

# Automated Storage & Retrieval System: From Storage to Service

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## ABSTRACT

*The California State University, Northridge (CSUN) Oviatt Library was the first library in the world to integrate an automated storage and retrieval system (AS/RS) into its operations. The AS/RS continues to provide efficient space management for the library. However, added value has been identified in materials security and inventory as well as customer service. The concept of library as space, paired with improved services and efficiencies, has resulted in the AS/RS becoming a critical component of library operations and future strategy. Staffing, service, and security opportunities paired with support and maintenance challenges, enable the library to provide a unique critique and assessment of an AS/RS.*

## INTRODUCTION

“Space is a premium” is a phrase not unique to libraries; however, due to the inclusive and open environment promoted by libraries, their floor space is especially attractive to those within and outside of the building’s traditional walls. In many libraries, the majority of floor space is used to house a library’s collection. In the past, as collections grew, floor space became increasingly limited. Faced with expanding expectations and demands, libraries struggled to identify a balance between transforming space for new services while adding materials to a growing collection. In addition to management activities like weeding, other solutions such as offsite storage and compact shelving rose in popularity as a method to create library space in the absence of new building construction.

Years later as collections move away from print and physical materials, libraries are beginning to reexamine their building’s space and envision new features and services. “Now that so many library holdings are accessible digitally, academic libraries have the opportunity to make use of their physical space in new and innovative ways.”<sup>1</sup>

The CSUN Oviatt Library took a novel approach and launched the world’s first automated storage and retrieval system (AS/RS) in 1991 as a storage solution to resolve its building space limitations. The project was a California State University (CSU) System Chancellor’s Office initiative that cost more than \$2 million to implement and began in 1989. The original concept “came from the warehousing industry, where it had been used by business enterprises for years.”<sup>2</sup> By leveraging and storing physical materials in the AS/RS, the CSUN Oviatt Library is able to create space within the library for new activities and services. “Instead of simply storing information materials, the library space can and should evolve to meet current academic needs by transforming into an environment that encourages collaborative work.”<sup>3</sup>

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Unfortunately, as the first stewards of an AS/RS, CSUN made decisions that led to mismanagement and neglect resulting in the AS/RS facing many challenges in becoming a stable and reliable component of the library. However, recent efforts have sought to resolve these issues and resulted in system updates, management, and functionality. Whereas in the past low-use materials were placed in AS/RS to create space for new materials, now materials are moved into the AS/RS to create space for patrons, secure collections, and improve customer service. As part of this critical review, the functionality and maintenance along with the historical and current management of the AS/RS will be examined.

## **BACKGROUND**

CSUN is the second-largest member of the twenty-three-campus CSU system. The diverse university community includes over 38,000 students and more than 4,000 employees.<sup>4</sup> Consisting of nine colleges offering 60 baccalaureate degrees, 41 master's degrees, 28 credentials in education, and various extended learning and special programs, CSUN provides a diverse community with numerous opportunities for scholarly success.<sup>5</sup>

The CSUN Oviatt Library's AS/RS is an imposing and impressive area of the library that routinely attracts onlookers and has become part of the campus tour. The AS/RS is housed in the library's east wing and occupies an area that is 8,000 square feet and 40 feet high arranged into six aisles. The 13,260 steel bins, each 2 feet x 4 feet, in heights of 6, 10, 12, 15, and 18 inches, are stored on both sides of the aisles enabling the AS/RS to store an estimated 1.2 million items.<sup>6</sup> Each aisle has a storage retrieval machine (SRM) that performs automatic, semiautomatic, and manual "picks" and "deposits" of the bins.<sup>7</sup>

The AS/RS was assessed in 2014 as responsibilities, support, and expectations of the system shifted and previous configurations were no longer viable. Discontinued and failing equipment, unsupported server software, inconsistent training and use, and decreased local support and management were identified as impediments for greater involvement in library projects and operations. Campus provided funding in 2015 to update the server software as well as major hardware components on three of the six aisles. Divided into two phases, the server software upgrade was completed in May 2017 followed by the hardware upgrade in January 2019.<sup>8</sup>

## **LITERATURE REVIEW**

The continued growth of student, faculty, and academic programs along with evolving expectations and needs since the late 1980s has required the library to analyze library services and examine the building's physical space and storage capacity. In the late 1980s, identifying space for increasing printed materials was the main contributing factor in implementing the AS/RS. In the mid-2010s, creating space within the library for new services was dependent on a stable and reliable AS/RS. "The conventional way of solving the space problem by adding new buildings and off-site storage facilities was untenable."<sup>9</sup> A benefit of an AS/RS, as Creaghe and Davis predicted in 1986 was, "the probable slow transition from books to electronic media, an AAF [Automated Access Facility] may postpone the need for future library construction indefinitely."<sup>10</sup>

The AS/RS has enabled the library to create space by removing physical materials while enhancing customer service, material security, and inventory control. "The role of the library as service has been evolving in lockstep with user needs. The current transformative process that takes place in academia has a powerful impact on at least two functional areas of the library:

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library as space and library as collection.”<sup>11</sup> In addition, the “increased security the AAF ... offers will save patrons time that would be spent looking for books on the open shelves that may be in use in the library, on the waiting shelves, misplaced, or missing.”<sup>12</sup> In subsequent years, library services have evolved to include computer labs with multiple high-use printers/scanners/copiers, instructional spaces, individual and group study spaces, makerspaces, etc., in addition to campus entities that have required large amounts of physical space within the library. “It is well-known that academic libraries have storage problems. Traditional remedies for this situation—used in libraries across the nation—include off-site storage for less used volumes, as well as, more recently, innovative compact shelving. These solutions help, but each has its disadvantages, and both are far from ideal. . . . When the Eastern Michigan University Library had the opportunity to move into a new building, we saw that an AS/RS system would enable us to gain open space for activities such as computer labs, training rooms, a cafe, meeting rooms, and seating for students studying.”<sup>13</sup> The AS/RS provides all the space advantages provided by off-site storage and compact shelving while adding much more value while mitigating negatives of off-site time delays and the confusion of accessing and using compact shelving.

## **STAFFING & USAGE**

### *1991–1994*

Following the 80/20 principle, low-use items were initially selected for storage in the AS/RS. “When the storage policy was being developed in [the] 1990s, the 80/20 principle was firmly espoused by librarians. . . . Thus, by moving lower-use materials to AS/RS, the library could still ensure that more than 80% of the use of the materials occurs on volumes available in the open stacks.”<sup>14</sup> Low-use items were identified if one of the following three conditions was met: (1) the item’s last circulation date was more than five years ago; (2) the item was a non-circulating periodical; or (3) items that were not designed to leave an area and received little patron usage such as the reference collection. In 1991, the AS/RS was loaded with 800,000 low-use items and went live for the first time later that year.

Staffing for the initial AS/RS department consisted of one full-time AS/RS supervisor (40 hours/week), one part-time AS/RS repair technician (20 hours/week), and 40 hours a week of dedicated student employees, for a total of 100 hours a week of dedicated AS/RS management. The AS/RS was largely utilized as a specialized service for internal library operations with limited patron-initiated requests. AS/RS operations were uniquely created and customized for each AS/RS operator as well as the desired task needing to be performed. Skills were developed internally with knowledge and training shared by word of mouth or accompanied with limited documentation.

### *2000 - Mid-2000s*

The AS/RS department functioned in this manner until the 1994 Northridge earthquake struck the campus directly and required partial building reconstruction to the library. Although there was no damage to the AS/RS itself or its surrounding structure, extensive damage occurred in the wings of the library. The damage resulted in the library building being closed and inaccessible. When the library reopened in 2000, it was determined that due to previous AS/RS low usage that a dedicated department was no longer warranted. The AS/RS supervisor position was dissolved, the student employee budget was eliminated, and the AS/RS technician position was not replaced after the employee retired in 2008. AS/RS operational responsibilities were consolidated into the Circulation Department and AS/RS administration into the Systems Department. Both circulation



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and systems departments redefined their roles and responsibilities to include the AS/RS without additional budgetary funding, staffing, or training.

In order for AS/RS operations to be absorbed by these departments, changes had to occur in the administration, operating procedures, staffing assignments, and access to the AS/RS. All five Circulation staff members and twenty student employees received informal training by members of the former AS/RS department in the daily operations of the AS/RS. The Circulation members also received additional training for first-tier troubleshooting of AS/RS operations such as bin alignments, emergency stops, and inventory audits. The AS/RS repair technician remained in the Systems Department; however, AS/RS troubleshooting responsibility was shared among the Systems support specialists and dedicated AS/RS support was lost. The administrative tasks of scheduling preventive maintenance services (PMs), resolving AS/RS hardware/equipment issues with the vendor, and maintaining the server software remained with the head of the Systems Department.

Without a dedicated department providing oversight for the AS/RS, issues and problems began to occur frequently. Circulation had neither the training nor resources available to master procedures or enforce quality control measures.

Similarly, the systems department became increasingly removed from daily operations. Many issues were not reported at all and became viewed as system quirks that required workarounds or were viewed as limitations of the system. For issues that were reported, troubleshooting had to start all over again and Systems relied on Circulation staff being able to replicate the issue in order to demonstrate the problem. System's personnel retained little knowledge on performing daily operations, and troubleshooting became more complex and problematic as different operators had different levels of knowledge and skill that accompanied their unique procedures.

#### *Mid-2000s-2015*

These issues became further exasperated when areas outside of Circulation were given full access to the AS/RS in the mid-2000s. Employees from different departments of the library began entering and accessing the AS/RS area and operated the AS/RS based on knowledge and skills they learned informally. Student assistants from these other departments also began accessing the area and performing tasks on behalf of their informally trained supervisors. Further, without access control, employees as well as students ventured into the "PIT" area of the AS/RS where the SRMs move and end-of-aisle operations occur. This area contains many hazards and is unsafe without proper training.

During this period, the Special Collections and Archives (SC/A) Department loaded thousands of un-cataloged, high-use items into the AS/RS that required specialized service from Circulation. These items were categorized as "Non-Library of Congress" and inventory records were entered into the AS/RS software manually by various library employees. In addition, paper copies were created and maintained as an independent inventory by SC/A. Over the years, the SC/A paper inventory copies were found to be insufficiently labeled, misidentified, or missing. Therefore, the AS/RS software inventory database and the SC/A paper copy inventory contained conflicts that could not be reconciled. To resolve this situation, an audit of SC/A materials was completed in spring 2019 to locate inventory that was thought to be missing.

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All bound journals and current periodicals were eventually loaded into the AS/RS as well, causing other departments and areas to rely on the AS/RS more heavily. Departments such as Interlibrary Loan and Reserves, as well as patrons, began requesting materials stored in the AS/RS more routinely and frequently. The AS/RS transformed from a storage space with limited usage to an active area with simultaneous usage requests of different types throughout the day. Without a dedicated staff to organize, troubleshoot, and provide quality control, there was an abundance of errors that led to long waits for materials, interdepartmental conflicts, and unresolved errors.

High-use materials from SC/A, as well as currently received periodicals from the main collection, were the catalysts that drove and eventually warranted change in the AS/RS usage model from storage to service. The inclusion of these materials created new primary customers identified as internal library departments: SC/A and Interlibrary Loan (ILL). With over 4,000 materials contained in the AS/RS, SC/A requires prompt service for processing archival material into the AS/RS and filling specialized patron requests for these materials. In addition, ILL processes over 500 periodical requests per month that utilize and depended on AS/RS services. The additional storage and requests created an uptick in overall AS/RS utilization that carried over into Circulation Desk operations as well.

#### *2015–Present*

The move from storage to service was not only inevitable due to an evolving AS/RS inventory, but was necessary in order to regain quality control and manage the library-wide projects that involved the AS/RS. The increased usage and reliance on the AS/RS required the system be well maintained and managed. Administration of the AS/RS remains within Systems and Circulation student employees continue to provide supervised assistance to the AS/RS. The crucial change was identified and emerged within Circulation for a dedicated operations and project manager. An AS/RS lead position was created with responsibilities for the daily operations and management of the system and service. However, this was not a complete return to the original staffing concept of the early 1990s. The concept for this new position focuses on project management and system operations rather than the original sole attention to system operations. The AS/RS lead is the point of contact for all library projects that utilize the AS/RS, relaying any AS/RS issues or concerns to Systems, and daily AS/RS usage. This shift is necessary due to the increased demand and reliance on the system that has changed its charge from storage to service.

### **CUSTOMER SERVICE**

The library noted over time that the AS/RS could be used as a tool in weeding and other collection shift projects to create space and aid in reorganizing materials. As more high-use materials were loaded into the AS/RS the indirect advantages of the AS/RS became more apparent.

Patrons request materials stored within the AS/RS through the library's website and pick up the materials at the Circulation desk. There is no need for patrons to navigate the library, successfully use the classification system, and search shelves to locate an item that may or may not be there. As Kirsch notes, "The ability to request items electronically and pick them up within minutes eliminates the user's frustration at searching the aisles and floors of an unfamiliar library."<sup>15</sup> The vast majority of library patrons are CSUN students that commute and must make the best use of their time while on campus. Housing items in the AS/RS creates the opportunity to have hundreds of thousands of items all picked up and returned to one central location. This makes it far easier for library patrons, especially users with mobility challenges, to engage with a plethora of library



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materials. The time allotted for library research and/or enjoyment becomes more productive as their desired materials are delivered within minutes of arriving in the building. As Heinrich and Willis state, “the provision of the nimble, just-in-time collection becomes paramount, and the demand for AS/RS increases exponentially.”<sup>16</sup>

AS/RS items are more readily available than shelved items on the floor, as it takes minutes to have AS/RS items returned and made available once again. “They may be lost, stolen, misshelved, or simply still on their way back to the shelves from circulation—we actually have no way of knowing where they are without a lengthy manual search process, which may take days. . . . Unlike books on the open shelves, returned storage books are immediately and easily ‘reshelved’ and quickly available again.”<sup>17</sup> Another advantage is there is no need to keep materials in call-number order with the unpleasant reality of missing and misshelved items. Items in the AS/RS are assigned bin locations that can only be accessed by an operator- or user-initiated request. The workflow required to remove a material from the AS/RS involves multiple scans and procedures that increase accountability that does not exist for items stored on floor shelves. Further, users are assured of an item’s availability within the system. Storing materials in the AS/RS ensures that items are always checked out when they leave the library and not sitting unaccounted for in library offices and processing areas. It also avoids patron frustration of misshelved, recently checked-out, or missing items.

## **SECURITY**

The decision to follow the 80/20 principle and place low-use items in the AS/RS meant high-use items remained freely available to library patrons on the open shelves of each floor. This resulted in high-use items being available for patron browsing and checkout, as well as patron misuse and theft. The sole means of securing these high-use items involved tattle-tape and installing security gates at the main entrance. Therefore, the development of policies and procedures for the enforcement of these gates was also required. Beyond the inherent cost, maintenance, and issue of ensuring items are sensitized and desensitized correctly, gate enforcement became another issue that rested upon the Circulation Department. Assuming theft would occur by exiting the building through passing through the gates at the main entrance of the library, enforcement is limited in actions that may be performed by library employees. Touching, impeding the path, following, detaining, searching, etc. of library patrons are restricted actions reserved for campus authorities such as the police and not library employees.

Rather than attempting to enforce a security mechanism in which we have no authority, the AS/RS provides an alternative for the security of high-use and valuable materials. Storing items in the AS/RS eliminates the possibility of theft or damage by visitors and places control and accountability over the internal use of materials. “There would be far fewer instances of mutilation and fewer missing items.”<sup>18</sup> Further, access to the AS/RS area was restricted from all library personnel to only Circulation and Systems employees with limited exceptions. Individual logins also provided a method of control and accountability as each operator is required to use a personal account rather than a departmental account to perform actions on the AS/RS. Materials stored in the AS/RS are, “more significantly . . . safer from theft and vandalism.”<sup>19</sup>

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## INVENTORY

Conducting a full inventory of a library collection is time consuming, expensive, and often inaccurate by the time of completion. Missing or lost items, shelf reading projects, in-process items, etc. create overhead for library employees and generate frustration for patrons searching for an item.

Massive, library-wide projects such as collection shifts and weeding are common endeavors undertaken to create space, remove outdated materials, and improve collection efficiency. However, actions taken on an open shelves collection is time consuming, costly, inefficient, and affect patron activities. These projects typically involve months of work that involve multiple departments to complete. Items stored within the AS/RS do not experience these challenges because the system is managed by a full-time employee throughout the year and not on a project basis. The system is capable of performing inventory audits, and does not affect public services. Therefore, while the cost of an item on an open shelf is \$0.079, the cost of storing the same item in the AS/RS is \$0.02<sup>20</sup>

Routine and spot audits ensure an accurate inventory, confirm capacity level of the system, and establish best management of the bins. AS/RS inventory audits are highly accurate and much more efficient than shelf reading with little impact to patron services. "While this takes some staff time, it is far less time-consuming than shelf reading or searching for misshelved books."<sup>21</sup>

Storing materials in the AS/RS is more efficient than on open shelves; however, bin management is essential in ensuring bins are configured in the best arrangement to achieve optimal efficiency. The size and configuration of bins directly affects storage capacity. Type of storage, random or dedicated, also influences capacity, efficiency, and accessibility of items.

The 13,260 steel bins in the AS/RS range in height from 6 to 18 inches. The most commonly used bins are the 10- and 12-inch bins; however, there is a finite number of these bin heights. Unfortunately, the smallest and largest bins are rarely used due to material sizes and weight capacity; therefore, AS/RS optimal capacity is unattainable and the number of materials eligible for loading limited by number of bins available.

The library also determined that dedicated, rather than random, bin storage type aided in locating specialized materials, reduced loading and retrieval errors, and enhanced accessibility by arranging highly used bins to reachable locations. In the event an SRM breaks down and an aisle becomes nonfunctional for retrieving bins, strategically placing the highest used and specialized locations in bins that can be manually pulled is a proactive strategy. However, this requires dedicated bins with an accurate and known inventory that has been arranged in accessible locations.

## LESSONS LEARNED

### *Disasters & Security*

In 1994, the AS/RS proved to provide a much more stable and secure environment than the open stacks when it successfully endured a 6.9 earthquake. The reshelving of more than 300,000 items required a crew of more than thirty personnel over a year to complete. Many items were destroyed from the impact of falling to the floor and being buried underneath hundreds of other



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items. The AS/RS in contrast consisted of over 800,000 items and successfully sustained the brunt of the earthquake's impact with no damage to any of the stored items.

Unfortunately, the materials that had been loaded into the AS/RS in 1991 were low-use items that were viewed as one step from weeding. Therefore, high-use items stored in open shelves were damaged and required the long process of recovery and reconstruction: identifying and cataloging damaged and undamaged materials, disposal of those damaged, renovation of the area, and purchase of new items. The low-use items stored in the AS/RS by contrast required a few bins that had slightly shifted be pushed back fully into their slots. AS/RS items have proven to be more secure from misplacement, theft, and physical damage from earthquakes as compared to items in open shelves.

### ***Maintenance, Support, and Modernization***

The CSUN Oviatt Library has received two major updates to the AS/RS since it was installed in 1991. In 2011, the AS/RS received updates for communication and positioning components. The second major update occurred in two phases between 2016 and 2018 and focused on software and equipment. In phase one, server and client-side software was updated from the original software created in 1989. In phase two, half the SRMs received new motors, drives, and controllers. Due to the many years of reliance on preventive maintenance (PM) visits and avoidance of modernization, our vendors were unable to provide support for the AS/RS software and had difficulty locating equipment that had become obsolete.

Preventive maintenance visits were used to maintain the status quo and are not a long-term strategy for maintaining a large investment and critical component of business operations. Creaghe and Davis note that, "current industrial facility managers report that with a proper AAF [Automated Access Facility] maintenance program, it is realistic to expect the system to be up 95-98 percent of the time."<sup>22</sup> PM service is essential for long-term AS/RS success; however, preventive maintenance alone is incapable of modernization and ensuring equipment and software do not become obsolete. Maintenance is not the same as support, rather maintenance is an aspect of support. Support includes points of contacts who are available for troubleshooting, spare supplies on hand for quick repairs, a life-cycle strategy for major components, and long-term planning and budgeting. Kirsch attested the following describing Eastern Michigan University's strategy: "Although the dean is proud and excited about this technology, he acknowledges that just like any computerized technology, when it's down, it's down." To avoid system problems, EMU bought a twenty-year supply of major spare parts and employs the equivalent of one-and-a-half full-time workers to care for its automated storage and retrieval system."<sup>23</sup> A system that relies solely on preventive maintenance will quickly become obsolete and require large and expensive projects in the future if the system is to continue functioning. Further, modernization provides an avenue for new features and functions to be realized that increase functionality and efficiency.

### ***Networking***

The CSUN Oviatt Library on average receives between three to four visits a year along with multiple emails and phone conversations requesting information from different libraries regarding the AS/RS. These conversations aid the library by viewing the AS/RS in different perspectives and forces the library to review current practices.

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The library has learned through speaking with many different libraries that needs, design, and configuration of an AS/RS can be as unique as the libraries inquiring. The CSUN Oviatt Library, for example, is much different than the three other CSU system libraries that have an AS/RS. Due to our system being outdated, it has been difficult to form or establish meaningful groups or share information because the systems are all different from each other. As more conversations occur and systems become more modern and standard, there is potential for knowledge sharing as well as group lobbying efforts for features and pricing.

### ***Buy In***

User confidence in any system is required in order for that system to be successful. Convincing a user base that moving materials from readily available open shelves and transferring them into steel bins housed within 40-foot-high aisles that are inaccessible will be difficult if the system is consistently down. Therefore, the better the AS/RS is managed and supported, the more reliable and dependable that system will be and the likelihood user confidence will grow. Informing stakeholders of long-term planning and welcoming feedback demonstrates that the system is being supported and managed with an ongoing strategy that is part of future library operations.

Similarly, administrators need confirmation that large investments and mission-critical services are stable, reliable, and efficient. Creating a new line item in the budget for AS/RS support and equipment life-cycle requires justification along with a firm understanding of the system. In addition, staffing and organizational responsibilities must also be reviewed in order to establish an environment that is successful and efficient. Continuous assessments of the AS/RS regarding downtime, projects involved, services and efficiencies provided, etc. aid in providing an illustration of the importance and impact of the system on library operations as a whole.

### ***Recording Usage and Statistics***

Unfortunately, usage statistics were not recorded for the AS/RS prior to June 2017. Therefore, data is unavailable to analyze previous system usage, maintenance, downtime, or project involvement. Data-driven decisions require the collection of statistics for system analysis and assessment. Following the server software and hardware updates, efforts have been taken to record project statistics, inventory audits, and SRM faults, as well as public and internal paging requests.

## **CONCLUSION**

The AS/RS remains, as Heinrich & Willis described it, “a time-tested innovation.”<sup>24</sup> Through lessons learned and objective assessment, the library is positioning the AS/RS to be a critical component for future development and strategy. By expanding the role of the AS/RS to include functions beyond low-use storage, the library discovered efficiencies in material security, customer service, inventory accountability, and strategic planning.

The CSUN Oviatt Library has learned, experienced, and adjusted its perception, treatment, and usage of the AS/RS over the past thirty years. Factors often forgotten such as access to the area, staffing and inventory auditing are easily overlooked, while other potential functions such as material security and customer services may not be identified without ongoing analysis and assessment. Critical review without a limited or biased perception, has enabled the library to realize the greater functionality the AS/RS is able to provide.



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## NOTES

- <sup>1</sup> Shira Atkinson and Kirsten Lee, "Design and Implementation of a Study Room Reservation System: Lessons from a Pilot Program Using Google Calendar," *College & Research Libraries* 79, no. 7 (2018): 916–30, <https://doi.org/10.5860/crl.79.7.916>.
- <sup>2</sup> Helen Heinrich and Eric Willis. "Automated Storage and Retrieval System: A Time-tested Innovation," *Library Management* 35, no. 6/7 (August 5, 2014): 444-53. <https://doi.org/10.1108/LM-09-2013-0086>.
- <sup>3</sup> Atkinson and Lee, "Design and Implementation of a Study Room Reservation System," 916–30.
- <sup>4</sup> "About CSUN," California State University, Northridge, February 2, 2019, <https://www.csun.edu/about-csun>.
- <sup>5</sup> "Colleges," California State University, Northridge, May 8, 2019, <https://www.csun.edu/academic-affairs/colleges>.
- <sup>6</sup> Estimated AS/RS capacity was calculated by determining the average size and weight of an item for each size of bin along with the most common bin layout. The average item was then used to determine how many could be stored along the width and length (and if appropriate height) of the bin and then multiplied. Many factors affect the overall capacity including: bin layout (with or without dividers), stored item type (book, box, records, etc.), weight of the items, and operator determination of full, partial, empty bin designation. The AS/RS mini-loaders have a weight limit of 450 pounds including the weight of the bin.
- <sup>7</sup> "Automated Storage and Retrieval System (AS/RS)," CSUN Oviatt Library, <https://library.csun.edu/About/ASRS>.
- <sup>8</sup> "Automated Storage and Retrieval System (AS/RS)," CSUN Oviatt Library, <https://library.csun.edu/About/ASRS>.
- <sup>9</sup> Heinrich and Willis, "Automated Storage and Retrieval System," 444-53.
- <sup>10</sup> Norma S. Creaghe and Douglas A. Davis. "Hard Copy in Transition: An Automated Storage and Retrieval Facility for Low-Use Library Materials," *College & Research Libraries* 47, no. 5 (September 1986): 495-99, [https://doi.org/10.5860/crl\\_47\\_05\\_495](https://doi.org/10.5860/crl_47_05_495).
- <sup>11</sup> Heinrich and Willis, "Automated Storage and Retrieval System," 444-53.
- <sup>12</sup> Creaghe and Davis, "Hard Copy in Transition," 495-99.
- <sup>13</sup> Linda Shirato, Sarah Cogan, and Sandra Yee, "The Impact of an Automated Storage and Retrieval System on Public Services." *Reference Services Review* 29, no. 3 (September 2001): 253-61, <https://doi.org/10.1108/eum000000006545>.
- <sup>14</sup> Heinrich and Willis, "Automated Storage and Retrieval System," 444-53.
- <sup>15</sup> Sarah E. Kirsch, "Automated Storage and Retrieval—The Next Generation: How Northridge's Success is Spurring a Revolution in Library Storage and Circulation," paper presented at the

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ACRL 9th National Conference, Detroit, Michigan, April 8-11 1999,  
<http://www.ala.org/acrl/sites/ala.org/acrl/files/content/conferences/pdf/kirsch99.pdf>.

- <sup>16</sup> Heinrich and Willis, "Automated Storage and Retrieval System," 444-53.
- <sup>17</sup> Shirato, Cogan, and Yee, "The Impact of an Automated Storage and Retrieval System, 253-61.
- <sup>18</sup> Kirsch, "Automated Storage and Retrieval."
- <sup>19</sup> Shirato, Cogan, and Yee, "The Impact of an Automated Storage and Retrieval System, 253-61.
- <sup>20</sup> Cost of material management was calculated by removing building operational costs (lighting, HVAC, carpet, accessibility/open hours, etc.) and focusing on the management of the material instead. The management of materials (or unit cost) is determined by dividing the total amount of fixed and variable costs by the total number of units; 400,000 items divided by \$31,500 in annual shelving student budget equals \$0.079 per-material per-year in open shelves; 900,000 items divided by \$18,000 in annual AS/RS student budget equals \$0.02 per-material per-year in the AS/RS.
- <sup>21</sup> Shirato, Cogan, and Yee, "The Impact of an Automated Storage and Retrieval System," 253-61.
- <sup>22</sup> Creaghe and Davis, "Hard Copy in Transition," 495-99.
- <sup>23</sup> Kirsch, "Automated Storage and Retrieval."
- <sup>24</sup> Heinrich and Willis, "Automated Storage and Retrieval System," 444-53.

