



Cost Comparison
of
Automated versus Manual
Materials Handling Operations
at
King County Library System

Prepared
for
King County Library System
by

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January 26, 2009

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Executive Summary

In order to evaluate the benefits of automated materials handling (AMH) systems, two similar libraries were compared (one with an AMH system and one without). The study found that costs related to materials handling at the automated library (library with an AMH system) were significantly lower than the manual library (library with no automation).

Costs were compared in four areas: the “cost” of unavailable resources (items such as books, DVDs, and CDs that are unavailable to customers because of backlogs in processing), the costs of frontline staff time spent on materials handling related requests, the costs of backroom staff assigned to materials handling processing, and the costs to customers.

To determine the cost of unavailable resources, the author establishes a “daily use cost” based on the average cost of acquiring a new library resource and the lifetime of the item in the library collection. The study found that \$12,950 more was spent per year on unavailable resources at the manual library.

The second cost area relates to frontline staff and the time spent dealing with three recurring problems related to materials handling that were significantly reduced at the automated library. The study found that \$55,098 more was spent on frontline staffing costs handling problems at the manual library.

The third cost comparison focuses on backroom staffing required to perform materials handling functions. The manual library spends \$75,712 more per year than the automated library.

Finally, the study considered the cost of the extra time spent by a customer going to the manual library expecting library material to be “on the shelf” based on the library catalog. Though the material had been checked in, it was waiting in a backroom unavailable to the customer. The study showed that customers at manual libraries may spend as much as \$84,845 per year on unnecessary trips to the library.

The report establishes that automated materials handling results in significant savings in four areas at KCLS. The report also notes that an automated materials handling system would likely yield even greater benefits at libraries lacking KCLS’ automated central sort operation which provides presorting and tote check-in for interlibrary delivery.

Introduction

In October, 2008, King County Library System contracted with Lori Ayre to assist them in evaluating the cost and benefits of their automated check-in systems. Automated check-in systems are part of a larger automated materials handling (AMH) system that also includes sorting of the material checked in. The KCLS Board sought additional information about the costs associated with the AMH systems versus the realized benefits. The goal was to engage a consultant who would perform an objective study of the value of the AMH systems being installed at KCLS branches.

At the time of study, KCLS had already installed AMH systems at six of their 43 libraries, and three more were in the process of being implemented. The Library believed that the six systems had been in operation long enough that any cost, time or staff savings associated with their use could now be quantified.

Materials Handling Environment

To consider the effect of the AMH systems, the broader materials handling environment at KCLS must be reviewed. This includes how interlibrary deliveries are handled and how customer returns are handled.

Six of the KCLS libraries have AMH systems installed. A library AMH system is composed of three components: a library sorter, the automated check-in station(s), and a staff induction station. The automated check-in station allows customers to induct their returns into the sorter which then checks in the item and sorts it to one of several shelving carts or delivery totes. The induction station functions like the automated check-in station but is designed for staff use. Both feed into the sorter via a system of conveyors.

All KCLS libraries benefit from a large, central sorter used for interlibrary deliveries. All sorting for interlibrary delivery is done in Preston. The Preston sorter communicates with the integrated library system to determine the status of each item and, based on the status, routes the item to the appropriate tote. The totes are then delivered to each library daily.

The Preston sorter not only sorts all of the material to totes but also builds a tote manifest which allows for tote level check-in at the library. When libraries receive a tote via interlibrary delivery, they check-in all the items at once (in a batch operation) by scanning just the bar code on the tote (instead of having to scan all 40-50 items in each tote). Tote check-in ensures that interlibrary delivery handling is very efficient.

Returns (items returned to each library by customers) are handled differently from interlibrary delivery. With returns, each item must be checked in and then rough sorted to a book cart for re-shelving. An automated library (library with an AMH system) handles returns differently from a manual library (library without an AMH system).

Workflow at Manual Library

At the manual libraries, most returns are dropped into book return slots. Back office clerks pull items out of the book drop bins and put them on a book cart. The clerk then takes the loaded book cart to a check-in station to process. At some libraries, it is possible to take the loaded bookdrop bin to the check-in station and work directly out of it.

Check-in stations consist of a workstation with scanner (so each item can be scanned into the system), printer (so hold slips can be automatically printed), and several book carts which are used to create grouped stacks of checked-in material (e.g. Adult returns, Children Returns, DVDs, Holds, etc). The stacks are then taken to a shelving cart that will eventually be fine-sorted and reshelved (by a page).

Some returns are taken to the service desks rather than dropped into the bookdrop (this is discouraged). Customers sometimes insist that the person staffing the service desk check-in their material right away because of the delay associated with dropping items into the book drop and actually getting checked in (and off the customer's account).

Interlibrary delivery is handled slightly differently from returns because the entire tote can be checked in at once. Each tote contains either all returns or all holds. Therefore, when a return tote is scanned, all the items in the tote can be removed and stacked in groups of similar items, without having to scan each item. The same system of shelving carts is used to rough sort items ready for reshelving. The items on the shelving cart are eventually fine-sorted by pages as part of the reshelving process.

When a hold tote is scanned, the holds slips are automatically printed out and these must be matched to the item in the tote. Once matched, each hold is put on a book cart for shelving on the holds shelf.

Workflow at Automated Library

A library with an AMH system never has to manually scan a return. Returns are either fed into the sorter by the customer using a self check-in station or are fed into the sorter by staff using an induction station. Customer returns are checked in immediately by the AMH system and a receipt is issued to the

customer. Because of the immediate check-in, customers rarely ask staff at service desks to check-in material for them.

The sorter is equipped with several sort locations configured with book carts or delivery totes. Items ready for reshelving are sorted to the book carts. Items that trigger a hold are routed to interlibrary delivery totes. The book carts at each sort location are used by pages when they do the fine sorting and reshelving.

Interlibrary delivery can be handled one of two ways: using the sorter to rough sort or rough sorting by hand to shelving carts. In the case of KCLS, staff has determined that it is preferable to use the sorter to rough sort material to shelving carts (or delivery totes) which doesn't take advantage of the tote check-in feature. So, even though each item still has to be removed from the tote, it eliminates the step of stacking similar items and then moving the stacks to shelving carts. By inducting them directly into the sorter, the items are checked in and sorted directly to the appropriate shelving cart or delivery tote.

Methodology

In order to identify the effects of using an AMH system, it is important to compare live operations rather than rely on a sequence of performance tests that are set up to measure the speed of tasks (e.g. the time it takes to check-in and shelve 100 interlibrary delivery items, the time it takes to check-in, rough sort and shelve 100 items from the book drop bins, the time it takes to feed 100 items into the sorter and get them back on the shelves, etc.) The problem with such tests is that it requires staff to do things in ways they don't normally do them.

The Problem with Using Performance Tests

If we were to limit the timed tests to some number of items (e.g. 100 items in the bookdrop), we would be able to get a "per item" time but it would be based on a sequence of events that never really happens in the library. Items don't get processed from start to finish by one person. And they are not batched in any set number of items (e.g. 100 items). One person may check-in the items in the bookdrop and then leave them on the carts at the check-in station. Then another person might come along who takes just one or two stacks of checked-in items from the check-in station (maybe just the adult books or the children's books, or just the DVDs and holds) and sort them to a shelving cart. Yet another person might do the actual re-shelving. Not only do different people do different tasks, they also do them on their own schedule. One task doesn't necessarily lead directly to the next without wait time in between.

Testing the speed of each discrete task (e.g. checking in 100 items, rough sorting to book carts, checking in and labeling holds) creates other problems for the kind of evaluation attempted here. One problem is that during the timed period, people tend to perform optimally. The other problem is that wait time between tasks goes unmeasured. Timing someone checking in 100 items or even one day's worth of daily delivery isn't likely to provide an accurate "per item" time because that person will be more focused on their work during the timed period than they would normally be, and they will want to do their best. This is generally referred to as the observer effect. In psychology, it is known also as "reactivity."¹

¹ Heppner, P.P., Wampold, B.E., & Kivlighan, D.M. (2008). *Research Design in Counseling* (3rd ed. ed.). Thomson. pp. 331.

Waiting is one of the seven “wastes” or *muda*² that are identified by the Toyota Production System (TPS) and Lean (<http://www.lean.org>). Both TPS and Lean are systems that work to optimize workflows in manufacturing as well as other types of business operations. When measuring the time a specific task takes, the wait time is eliminated. This is one of the most time consuming aspects of an inefficient workflow. Because automation removes much of the wait time associated with materials handling, it was important to find a way to compare the operations without eliminating “wait time” from the equation.

Compare Similar Live Operations

Therefore, rather than setting up scenarios that made it possible count steps or measure time but which altered the natural flow of the work and removed the waste of “wait time”, we decided to find a way to compare live operations. We considered comparing “before AMH” and “after AMH” scenarios at one library but found that the data required to make useful comparisons wasn’t available. Luckily, we were able to identify two very comparable libraries, one which had implemented AMH and one which was still operating manually.

Kent and Federal Way were chosen because of similarities in circulation, delivery volume, collection size, and physical size. An AMH system composed of a sorter with 15 sort locations (8 book carts, 6 totes, one exception bin), two automated check-in stations and one staff induction station was installed at Federal Way in December, 2006. Kent Library has no sorter or self check-in system.

	Federal Way	Kent
Daily Check-ins	1850	1873
Return to Shelve totes processed per day	530	476
Hold totes processed per day	541	591
Size (sq feet)	25,000	22,500
Collection Size	180,000	159,000
AMH CKI	AMH since Dec, 2006	No AMH

Identifying Relevant Factors

Introduction of AMH dramatically changes how a library works including how staff are deployed, how quickly material is back on the shelves and available to

² See the muda entry in Wikipedia for a more detailed description of the wasteful activities that do not add value to a production system as defined by the Toyota Production System. Available from [http://en.wikipedia.org/wiki/Muda_\(Japanese_term\)](http://en.wikipedia.org/wiki/Muda_(Japanese_term)).

customers (turnaround time), and how staff interact with customers. For example, with an AMH system that includes self check-in, the number of times customers ask to have their material checked in at the desk is practically eliminated because all returns (using the self check-in system) are immediately checked it.

When material is backlogged, staff are asked to perform certain tasks for customers that don't come into play when all material is checked in and reshelfed the same day. For example, when an item is returned that triggers a hold, the customer gets notified that their hold is ready. If the back office staff do not get the hold up on the hold shelf before the customer comes to pick it up, it requires frontline staff to go to the backroom to find the unshelved item. Sometimes an AMH system eliminates backlog and problems like this go away; however, an AMH system improperly sized or staffed may not eliminate 100% of the backlog so these problems may still occur.

In order to identify as many pertinent effects as possible, we compared how quickly Kent and Federal Way were able to get items back on the shelves and available to customers (e.g. slow turnaround results in more library resources being unavailable), and we tried to identify all the ways that the two operations differed in the time demands on frontline staff, back office staff, and customers.

Unavailable Resources

When library resources are sitting in the backroom on a book cart, in a tote or waiting to be processed, they are unavailable to customers. Unavailable material represents wasted resources: items that have been purchased by the library but which the customer can't use. While we can all agree that taking a long time to get something back on the shelf is not a good thing, it isn't easy to assign a dollar value to that delay. In order to provide a useful measure of the effects of the AMH system, it was important to develop a formula that resulted in a monetary cost per day.

In order to define a daily value of a library resource (e.g. book, CD, DVD), the acquisition cost was established (the cost purchase³ the item plus the KCLS CMS Department costs⁴). The acquisition cost was then divided by the number of days the item remained in the collection⁵.

³ Average purchase cost came to \$28.24 per item. This includes the cost of Easy Fiction, Board Books, Easy Nonfiction, Children's Fiction, Adult, Adult CD, DVD, and CD purchase costs plus the average vendor processing costs associated with each material type (e.g. DVDs cost \$23.26 each to purchase plus an additional \$2.19 in processing).

⁴ KCLS processing costs represents the time spent in technical services to both select and acquire the book. It also includes the cost of doing additional processing once the book actually arrives. This cost was set at \$3.49 per item and was calculated by determining the total cost of CMS staff divided by the number of new items per year (\$5.81), then dividing

The result established an average daily cost per item of two cents (\$.02).

Having determined the daily value (cost) of a resource, it was next necessary to compare the situations where Kent and Federal Way differed in how long an item was "unavailable." Because the calculation was done on a per day basis, a "day" increment was used. This means that if material was returned and reshelfed within one day, it was not counted as "unavailable" but if it took two days to get it back on the shelf, the cost applied was \$.02 per item per day.

Two situations resulted in material being unavailable: when items are returned and checked in, but don't make it to the shelves; and when items are returned but not checked in.

Frontline Staff Time

In order to compare the effect of AMH systems on frontline staff time, three "incidents" were identified that affect frontline staff and relate to the AMH system. The three incidents are "Claims Returned," "Find Items on Book Cart," and "Request Check-ins."

Claims Returned are incidents in which a customer claims to have returned an item but the catalog does not indicate that it has been checked in. These types of incidents are usually handled by Library Assistants who work at an average hourly rate of \$26 (including KCLS overhead.) Each such incident takes 25 minutes⁶ of the Library Assistant's time. Therefore, each Claims Returned incident costs \$10.92.

Find Items on Book Cart are incidents in which an item is listed as checked in but it has not been shelved. Because the item shows as "available" in the catalog, customers often come into the library to get the newly available item. Because they are not shelved, Librarians (\$43 hourly rate including KCLS overhead) must go the backroom and find the item on a shelving cart. Each incident requires approximately six minutes of the Librarian's time at a cost of \$4.30 per incident.

Request Check-ins are situations where customers ask staff to manually check-in items immediately. These incidents are generally handled by Library

number by the percentage of the departments time that is actually spent on these tasks described above (60%).

⁵ KCLS determined that, on average, an item remains in the collection for 5.5 years.

⁶ Karen Daniel, KCLS Circulation Supervisor, provided this figure. She broke down the transaction as follows: discussion with patron - 10 minutes, shelf check at your branch - 3 minutes, calling owning branch or where the item was returned for a shelf check - 5 minutes, making decision - 2 minutes, contacting patron about decision - 5 minutes.

Assistants (\$26/hour including KCLS overhead) and take approximately one minute per incident⁷ at a cost of \$.43/incident.

Backroom Staff Time

The two libraries staff their backrooms differently. Kent's backroom staff manually check-in material from book drops and process delivery. Federal Way staff feed all material into the sorter via the staff induction station. A "rover" position replaces carts and totes on the sorter, makes sure nothing jams, and generally monitors the sorter. All positions are staffed by Library Assistants (\$26/hour).

In order to compare the two operations, we compared the weekly cost of all staff scheduled to perform backroom materials handling functions (processing book drop returns, processing totes, processing holds, inducting material into the sorter, check-in, sorting, and sorter "rover").

Customer Time

When an item is checked in but not available on the shelf, a customer who is monitoring the item's status in the catalog can make the mistake of coming to the library to get the item only to find that it isn't really available. Depending on the customer, they may leave the library frustrated and discontinue using the library (per a previous KCLS study, 20% of customers do just that), or they may request staff assistance. In order to measure this impact on customers, we assumed that the customer spends 30 minutes round trip, and makes the trip via car (driving 5 miles). Customer time is valued at the Page Hourly rate (\$12.68). We further assumed that such an incident occurs with only 5% of items that are listed as "available" in the library catalog but are actually still parked in the backroom. Based on these assumptions, the cost to the customer (per incident) comes to \$11.38.

⁷ When a customer requests that one or two items get checked in, it may only take a minute but more often it is a parent with 10-20 picture books that wants them all checked in so a new 20 can be checked out...so this estimate is probably too conservative.

Results of Comparisons

When we compared all the relevant effects described above, including the cost of unavailable resources, cost of time spent on incidents involving frontline staff, costs of materials handling staff, and costs of customer time, we found that there was difference of \$228,605 between the automated and manual libraries (see Appendix: Charts Showing Comparison of Costs.)

In the case of unavailable resources, the manual library left 584 items unshelved each day (these items were checked in so would show in the catalog as "available"). The automated library left 160 such items unshelved (74% reduction). This results in an annual cost difference of \$3,010. In terms of items that were returned and not checked in (which means they were also not shelved), the automated library was able to keep up (no backlog), whereas the manual library left 1400 items per day. The annual cost difference of these unshelved and unchecked-in items comes to \$9,940 per year. The total annual cost difference of unavailable resources comes to \$12,950 annually.

In terms of frontline staff time spent on three kinds of incidents that are largely avoided when AMH systems are used, we found that the cost difference was \$55,098 annually. The primary difference was in Request Check-ins which were reduced to 5 per day at the automated library and as high as 315 at the manual library (cost difference: \$47,322). The manual library reported 12 Claims Returned incidents per week and the automated library reported five for a cost difference of \$3,975. The automated library rarely (.5 times per week) has to send the Librarian looking for an item in the back room (Find Items on Book Cart) whereas Librarians at the manual library do this 17.5 times per week for a cost difference of \$3,801.

Materials handling staffing costs⁸ yielded the greatest cost differences. The automated library schedules Library Assistants 86 hours per week to do materials handling tasks (68 hours staff induction to sorter and 18 sorter rover hours). The manual library schedules 142 hours per week in materials handling (staffing check-in stations, book drop, tote check-in). Annually, the manual library spends \$75,712 more per year on backroom materials handling staff than the automated library.

Because of the large number of checked in items that do not get shelved at the manual library, more customers probably go to the library expecting to find a book on the shelf that is not. Based on our assumptions (customers come in expecting to find 5% of the items listed as "available in the catalog), we

⁸ Staff involved in shelving material were not counted in these scenarios because the time it takes to fine sort and shelve material is unaffected by the AMH system.

estimate that 8 automated library customers make a wasted trip each day while 29 manual customers do so for an annual cost difference of \$84,845.

Conclusion

Based on the comparisons of two very similar libraries, one with an AMH system (two automated self check-in stations, a staff induction station, and a sorter that sorts directly to shelving carts and delivery totes), the materials handling staffing costs are considerably higher at the manual library. In addition, significant amounts of frontline staff time are spent resolving undesirable incidents that are largely avoided at the library with the AMH system. Though more difficult to quantify, AMH systems also result in higher utilization of library resources by decreasing turnaround time, and also likely reduce situations in which customers come to the library for an “available” item that is not yet shelved.

Considering the fact that the KCLS system also provides tote check-in capability which significantly reduces the amount of time needed for the manual library to process interlibrary deliveries, this study (which focused on the difference between an automated KCLS library and a manual KCLS library suggests that installing an AMH system at a library without such a central sort operation would yield even greater savings than those demonstrated here.

Appendix: Charts Showing Comparison of Costs
November, 2008

Unavailable Resources					
Unshelved Returns	Fed	Kent	Calculations on Difference	Annual Cost Difference	Percent Reduction
Items unshelved same day	160	584	424		73%
Cost per item per day			0.02		
Cost of unavailable resources per day			\$ 8.48		
Difference in cost per year of unavailable resources				\$ 3,010	
Returned but not Checked In	Fed	Kent	Calculations on Difference	Annual Cost Difference	Percent Reduction
Items returned but not checked in per day	0	1400	1400		100%
Cost per item per day			0.02		
Cost of unavailable resources per day			\$ 28.00		
Difference in cost per year of unavailable resources				\$ 9,940	
DIFFERNCE IN COST OF UNAVAILABLE RESOURCES AT NON-AMH LIBRARY PER YEAR				\$ 12,950	

Cost per item per day = costs associated with acquiring item / number of days item remains in collection (5.5 years)

Library is open 355 days a year. Days open is multiplied by daily cost of unavailable resource.

Appendix: Charts Showing Comparison of Costs
November, 2008

Frontline Staff Time Wasted					
Claims Returned	Fed	Kent	Calculations on Difference	Annual Cost Difference	Percent Reduction
Claims Returned per week	5	12	7		58%
Minutes Spent per incident			25		
Hourly Rate of LA			26		
Cost per incident			\$ 10.92		
Difference in cost per year				\$ 3,975	
Find Items on Book Cart	Fed	Kent	Calculations on Difference	Annual Cost Difference	Percent Reduction
Number of times a Librarian has to go to backroom to find an item on a shelving cart for a customer (per week)	0.5	17.5	17		97%
Minutes spent per incident			6		
Hourly rate of Librarian			43		
Cost per incident			\$ 4.30		
Difference in cost per year				\$ 3,801	
Request Checkins	Fed	Kent	Calculations on Difference	Annual Cost Difference	Percent Reduction
Number of times customer requests manual check-in (per day)	5	315	310		98%
Minutes spent per incident			1		
Hourly rate of LA			\$ 26.00		
Cost per incident			\$ 0.43		
Difference in cost per year				\$ 47,322	
TOTAL FRONTLINE STAFF COSTS SPENT PER YEAR AT NON-AMH LIBRARY				\$ 55,098	

Kent reported 11 but Newport Way actually counted and got 13 in one week. So averaged.

Sometimes only 1-2 items per incident, other time 15 picture books so this is probably too conservative.

Appendix: Charts Showing Comparison of Costs
November, 2008

Backroom Staff Time Wasted					
Backroom Staff Hours	Fed	Kent	Calculations on Difference	Annual Impact	Percent Reduction
Hours backroom check-in stations are staffed per week		142			
Hours staff induction is staffed per week	68	0			
Hours sorter rover is staffed per week	18	0			
TOTAL backroom MH hours per week	86	142	56		39%
Hourly Rate of LAs			\$ 26.00		
Difference in weekly cost (LAs) backroom staff	\$ 2,236	\$ 3,692	\$ 1,456		
TOTAL BACKROOM STAFF COSTS SPENT PER YEAR AT NON-AMH LIBRARY				\$ 75,712	

11 L.A. hours during the week and 8 L.A. hours on the weekend

Conflicting estimates:
Deatrice Barber said: On a good day, circ staff do rover duties 4 hours a day (28 per week?)
Assistant says it is closer to 2 hours per week.
Comprised at 2 hours per week (5 days) and 4 hours per week (2 days)

Appendix: Charts Showing Comparison of Costs
November, 2008

Customer Time					
	Fed	Kent	Calculations on Difference	Annual Impact	Percent Reduction
Number of items showing "Available" in catalog but not on shelf yet	160	584	424		73%
Percentage of "Available" items customers look up and come in to library to get	5%	5%	5%		
Number of "incidents" per day	8	29	21		
Customer time per incident (search and trip to library)			\$ 6.98		
Driving cost (assuming 5 miles)			\$ 4.40		
Total customer cost per "incident"			\$ 11.38		
Cost per day			\$ 239		
CUSTOMER COST OF WASTED TRIP TO LIBRARY				\$ 84,845	

Assumine page hourly rate for patron, 30 minutes per trip plus 3 minutes looking up item.

Assuming 5 mile trip and using cost per mile from commutesolutions.org.

Appendix: Charts Showing Comparison of Costs
November, 2008

Breakdown of Costs				
Total Annual Costs Elimated with AMH CKI			\$ 228,605	
	Percentage of Total		Cost	
Annual Cost of Unavailable Resources	5.7%		\$ 12,950	
Annual Cost of Frontline Staff Time	24.1%		\$ 55,098	
Annual Cost of Backroom Staff Time	33.1%		\$ 75,712	
Annual Cost of Customer Time	37.1%		\$ 84,845	