Cost Analysis

Authored by Mark Lorie, JHU graduate student, this document provides an analysis of the cost of implementing CAPM. The approach and the basic assumptions used in this analysis as well as the costs for implementing the system at JHU and in general are categorized and explained. Some of the risks associated with the implementation of CAPM are explored.

Cost Analysis for CAPM

Mark Lorie, Graduate Student
Department of Geography and Environmental Engineering
Johns Hopkins University

Introduction

Moravia Park is an off-site shelving facility for the Johns Hopkins University (JHU) Milton S. Eisenhower Library (MSEL). Moravia Park provides shelving for books that do not fit into the shelving area at the MSEL. Books that are not considered high use materials (*i.e.*, have not been checked out in a specified amount of time) are shelved at Moravia Park. When an individual would like to look at a book shelved at Moravia Park, he or she must submit a request via fax, email, or by filling out a form on the web or at MSEL. The requested materials are then delivered to MSEL within 2 to 24 hours. The request process is similar for journal articles, although the waiting period may be less since the articles can be faxed to the user or scanned into a portable document format file and sent electronically. The implementation of CAPM will give library patrons real time access to books shelved at Moravia Park through the use of scanned images posted to a webpage.

This document provides an analysis of the cost of implementing CAPM. The next section describes the approach and the basic assumptions used in this analysis. The costs for implementing the system at JHU and in general are categorized and explained in the Section 3. Some of the risks associated with the implementation of CAPM are explored in Section 4. Finally, some brief conclusions are offered in section 5.

Approach and Basic Assumptions

This cost analysis provides information on the initial expenditures for the components that comprise the CAPM system, and expected costs for the operation and maintenance of the system. Additionally, opportunity costs associated with changes to the setup of Moravia Park will be considered (see *Figure 1*). The analysis presents a general framework for costs likely to be incurred in implementing the system, utilizing numbers specific to JHU. There will be some differences in the costs faced by JHU and those faced by other institutions since the development costs for the CAPM system were covered by a grant to JHU. Therefore, JHU will not face costs for

some of the hardware, whereas other institutions might incur these costs. The Andrew W. Mellon Foundation awarded the grant to JHU.

Figure 1: Components of the Costs for Implementing CAPM

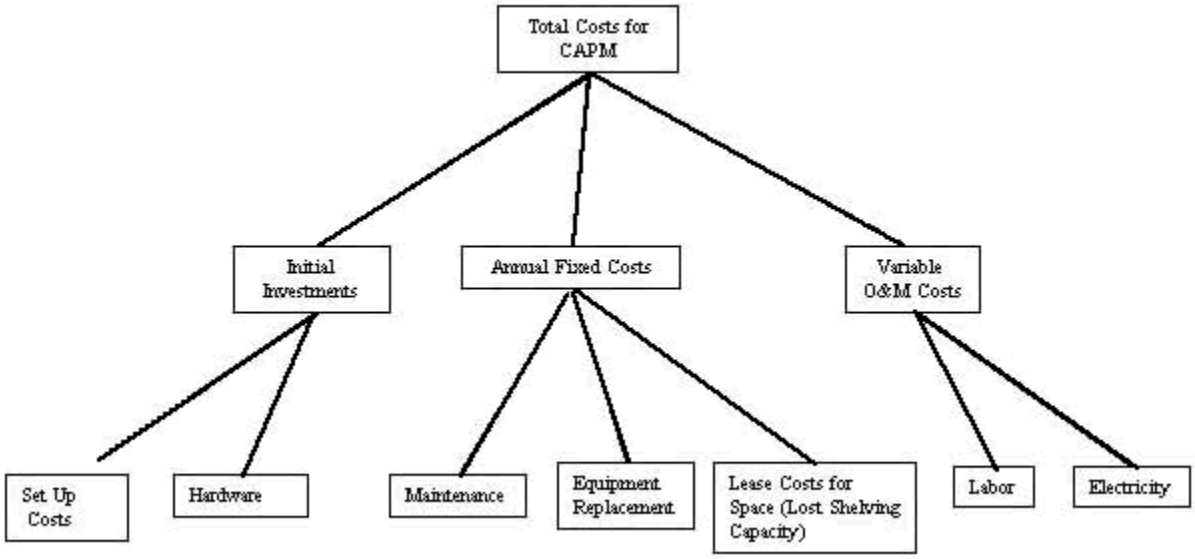


Figure 1 depicts how the costs for the system break down. The total cost can be divided into three categories: (1) initial investments, (2) fixed O&M costs (which do not depend on usage level), and (3) variable O&M costs (which depend on utilization). Each of those categories can be further separated into more categories. One time costs include initial investments and replacements for hardware. Relevant one time costs are:

- Robot Costs
- Page-turner costs
- Costs of book containers
- Costs for scanners
- Computer charges
- Set up costs

The annual costs assessed include:

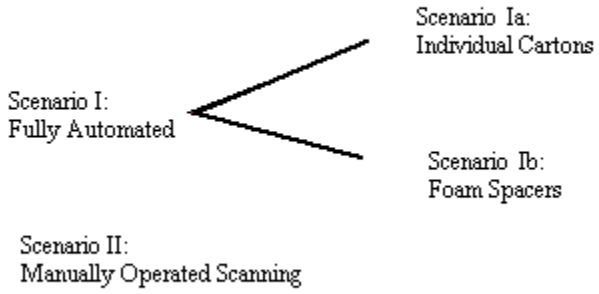
- Labor
- Equipment Maintenance
- Building space due to reduced storage capacity

As the use of the system grows and its capacity is expanded, some of the fixed annual costs will become variable. However, for this analysis they are considered fixed. The only variable O&M cost considered is increased electricity usage.

Each category will be described in detail below. It is important to recognize that the operating costs will be incurred annually, while fixed costs are one-time costs that will be incurred at the inception of the project, or may be paid back over a period of time. A ten-year time horizon is considered in this analysis (if this is not explained later, we should mention that this timeframe was chosen because we assume that the CAPM technology may be obsolete in 10 years).

Since the system is still under development, there are many uncertainties and some degree of flexibility with regard to the design of CAPM. Two basic operation scenarios are considered See figure 2). The first scenario (Scenario I) considers a completely automated system. Under this scenario, a robot retrieves a book from a shelf and brings it to a scanner where the appropriate pages are scanned with the help of an automated page-turner. The robot then returns the book to the shelves.

Figure 2: Scenarios Considered



There is an important uncertainty associated with the fully automated scenario. In order to extract a single book from a shelf, the robot will require spaces on each side of every book. Currently, books at Moravia Park are stored in large boxes with about 10 to 20 books per box. Two possibilities for creating the required spaces between books are considered. One possibility (Scenario Ia) is that books will be stored in individual cartons, such as those used for VHS videos. Each carton, slightly larger than its book, will be stored in the larger boxes as the books themselves are in the current system. Another possibility (Scenario Ib) is that books will be stored in large boxes as they are now, with the spaces created by placing pieces of foam between

each book.

Under Scenario II, there is no automated page-turner. In this case, a robot retrieves the box containing a requested book from a shelf and brings it to a scanner. A person then scans the requested book, replaces it in the box, and the robot returns the box to the shelf. Under this partially automated scenario, books are stored in the boxes as they are now (i.e., about 10 to 20 books per box and no spaces between the books).

At the initial implementation, CAPM will operate as the partially automated system described above. However, it is the ultimate goal of JHU to have a fully automated system, thereby maximizing the possible benefits to library patrons. It is anticipated that the robotic page-turner will be developed in a follow up project. Therefore, it is assumed in this analysis that the upgrade to make CAPM a fully automated system will occur five years after the initial implementation. Therefore, all additional costs associated with the fully automated system will be incurred in year 5. For comparison, the analysis also considers CAPM remaining as a partially automated system throughout the ten-year time horizon.

Once numbers have been determined for each cost category, a total cost for the ten year period can be determined and presented in present worth terms (i.e., in 2001 dollars). The costs can also be expressed as a cost per use. A cost per use number represents the levelized cost–the amount that would have to be charged per use in order to recover all the costs over the assessed time period. There are no plans to implement a fee per use system for CAPM; the costs per use numbers are presented for information purposes only.

To calculate cost per use values, some assumptions about demand for CAPM's services were made. Currently, library patrons request 60 items per day from Moravia Park. A range of use levels centered at the current value was used. To examine the possibility of CAPM being used less than the current system is used; use rates of 20, 30, and 50 requests per day were analyzed. Growth in demand was also considered by analyzing cost per use values for request rates of 75 and 100 per day.

3. Costs to Implement CAPM

3.1 Fixed Costs

Robot: The cost of the robot is not considered in the analysis for JHU because the development of the robot was funded by the grant from the Mellon foundation. In general, however, the robot would have to be purchased at the time of implementation. The estimate for the cost of the robot is based on manufacturing additional robots, not the development costs. The JHU Mechanical Engineering

Department estimates that a robot will cost between $50,000 and $100,000.

Page Turner: It is anticipated that the page turner will be developed with grant support, so it will not be one of the costs associated with JHU's implementation of CAPM. For other institutions implementing CAPM, the cost of the page-turner is estimated by the JHU Mechanical Engineering Department to be between $5,000 and $50,000. This range represents possible costs for manufacturing additional page turners.

Scanner: For Scenario I, only one scanner will be used. The initial cost of that scanner is not considered in the analysis for JHU because Minolta donated the scanner for the purposes of developing the CAPM system. However, Scenario II will require two scanners (see queuing analysis under the Labor section of this chapter). Therefore, for Scenario II, one scanner will have to be purchased when the system is implemented, resulting in an initial cost of $15,000. The estimated lifetime of the scanners is five years. Based on this ten-year analysis, replacement costs for the scanners will be incurred during the fifth year. For the Scenario I, this replacement cost will be $15,000, while for Scenario II it will be $30,000 since two scanners will have to be replaced.

Other institutions will have to purchase both of the initial scanners, as well as a replacement in year five. Therefore, other institutions will incur an additional $15000 as an initial cost.

Computer Investments: The computer components of the CAPM system will essentially take advantage of the existing system, so it is unlikely that an upgrade of either MSEL's Horizon system or the network will be needed. The only computer charges will be for PCs needed for the operation of the scanners and the robots. The purchase of these computers will be covered by the CAPM development grants and, therefore, not considered in this analysis. Maintenance will also be minimal and covered during the normal maintenance performed on the Horizon system.

The expected lifetime of the computers is five years. Since this analysis is based on ten years, it will have to include the lifetime of the computers. The cost of the PCs is $10,000 based on estimates provided by representatives of MSEL. For the purposes of this analysis, this covered under the development grants.

The costs for computers at other institutions are largely dependent on the existing computer network and other facilities at the place of intended implementation. If the existing system can't support CAPM, then substantial costs may be incurred in order to upgrade the computer network. For the purposes of this evaluation, it is assumed

that the existing computer facilities are adequate. Therefore, the only costs in this category will be for purchasing two PCs to operate the robot and the scanner. Based on estimates provided by representatives of JHU MSEL, the cost of the PCs is $10,000 each. The expected lifetime for the computers is five years so the cost for the PCs will be incurred at the inception and during the fifth year.

Book Containers: The book containers serve two purposes. The motivation for considering book containers was to facilitate automated retrieval. A preservation librarian indicated that these containers could also provide preservation benefits with appropriate materials lining the boxes.

The first type under consideration is a modification of the current book containers. These are large boxes that will be used to store multiple books. When CAPM is upgraded to be fully automated these boxes would still be used, with the addition of the foam spacers as described above. The second possibility is to use the small cartons, similar to the cartons that hold VHS videos. In this case, the books will be stored individually in the cartons, and the cartons will be stored in the larger boxes.

As previously noted, MSEL plans to begin using the second bay of Moravia Park regardless of whether CAPM is implemented. Therefore, the larger boxes similar to those used now will be purchased with or without CAPM and their cost will not be attributed to the CAPM project. Since CAPM initially will be implemented as a partially automated retrieval system, only these larger boxes will be required at its inception. When the system is upgraded, the individual cartons may have to be purchased, depending on which method for creating the needed spaces is chosen. Since a projected cost for the foam spacers is not yet available, this analysis will assume that the individual cartons option will be used and will incorporate the associated cost. The cost of the individual containers is estimated to be between $1 and $3 each.

Book Container Calculations: It was mentioned above that with the planned shelf configuration, the robot would service 432,000 books.. Therefore, 432,000 individual cartons will have to be purchased. This results in a cost of $432,000 if the cartons are $1 each and $1,296,000 if the cartons on $3 each. Again, it is assumed that these figures can be generalized to other institutions.

Setup Costs

If an institution implements CAPM in shelving facility that already contains a significant amount of books, significant set up costs will be incurred. These setup costs will be incurred only at the beginning of the project and include labeling and rearrangement of the books. In the case of JHU, the second bay of Moravia Park

(where CAPM is likely to implemented) is not yet in use and contains no books. Some books may have already been shelved in the second bay by the time CAPM is operational. Therefore, set up costs for JHU will most likely be minimal. To assess the cost associated with set up, however, the characteristics of the JHU facility (e.g., size, number of books) and the wage rate at JHU have been utilized. As with other cost categories, these values to are likely to be different at other institutions. However, the numbers determined for JHU should be representative of the costs faced by other institutions.

Set Up Calculations

A range of values is determined using an estimated number of minutes associated with the work to be performed on each book and a wage rate. The labor rate is based on a medium level Johns Hopkins University Grade 35 employee. Benefits are not included because it is assumed that temporary employees will perform these tasks.

Books	432,000	432,000
Minutes/Book	3	5
Total Time (hours)	21,600	36,000
Hourly Wage	$12.00	$12.00
Labor Costs	$259,200	$432,000

3.2 Operating Costs

Labor: Labor costs fall under the category of operation and maintenance and will be incurred yearly. Although labor costs will differ between institutions, salaries at JHU will be used for this analysis. At JHU, each job is assigned a grade level. For each grade, there are three salary levels that may be applied to a position. The salary level depends on the experience and length of service attained by the individual filling the position. The following table provides values for the salary levels for grades 32, 33, 35, 36, and 38. To find the hourly rate, the salary can be divided by 1,950 hours/year.

	Low	Medium	High
Grade 32	13,413		
Grade 33	15,043		
Grade 35	18,534	22,705	26,876
Grade 36	20,788	25,465	30,141
Grade 38	25,623	32,029	38,434

For the purposes of this investigation, the benefit rate will be included in the labor costs. The full time benefit rate is 28.5%.

The current employees at Moravia Park are classified as the following grades: cataloger–grade 35, Moravia Park staff–grade 36, Moravia Park supervisor–grade 38. With the partially automated scenario, a person will be needed to fill the page-turner position. It is anticipated that the position will be classified as a low level Grade 32 or Grade 33.

Scenario I: It is assumed that the implementation of CAPM will increase the demand for books at Moravia Park. The increased demand may not be noticed immediately. However, awareness of the existence of CAPM will spread with time and it is likely that use will increase as the number of people aware of CAPM rises. Additionally, since MSEL maintains a zero growth policy for housing books onsite, a greater number of books will be shelved at Moravia Park in order to keep up with current acquisitions. With a greater number of books shelved at Moravia Park, the probability increases that library patrons will require the books shelved off-site.. Assuming demand for CAPM grows, it is likely that labor costs will increase with the addition of CAPM. Currently, Moravia Park carries 4.5 full-time positions. Two full time (Grade 38 and Grade 36) individuals and one part time (Grade 36) individual work at Moravia Park. Two cataloguers (Grade 35) are also employed for Moravia Park-related activities but work at MSEL. An additional three catalogers have been aiding Moravia Park when needed but are not represented in the budget calculations. Since it is sometimes difficult to keep up with the current demand, it is probable that CAPM will result in the need for more full time cataloger. Also, depending on the demand for CAPM, it is possible that more staff will be needed at Moravia Park to keep up with cataloging and physical requests. This can be accomplished by upgrading the part time position to a full time position. Therefore, it is estimated here that for a fully automated CAPM, an increase of 1 grade 35 cataloger and 0.5 grade 36 Moravia Park staff person will be needed.

Scenario II: The same increases in demand are estimated for a partially automated CAPM as for a fully automated CAPM. Thus the labor increases detailed in the previous scenario apply to Scenario II as well. Without an automated page-turner, there will be additional labor needs since library employees (grade 32) will have to perform the scanning. Using work-study students is not a viable option for the library due to liability issues. To meet anticipated demand, 2 grade 32 employees will have to be hired to do the scanning for the CAPM system (see queuing analysis below). Relying on manual scanning also means that CAPM will only be available during normal business hours (i.e., approximately 8 a.m. to 4 p.m.).

	Grade	Grade Level	No. Positions	Salary	Salary + Benefits	Total($/year)

Automated CAPM	Grade 35	Mid	1	$22,705 $29,176	$46,000
	Grade 36	Mid	0.5	$25,465 $32,722	$$46,000
No Page Turner CAPM	Grade 32	Low	2	$13,413 $17,235	$80,000
	Grade 35	Mid	1	$22,705 $29,176	$80,000
	Grade 36	Mid	0.5	$25,465 $32,722	$80,000

As mentioned above, CAPM will initially operate as a partially automated system. It is assumed that the system will be upgraded in year 5. In this case, the labor costs will be $80,000 range for the first 5 years and will be $46,000 for years 6 through 10. If CAPM is not upgraded, the labor costs will be $80,000 throughout the 10 years period.

An important issue relevant to hiring staff for scanning requested books is the ability of the CAPM system to handle anticipated usage rates. Queuing theory (Ury, 1991) can be used to determine what levels of usage various configurations of the system can handle. Simple queue calculations rely on two parameters: arrival rate and service rate). The amount of time it will take CAPM to fully process a request will depend on the location in the stacks of the requested item and the length of the document to be scanned and whether the document has been scanned previously. It is estimated that the average processing time will be 10 minutes. Therefore, with two manual scanning stations (i.e., two scanners and two employees), on average CAPM will be able to service 12 requests per hour under Scenario II. Currently, the average request rate for items at Moravia Park is approximately 60 per day. Some of these requests are made after normal business hours. However, for this analysis, it is assumed that all requests will be made during normal business hours, when the partially automated CAPM will be available for use. Therefore, using an 8-hour day, the current level of 60 requests per day translates into 7.5 requests per hour.

The traffic intensity, the ratio of the request rate to the total service rate (i.e., the service rate for each server times the number of servers), can be used to determine if a queue will be stable. Stability refers to whether the service can, on average, keep up with the requests. If service cannot keep up with the requests, a backlog will grow indefinitely. If the traffic intensity is less than one, the queue will be stable. For the current level of requests and with two scanners and two manual page turners, traffic intensity is .625, so the system will be stable. Of course as demand grows, the traffic intensity will approach one and the system will become unstable. It is also important

to consider the probability of there being a queue, the average number of people in the queue (when there is one), and the average wait time for a patron in the queue (when there is one). The following table presents these statistics for the CAPM system under some of the expected request rates mentioned in the introduction.

Rate Request	Service Rate	Total Service Rate with 2 Servers	Traffic Intensity	Probability of a Queue	Av. Length of Queue	Av. Wait Time in Queue (hours)
7.5	6	12	.62	.48	.81	.11
9.4	6	12	.78	.69	2.5	.26
12.5	6	12	1.04	.98	22	1.8
7.5	7.5	15	.50	.48	.81	.08
9.4	7.5	15	.63	.33	.33	.04
12.5	7.5	15	.83	.76	3.8	.30

The data in the table indicate that with an average service time of 10 minutes (i.e., = 6 requests per hour), the probability of a queue becomes significant when the request rate reaches about 75 per day (i.e., 9.4 per hour). If the average service time is 8 minutes (i.e.,= 6 requests per hour), the probability of a queue becomes significant as the request rate approaches 100 per day (i.e., 12.5 per hour). If demand grows to these levels and the probabilities associated with queuing become significant, it is possible that there will be a need to hire an additional manual page-turner and purchase another scanner. However, it is anticipated that demand will not grow to these levels before CAPM is upgraded to the fully automated system.

Since the robotic page turner is yet to be developed, it is difficult to determine how it will impact the service rate of the system. As an upper bound, we can assume that it will not speed up the system at all and that the average service time will be about 10 minutes. However, it will enable the system to run about 20 hours per day (the system will have to come down daily for battery charging and occasional maintenance). If usage of the system does in fact grow to 100 requests per day (or 5 requests per hour), a queuing analysis shows that the fully automated system with the above average service time will be able to handle such growth. Under such conditions, the traffic intensity would be about .42 and the probability of a queue would be about .25.

A final issue relates to the labor requirements of other organizations that might implement CAPM. Labor requirements introduced by CAPM will differ from one institution to another, as will the salary levels. Some institutions may have adequate staff to cover the increased cataloging needs associated with CAPM, while some may

not. Demand may also differ resulting in various labor requirements. Therefore, the labor costs associated with CAPM may vary widely. In order to generalize the results of this analysis, however, the same range of labor requirements and costs faced by JHU will be assumed for other institutions.

Maintenance Costs

Maintenance costs are applicable to the robot, page-turner, scanner, and computer systems. The JHU Mechanical Engineering Department, who will develop the page-turner, estimates the maintenance costs of the page-turner to be equivalent to a medium sized photocopier. Based on costs of maintenance contracts for a medium sized, medium use photocopier, the maintenance cost for the page turner is estimated to be $2,500/year. The maintenance for the robot is anticipated to be equivalent to that of the page-turner. Maintenance contracts for scanners currently used at JHU cost approximately $4500/year per scanner. Therefore, this value will be used for the cost of maintenance for the scanner used in CAPM.

Penalty for Reduced Storage Space: As discussed in section 2, there are two options for book storage: Scenario IIa and Scenario IIb. Both options will result in reduced storage capacity and this must be accounted for in the costs.

Shelf Configuration

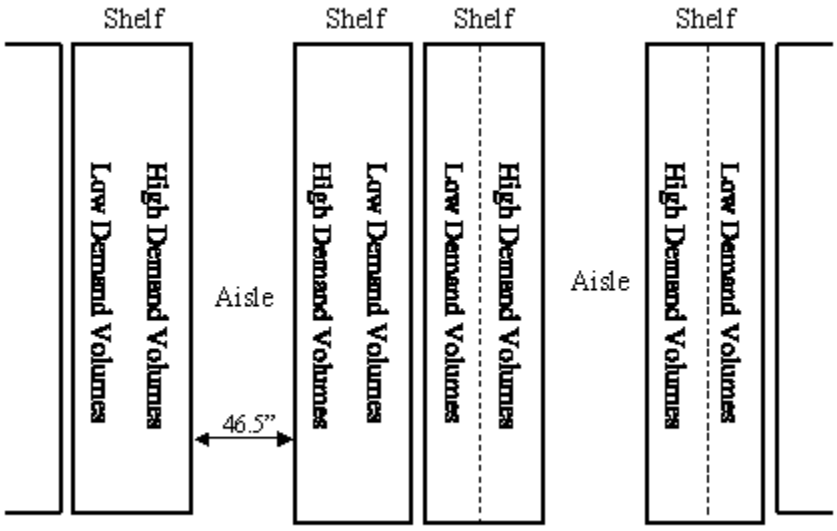
The current method of retrieval in the first bay of Moravia Park is a human operated machine similar to a forklift. The use of this machine requires large aisles between the shelves (approximately 46.5 inches) to give the machine proper clearance for operating and turning. With the current method of retrieval, the boxes of books are stored two rows deep on the shelves. It was initially assumed that the robot would not be capable of retrieving books that are stored in the back row. One way to account for this limitation is to configure the shelves in the second bay differently from how they are configured in the first bay. One major difference would be storing the boxes of books one layer deep on the shelves. This would introduce a significant loss of storage capacity. However, the robot platform will only require about 36 inches of space between the shelves (as opposed to the 46.5 inches in the current configuration). This reduced spacing between the shelves will offset some of the loss of storage capacity due to shelving books one layer deep.

Currently, a bay in Moravia Park holds 18 shelving units that are approximately 40.5 inches deep, one shelving unit that is approximately 20.1 inches and another that is estimated to be 22.4 inches. There are 10 aisles having a width of approximately 46.5 inches. Should it be decided to configure the second bay differently from the first bay, the space could be reallocated to incorporate CAPM so that there are 30 shelving units

having a depth of 22.4 inches separated by 15 aisles having a width of 36 inches.

The current bay has 18 rows of double depth storage and two rows of single depth storage. This is equal to 38 rows of single depth storage. The bay to accommodate CAPM would have 30 rows of single depth storage. If the bay were set up to incorporate CAPM, a loss of 8 rows of single depth storage would occur. This is equivalent to a loss of about 21% of the current storage capacity. In terms of books, the new arrangement would accommodate approximately 670,000 books rather than the 850,000 books currently stored.

The other option for dealing with the robot's retrieval limitations is to configure the storage and shelves as they are in the first bay (i.e., two layer deep storage and shelves 46.5 inches apart; see *Figure 2*). The front rows of storage (those accessible to the robot) could then be used to store high demand volumes, while the back rows of storage could be used to store low demand volumes. With the highest demand volumes stored in front, the robot could be relied upon to fulfill most of the requests for materials. With the shelves 46.5 inches apart, the current method of manual retrieval would still be feasible and could be used on the relatively rare occasion that a low demand item is requested. This configuration will introduce no loss of storage capacity and therefore no costs in this category. Currently, MSEL plans to set up the second bay of Moravia Park using this configuration. It has not yet been decided whether high demand volumes will be shelved in the front rows of the shelves.



Book Storage: As noted above, the robot in a fully automated CAPM system will

require spaces on each side of every book to extract the books from the boxes. This will cause a loss of storage capacity that must be included in the cost analysis. The amount of storage lost will depend on how the spaces are created. One option (Scenario IIa) is to store the books in individual cartons, similar to those used for VHS videos. Each carton would be slightly larger than its book, creating the required spaces. The cartons would be stored in larger boxes similar to those used now. Another option, Scenario IIb, is to use only the larger boxes (no cartons) with foam spacers between each book. Using the cartons will involve a greater loss in storage since each book will have space on *both sides* within its carton, essentially doubling the space between each book. Using the foam spacers will have only the necessary space *between* each book (See *Figure 3*).

Since it is assumed that CAPM will be upgraded in year 5, the following annual costs will be incurred at that time.

Calculations

At this time it is anticipated that the robot will need either 1/8 inch or 1/4 inch on each side of every book for it to be able to grab a book and extract it. As stated above, the two options for creating these spaces will result in different losses of storage capacity.

If individual cartons are used to create the needed spaces, there will be a space on each side of every book within a box. If the spaces are 1/8 inch, this is equivalent to 1/4 inch between each book, and 1/8 inch between the end books and the side of the box. There will be 20 front row shelves accessible to the robot, each being about 100 feet long and having 15 rows of storage. There will be 18 back row shelves that will not be accessible to the robot. Without spaces between the books, the total storage of the second bay of Moravia Park would be approximately 1,026,000 books (540,000 on the front shelves and 486,000 on the back shelves). With spaces created using the individual cartons, the front shelves will be able to store approximately 432,000 books for a total storage of 918,000 books (see appendix 2 for spreadsheet calculations). Therefore, the loss of storage capacity due to the cartons would be 108,000 books, or 10.5 percent.

This loss of storage capacity can be assigned a dollar value based on the annual leasing costs for Moravia Park. The lease rate is $140,000 per year. If the book storage bays account for approximately 80% of the area in Moravia Park, the approximate cost attributed to book storage is $112,000. Thus, with 10.5 percent of the capacity lost, an annual cost of $11,800 could be attributed to CAPM.

As mentioned, it is possible that the robot will need 1/4 inch spaces to grab a book. A

similar set of calculations can be done to derive opportunity costs of creating the 1/4 inch spaces using individual cartons. The 1/4 inch spaces would result in an annual opportunity cost of $19,600.

Foam Spacers Option: If the needed spaces between books are created using foam spacers and the needed spaces are 1/8 inch in size, there will be 1/8 inch between each book and between the end books and the side of the box. Using the same figures as in the calculations for the individual cartons, it was found that the foam spacers would result in a storage loss of 72,000 books, or 7 percent. Therefore, creating the necessary spaces in this way will result in a lost storage capacity annual cost of $7,900. If the spaces needed between the books is 1/4 inch and the foam spacers are used, the annual opportunity cost would amount to $11,800.

It is difficult to determine how much of a cost for lost storage capacity would be faced by other institutions. The number depends largely on the size of the facility, the cost for leasing the facility and the configuration of the shelves within the facility. However, since a fully automated CAPM will require spaces between books, every institution using the CAPM system will incur the associated opportunity cost, i.e., facilities will be able to shelve fewer books and a cost must be assigned to such losses. For purposes of comparison, it will be assumed here that other institutions will face costs for lost capacity similar to those faced by JHU. Though this is not realistic, it is the best way to ensure that this unavoidable cost is included in the assessed costs for implementing CAPM at institutions other than JHU.

Variable O&M Costs

Electricity Costs: Electricity is a cost that will be incurred on a yearly basis and will vary depending on usage of the system. The components of CAPM that will require electricity are the robot, the page-turner, and the scanner.

Robot: The robot receives its operating power from two batteries that are part of the base of the robot. The robot is expected to be able to operate for eight hours from fully charged batteries. No more than one charge per day will be needed to meet anticipated usage rates of the CAPM system. Being charged once per day, the robot will use approximately 2.2 KWH/day.

Page-Turner**:** Although it is still in development, the JHU Mechanical Engineering Department estimates that the automatic page-turner will use 500 watts of electricity at peak usage and 50 watts while it is inactive. For anticipated usage rates, it can be estimated that the page-turner will be at peak usage for no more than 16 hours per day and will be inactive for the other 8 hours. Therefore, the page-turner will use about 8.4

KWH/day. The cost of the electricity to run the page-turner will be incurred starting in year 5.

Scanner:The brochure for the Minolta DPCS 3000 scanner indicates a peak consumption of 1 kilowatt. It is expected that the scanner will operate no more than 16 hours per day. This results in a use of 16 KWH/day. Since two scanners will be used under Scenario II, 32 KWH/day will be used.

Calculations

Under Scenario II, the robot and two scanners will result in an increase in electrical usage of 34.2 KWH/day. Under Scenario I, the robot, page-turner and one scanner will result in an increase of electrical usage of approximately 26.6 KWH/day. The average electricity rate paid by JHU over the last 4 years is $0.05225/KWH. This value will be used here. Under Scenario II, the additional electricity costs will amount to $1.79 per day, or $652 per year. The increase in electrical usage Scenario I will cost $1.39 per day, or $507 per year.

It is assumed that these figures for electricity costs are representative of those that would be incurred by other institutions. Hence, the same numbers will be used in summing up the costs for organizations other than JHU.

Total Costs

The total of the annual expenses will be expressed in present dollars. A specific percent was added to the annual expenses to account for salary increases and inflation. A value of present worth expresses the total flow of future expenditures as a one-time expenditure at the end of year zero.The following tables depict the estimates of the present worth of the total cost of CAPM for JHU and for other institutions

	JHU	
Present Worth	Fully Automated CAPM	Partially Automated CAPM
Low	$1,319,000	$1,405,000
High	$2,449,000	$2,442,000

	Other Institutions	
Present Worth	Fully Automated CAPM	Partially Automated CAPM
Low	$1,435,000	$1,516,000
High	$2,660,000	$2,603,000

It is also useful to examine how much fixed and variable costs contribute to the total

costs. The tables below provide information on the fixed and variable components of the costs.

		JHU	
Category		Fully Automated CAPM	Partially Automated CAPM
Low	Fixed	$710,000	$721,000
	Variable	$548,000	$684,000
High	Fixed	$1,747,000	$1,758,000
	Variable	$703,000	$684,000

		Other Institutions	
Category		Fully Automated CAPM	Partially Automated CAPM
Low	Fixed	$826,00	$832,000
	Variable	$609,000	$684,000
High	Fixed	$1,958,000	$1,919,000
	Variable	$702,000	$684,000

Cost Per Use

An initial estimate of the expected usage will be determined by the user survey. However, for the purposes of this evaluation, a range of usage values will be provided. As a reference, the current number of daily requests for books and articles from Moravia Park is approximately 50. Using a range of values centered at this current average, estimates of cost per use can be determined. These numbers provide a more realistic presentation of the costs that can easily be compared to the willingness-to-pay data gathered in the user survey.

Based on the total costs, values of cost per use were calculated and are presented in the following tables. A 5% increase in annual usage was estimated to account for user familiarity with CAPM.

JHU	Usage/Day		Cost/Use
Fully Automated CAPM	100	Low	$3.81
		High	$7.07
	75	Low	$5.07
		High	$9.42
	50	Low	$7.61
		High	$14.13
	30	Low	$12.69

		High	$23.56
	20	Low	$19.03
		High	$35.33
No Page Turner CAPM	100	Low	$4.05
		High	$7.05
	75	Low	$5.40
		High	$9.39
	50	Low	$8.11
		High	$14.09
	30	Low	$13.51
		High	$23.48
	20	Low	$20.27
		High	$35.23

Other Institutions	Usage/Day		Cost/Use
Fully Automated CAPM	100	Low	$4.22
		High	$7.68
	75	Low	$5.62
		High	$10.23
	50	Low	$8.43
		High	$15.35
	30	Low	$14.05
		High	$25.59
	20	Low	$21.08
		High	$38.38
No Page Turner CAPM	100	Low	$4.37
		High	$7.51
	75	Low	$5.83
		High	$10.01
	50	Low	$8.75
		High	$15.02
	30	Low	$14.58
		High	$25.03
	20	Low	$21.87
		High	$37.55

The above tables present cost per use data based on the total costs for the CAPM system. It is also useful to examine cost per use data calculated using only the O&M costs. As assessed in this chapter, the only differences between the general case and the case for JHU are initial investment costs (e.g., the robot, scanner etc.). As mentioned, the O&M costs will vary across institutions. For this chapter, however, the O&M figures determined for JHU are considered to be representative of those likely to be encountered at other institutions. Therefore, the O&M costs are the same for both cases and the following table is valid for both JHU and the general case. Furthermore, the O&M costs in Scenario II were not represented by ranges. Hence, there is only one cost per use value for each usage level in Scenario II.

	Usage/Day		Cost/Use
Automated CAPM	100	Low	$1.76
		High	$2.03
	75	Low	$2.34
		High	$2.70
	50	Low	$3.51
		High	$4.05
	30	Low	$5.86
		High	$6.76
	20	Low	$8.79
		High	$10.13
No Page Turner CAPM	100		$1.97
	75		$2.63
	50		$3.95
	30		$6.58
	20		$9.87

If one is unfamiliar with costs of library services, some of these values may seem high. However, many of these cost per use values are not unlike the costs of another commonly used library service, interlibrary loan (ILL). The following table summarizes the mean cost to libraries for providing ILL. These values are based on a 1998 study of North American college and research libraries (Jackson, 1998).

Mean Cost	Research University Libraries	College Libraries
Borrowing Unit Cost	$18.35	$12.08
Lending Unit Cost	$9.48	7.25
Combined Unit Cost	$27.83	$19.33

Comparing the cost per use data for CAPM and the average ILL costs one can see that under most scenarios CAPM costs less than ILL. In fact, only if the use of CAPM is very low (indeed, much lower than is expected) do the cost per use numbers based on the total costs begin to exceed the costs for ILL. The cost per use for CAPM based only on the O&M costs are much lower than ILL for all usage levels analyzed. This is not to suggest that the CAPM system can replace ILL and offer cost savings–the systems provide different services and are not necessarily substitutes. The comparison is made to show that the costs for CAPM are less than another widely used library service.

Risk

This risk analysis is designed to look at the costs associated with the implementation of CAPM that would be recoverable if the system does not function as expected. It is important to differentiate the sunk costs from those that can be avoided should a decision be made to terminate the CAPM program before the lifetime assumed in the previous sections. Other studies have shown that many projects do not make careful studies of risk. A survey of 200 British companies showed that for projects having budgets greater than 660,000 pounds, 90 percent were over budget, 98 percent had changed specification, 60 percent were over time, and 20 percent were inappropriate (Willcocks and Griffiths, 1994). In the instance of CAPM, the demand and benefits will be projected based on a user survey conducted during the fall of 2000. The costs are being assessed through this analysis. Technological feasibility is not expected to be a problem.

If CAPM is implemented and the demand projected by the survey does not materialize then CAPM may be discontinued. It is unlikely that the much of the money invested in the project could be recovered. The robot and the page-turner (if it is already implemented) are sunk costs. The amount of money that could be obtained for selling the robots would be minimal compared to the cost required to produce them. Expenditures on the book cartons (those used to create the spaces between the books) are also sunk costs. Although, the cartons would not have to be removed, they would serve little purpose without the CAPM system. Additionally, funds spent on book set-up are not recoverable.

If CAPM is terminated after it is upgraded to a fully automated system, the spaces between the books needed by the robot will present a problem. As discussed, these spaces result in a loss of storage capacity with an annual cost on the order of $10,000. If the CAPM system is removed MSEL either will have to invest time and resources to remove the spaces, or it will have to absorb the annual costs associated with the

loss of storage. At this time, it is difficult to determine which option would be economically optimal. Some pertinent factors in such a decision would be the existing rate of acquisitions and the rate at which the second bay of Moravia Park is being filled. Clearly this aspect of the project does present some risk.

If CAPM is terminated after five years of service, funds allocated to replacement PCs and a replacement scanner (recall that these items are expected to be replaced in year 5) likely are recoverable costs. These components could easily be used in other contexts, and although there would be some costs associated with transferring them, the cost would be minimal compared to the value of the machines.

Conclusion

In the face of increasing pressures on storage space and decreasing budgets, libraries are forced to consider new means for managing their expanding collections. Off-site shelving has emerged a cost-effective way to meet this challenge. However, off-site shelving results in decreased ability to browse. It is hoped that CAPM can remedy this problem by speeding access to materials stored off-site and by opening off-site collections to patron browsing.

This chapter has summarized the costs involved in implementing the CAPM system. The most important result of this analysis is that the costs per use for CAPM are likely to be comparable to or less than that for ILL. Although CAPM requires significantly more initial investment than ILL, the comparison of the two shows that, in the long run, the costs for CAPM are within a range that is reasonable for most libraries. Furthermore, this result warrants that any decisions about CAPM be based on the comparisons of these cost per use values with anticipated patron benefits.

In conclusion, Leblanc (1995, p. 301) quotes Thomas Mann as saying "to spend enormous amounts of money assembling book collections and then to make access to them only superficial, partial, incomplete, and haphazard is to throw money away rather than to use it prudently." In many cases, CAPM might represent a prudent use of library funds.

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