Materials Handling Systems for Libraries

By Richard W. Boss

While librarians don't like to think of libraries as warehouses for books, there are a number of technologies developed for warehouses that can be beneficially used in libraries. Among these are return/sorting systems and automated storage/retrieval systems (AS/RS), collectively known in the warehousing industry as materials handling systems. When used in libraries the former consists of book drops, conveyors and multi-bin, tote, cart, or book truck sorters that cut down on manual handling of books and other library materials being returned. The simplest type of return/sorting system is a patron self-service unit that handles check-in and limits sorting to items to be reshelved and those that have reserve requests against them. The most complex is able to sort returned items into scores of categories. AS/RS consists of computer-driven robotic retrieval of densely stacked storage bins, thus cutting down on the amount of space required to house a collection.

Return/sorting systems can be cost effective in all sizes of libraries, but particularly so in libraries with large circulation volumes. AS/RS is cost effective only in libraries with quite large collections, usually libraries that have at least 250,000 little used volumes.

Return/Sorting Systems

Return/sorting systems—the library community’s term for what are more commonly called “conveyor/sortation systems” in the warehouse industry—move materials from the point of return to sorting equipment that can scan barcodes or RFID tags to ascertain into which of several bins, totes, trolleys (carts that accommodate a single stack that can be tilted at any one of several angles), or special book trucks that can be used for reshelving. While there are scores of manufacturers of such systems for warehouses, libraries have been most interested in companies that also offer book drops or patron self-service discharge units that front-end the conveyor to reduce handling and that interface with an integrated library system for automated check-in and the re-activation of security tags.

The front-end can be a book drop that drops returned materials onto a conveyor for
transport to a sorter or it can be a return unit that handles the actual check-in by straightening the items and scanning barcodes or tags as they drop, sending the information to the interfaced integrated library system, and sorting the items into two bins for returns and reserves. Optionally, twin conveyors can move the items to another location, even to a larger back-end sorting machine.

The former approach can handle much higher return rates per book drop because patrons do not have to position and/or drop items one by one, and there is no delay getting items onto the conveyor. While it reduces the cost of having several expensive return units, it requires relatively expensive high-volume back-end sorting equipment to deal with the flow from multiple book drops. The latter approach, in which a simple two-part sort is done at the return unit, can be used with back-end sorting equipment, but is more often used in small libraries that only need one or two book drops.

Patron self-charge/discharge units can be used with a return/sorting system, but are not discussed in detail in this TechNote because they are very familiar to librarians. For those who do need information about them, the best sources are the Web sites of

- Integrated Technologies (www.integratedtek.com),
- Kingsley Company (www.kingsley.com),
- Libramation (www.libramation.com),
- 3M (http://solutions.3m.com/wps/portal/3M/en_US/library/home/products),
- TechLogic (www.tech-logic.com).

For libraries with large circulation volumes, a minimum of 250,000 returns a year, the more expensive back-end sorting equipment is more cost effective. Because it can be configured with scores of bins, totes, carts, or book trucks; items can be automatically sorted by location, including locations in branches and other libraries. This dramatically reduces staff time.

Wheeled bins have the greatest capacity, as many as 200 items each; totes can accommodate as many as 25, as much as most staff can lift; trolleys at least 30; and special book trucks as many as 50. The advantage of special book trucks is that they can be used for reshelving. However, much more complicated sorting equipment is required to place items on a special book trucks as opposed to dropping them in a bin or tote, or onto a trolley that takes a single vertical stack.

**Benefits**

The greatest benefit of return/sorting systems is the reduction in ongoing operating costs as the result of a significant reduction in the handling of returned items by library staff. Staff members do not have to empty book drops, move materials, check them in, re-activate the security tags, and place them on book trucks. Anecdotal evidence suggests that the initial investment can be recovered in reduced labor costs in as few as four years. Rather than reducing staff, most libraries utilize the savings to redeploy staff to direct customer service.

The benefit for library patrons is that materials are ready more quickly for reshelving, thus increasing the availability of materials.
Finally, the use of return/sorting systems reduces the incidence of repetitive motion injuries for staff.

**Drawbacks**

While RFID tags do not have to be in a specific position in order for a system to read them, items with barcodes—which are less expensive than RFID tags—must be facing up and reasonably parallel to the front of a return unit. This not only requires a more costly return unit design, but also greater care on the part of patrons returning materials.

Relatively high start-up cost is the greatest drawback to return/sorting systems. Return/sorting systems typically cost a minimum of $50,000 for a two or three-bin sorter without conveyors and $70,000 for a five-bin sorter including limited conveyors. In both cases, shipping, installation, and training are included. Four of the five bins might be adult, children's, A-V, and reserves. The fifth usually is a "reject" bin for items that the sorter cannot categorize. Only some small return/sorting systems can be expanded beyond five bins.

A 50-bin system would cost a minimum of $750,000 to substantially more than $1,000,000 depending on the size and complexity of the conveyor component.

**Major Vendors**

Seven major vendors of return/sorting systems were pursuing the library market as of the third quarter of 2010: EnvisionWare, Integrated Technology Group, Libramation, Lyngsoe Library Systems, MK Sorting Systems, Tech Logic, and 3M. While the fourth and fifth are European companies, they have a significant North American presence.

**EnvisionWare**

EnvisionWare ([www.envisionware.com/en/sorters](http://www.envisionware.com/en/sorters)) markets a return/sorting system designed by P.V. Supa of Finland and manufactured for EnvisionWare by it in Texas. It is highly modular, expanding from as few as three to as many as 253 bins, totes, or ergonomic carts. Its modularity makes the smallest 3-bin system somewhat more expensive than 3-bin systems that are less modular. It can be used with either barcodes or RFID and can reactivate electro-magnetic security strips.

**Integrated Technology Group**

ITG ([www.integratedtek.com](http://www.integratedtek.com)) offers the Compact FullSort 3, Compact FullSort 5, and FullSort systems that are modularly expandable. Each checks in returned items, reactivates RFID security bits, separates hold items and assigns other items to bins according to library-defined criteria. They interface with most standard slot-style in-wall book drops.

**Libramation**
Libramation (www.libramation.com) is the vendor of the ACT-Return and ACT-Sorting units. The minimum configuration is a single return station with 3-way sorting of materials. It can be expanded to multiple interior and exterior return stations with as many as 200 bins as allowed by the SIP2 protocol. As of the third quarter of 2010, the company does not appear to have sold one larger than 25 bins. Both barcodes and RFID tags can be used with the system. The return units come with a receipt printer. The sorter can be configured with standard book bins, ergo-bins, or trolleys. Most of the components in the system are manufactured by Kno-Tech, a sister company in the Netherlands. Libramation has undertaken some joint ventures with MK Sorting Systems when a very large system is required.

Lyngsoe Library Systems

The company (www.lyngsoelibrarysystems.com) is the former FK Logistics Library Solutions, a subsidiary of Lyngsoe Systems since 2009. It also includes the former Codeco Company, a manufacturer of self-service return systems. There are two models of the Library SortMate system, the simpler is a two-bin sorter that can sit behind a book drop and allow items to be automatically checked-in and to have RFID security tags turned on. The book drop can be incorporated into patron self-service charge/discharge unit. At a green signal light, a patron returning an item at the unit must feed books one at the time into a slot. The items then pass through a short conveyor with an RFID reader (and/or barcode reader) and built-in antenna that interfaces with the integrated library system. There are two bins, one for reshelving and one for items that have reserves against them, the tags of which are unreadable, or that do not belong to the library. A printed receipt can be issued at the option of the library. Staff is signaled when a bin is full.

The larger system, of which the company has installed approximately 800 worldwide for a number of industries, performs the same functions, but has a more extensive conveyor system known as the Compact Sorter that leads from multiple SortMate Sorters via conveyors to a multi-bin configuration that can sort items by library location, including branches and other libraries. The largest installation in a library is the four return/71-bin system at the Aarhus Library of Denmark. It can handle up to 4,500 items an hour.

Lyngsoe also offers an AS/RS.

MK Sorting Systems

MK (www.mk-sorting-systems.com) is a German manufacturer of patron self-charging and discharging equipment, return stations, and conveyor/sorting systems. Until recently, it sold all but its very largest conveyor/sorting systems for libraries through distributors.

There are two sorting equipment options, a two-way sorter and a three-way sorter. The first sorts into just two bins or onto two conveyors; the second sorts into as few as three bins, with two-bin modular expansion to five, seven, nine, and even more bins up at least 200. The system can be configured to drop materials into bins or place them onto trolleys.
Tech Logic

Tech Logic (www.tech-logic.com) offers 3-bin and 5-bin QuickSort systems that are designed for small libraries and branches. They work with interior or exterior book drops, handle automated check in, reset security on either barcode labels or RFID tags, and print patron receipts. They use low-cost bins or totes. The larger “Ultra Sort” return/sorting system moves books and other library materials from wall or counter-mounted return drops or patron self-discharging units via conveyors to machinery which squares the books and other library materials, scans the barcodes or RFID labels to discharge them, re-activates the security tags, and rotates and places them on special book trucks ready to be reshelved or into ergonomic bins, units that are self-leveling so that staff do not have to bend over to remove materials.

The Greensboro Public Library of North Carolina was the first North American library to install a Tech Logic return/sorting system in late 1998. At that time, it was the first major system in a North American library. The company’s largest installation is at the Seattle Public Library. That system includes a 72-bin sorter for the main library, plus a 40-bin sorter for interagency movements of materials.

3M

3M (www.3M.com/library) has two return/sorting systems. The 3M Intelligent Return and Sorter System SL accommodates one return and up to three bins. [It works only with bins]. It is compatible with both barcodes and RFID tags, and also with EM (electromagnetic) security strips. A paper receipt is optional. The larger FX system can handle up to four returns and 15 sort locations. It comes with a standard receipt printer. The other features are the same as those for the SL.

As of mid-2010, most of the installations were in small libraries, including the Gail Borden Branch Public Library in Elgin (IL) the St. Joseph Public Library in South bend, and the Oglethorpe Mall Branch Library in Savannah.

Automated Storage/Retrieval Systems

An automated storage and retrieval system (AS/RS) is designed to store lesser used materials in a minimum of space by eliminating stack aisles, storing materials by size, and using building volume more efficiently.

Items to be stored are assigned to and placed in a bin according to size, and each bin is assigned a location. The bin address is entered into the computer, which is interfaced with the library’s integrated library system. The bins are then placed in an industrial rack assembly. A large assembly may be up to 50 feet high and 90 or more feet long. A computer-controlled mini-load crane (an electrically-driven forklift-like mechanism running on floor-mounted and overhead rails in the space between racks) moves into and out of the rack assembly removing and replacing bins. When an item is requested, the bin location is sent to the mini-load crane, which retrieves the bin and carries it to the operator. The operator, guided by a visual display on a PC-based workstation, takes the
item from the bin and places it on a conveyor or in a pneumatic tube for delivery to the service desk.

Elapsed time for retrieval from the AS/RS is from one to ten minutes, but, by taking advantage of the data maintained by the computer, high-demand items can be moved to the front of the rack assembly after they have been used and returned, thus minimizing retrieval time for more frequently requested materials. In a library application, 40 retrievals per hour per operator is common, but it can be as high as 100 if almost everything which has circulated recently is in the nearest bins. [Few of the libraries using AS/RS report an average of more than 170 retrievals a day]. Returning the item to storage follows the same procedure in reverse and requires a comparable amount of time.

Benefits

There are several benefits to AS/RS, among them low storage space requirements, high patron success rates, good collection preservation, and low ongoing costs.

Storage Space Requirements

The major benefit of AS/RS is a dramatic reduction in library materials storage space. Storage of 250,000 books and book-equivalents requires no more than 1,250 square feet as compared with 25,000 square feet using conventional shelving. The "fullness" of the shelves can have a negative impact on the management of materials in open stacks. At 85 percent full, it is increasingly difficult to reshelve items and keep shelves in order. Periodic shifting of the collections makes significant demands on staff time. In contrast, there is no negative impact related to the "fullness" of an AS/RS bin-even at 100 percent.

High Patron Success Rate

The "success rate" of patrons is increased when AS/RS is used to store books and other library materials. The success rate is the percentage of materials sought that a patron is actually able to locate. It is the product of the "holdings rate" and the "availability rate." A library with extensive holdings may have 90 percent of what patrons seek in the catalog, but if only 60 percent of the catalog holdings can be found, the success rate is only 54 percent. On the other hand, a library with a holdings rate of 80 percent and an availability rate of 90 percent would make patrons 72 percent successful.

A major factor in achieving a high availability rate, and thus potentially a high success rate, is the availability of materials either in the AS/RS or identified in circulation records as outstanding to a known patron and subject to recall or reservation.

Any open access approach is subject to items being out of order as the result of reshelving by patrons, the intentional misplacement by patrons seeking to restrict access to all but themselves, or even theft. Since patrons do not have access to the AS/RS and the system retrieves only the bin in which the inventory shows the item is to be housed, there is virtually no chance of losing track of an item.
Collection Preservation

A collection must be protected not only against theft, but also against heat, humidity, and seismic activity. Heat and humidity can be controlled by a properly adjusted HVAC system but any collection open to patrons must be controlled within a range comfortable for humans, 65-75 degrees and 40-60 percent humidity. Areas closed to patrons can have the temperature reduced to 50 or lower and the humidity to 30 percent, thus extending the life of the materials. Each degree below 65 adds at least a year to the life of printed materials.

The extent of seismic damage is very much dependent on the strength and flexibility of the shelving or other storage equipment. Bracing is necessary to limit lateral movement and crossbars to reduce the risk of the domino effect if one unit topples against another. Theoretically, an AS/RS is structurally better able to withstand seismic activity than conventional open stack shelving. That was confirmed in the earthquake that struck the University of California at North Ridge. The AS/RS sustained only minor damage, and no books were damaged. A considerable amount of conventional shelving collapsed and even that which withstood the quake spilled large numbers of books into the open aisles between ranges.

Low Long-term Costs

All costs in this section have been collected by the author in his capacity as a consultant to libraries investigating and/or implementing AS/RS.

The cost of constructing and equipping a library’s stacks area is approximately $20 per volume; the cost of constructing and equipping an AS/RS is approximately $4.00 per volume, however, this difference is realized only if an AS/RS accommodates at least 250,000 volumes.

The ongoing cost for maintaining the space required for an AS/RS is also lower. For example, the cost of maintaining 1,250 square feet of space with a ceiling height of 40 feet (HVAC and custodial) is approximately $10,000 per year. The custodial cost is low because the area is small and not open to the public; the HVAC cost is slightly higher because the great ceiling height and stricter temperature and humidity controls. In contrast, the cost of maintaining 25,000 square feet of open stacks space is approximately $37,500 per year.

Maintenance of the equipment for a system requiring 1,250 square feet of space costs roughly $6,250 per year, plus an allowance of about $2,000 per year for computer replacement. In addition, an onsite technician is highly desirable. A technician will cost over $45,000 per year (including 23 percent for fringe benefits).

An AS/RS will require at least one operator each hour a library is open. One should also assume that peak activity will be up to three times the average, therefore, requiring two or three operators during some hours. Assuming that the materials in the AS/RS have been selected on the basis of low frequency of use, it is likely that no more than 15,000 retrievals per 100,000 volumes will occur each year. Open stacks circulation averages
as high as 200,000 circulations per 100,000 volumes. Assuming as many as 37,500 retrievals and 37,500 "rebinnings" in a year in an AS/RS collection of 250,000 volumes, it would take at least 4,063 hours of staff time to handle the workload. The actual number of hours might be somewhat higher because of peaks and valleys in the activity. If one assumes 5,000 hours, the cost for 8.0 FTE (full-time-equivalent) staff would be $55,000 per year—a figure that assumes an hourly cost of $11.00.

While the open stacks shelving itself will require very little maintenance or repair for twenty or more years, reshelving, shelf-reading, and shifting will require a minimum 17,500 hours a year (8.75FTE) at a cost of $11.00 an hour—a total cost of $96,250 a year.

**Drawbacks**

There are a number of drawbacks to AS/RS, including perceived risk of investing in an unfamiliar technology, loss of "browsability," inappropriate selection, and inadequate prompting.

**Perceived Risk of Investing in an Unfamiliar Technology**

An AS/RS with a capacity for 250,000 volumes (books and book-equivalents) requires a system with at least three cranes aisles, six end-of-aisle workstations, 2,500 bins, and an electric track vehicle delivery system. The start-up cost will be as high as $700,000—a figure that includes a conveyor or mechanical delivery system between the AS/RS and a public service desk.

While there is considerable disagreement among architects about the cost of building a 40-foot high chamber with a floor-loading of 300 pounds per square foot, the median cost quoted by the few architects who have experience with AS/RS is $250 per square foot, plus the cost of the AS/RS. The total space needed to accommodate 250,000 volumes is as much as 1,250 square feet; thus, the space would cost at least $312,500, bringing the total capital outlay to $1,012,500.

The cost of building and equipping 25,000 square feet of open stacks space for 400,000 volumes would be approximately $4,375,000 if one assumes a cost of $175 per square foot.

While investing millions of dollars in the addition of space and equipment for open stacks is virtually risk free, there is a perception that investing that amount of money in a technology that is not very well known is risky. Librarians have committed that much money only to bricks and mortar and well established technologies such as integrated library systems and electro-mechanical compact storage.

**Lack of Browsability**

"Browsability" is the opportunity to browse the shelves to look not only for that which has already been identified, but for related materials. This serendipitous discovery factor is important to many patrons. On the other hand, many patrons would like to limit the
retrieval time. They want to obtain a few titles quickly.

Unless a library makes a good case for the use of AS/RS, the decision to install it can be controversial.

The quality of bibliographic access is always an issue, but particularly so if patrons cannot examine materials on the shelves. Even a catalog that conforms to the Anglo-American Cataloging Rules II does not answer all questions a person searching the catalog may have. For example, one California State University at Northridge faculty member interviewed by the author was using materials written in Greek and the online patron access catalog was, in his opinion, not complete enough for him to determine if a book was the translation of a specific edition he was seeking. In an open access environment, he would go to the stacks to examine materials and browse, but in a restricted access environment the catalog must substitute both for known item look-up and for browsing in the stacks. He was unaware that there was no limit on the number of items he could request from the AS/RS and that the staff had been instructed to make no comments about a request for a large number of items.

If the bibliographic records were to include links to the tables-of-contents of monographs, the need for browsing would be substantially reduced.

**Inappropriate Selection**

An obvious choice for an AS/RS are materials which have not circulated for a long time, but equally suitable are materials not traditionally subject to browsing in open stacks such as bound volumes of journals. The greatest source of frustration for patrons is the storage of very popular materials in an AS/RS. Rather than finding best sellers on special display racks or in the open stacks, patrons must submit a special request.

The return to the open shelves of materials which circulate two or more times in rapid succession from the AS/RS has been an effective way of limiting patron frustration.

**Inadequate Prompting**

It is essential that there be well-designed prompt screens in the online patron access catalog to alert users to the fact that an item is readily available onsite in an AS/RS, subject to request and retrieval in a matter of a few minutes. When the prompts are inadequate and patrons go to the open shelves looking for materials, there can be a serious public relations problem.

**Mechanical Failure**

The life expectancy of an AS/RS is 30 years or more, although moving components will require regular servicing, and replacement of computer equipment should be anticipated at least seven times during this lifespan period. Mechanical failure will occur, therefore, it is essential that library staff be able to handle most problems. Ideally, a library would have an AS/RS technician on staff.
Materials that cannot be retrieved because of mechanical failure of retrieval equipment are worse than lost as patrons may blame the library staff for the failure.

The 98 percent reliability level of AS/RS systems is high by most standards but, in a library open 100 hours per week, the loss of access two percent of the time could be up to two key hours during the week. However, most of the downtime consists of jammed or misaligned bins; a problem staff can fix within minutes by merely giving the robot a different address past the problem point. That allows the technician time to schedule his/her work so that the most critical problems are addressed first.

**Major Manufacturers**

While more than a dozen companies manufacture AS/RS equipment, only two, H.K. Systems (www.hksystems.com) Industry and Lyngsoe (www.Lyngsoelibrarysystems.com) have targeted libraries. The foregoing description of the technology in this Tech Note is, therefore, based on their products.

Every AS/RS is a custom designed and installed system that uses standard components. The first in the United States was at the University of California at Northridge in 1991 and the largest to date is that at the University of Utah, a system with 19,173 storage bins that can accommodate more than two million volumes. As of mid-2010 there were no AS/RS’ in public libraries in North America, but some large libraries were investigating them.

While none of the other major manufacturers of AS/RS have pursued the library market, a library may want to investigate AS/R Systems (www.asrsystems.com), Dematic (www.dematic.com), Remstar (www.remstar.com), and Viastore (www.viastore.com).