Museum storage space estimations: In theory and practice

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PREVENTIVE CONSERVATION

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ABSTRACT

Storage space is a major concern for most museums all over the world, yet practical guidance to assess current space usage or future space needs may not be entirely adapted to the needs of non-specialized users. Six published storage space estimation methods are reviewed, compared and tested on a sample storage area, revealing that further guidance to elucidate key concepts and reduce uncertainty is needed.

INTRODUCTION

Worldwide, most museums struggle with storage space; over 60 percent claim that space is insufficient to store their collection, and 25 percent claim that it is difficult or impossible to circulate within storage due to overcrowding (ICCROM-UNESCO 2011). Well-managed storage areas require a holistic approach of which space planning is only one element (ICCROM-UNESCO 2011–2014). Yet, overcrowding can aggravate existing risks or generate new ones: damage through handling, undetected pest infestations, theft or misplacement of objects, or ineffective emergency response. Overcrowding may also diminish a museum's capacity to use collections for the benefit of society through learning, interpretation, exhibitions and research.

Effective space management requires planning. As shown by the Canadian Conservation Institute's (CCI) workshops on storage reorganization, estimating storage space is not straightforward. Museums with reduced resources who wish to assess space efficiency or understand the remaining 'useful life' of their space still feel that they must rely on external assessments. Some do-it-yourself guidance exists, but not all of it is easily accessible or in a ready-to-use format.

This article explores the process of storage space estimation from the perspective of the end user, in this case a staff member without access to outside expertise. Six published methods intended for mixed collections are reviewed and compared by test subjects on a sample storage area containing 257 objects. Perceptions on space estimation were also collected by way of an online survey (224 respondents from 50 countries). This study aims to define key parameters for the development of additional tools for small- and medium-sized museums.

WHY ARE MUSEUMS ESTIMATING STORAGE SPACE?

Whether for internal purposes or for a larger project, the motives and objectives of museum storage space estimations are many, and may focus on an existing storage area, or look into the future at a new yet-to-be-defined space (Figure 1).

PUBLISHED STORAGE SPACE ESTIMATION METHODS, IN THEORY

Defining storage space requirements is a complex task because it involves translating into physical space certain factors that are inherently difficult to quantify, such as projected collection growth and requirements for collections access, use and preventive conservation. While museums may be using different methods (e.g. collections database) to calculate space requirements, this article focuses on published space estimation methods, which will be categorized as approximate (methods A, B, C, D) or precise (methods E, F).

A – Basic order-of-magnitude

This method is part of the "Planning for Collections Storage" chapter in the Lord Cultural Resources' *Manual of Museum Planning*. In this chapter, order-of-magnitude calculations are described as being sufficient for preliminary planning documents, but not to convince a governing board to launch into a large capital project. This method requires the user to adjust the existing floor space to reduce overcrowding and for the possible replacement of fixed shelving with compact shelving. Five- and ten-year floor space projections are made based on a historic annual growth factor (Maximea 2012).

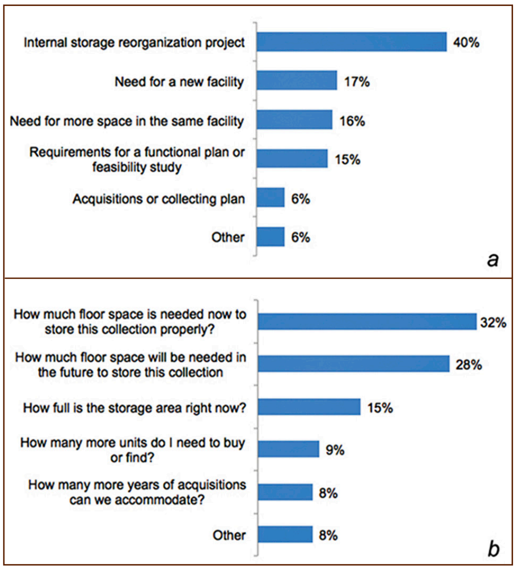

Figure 1
According to 127 respondents working for or in small to large museums: (a) the main reason for estimating space on a recent project; (b) the top question they were trying to answer

B – Guesstimating storage space

This method was developed as an alternative to an object-by-object approach (specifically, to method E below), to produce quick answers required for funding bids and options appraisals. It is presented as useful for 'large collections, where most of the objects are relatively small, the sort one person can lift unaided' at the 'feasibility stage in planning storage' (Chapman 1998, 34, 42). This method begins with a visual estimation of the collection volume, which is adjusted for overcrowding. This volume is then converted into current and future floor space requirements for fixed shelving, compact shelving and open storage, taking into account a storage room lifetime and collection growth factor, and safe collections access. The degree to which the space will accommodate the collection is then determined by dividing each floor space requirement (fixed, compact, open – either current or future) by the total floor space available.

C – RE-ORG

This method is one element in a much larger methodology for storage reorganization – *RE-ORG* (www.re-org.info) – developed as a self-teaching tool for small museums by the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in partnership with the United Nations Educational, Scientific and Cultural Organization (UNESCO). The space estimation method is divided into four steps, beginning with an inventory of existing storage units, followed by a shelf-by-shelf (or unit-by-unit) visual estimation of fullness, overcrowding and room height usage, then by a calculation of effective use of floor space by storage units, and finally, by an overall calculation of the percentage of the fullness of storage when including overflow objects stored on the floor and extra unused units that may be available. Collection growth is considered, but only in the following phase of the methodology.

D – US National Park Service Conserve O Grams

Two guides or *Conserve O Grams* were developed by the United States National Park Service (NPS) focusing on the needs of NPS-operated interpretation centres and museums. The first guide, entitled *Determining museum storage equipment needs* (NPS 1997a), is a stepwise method to define storage unit needs using a list of different unit types that are associated to typical numbers of objects (of various types) they can contain. Using this calibration tool, collection numbers can be converted into unit numbers. The second guide, entitled *Determining museum storage space requirements* (NPS 1997b), focuses on creating a space-efficient and access-friendly layout using cut-outs of the previously identified unit types and numbers (to scale); this method can be used to evaluate whether the units identified in the first guide would fit in a space of known dimensions.

E – Estimating space for ethnographic collections

This method was developed for training purposes in the context of the Prevention in Museums in Africa (PREMA) international courses organized by ICCROM throughout the 1990s. It was designed for large ethnographic collections numbering thousands or hundreds of thousands of objects, where precision is said to be more critical and 'well-documented and credible estimate of the additional space needs' are required. The method is presented as 'accurate and fast' (Walston and Bertram 1992, 137). The starting point is to measure the footprint of each object (or groupings of similar objects) using decimetre (dm) increments and grouping them in height categories. The footprints are then augmented by a 'buffering coefficient' and a collection expansion estimate. Adding the augmented footprints produces a total shelf space requirement (dm^2) per object group, per height category. Shelf space requirements are then multiplied by heights to calculate the total collection volume. Further calculations are suggested to convert volumes into storage units and floor space requirements. The inherent biases of this method and their impact on the accuracy of the results have been reviewed elsewhere (Païn 2009).

F – Detailed calculation method (Lord)

This method is part of the "Planning for Collections Storage" chapter in the Lord Cultural Resources' *Manual of Museum Planning*. It is presented as a more complete and credible alternative to an 'order-of-magnitude' calculation that can account for the 'storage problems that may have built up over many decades' and overcome the challenges of estimating space in storage areas that are 'so crammed and inaccessible'. Among the three detailed calculations presented, the 'more practical' approach uses in-house knowledge to develop size categories tailored to the collection categories, much as in method E. The total object footprint is converted into storage unit footprints by using a 'stacking factor', and a 60 percent circulation factor is applied to determine how much floor space would be required when using fixed shelving; this figure is then adjusted to show the floor space required to store the same collection using compact shelving (Maximea 2012, 277–279).

PUBLISHED STORAGE SPACE ESTIMATION METHODS, IN PRACTICE

Each method was applied, one by one, on a storage area (41 m^2) containing 257 objects (mostly agricultural and domestic items of various sizes) made available by the City of Ottawa's Shared Museum Resources (SMR)

Figure 2
Overview of the case study storage area, Ottawa Shared Museum Resources

Figure 3
Test subjects applying a precise space estimation method

(Figures 2–3). The testing team included the authors and an SMR staff member. The testers had no working familiarity with the methods, with the exception of the main author who helped develop the RE-ORG method. The aim of this exercise was to better understand the possibilities offered by each method and to identify obstacles and areas of uncertainty in their application. It was not designed to make definitive statements about which method provides the most accurate results.

An initial review of each method with the testing team revealed that additional guidance would be required since some methods lacked clear steps to follow and did not define technical terms (A, F); one did not include sample tables for data recording (B). Hence, a one-page 'cheat sheet' of sequential steps and data tables was created for each method. This may have contributed to improving the precision of the results, but it was a necessary step to ensure that all testing could be concluded in one day. Each team member worked independently to minimize biases in opinions and results. A standard annual collection growth rate of 2 percent and time span of 10 years were used when required. Overall, the testing team found that each method had desirable features, but few were easily applied in their published form. The results are summarized in Table 1.

DISCUSSION

Opening the black box: Improving transparency

This exercise confirms that personal interpretations of terminology, and perceptions of what constitute problematic or acceptable situations (e.g. is it too crowded or is there still room for more?) are so varied that ensuring reproducibility, consistency, and thus the credibility of results, becomes a major challenge – particularly for novice users. Personal experience, knowledge, and even personality can have a significant impact on the results.

Some methods provided explicit instructions on how to derive a 'buffering factor' for objects (E), how to calculate overcrowding (C), or benchmarks on what constitutes 'safe access' to collections (C). Yet, in most cases, a number of 'black box' decisions (decisions with known inputs and outputs but for which the thought process is unclear) are solicited, in particular for 'overcrowding', 'compaction', 'stacking', 'circulation space', 'historic annual growth', and even to define 'groups of similar objects'.

Table 2 shows that the inherent variability of these methods has led to some serious discrepancies between test subjects when using the same method (F), and between methods when measuring the same quantity (A, B, F). The extent to which human perception influences results, even when measuring something tangible (a collection and a storage space), is a clear indication that each process should be made more explicit and transparent, so those who later interpret the results understand how the calculations were made, thus enabling them to qualify their conclusions accordingly.

Improving transparency could be approached in different ways: one is through careful documentation of thought processes and paths not taken, as has been suggested for recording conservation decisions with decision diagrams (Michalski and Rossi-Doria 2011); another is to guide users by

Table 1

Summary of the review of space estimation methods, highlighting potential uses, strengths and weaknesses for each

		Possible uses								
	Approximate or Precise	Current floor space needs	Future floor space needs	Current fullness (%)	Collection fitting in a space	Storage unit requirements	Storage system comparison	Developing a storage layout	Strengths	Weaknesses
A - Basic order-of-magnitude	Approximate	✓	✓		✓		✓		• Speed. • Adequate for mixed collection. • Answers key questions. • Ability to see benefits of compact storage. • Calculation table is a useful feature.	• 'Compaction factor' is not defined. • Calculations in table not sufficiently explicit. • No benchmarks to assess suitability (i.e. for overcrowding). • Unusable floor space and overflow objects stored on floor not accounted for. • Would require a step-by-step approach.
B - Guesstimating storage space	Approximate	✓	✓	✓	✓		✓		• Speed. • Simplicity of the calculations. • Ability to compare various storage options side-by-side (fixed, compacted, open). • Accounts for annual growth. • Works well for a mixed collection. • Access and circulation requirements are made explicit and integrated into calculations.	• Method to account for overcrowding is not provided. • Schematic diagrams of density of various storage options per footprint are of little use if no benchmarks are provided as to what constitutes good or bad density. • Unusable floor space and overflow objects stored on floor not accounted for.
C - RE-ORG	Approximate			✓		✓		✓	• Useful supporting materials (forms, case studies, examples, guidelines). • Good compromise between approximate and precise methods. • Reasonable confidence in the reliability of results. • Provides explicit benchmarks for good access (maximum 2 or 3 objects moved to retrieve another). • Overcrowding calculations are explicit. • Available online in English, French and Spanish.	• Fragmentation of method in different worksheets makes it difficult to focus on estimating space only (if not embarking on a full storage reorganization project). • Scattered worksheets make it difficult to print a package to work in storage. • Does not immediately account for collection growth (only later in Phase 2). • Method to handle overflow objects stored on floor is confusing.
D - National Park Service	Approximate	✓			✓	✓	✓	✓	• Simplicity; clarity of instructions. • Inclusion of typical storage unit capacities per object type; useful when there are no units. • Hands-on and low-tech approach; visual and requires few calculations. • Appropriate level for non-specialists. • Available online.	• Does not account for collection growth. • Refers to 'typical' storage units that may not be available everywhere. • No definition or benchmarks provided for 'safe movement', 'adequate access', while precise aisle widths are provided.
E - Ethnographic. collections	Precise	✓	✓		✓	✓			• Clarity of methodology; illustrative examples. • Takes into consideration oversized objects that have unique storage requirements. • Factoring in a set 'buffering' factor for safe access to objects removes any guessing of whether each object has enough circulation space or is too crowded.	• Time consuming. • Best suited for a well-organized, homogeneous collection (determining "object categories" is difficult otherwise). • Difficult to determine where to draw the line with object category specificity.
F - Detailed calculation	Precise	✓			✓				• Presumably produces reliable, accurate results.	• Time consuming. • Best suited for a well-organized, homogeneous collection (determining "object categories" is difficult otherwise). • No definition provided for 'stacking factor'. • Would require a step-by-step approach. • No use for some gathered information (e.g. object height, % total objects).

Table 2

Summary of results for the space estimation exercise. Asterisks (*) indicate results expressing the same quantities (space need in 10 years assuming compact storage is installed). Relative standard deviation is an indication of the degree of variance between test subjects. Method D was excluded from the exercise as it is not calculation based

	Subject 1	Subject 2	Subject 3	Relative standard deviation	Average time per object	Observations about the variance in results
A **Basic order-of-magnitude** *10-year projection, compacted (m^2)	33.5 m^2	29.9 m^2	35.2 m^2	3%	9 s	Discrepancies due to the different figures used for 'overcrowding' (0%, 20%, 30%) and 'compaction factor' (32%, 50%, 46%). Subjects perceived safe access and gained floor space through compaction differently.
B **Guesstimating storage space** *10-year projection, compacted (m^2)	16.2 m^2	18.0 m^2	14.0 m^2	4%	9 s	Discrepancies originate from 'overcrowding' that had to be mentally included in the calculated 'collection volume' (27 m^3, 30 m^3, 23 m^3). Subjects perceived safe access differently.
C **RE-ORG** Fullness of storage, now (%)	44.0%	40.0%	58.0%	7%	11 s	Discrepancies originate from the step that requires users to imagine overflow objects on the floor as though they were inside units to determine the impact on the overall fullness. Subjects' mental mapping was different.
E **Ethnographic collections** 10-year projection, fixed shelving (m^2)	14.4 m^2	9.5 m^2	8.6 m^2	10%	34 s	Discrepancies partly originate from degree of approximation used when defining 'categories of similar objects'. Subjects used 9, 22, and 32 categories, respectively. Total number of objects numbers also varied between subjects.
F **Detailed calculation** *10-year projection, compacted (m^2)	17.5 m^2	326.8 m^2	835.2 m^2	35%	36 s	Discrepancies partly originate from degree of approximation used when defining 'categories of similar objects': 9, 22, and 32 categories respectively, but mostly due to confusion over the term 'stacking factor' (not defined in the method description).

providing methodologies, benchmarks or decision calibration tools to ensure that the results are derived from similar thought processes.

To be, or not to be, precise

Commenting on the accuracy of these methods (how the results obtained compare to a 'correct' value) is complicated by the compounded errors that originate from human perception. That said, considering the small size of the SMR storage area and that the space was not especially overcrowded (every object visible and easily retrievable, aisles mostly uncluttered), some 10-year projections seemed more plausible (A, B) than others (E, F).

In addition to human perception errors, it has been demonstrated that some of the inaccuracy in precise methods originates from variables that cannot be controlled, e.g. the objects' size (the smaller the better), the variability in object sizes (the more varied the better), or the last digit in the dimensions of single objects (the closer to 1 and the farthest from 9, the better); these variables influence the under- or overestimation of space requirements significantly (Païn 2009). Perhaps as a security blanket, some approximate methods included disclaimers that more precise calculations should be used for larger projects (A) or for purposes beyond the feasibility stage (B). This perception was echoed by the respondents to our survey, particularly when estimations would have external uses, or would be tied to a budget. But do the precise methods really yield more accurate results? An important question for smaller institutions is whether an approximate method could be good enough (sufficient confidence in the data) to support a project, or to convince decision makers.

Realistically, it will not always be possible to use a precise method for all projects because of time, money and staff constraints. If objects have excellent documentation that includes measurements for all objects, it may be feasible, for example, to estimate storage unit requirements by using a spreadsheet and dividing the collection volume by volume available in a single unit. However, in many institutions object documentation is often incomplete (ICCROM-UNESCO 2011). This was the case in the SMR storage area, where dimensions had not always been recorded consistently in the past and the collection database could not be used to automate calculations.

Although using a database may work in some cases with objects of regular and easily predictable dimensions, in other cases this is not possible, as these rarely (if ever) indicate whether objects are stored on their side or upright, whether they have enclosures or mounts and of what size, or whether the current storage conditions are acceptable. For segments of the collection where dimensions are fairly regular, it may be possible to extrapolate based on defined volumes, but for peculiar objects (heavy, large, awkwardly shaped), object-by-object or precise methods may be needed. Rare are the projects that would not require a hybrid method.

Assumptions

With the exception of method C, it is significant that most methods assume that storage areas are reasonably well organized, as guidance is seldom provided on how to account for overcrowding, objects that do not belong to the collection, or overflow objects on the floor (A, B, E, F). Even one method (D) – introduced as being useful for situations where objects are stored 'haphazardly in a variety of places: on the floor, on top of file cabinets, on multipurpose shelving and in cabinets with non-museum items' or in an overcrowded space – begins by defining unit needs based on known object quantities and sizes, which may be difficult to define in a disorganized storage area that likely has incomplete documentation (NPS 1997b). Given the poor state of museum storage worldwide, it is surprising that overcrowding is not taken into consideration more in estimation methods.

A recurring assumption in some methods (A, B, F) and in the general literature on storage planning is that a consultant will be hired later in the process (Verner Johnson and Horgan 1979, Bordass 1996). In larger or better-funded projects, it may be possible to conduct a first 'quick and dirty' estimation and then commission a specialist (conservator, shelving contractor, architect firm) to find solutions for specific spaces or to define the requirements for a new space. However, for many small- to medium-sized museums, this will not be possible. The 'quick and dirty' estimation might be the only one, so a better tool is needed for them.

Making the best of what exists

Regardless of their current shortcomings, some general advice can be provided to reduce uncertainty and improve consistency when applying the existing published methods:

- *Calibrate visual estimations.* When working with a colleague on a method that requires shelf-by-shelf or unit-by-unit visual estimations (C), or an overall estimation of overcrowding (A, B), assess the first few storage units together so that each team member has the same conception of fullness, e.g. what '80 percent full' or '150 percent full' means to both people.
- *Develop working benchmarks.* Define some rules-of-thumb that will be used throughout the process to decide what constitutes 'overcrowded', 'enough space for access', or a decent category of objects of similar size. Present these to colleagues to see if they make sense to them.
- *Document the process and be transparent.* Clearly define and disclose the context, the specific questions to be answered, and the boundaries: the working assumptions (e.g. objects will remain in this space), what is included or excluded from the calculations (e.g. objects on the floor, non-collection items), and how any 'black box' decisions that can be potentially influenced by human judgment were made.
- *Double check precision.* When using approximate methods that can be applied reasonably quickly, ask a colleague to do his or her own assessment and compare your results.
- *Double check accuracy.* Make a drawing to scale by hand or by using a free program such as SketchUp (www.sketchup.com), or use the cut-out system proposed in method D, to see what the results mean in concrete terms. Do they still make sense?

CONCLUSION

Based on this review, what is currently available in the published literature on storage space estimation still requires more information and tools to assist users in reducing the level of uncertainty in their calculations. Eliminating uncertainty altogether is not a realistic goal, especially given the variability in project structure and scale, operational and collection requirements, and the sometimes-irregular physical characteristics of spaces. Eliminating the influence of personal perceptions is probably not a realistic goal either. Further developments should aim to provide unambiguous, stepwise instructions that help to make decisions based on clearly defined criteria and benchmarks, and should elicit careful documentation and transparency from its users. A useful space estimation method should be able to provide a meaningful estimate to avoid those unfortunate events when collections are brought into a space for which the requirements have been largely underestimated, or where a large acquisition is made on the assumption that the storage area can still accommodate it.

In most countries, given the current trend in the museum sector towards increasing workloads and fewer staff, access to tools that provide quick, reasonably reliable and credible results is desperately needed. Because there seems to be a general lack of support for storage-related activities (ICCROM-UNESCO 2011), a useful space estimation method would also help museum staff highlight the urgency of the situation to senior managers or the governing body.

The CCI, in collaboration with ICCROM and other partners, is developing new guidance to support project-based, distance-learning activities on storage reorganization as part of a wider initiative called RE-ORG International. This guidance will include a simple tool for estimating storage space that combines the most useful elements of each method (available online in 2016 at http://re-org.iccrom.org).

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