2023)

During the comprehensive issue identification process in the collection, a notable concern has surfaced regarding the presence of foxing on a significant number of paper works, comprising approximately 8% or 69 pieces within the collection (Fig. 167). These discolorations serve as clear indicators of chemical or internal damage (Fig. 169.), signifying the urgent need for specialized conservation treatments to stabilize and restore these delicate artworks. Addressing this specific type of damage is crucial to ensure the long-term preservation and aesthetic integrity of these valuable pieces.

Fig. 167. Foxing on paperwork in the collection.
Source: Miss.Pornganok Sadakorn (25 May 2023)

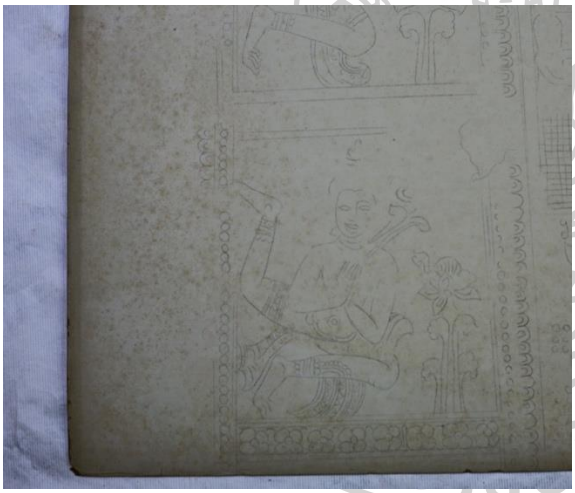

Fig. 168. Biological damage on paperwork.
Source: Miss.Pornganok Sadakorn
(25 May 2023)

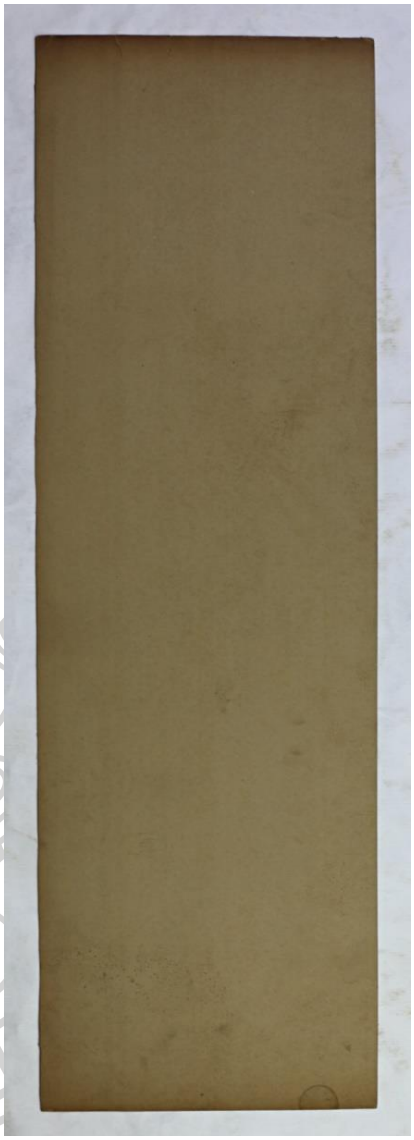

Fig. 169. Degradation of paper.
Source: Miss.Pornganok Sadakorn
(25 May 2023)

In addition to the chemical/internal damage, it is equally important to highlight that approximately 44 pieces of the collection, which are also paper works, have been afflicted with biological damage (Fig. 168). This issue demands immediate attention, emphasizing the need for proper preservation and urgent storage arrangements. Neglecting the conservation of these biologically damaged works could lead to further deterioration, potentially causing irreversible harm to the collection's cultural and historical significance.

Therefore, as soon as this collection of works arrived at the conservation lab, conservationists started working on their conservation and cleaning mold from paper to prevent future degradation of the material's state.

3.4. Collection growth rate

For Ruam Samai Museum, the process of expanding and enriching a collection of antiquities, art items, or museum specimens within the constraints of a museum is referred to as growing a collection within the confines of a museum. This expansion can be accomplished through a variety of means, including acquisitions, donations, purchases, loans, and even field surveys undertaken by museum staff.

Based on a comprehensive examination of collection growth data, specifically focused on the period from 2020 to 2023, it has been ascertained that the collection exhibited a discernible progression. The collection consisted of 4,365 pieces in the year 2020, which subsequently increased to 5,359 pieces by 2021. As of May 27, 2023, the collection has expanded further, encompassing a total of 6,686 pieces. The analysis reveals that the growth rate of the collection exhibits an annual increment of no greater than 25% (Fig. 170). These figures attest to a notable upward trend in the collection's growth, as substantiated by the tabulated data below.

By monitoring the growth of the collection over time, museums can effectively engage in space planning activities. This process enables them to anticipate the storage space requirements necessary to accommodate the continuous expansion of the collection. Consequently, museums can devise strategic plans for acquiring additional storage solutions, such as shelves, cabinets, or other appropriate means, in order to effectively manage and accommodate the growing collection.

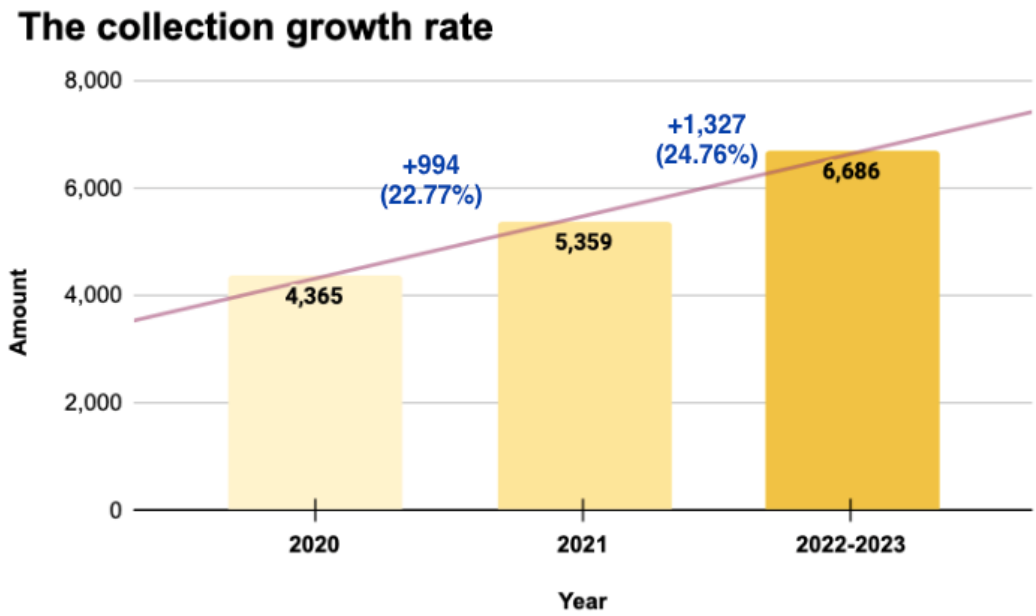

Fig. 170. The chart showing the collection growth rate.
Source: Miss.Pornganok Sadakorn (25 May 2023)

However, there may be exceptions in institutions where separate departments operate almost as separate entities, such as having their own rare book rooms for safe and secure paper storage. The organizing principles for storage by medium involve grouping objects together by organic materials, inorganic materials, synthetic materials, and composite or mixed media objects. Within these groupings, objects may then be further grouped by material and object type, and then by storage method for each type of specimen, artifact, or work of art. Storage by medium or material is a widely adopted and flexible mode of collection storage for artifact and art-based collections, unless there are important reasons to adopt some other mode.

4. Planning for storage space framework

4.1. Building structure and space

For the structure of the storage building, as mentioned earlier in Chapter 2 regarding the approach to be used in designing the building's configuration, the principle adopted is “Stack effect ventilation”. The senior conservator suggests that the building should be designed in the form of an Atrium building to align with this principle.

However, there is currently no initial building design established. Only information such as the building's location, area, access roads, and regulatory guidelines are available. Consequently, in this thesis, these principles are employed to formulate a preliminary prototype plan. This prototype will provide a foundational structure for the architects' forthcoming detailed design stages, ensuring congruence with the requirements of the senior conservator and collection owner.

The storage building prototype presented in this thesis adopts the atrium building concept. This design will influence the setup of storage facilities, the calculation of storage space within the building, and the arrangement of storage areas across different sections, as detailed in this chapter. These considerations encompass aspects such as the placement of furniture for object storage, all grounded in the available foundational data.

The construction of large warehouses is subject to specific restrictions mandated by the building law, which dictate a maximum area of 2,000 sqM per building and a height limit of 15 meters. The information from “SAC Subhashok Art Storage LAW & REGULATION STUDY,” 2020 suggest the available construction options encompass the construction of one building with three floors, resulting in an approximate combined total building area ranging from 5,000-6,000 sqM (Fig. 171 and 172).

Fig. 171. Illustration of the new museum storage location and approximate size of the area.
Source: Miss.Pornganok Sadakorn (12 May 2023)

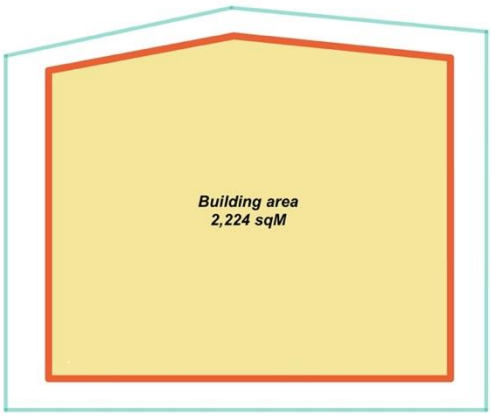

Fig. 172. Illustration of the estimated building area of the museum storage.
Source: Miss.Pornganok Sadakorn (12 May 2023)

Therefore, the current data is used to approximate the design of the space. The building will consist of three floors, each with a height of 5 meters. The width and length of the building are both 44.7 meters, based on the studied building's dimensions. Each floor will have an area of 1,998.09 square meters, resulting in a total approximate building area of 5,994.27 square meters (without considering engineering and architectural details such as wall thickness and others). This obtained data will be utilized to create a preliminary building layout for the purpose of evaluating the storage space for the collection.

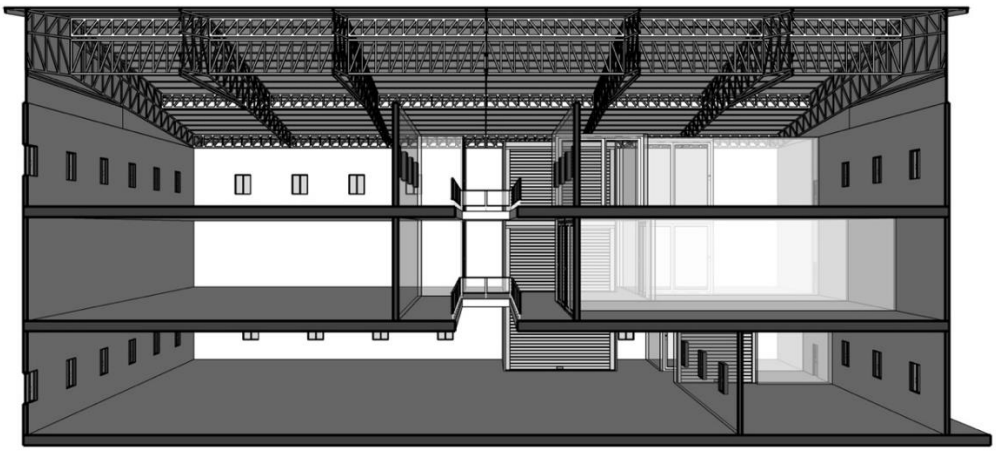

Fig. 173. An illustration of a building structure using the Stack Effected Ventilation concept for the Ruam Samai Museum storage.
Source: Miss.Pornganok Sadakorn (15 August 2023)

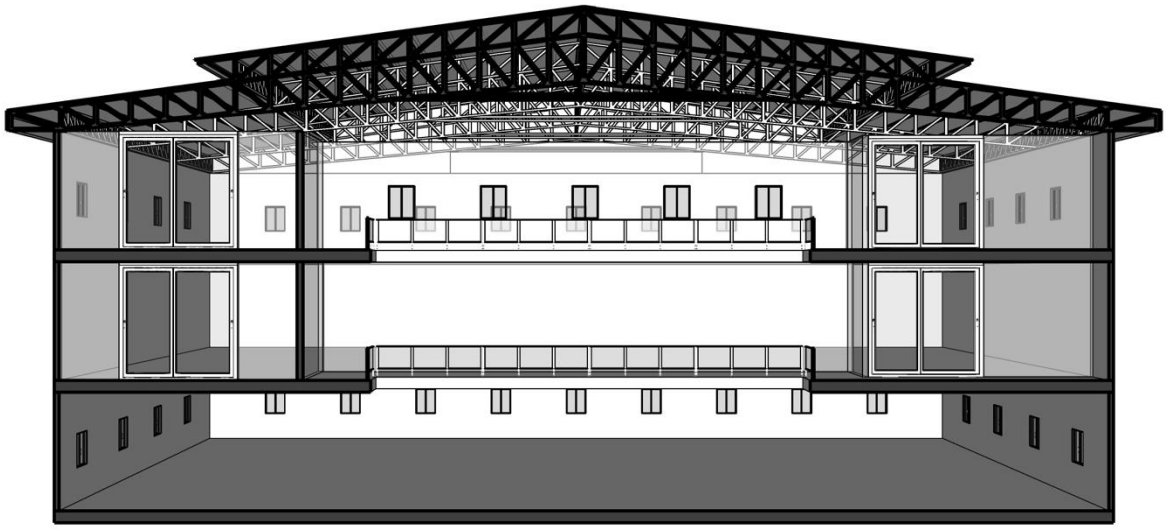

Fig. 174. An illustration of a building structure using the Stack Effected Ventilation concept for the Ruam Samai Museum storage.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Based on the gathered information and the concept of stack effect ventilation, this thesis has developed a preliminary building design. The central area of the building is envisioned as an atrium building resembling a central void, intended to allow air to enter through windows. This design leverages the stack ventilation principle, wherein the ground and upper levels are equipped with windows that align with the stack effect to facilitate air circulation throughout the building, eliminating the need for conventional air conditioning. Nevertheless, considering the sensitivity of certain materials to environmental conditions, the storage rooms housing items such as paper, paintings, photography, textile, glass, and animal products have been designed with controlled temperature and humidity using an HVAC system to prevent any damage to the collection (Fig. 175). For the rooms requiring controlled temperature and humidity, they are strategically located on the second floor to mitigate potential risks, such as flooding or water leakage from the ceiling.

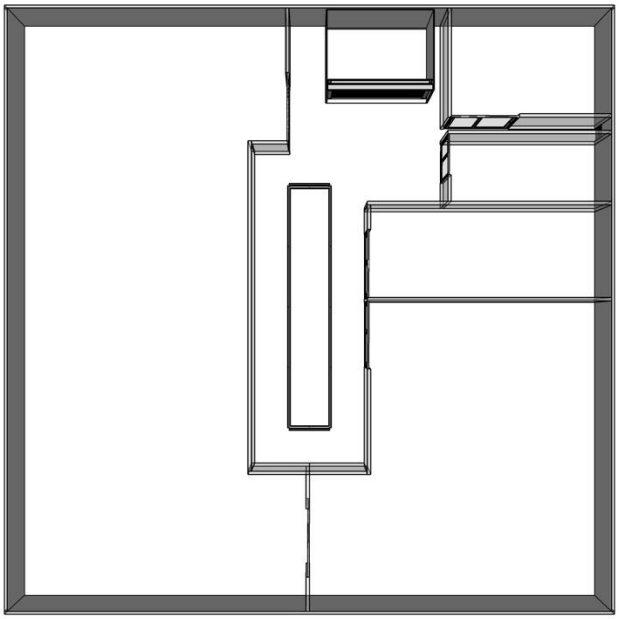

Fig. 175. An illustration at the second floor.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Regarding the building's roof, the conservator recommends a heat-reflective roof that avoids using metal sheets. The roof's dimensions, both in width and length, should extend as much as possible along the sides of the building to prevent sunlight from entering the interior. This design also serves to shield the walls from heavy rain during downpours. Furthermore, the roof's design should align with prevailing wind directions to complement the building's internal airflow system. In cases of rainfall, the number and size of windows must be considered, and they should be designed to harmonize with the overall architectural vision. The design of these windows requires careful consideration and material selection, allowing for proper ventilation while ensuring protection against insects, dust, and security concerns. These factors necessitate close collaboration between architects and engineers in the design process.

Finally, it's important to note that the final architectural design might not precisely align with the concepts discussed in this research, as the information provided here serves solely to support the evaluation of collection storage space.

4.2. Determining of storage facilities

4.2.1. Quantification of needed storage space

From Chapter 2 and 3, the design of Ruam Samai Museum storage facilities and space requirement can be outlined as follows:

Floor 1: This floor consists of various functional areas, including the service yard, receiving Area, loading dock, equipment room, fumigation room, crate storage area, registration area, holding area, and photo area. Additionally, there's dedicated storage space for wooden objects such as furniture, cabinets, tables, and chairs, which require substantial room due to their size and quantity. Based on the collection analysis data, wooden objects demand the most storage space, totaling 995.12 m^3 or 67% of the entire collection. And storing stone and big sculptures that requires the space totaling 8.3 m^3.

Fig. 176. A floor plan at 1st floor.

Source: Miss.Pornganok Sadakorn (15 August 2023)

The total floor area is around 9,990.45 m^3. After allocating space for purposes other facilities, storage rooms area will be approximately 7,125.45 m^3 of space remaining for storage rooms. However, according to theoretical standards, an

additional 20-30% of the storage room area should be set aside for walkways and other utility spaces within the storage room. This adjustment would result in an estimated 4,260.45 m^3 of space available for storage room (Fig. 176). Based on the preliminary data currently available, the collection requires approximately 1,003.42 m^3 of space. This indicates that there is still sufficient room for collection growth within the designated storage area.

Floor 2: This level features the loading dock, conservation lab and office spaces, as well as specialized storage rooms for different types of objects such as paintings, paper, photography, textiles, glass, and animal products. Based on the collection analysis data, the space requirements for different types of artworks are as follows:

- Painting: 28.32 m^3
- Paper, photography, and textile: 185.8 m^3
- Glass objects: 14.6 m^3
- Animal Products: 0.2 m^3

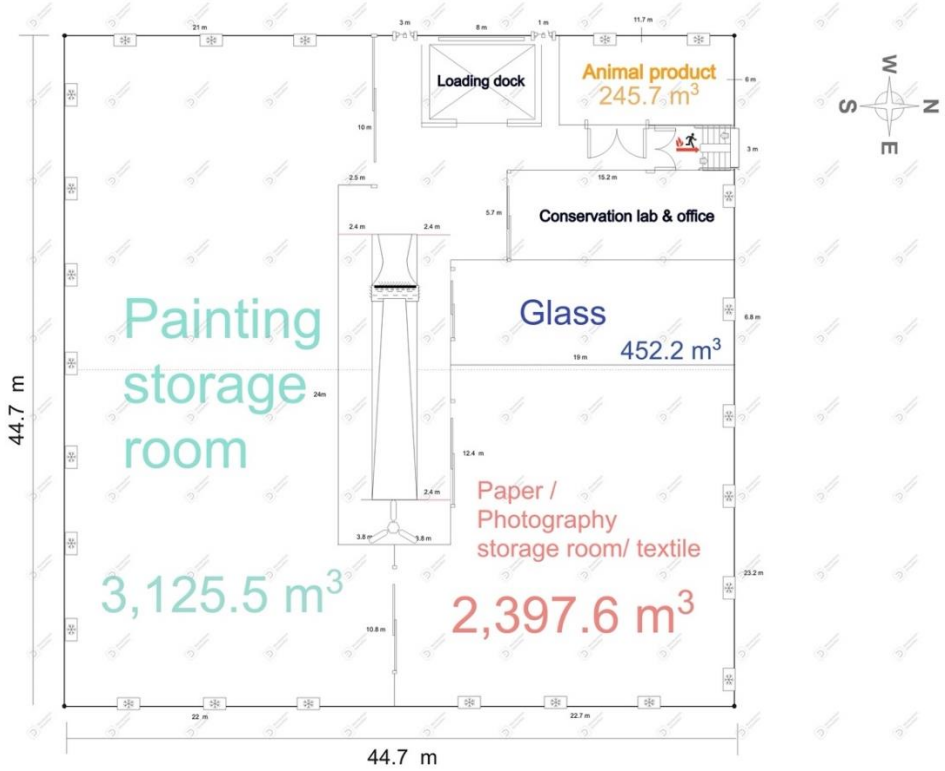

Fig. 177. A floor plan at 2nd floor.

Source: Miss.Pornganok Sadakorn (15 August 2023)

For the second floor, the available area will not be the same as the first floor due to the need to allocate space for air ventilation space in the central area. Therefore, after allocating space for utility purposes, there will be a total of 8,292.75 m^3 of space remaining for storage rooms (Fig. 177). After further allocating space for walkways within each room, the remaining storage areas are as follows:

- Painting room: 3,125.5 m^3
- Paper, photography, and textile room: 2,397.6 m^3
- Glass objects room: 452.2 m^3
- Animal Products room: 245.7 m^3

Floor 3: On the third floor, there are loading docks and storage rooms for ceramics, metals, plastics, and electronic objects. According to the collection analysis data, the space requirements for different types of materials are as follows:

- Metals: 210.4 m^3
- Ceramics: 26 m^3
- Plastics and Electronics: 25.32 m^3

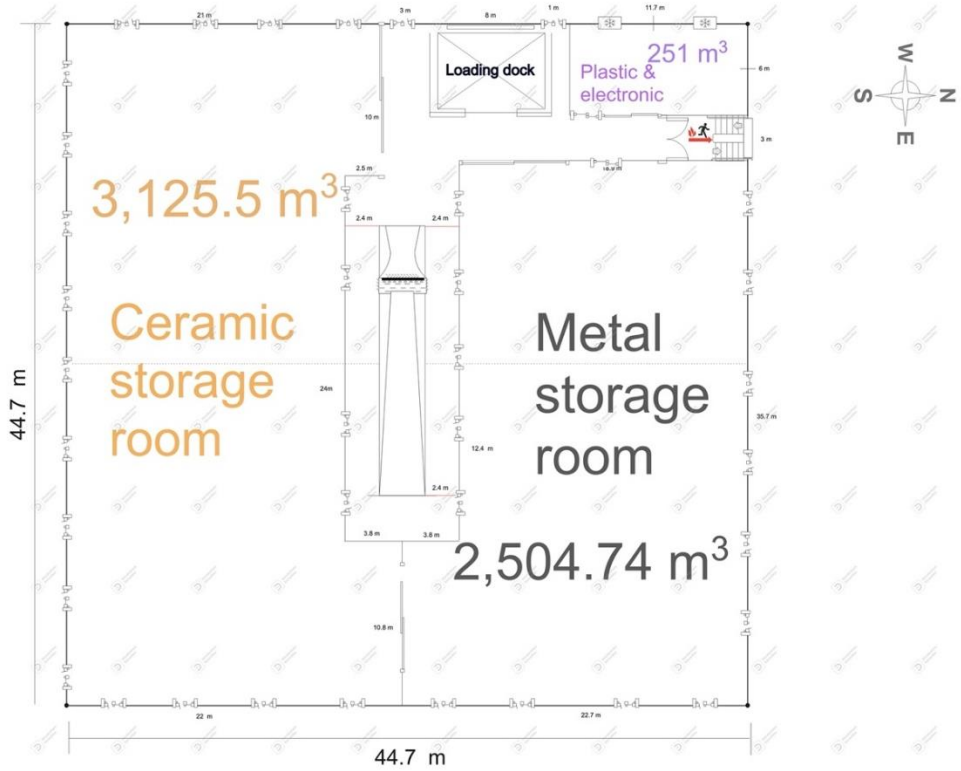

Fig. 178. A floor plan at 3rd floor.

Source: Miss.Pornganok Sadakorn (15 August 2023)

The total floor area of the third floor available for storage rooms is 8,189.6 m^3 (Fig. 178). After allocating space for walkways within each room, the remaining storage areas for each type of material are as follows:

- Ceramic Room: 3,125.5 m^3
- Metal Room: 2,504.74 m^3
- Plastic and Electronic Room: 245.7 m^3

These proposed allocations aim to efficiently accommodate the diverse collection while addressing the specific spatial requirements of various artifact types.

4.2.2. Space requirement for collection growth

After quantifying the required storage space in the previously mentioned, it becomes evident that the storage areas for each room have sufficient space to accommodate future incoming artworks. This conclusion is based on data obtained from the collection analysis and the projected collection growth rate. The analysis indicates that the collection's growth rate is expected to increase annually by no more than 25%. This information can be used to estimate the storage space needed for future years, as shown in the following table:

Table 5. The space requirement for next 10 years.

			Space requirement (m^3) for next 10 years										
	Space area (m^3)	Room	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
1st floor	4,260.45	Wood/ stone	1,003.3	1,254	1,568	1,960	2,450	3,062	3,827.5	4,784	5,980	7,475	9,344
2nd floor	3,125.5	Painting	28.32	35.4	44.25	55.3	70	87.5	109	136.7	170	213.6	267
	2,397.6	Paper/ photography/ textile	185.8	232	290	362.5	453	566	707.5	884	1,105	1,382	1,727
	452.2	Glass	14.6	18.25	22.8	28.5	35.6	44.5	55.6	69.5	87	108.6	135.8
	245.7	Animal products	0.2	0.25	0.3	0.4	0.5	0.6	0.75	0.93	1.2	1.5	1.8
3rd floor	3,125.5	Ceramic	26	32.5	40.6	50.7	63.5	80	100	125	156	195	243.7
	2,504.74	Metal	210.4	263	328.7	410	513.6	642	263	328.7	411	513	642
	245.7	Plastic/ electronic	25.32	31.65	40	50	62.5	78	97.5	122	152	190	238

From Table 5, it can be observed that if there is a 25% increase in objects entering the storage each year, the wood and stone storage room will be able to accommodate objects until the year 2029, which is 6 more years. For other storage

rooms, there will still be sufficient space to accommodate new objects each year. However, it's important to note that this data is a preliminary assessment and does not account for factors such as shelf sizes and storage box dimensions, which could introduce variability in the numbers. Therefore, this information is used for a preliminary evaluation of museum storage furniture layout and as a basis for future design planning of the museum storage building.

Suggestion of storage system

4.3. Determining and laying out the storage furniture system

After designing the storage room layout and evaluating storage space for various types of items within the storage building, the next step is to determine a shelving and storage furniture system that best suits the storage needs of each item type while prioritizing maximum risk and safety considerations. This includes considering factors such as material type, size, weight, condition, and environmental conditions, as well as accessibility within the space.

Floor 1: house a total of 838 pieces of wood and stone objects, such as furniture, buddha statue, manuscript cabinet, sculpture, weapon, kitchenware, vessel, etc.

There are two potential storage system options to consider. The first option is to implement a high-density mobile shelving system. This system aims to optimize space utilization by compacting storage units together, saving valuable floor space. However, it's important to note that the cost of this system is relatively high in Thailand.

Considering this cost factor, an alternative option is to utilize an open-storage system, such as steel adjustable shelving. Items with a height not exceeding 1 meter can be efficiently stored on these shelves, with the overall shelf height not exceeding 4 meters.

Additionally, for items with a larger width and weight, such as cabinets and tables, they can be placed on the floor with protective pallets underneath to prevent moisture absorption from the ground. Smaller items can still be effectively organized within drawer cabinets.

This is the breakdown of storage requirements for different items in *wood category (772 pieces).*

1. Chairs (180 units):

Dimensions: Width 50 cm, Length 70 cm, Height 100 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 300 cm, 16 chairs per shelf

Required Shelf Space: Approximately 108 m^3 (12 shelves)

2. Long wooden benches (37 units):

Dimensions: Width 60 cm, Length 200 cm, Height 100 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 300 cm, 4 benches per shelf

Required Shelf Space: Approximately 90 m^3 (10 shelves) (Fig. 180)

3. Small cabinets (20 units):

Dimensions: Width 50 cm, Length 50 cm, Height 50 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 300 cm, 24 cabinets per shelf

Required Shelf Space: Approximately 9 m^3 (1 shelf)

4. Large cabinets (100 units):

Dimensions: Width 80 cm, Length 150 cm, Height 250 cm (average)

Storage: Place on the floor with pallets

Required Storage Space: Approximately 600 m^3. (Fig. 181.)

5. Tables (30 units):

Dimensions: Width 100 cm, Length 100 cm, Height 100 cm (average)

Storage: Place on the floor with pallets

Required Storage Space: Approximately 150 m^3.

6. Manuscript cabinets (22 units):

Dimensions: Width 90 cm, Length 150 cm, Height 200 cm (average)

Storage: Place on the floor with pallets

Required Storage Space: Approximately 148.5 m^3.

5. Small manuscript cabinets (7 units):

Dimensions: Width 50 cm, Length 60 cm, Height 60 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 200 cm, 20 cabinets per shelf

Required Shelf Space: Approximately 9 m^3 (1 shelf)

6. Large buddha statues (7 units):

Dimensions: Width 60 cm, Length 120 cm, Height 250 cm (average)

Storage: Place on the floor with pallets

Required Storage Space: Approximately 25.2 m^3.

7. Small buddha statues (32 units):

Dimensions: Width 60 cm, Length 60 cm, Height 90 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 300 cm, 15 statues per shelf

Required Shelf Space: Approximately 27 m^3 (3 shelves)

8. Ceremonial items (46 units):

Dimensions: Width 50 cm, Length 50 cm, Height 50 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 200 cm, 30 items per shelf

Required Shelf Space: Approximately 18 m^3 (2 shelves)

9. Miscellaneous items (215 units):

Dimensions: Width 30 cm, Length 50 cm, Height 40 cm (average)

Storage: Adjustable shelves of 300 cm x 60 cm x 300 cm, 30 items per shelf

Required Shelf Space: Approximately 72 m^3 (8 shelves)

10. Kitchenware items (18 units):

Dimensions: Width 50 cm, Length 50 cm, Height 50 cm (average)

Storage: Adjustable shelves size of 300 cm x 60 cm x 200 cm, 18 items per shelf

Required Shelf Space: Approximately 9 m^3 (1 shelves)

11. Sculptures (12 units):

Dimensions: Width 60 cm, Length 60 cm, Height 60 cm (average)

Storage: Adjustable shelves size of 300 cm x 60 cm x 200 cm, 15 items per shelf

Required Shelf Space: Approximately 9 m^3 (1 shelves)

12. Other small objects (17 units):

Dimensions: Width 30 cm, Length 50 cm, Height 40 cm (average)

Storage: Adjustable shelves size of 300 cm x 60 cm x 300 cm, 30 items per shelf

Required Shelf Space: Approximately 9 m^3 (1 shelves)

13. Weapon items (29 units):

Dimensions: Width 30 cm, Length 50 cm, Height 40 cm (average)

Storage: Drawer cabinet size of 250 cm x 60 cm x 200 cm, 30 items per shelf

Required Shelf Space: Approximately 7.5 m^3 (1 shelves) (Fig. 182)

The breakdown of storage requirements for different items in *stone category (66 pieces) following:*

1. Accessories and miscellaneous items (20 units):

Dimensions: Width 20 cm, Length 20 cm, Height 5 cm (average)

Storage: 16 Drawer cabinets size of 150 cm x 60 cm x 200 cm, 320 items per shelf

Required Shelf Space: Approximately 4.5 m^3 (1 cabinet)

2. Buddha statues (21 units):

Dimensions: Width 30 cm, Length 30 cm, Height 120 cm (average)

Storage: Adjustable shelves size of 300 cm x 100 cm x 300 cm, 20 items per shelf

Required Shelf Space: Approximately 30 m^3 (2 shelves)

3. Sculptures (25 units):

Dimensions: Width 50 cm, Length 100 cm, Height 100 cm (average)

Storage: Adjustable shelves size of 300 cm x 100 cm x 300 cm, 9 items per shelf

Required Shelf Space: Approximately 45 m^3 (3 shelves)

Therefore, the area required for arranging storage furniture and organizing storage system for items on the 1st floor should amount to approximately 1,262.7 m^3. This is consistent with the quantification of needed storage space that mentioned in the previous section. (Fig. 179).

Laying out the storage furniture system at 1st floor

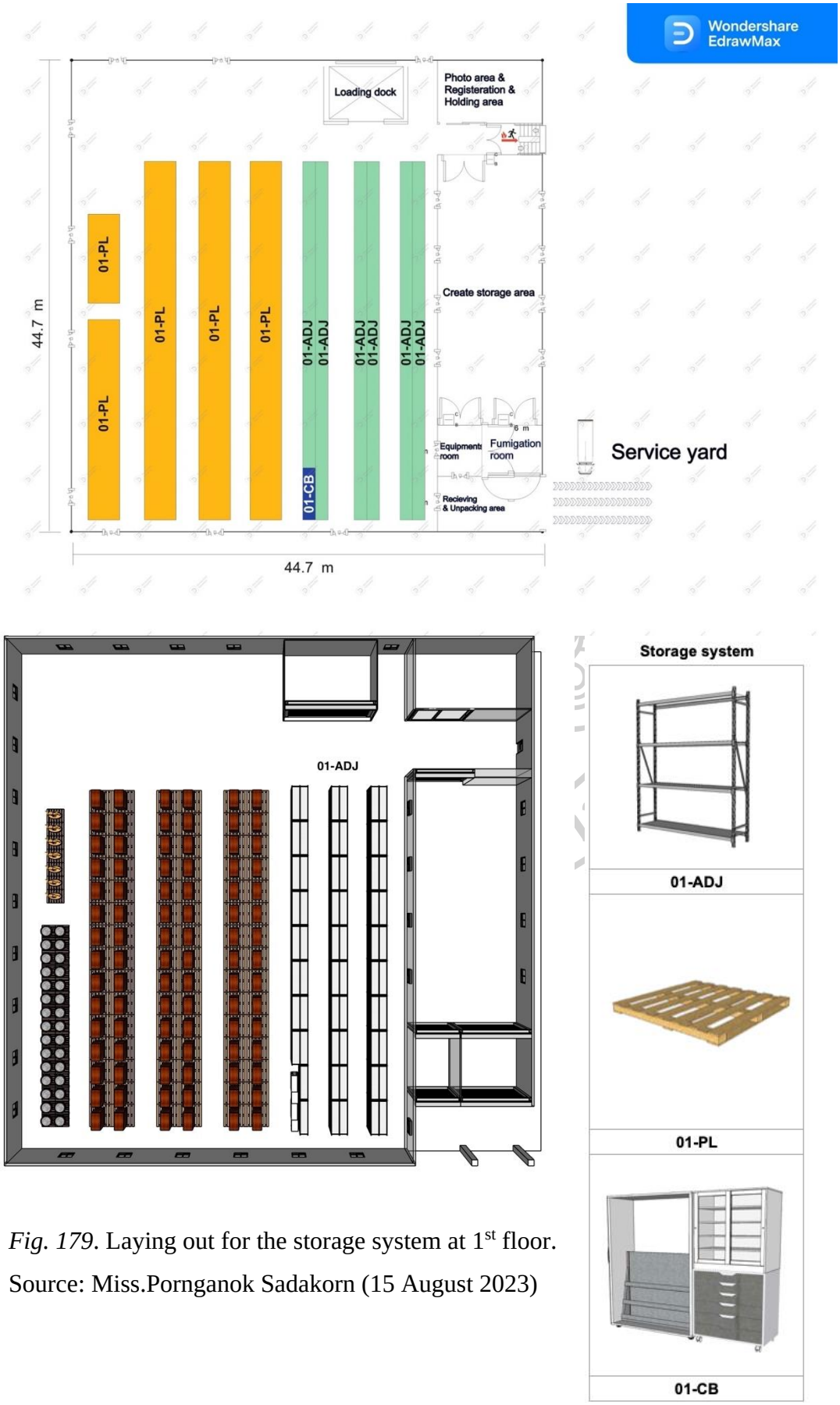

Fig. 179. Laying out for the storage system at 1st floor.
Source: Miss.Pornganok Sadakorn (15 August 2023)

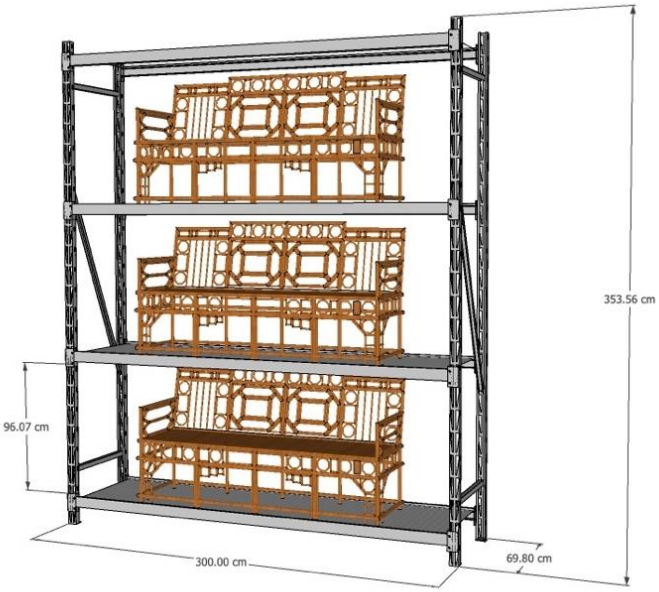

Fig. 180. The storage arrangement of long wooden benches on shelves.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Fig. 181. The storage arrangement of wooden cabinet on pallet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

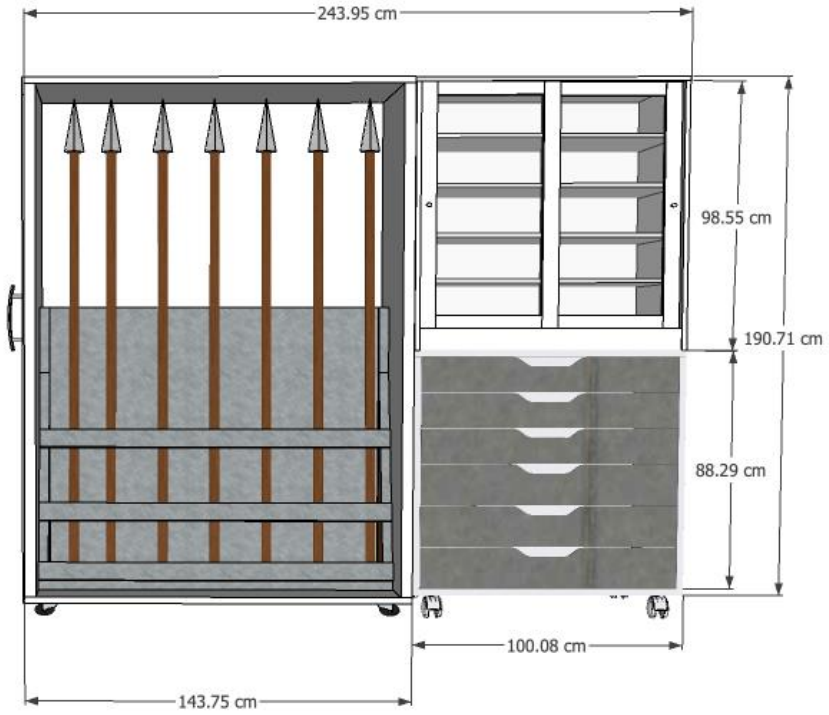

Fig. 182. The storage arrangement of wooden weapon in cabinet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Floor 2: The second-floor area will be used to store various types of artworks, including paintings on canvas, paper, photography, textiles, glass, and animal products, totaling 1,201 pieces.

For paintings on canvas, most of them come with frames and hanging equipment for storage. Therefore, these artworks can be efficiently stored using an art rack system. This system not only saves storage space but also minimizes the risk of overlapping artworks, particularly for larger pieces. This storage system is especially useful for artworks that have substantial dimensions. The space requirement for storing paintings on canvas is 28.32 m^3 for 839 pieces. Therefore, when compared to the initially designed area, there appears to be sufficient space to accommodate all items of this type. However, it's worth noting that the largest painting in this collection measures approximately 300 cm in width, 300 cm in length, and 300 cm in height. As a result, the height of the art rack should be around 3.5 to 4 meters to accommodate such large-sized items.

The configuration of the art rack screen system can vary based on user preferences. There are different options available, such as freestanding pull-out screens that can be pulled out from the sides, compact mobile storage with sliding mechanisms that move forward, or wall-mounted art racks and screens that utilize wall space effectively. The choice of system will depend on the user's specific needs and preferences.

For smaller-sized paintings, particularly those with dimensions around 50 cm wide and no longer than 50 cm, a suitable storage solution involves using designated storage shelves intended for smaller or delicate pieces. Each storage shelf is approximately 60 cm wide, 60 cm deep, and 60 cm high, accommodating one compartment. The combined length of the shelves can extend up to 6 meters and the height can reach up to 1.8 meters, to accommodate a total of 250 pieces of artwork.

The paper works consist of a total of 100 pieces, divided into two types: with framed pieces totaling 56 and without framed pieces numbering 44. Paper artworks with framed can be stored using the same system as painting on canvas. And without framed pieces can be stored in envelopes or mounted and can also be stacked together in map cabinets. The largest size of paper artwork in the collection is approximately 120 cm wide and 130 cm long. Therefore, the storage cabinets should have sufficient width and length to accommodate the paper artworks. The dimensions of the drawer cabinets should be around 150 cm wide and 150 cm long. Each cabinet can store approximately up to 100 pieces of artwork (10 pieces per drawer). The same storage approach can be applied to the photography collection as well.

For the textiles collection, there are a total of 8 pieces, which is relatively small in quantity but has relatively large dimensions. It is necessary to store them in a rolled format. The largest size of fabric in this collection is 300 cm wide and 300 cm long, depicting a textile painting from India. Therefore, it is advisable to choose a storage furniture system specifically designed for textiles, such as steel cantilever shelving. The shelving should have a length greater than the dimensions of the textiles to ensure proper storage.

For the glass objects, which mainly consist of kitchenware pieces and are not significantly large, they can be stored in cabinets. The total number of glass objects in the collection amounts to 69 pieces, with dimensions approximately 40 cm wide, 30

cm long, and 50 cm high. Therefore, storage units of around 120 cm wide, 100 cm long, and 2 meters high are needed, with an estimated requirement of about 5 cabinets (Fig. 184).

As for the animal product objects, there are 185 pieces in the collection, such as ivory carvings and ornamental pieces made from bird feathers. These objects are relatively small, with dimensions around 15 cm wide, 50 cm long, and 15 cm high. They can be placed inside boxes or trays before being stored in cabinets or drawer cabinets. Each cabinet should have dimensions of approximately 200 cm in width, 100 cm in length, and 200 cm in height, approximately 9 cabinets needed (Fig. 183).

Laying out the storage furniture system at 2nd floor

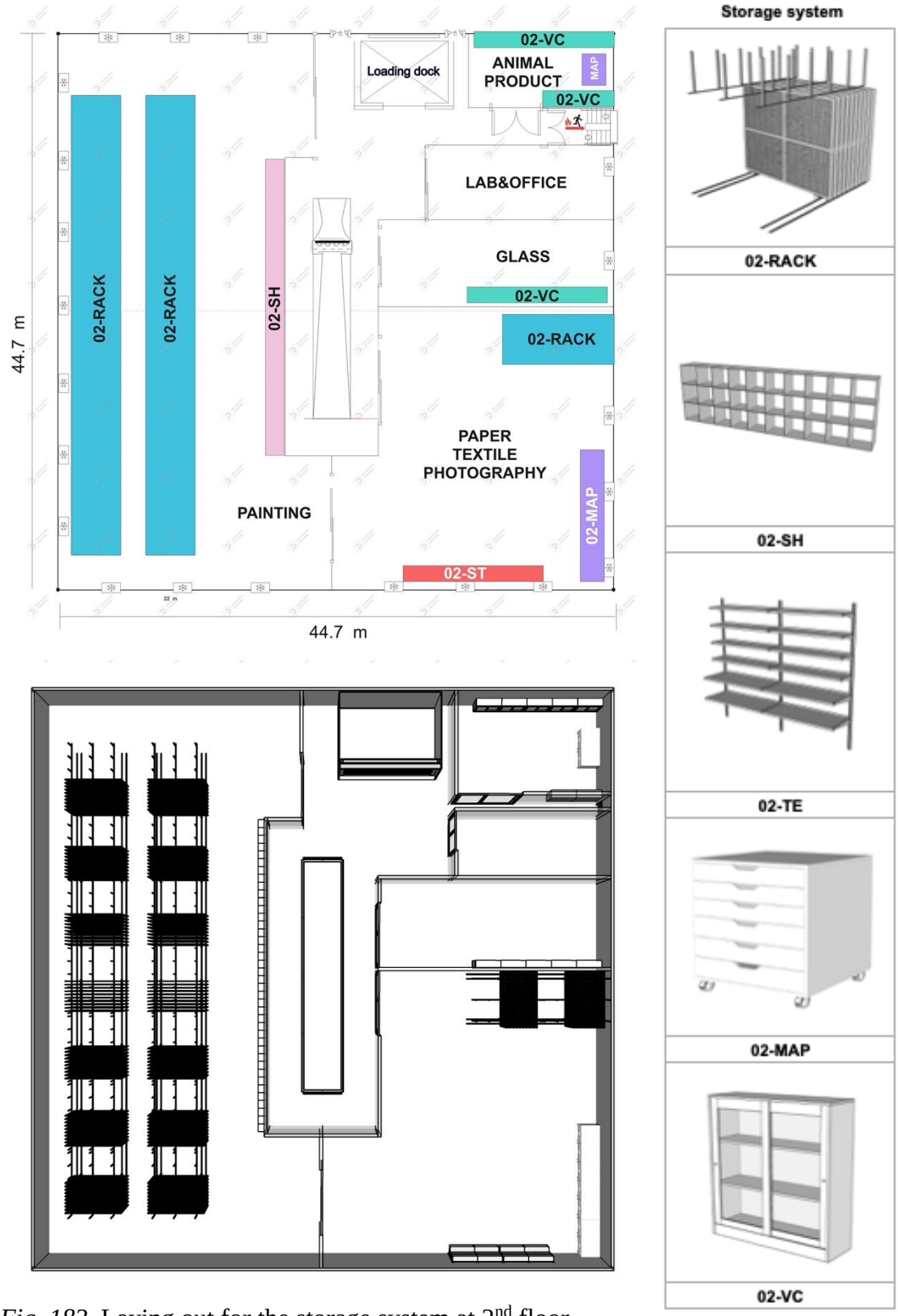

Fig. 183. Laying out for the storage system at 2nd floor.

Source: Miss.Pornganok Sadakorn (15 August 2023)

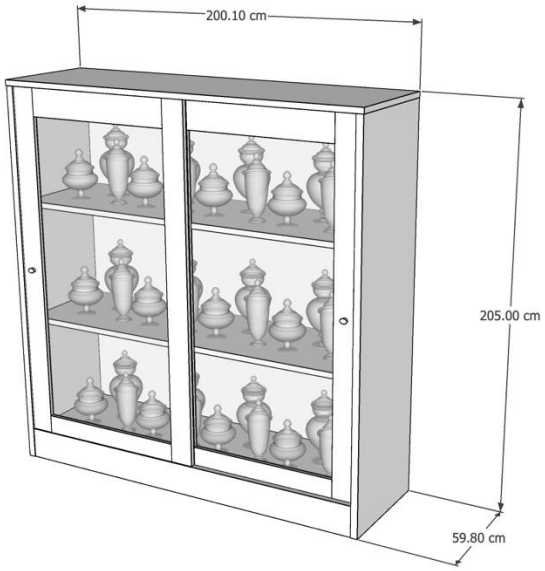

*Fig. 184.*The storage arrangement of glass collection in cabinet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Floor 3: The third floor serves as a storage area for ceramic, metal, plastic, and electronic objects, totaling 3,865 pieces.

The ceramic collection comprises a total of 1,966 pieces, making it the most extensive category within this collection. Due to the relatively low environmental risk associated with ceramics, they can be stored using an open system storage approach, such as metal adjustable shelving and cabinets. Examples of ceramics in this collection include Chinese vessel, kitchenware, coins, and more. This is the breakdown of storage requirements for different items in *ceramic category*.

1. Ceremonial items (74 units):

Dimensions: Width 20 cm, Length 10 cm, Height 40 cm (average)

Storage: Adjustable shelves size of 300 cm x 60 cm x 200 cm, 60 items per shelf

Required Shelf Space: Approximately 18 m^3 (2 shelves)

2. Coin items (391 units):

Dimensions: Width 3 cm, Length 3 cm, Height 1 cm (average)

Storage: Tray with drawer cabinet size of 100 cm x 60 cm x 100 cm, 300 items per shelf (Fig. 186)

Required Shelf Space: Approximately 3 m^3 (2 shelves)

3. Furniture (16 units):

Dimensions: Width 50 cm, Length 50 cm, Height 50 cm (average)

Storage: Adjustable shelves size of 300 cm x 60 cm x 300 cm, 18 items per shelf

Required Shelf Space: Approximately 9 m^3 (1shelves)

4. Iconography items (56 units):

Dimensions: Width 30 cm, Length 30 cm, Height 70 cm (average)

Storage: Adjustable shelves size of 300 cm x 100 cm x 300 cm, 30 items per shelf

Required Shelf Space: Approximately 15 m^3 (2 shelves)

5. Instrument and kitchenware (815 units):

Dimensions: Width 20 cm, Length 15 cm, Height 30 cm (average)

Storage: Visible cabinet size of 300 cm x 40 cm x 200 cm, 60 items per shelf

Required Shelf Space: Approximately 84 m^3 (14 cabinets)

6. Miniature items (66 units):

Dimensions: Width 10 cm, Length 10 cm, Height 10 cm (average)

Storage: Tray and drawer with cabinet size of 100 cm x 60 cm x 100 cm, 300 items per shelf

Required Shelf Space: Approximately 9 m^3 (1 cabinet)

7. Miscellaneous items (185 units):

Dimensions: Width 30 cm, Length 15 cm, Height 20 cm (average)

Storage: Visible cabinet size of 300 cm x 40 cm x 200 cm, 50 items per shelf

Required Shelf Space: Approximately 24 m^3 (4 cabinets) (Fig. 187)

8. Painting items (6 units):

Dimensions: Width 70 cm, Length 70 cm, Height 5 cm (average)

Storage: Painting screen rack on wall size of 280 cm x 280 cm, 16 items per rack

Required Shelf Space: Approximately 7.84 m^3 (1 rack)

9. Sculpture items (250 units):

Dimensions: Width 30 cm, Length 20 cm, Height 40 cm (average)

Storage: Visible cabinet size of 300 cm x 50 cm x 200 cm, 40 items per rack

Required Shelf Space: Approximately 52.5 m³ (7 cabinets)

10. Vessel items (107 units):

Dimensions: Width 50 cm, Length 50 cm, Height 90 cm (average)

Storage: Visible cabinet size of 300 cm x 60 cm x 300 cm, 30 items per rack

Required Shelf Space: Approximately 36 m³ (4 cabinets)

For the metal collection, consisting of a total of 1,856 pieces, it's divided into subcategories such as coins, sculptures, Buddha statues, accessories, and more. Metal objects, it's essential to store them in a tight and secure manner, using cabinets or boxes to protect them from moisture and external air. In the case that use the adjustable shelves, can use the Tyvek cover the shelf to protect from humidity.

This is the breakdown of storage requirements for different items in *metal category.*

1. Accessories (500 units):

Dimensions: Width 15 cm, Length 15 cm, Height 15 cm (average)

Storage: Drawer wit cabinet size of 100 cm x 60 cm x 100 cm, 80 items per cabinets)

Required Shelf Space: Approximately 21 m³ (7 shelves)

2. Ceremonial items (50 units):

Dimensions: Width 70 cm, Length 70 cm, Height 70 cm (average)

Storage: Adjustable shelves size of 300 cm x 80 cm x 300 cm, 12 items per shelf Required Shelf Space: Approximately 60 m³ (5 shelves) (Fig. 188)

3. Furniture and iconography (124 units):

Dimensions: Width 70 cm, Length 80 cm, Height 80 cm (average)

Storage: Adjustable shelves size of 300 cm x 100 cm x 300 cm, 12 items per shelf Required Shelf Space: Approximately 165 m³ (11shelves)

4. Buddha statue (11 units):

Dimensions: Width 80 cm, Length 80 cm, Height 250 cm (average)

Storage: Place on the floor with pallets

Required Shelf Space: Approximately 35.2 m³

5. Kitchenware items (93 units):

Dimensions: Width 20 cm, Length 20 cm, Height 30 cm (average)

Storage: Visible cabinet size of 200 cm x 40 cm x 200 cm, 75 items per rack

Required Shelf Space: Approximately 8 m^3 (2 cabinets)

6. Miscellaneous items (630 units):

Dimensions: Width 40 cm, Length 40 cm, Height 40 cm (average)

Storage: Visible cabinet size of 200 cm x 40 cm x 200 cm, 28 items per rack

Required Shelf Space: Approximately 92 m^3 (23 cabinets)

7. Sculpture items (75 units):

Dimensions: Width 30 cm, Length 430 cm, Height 40 cm (average)

Storage: Visible cabinet size of 200 cm x 40 cm x 200 cm, 40 items per rack

Required Shelf Space: Approximately 8 m^3 (2 cabinets)

8. Vessel items (12 units):

Dimensions: Width 20 cm, Length 15 cm, Height 30 cm (average)

Storage: Visible cabinet size of 200 cm x 40 cm x 200 cm, 60 items per rack

Required Shelf Space: Approximately 4 m^3 (1 cabinets)

9. Weapon items (66 units):

Dimensions: Width 10 cm, Length 60 cm, Height 5 cm (average)

Storage: Visible cabinet size of 200 cm x 40 cm x 200 cm, 30 items per rack

Required Shelf Space: Approximately 12 m^3 (3 cabinets)

For the plastic and electronic objects in this collection, there are a total of 43 pieces, with an average size of approximately 80 cm in width, 60 cm in length, and 50 cm in height. It is necessary to arrange them in adjustable shelving covered with Tyvek fabric to protect against dust and allow for proper ventilation. The size of each shelf and the quantity used are as follows: each shelf is 300 cm wide, 100 cm long, and 300 cm high. There will be a total of 4 shelves (Fig. 185).

Laying out the storage furniture system at 3rd floor

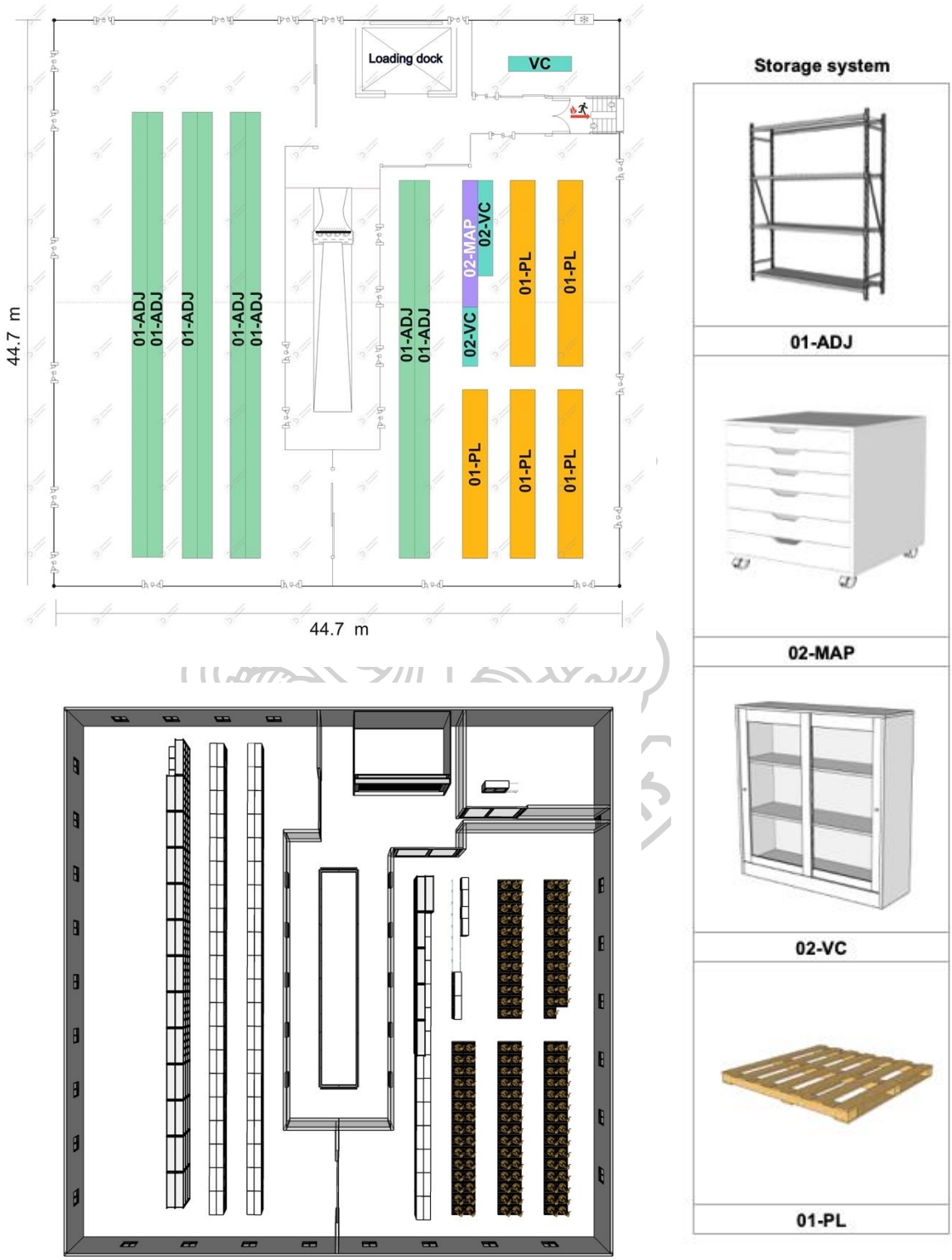

Fig. 185. Laying out for the storage system at 3rd floor.

Source: Miss.Pornganok Sadakorn (15 August 2023)

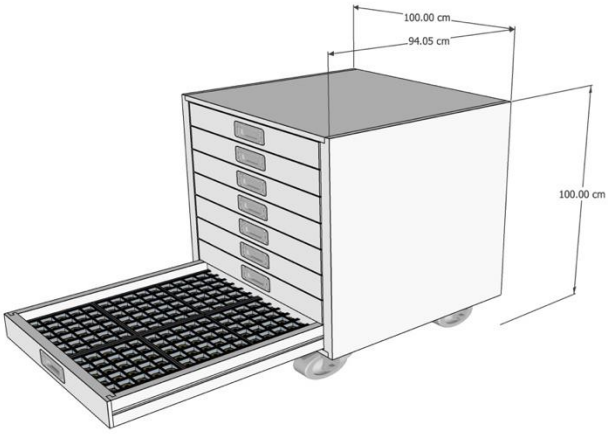

Fig. 186. The storage arrangement of coin with tray in cabinet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

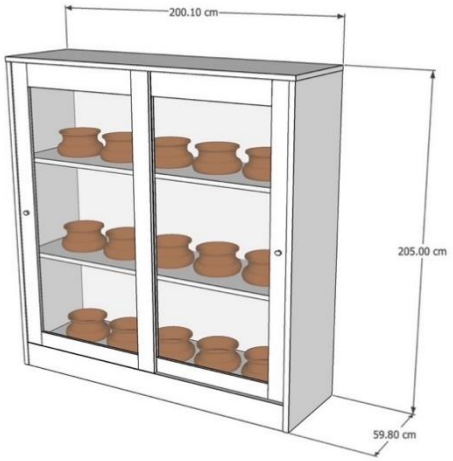

Fig. 187. The storage arrangement of pottery in cabinet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

Fig. 188. The storage arrangement of ceremonial object in cabinet.
Source: Miss.Pornganok Sadakorn (15 August 2023)

4.4. Inventory management

4.4.1. Grouping and accession number of collection

As discussed in Chapter 3, which delves into collection analysis, the process involves categorizing items within a collection based on the material type of the objects. Categorizing items by material type greatly facilitates their storage by ensuring that each material type is appropriately accommodated. Furthermore, this categorization system significantly enhances the accessibility of objects, making the search process much more convenient. This is achieved by aligning the accession numbers of objects with their respective material categories, thereby establishing a seamless connection. Consequently, the accession numbers assigned to objects within this collection serve to indicate a specific material type and usage category. This structured approach streamlines the organization of items, leading to efficient storage and effortless retrieval, ultimately contributing to the overall management of the collection.

Regarding the antique collection, the classification and assignment of accession numbers are contingent upon categorizations, notably with respect to material composition and intended functionality. These antique objects are endowed

with an accession number structured as “SA.Material.Function.No._Year”. As an illustration, consider the instance of SA.TE.Acc.01_2022.

In this nomenclature, 'SA' represents the abbreviated form of the Subhashok Angsuvarnsiri collection, 'TE' stands for textile (indicating the material), 'Acc' signifies accessories (indicating the function), and 'No.' denotes the sequential order of the object, such as 1, 2, 3, and so forth. The appended year is a reference to the year of accession.

The following enumeration encapsulates nine discrete categories, each denoted by its abbreviated form, that encapsulate the diverse constituents of the antique collection based on material composition:

1. Animal product (AP)
2. Ceramic (CE)
3. Glass (GL)
4. Metal (ME)
5. Paper (PA)
6. Plastic (PL)
7. Stone (ST)
8. Textile (TE)
9. Wood (WD)

And this is a list of 14 functional groups, each represented by an abbreviated form, that comprehensively classify the varied components of the antique collection based on their intended purposes:

1. Accessories (Acc)
2. Ceremonial (Cer)
3. Coin (Cin)
4. Furniture (Fur)
5. Iconography (Icn)
6. Instrument (Ins)
7. Kitchenware (Ktw)
8. Manuscript cabinet (Mnc)
9. Miniature (Min)
10. Miscellaneous (Msc)

11. Painting (Pnt)
12. Sculpture (Scu)
13. Vessel (Vsl)
14. Weapon (Wpn)

Within the realm of artwork categorization, three primary groups are discernible as expounded in the collection analysis chapter, namely Thai Modern art, Thai contemporary art, and international art. Contrary to the methodology applied to the antique collection, the accession numbering for these groups is distinct. In this scheme, the registration number is composed predominantly of the artist's name, followed by the work's category, the year of acquisition into the collection, and a sequential order number.

Regarding the inclusion of the artist's name within the accession number, an artist ID specific to each creator, as logged in the system, is utilized. The work's category is classified into eight distinct types:

1. Painting
2. Sculpture
3. Print
4. Mixed media
5. Video
6. Photography
7. Installation
8. Paper

An illustrative instance of an accession number for artworks would be SA-A12-1-2012-01. In this instance, 'SA' abbreviates the Subhashok Angsuvarnsiri collection, 'A12' corresponds to the artist ID related to the twelfth listed artist. The subsequent '1' signifies the work's category, specifically painting. This is followed by the year of acquisition, denoted as '2012,' and concludes with the sequential order of the work, '01'.

Consequently, to enable a thorough understanding of the procedure involved in retrieving objects from the collection, it is essential to undertake an examination of the data concerning the interpretation of accession numbers, coupled with the utilization of the database manual specific to this collection.

The process of designating accession numbers in this manner is correlated with the systematic arrangement of objects based on their materials, rendering retrieval more facile. Additionally, it corresponds to the identification of storage locations within each room, shelf, cabinet, and other storage facilities. Furthermore, it is intertwined with the online database system employed by the museum, as the system's categorical classifications align with the accession numbers. Further elaboration on these aspects will be addressed in the subsequent section.

4.4.2. Collection management system (CMS)

Currently, the Ruam Samai Museum employs an online database system through the platform known as Artlogic Database (Fig. 189). This adoption stems from the system's prior utilization within SAC Gallery, originally designed for art trading purposes. The founder of SAC Gallery is also the same individual behind the establishment of Ruam Samai Museum. This shared ownership prompted the recognition of the potential of this system to be adapted as a database solution for the museum.

While the Artlogic system is primarily designed to serve as an integrated solution tailored to galleries, artists, and collectors, its functionalities can be strategically applied and adapted to suit the needs of a museum collection. It provides a centralized database that empowers businesses to comprehensively manage information concerning clients, suppliers, artists, and the entire spectrum of transactions, dialogues, and offerings.

However, what further highlights the versatility of the Artlogic system is its capability to effectively address various aspects of museum operations. Several functions within Artlogic can be seamlessly tailored and customized to suit the unique demands of a museum's collection. These functions encompass categorization management, a robust search engine, location tracking, loan management, shipping coordination, packing logistics, exhibition management, and the recording of condition and conservation information. Importantly, these features are available in both the Thai and English languages, ensuring that the system is accessible and accommodating to users from different linguistic backgrounds.

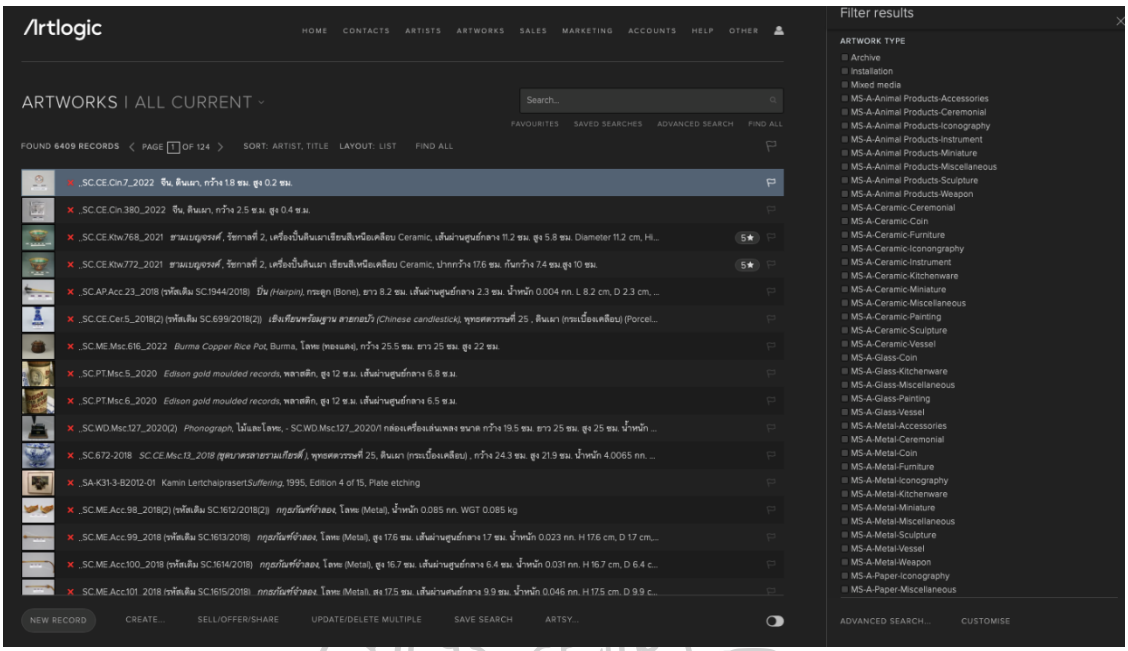

Fig. 189. Ruam Samai Museum database powered by the Artlogic system.

Source: Ruam Samai Museum database (2 August 2023)

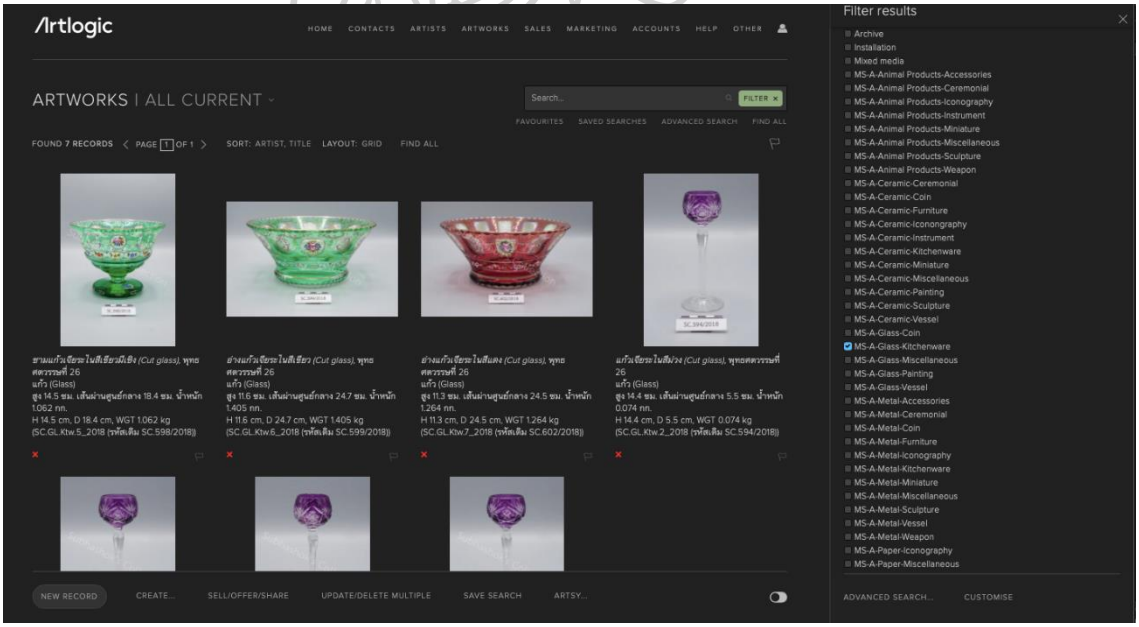

Fig. 190. Displaying the database containing the glass collection (kitchenware) utilizing the Artlogic system.

Source: Ruam Samai Museum database (2 August 2023)

The categorization system within Artlogic corresponds directly to the categories of each object, whether they are antiques or artworks. Artlogic's system can customize various grouping methods according to specific requirements (Fig. 190). This can be observed in the image displayed, which showcases the categorization of antique objects based on material and usage groupings. Items within the same category are placed under a single group to facilitate ease of search.

Moreover, Artlogic incorporates a search engine feature where users can input relevant keywords pertaining to a specific object. This functionality relies on the integration of accurate and comprehensive database entries. Therefore, it becomes essential to input all pertinent information about each object to ensure a seamless search experience. This meticulous data input process enables researchers, curator, conservators, and collection managers to utilize the database more efficiently, ultimately enhancing their ability to access and navigate the information.

Conclusion

The process of gathering information for the spatial planning of storage facility for Ruam Samai Museum project in Chiang Mai focus on the priciple of preventive conservation approach. This encompasses designing the storage facility to understand with environmental considerations and internal air circulation. Furthermore, it involves the information on object storage, including materials, equipment, and furniture, to ensure that the museum's collection are appropriately and safely preserved.

The insights drawn from collection analysis have provided a deeply understanding of the Ruam Samai Museum's collection types, material compositions, condition, collection growth rate and object space requirements. These fundamental insights play a crucial role in guiding storage space management and furniture system design to meet optimal suitability for collection.

The findings in this thesis offer a model scheme for effective planning storage space and facilities, which can serve as a foundational framework for architects and engineers involved in designing the storage facility. This framework aids in managing spatial aspects and fosters a shared comprehension among the team for creating a museum space that aligns seamlessly with the collection that seamlessly aligns with the collection's preventive conservation principles.

However, it's important to note that the matter of stack effect ventilation in building design, discussed in this thesis, demands further exploration, consultation, and collaboration with architectural and conservation experts. Given the potential risks associated with window installations to facilitate proper air circulation, it's essential to address various environmental factors such as insects, dust particles, light exposure, and safety concerns. This calls for ongoing discussions and collaborative efforts among architects, engineers, and conservationists to develop comprehensive strategies for the museum's future design.

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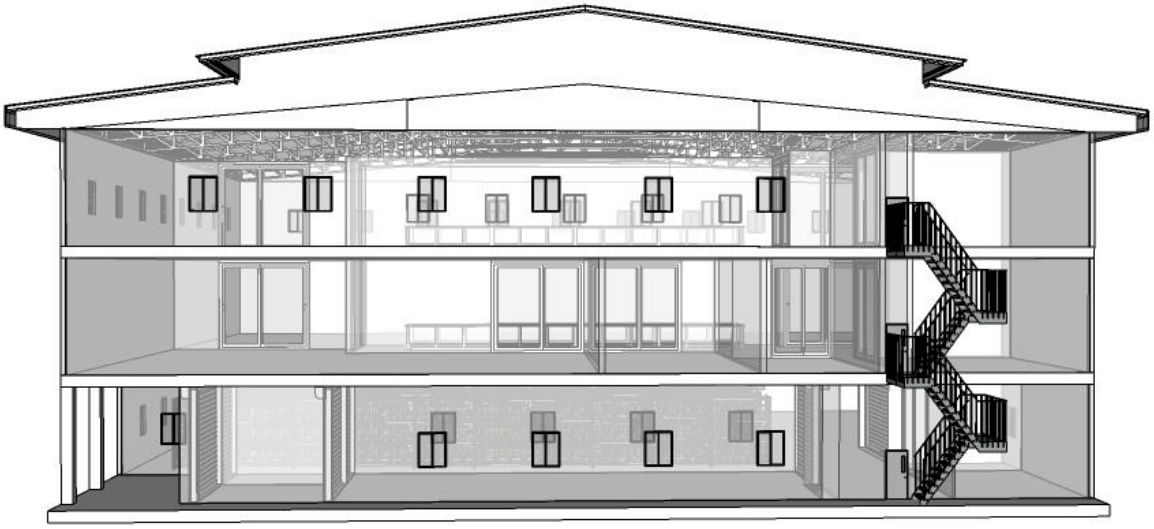
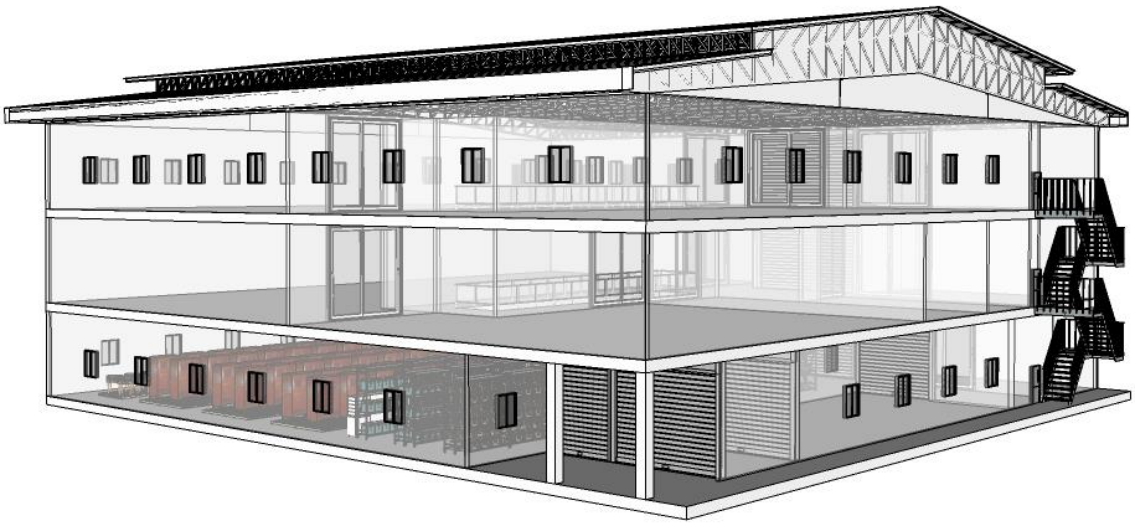
Appendix : Storage building structure for Ruam Samai museum.





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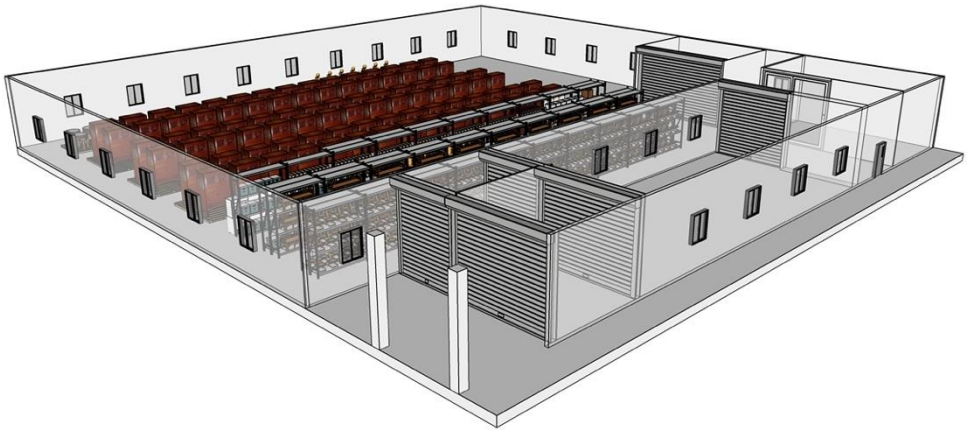
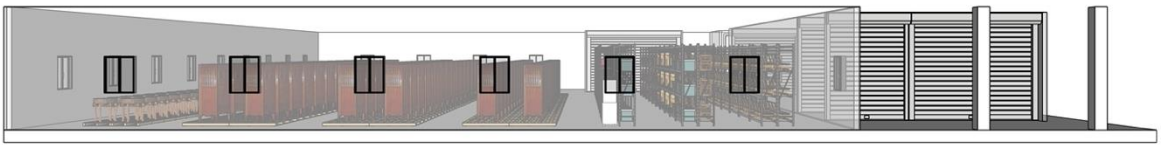
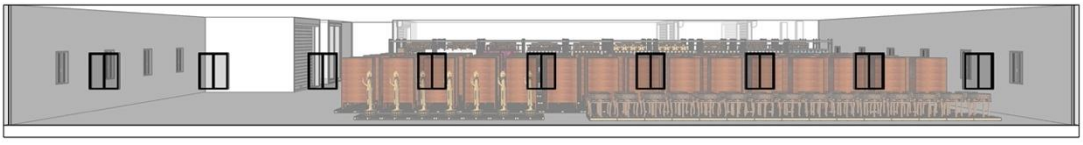
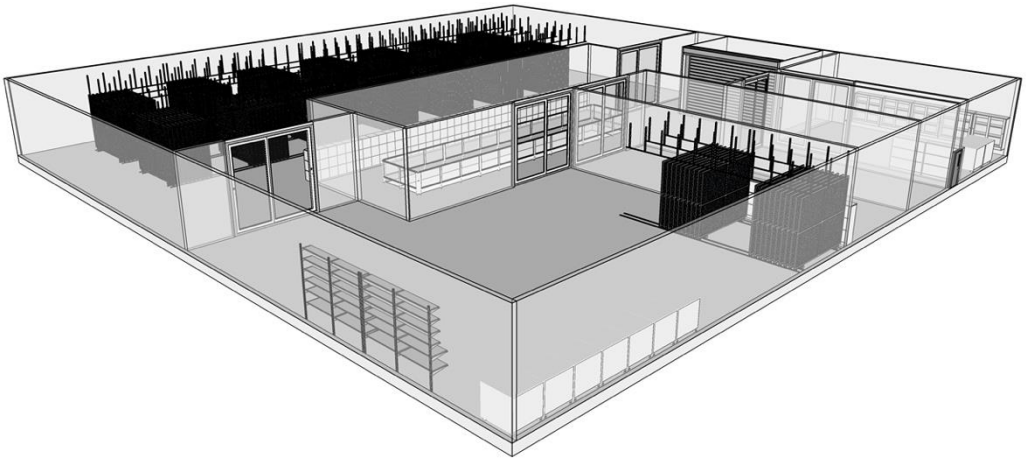


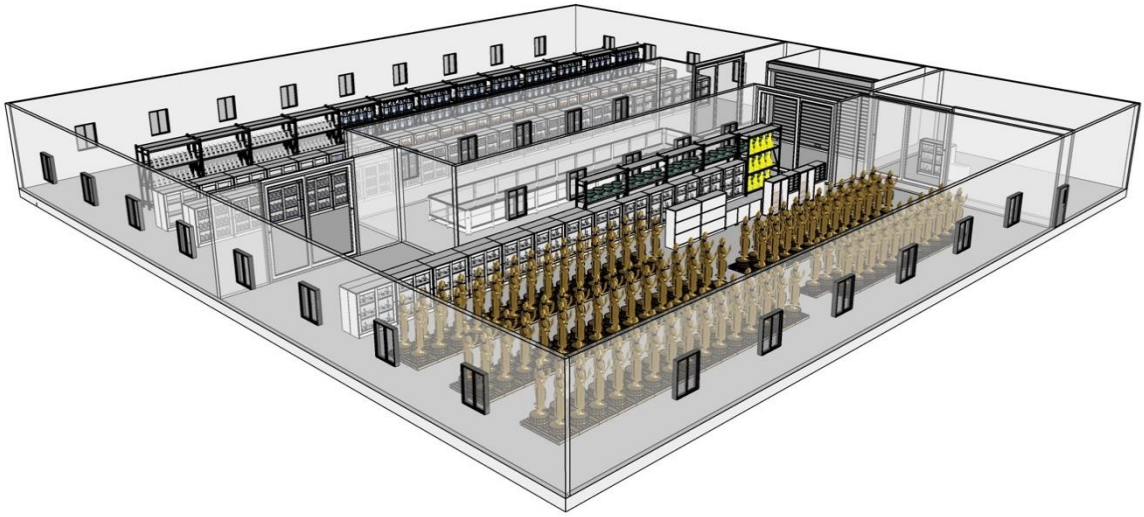




2nd floor



3rd floor



VITA

NAME	Pornganok Sadakorn	
INSTITUTIONS ATTENDED	2018	Bachelor's degree from Faculty of Painting Sculpture and Graphic Art (Art Theory), Silpakorn University.