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Key Factors of Circulation System Analysis and Design

Librarians must frequently judge circulation systems on the basis of widely disparate descriptions that make comparisons difficult. A way is needed to place various systems into a common perspective or framework, so that their similarities and differences can be readily understood. This paper explains basic (and largely familiar) concepts and components that are common to manual, machine-aided, and computer-based systems, and documents their significance as key factors in the analysis and design of academic library circulation systems. Cost factors are not discussed.

Introduction

LIBRARIANS ARE FREQUENTLY put into the position of judging circulation systems—at professional meetings, in sales presentations, upon reading library literature. The variety of systems (e.g., manual, machine-aided, computer-based) and the varying qualities of their descriptions often make understanding and comparing systems difficult, particularly since proponents of specific systems may only emphasize selected features. What is needed is an explanation of fundamental concepts and components that provides a general framework for viewing systems. This paper therefore attempts to explain key factors in the analysis and design of academic library circulation systems. Let us begin by making several assumptions and definitions.

The basic purposes of a circulation system are to record, regulate, and control the movement (absences) of library materials from their designated locations. Consequently, a circulation system for an academic library may become an intricate combination of policies, procedures, data processing, equipment, and staff, the operations of which may demand a significant portion of the library budget.[1]

To fulfill its purposes a circulation system must contain records for items such as books, journals, and microforms that have been removed from the locations indicated for them by library catalogs. It is assumed here that a circulation system contains a file of these records, called an absence file. The term absence file is preferred to charge file, since a file of this nature will inevitably hold records for items that are absent for reasons other than library charges of items to patrons. It is important to recognize this in basic terminology and considerations, since the cause of an item's absence determines how its absence record is processed to secure the item's return.

A circulation system may also contain other kinds of records. The library may maintain files of user records (e.g., a

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file of registered borrowers) and item records (e.g., an accession book or computer-held shelflist). Different combinations of files like these may be used for circulation control, depending upon a library's circumstances.

Special user-held and item-held records such as borrower identification cards and manual or punched book cards may also be employed in a circulation system. Since these records serve as sources of borrower and book information for charges, it is convenient to call them source records.

There are also transaction records which may be created for a variety of transactions that can occur between the library and its users: charging and discharging items, placing reserves on circulating books for users who have requested them, settling fines, etc. Charge records may be updated for subsequent transactions such as reserve requests and discharges, although some transactions such as fines handling may require new records and special files. For a library to ensure that items carried by exiting users have been properly charged, some form of transaction evidence—typically cards or slips—is required. This evidence may contain return dates upon which items are due, for the borrowers' convenience.

Together these elements furnish a set of key factors by which circulation systems may be described and typed: the media and data of source records and absence records; the techniques of data transfer by which book and borrower data are combined to create charge records; the kinds of transaction evidence; and the existence, storage characteristics, and processing of library files of user, item, and absence records. This paper documents the significance of these and other factors in the analysis and design of academic library circulation systems.

It has been useful in the following discussion to introduce still more nonstandard terms for concepts which are usually referenced in circulation system literature by the names of particular examples. The use of such terms may inconvenience some readers, but that is the cost of attempting to deal in generalities rather than specifics. As the large number of circulation systems described here and elsewhere indicates, a range of possibilities rather than a single answer exists for many aspects of circulation system design. It is therefore important to think in terms of general concepts rather than of particular examples. Different terms have thus been liberally used to supplement standard ones, to avoid conceptual limits that might otherwise be imposed. Where new or different terms are used, the familiar ones to which they are related are usually mentioned as examples.

Information Requirements

Two basic information needs are usually considered minimum requirements for academic library circulation systems: R^1, the provision of locational information about items absent from their proper locations, and R^2, the provision of processing and control information necessary to regulate these absences. An optional requirement is R^3, the provision upon request of information about specified users' transactions. There is another, more general need for managerial or statistical information about circulation system operations which will not be analyzed here.

Basic File Processing Capabilities

Beyond updating the absence file by adding new records and changing and removing old ones to record new transactions and changes in absence status (e.g., recording that books have been loaned or returned or reserved by a patron), other, special capabilities are needed to satisfactorily process it for R^1 and R^2 requirements: the capability to answer locational queries with reasonably current information, within a satisfactory response time; the capability to discharge returned items rapidly and to identify special categories and pieces and generate appropriate notifications (e.g., identify overdue books and items that have been reserved by users, and send fines bills and reserve notices); and the capability to identify and process records for overdue loans and for other kinds of absences periodically (e.g., to search for lost books). Even a quick comparison of how systems provide these capabilities and what their methods imply for R^1 and R^2 performance in a particular library is one way of evaluating alternative designs.

Absence Categories and Processing Phases

The term item absence is used to indicate the physical removal of a library item from its assigned location. Item absences may be classified into categories like those shown in Figure 1: lost items, one-day loans, etc. Here absence categories are primarily distinguished as controlled or uncontrolled, based on accessibility by call number of corresponding absence records. If a record for a missing item can be looked up by call number, then the library knows about or has control of the absence. Whether individual absence categories are eliminated (rather minimized), allowed but controlled, or ignored defines circulation system scope and sometimes other library requirements as well. Consider, for example, trying to minimize some of the uncontrolled categories shown by Figure 1. Denying public access to bookstacks to reduce thefts and misshelving, or increasing staff to speed shelving of returned items may have been significant policy and cost implications.

To control a category of absences through a circulation system requires that special (absence) records be created and processed for them. Depending upon the category, these requirements may become major system design and cost factors. For example, if special locations of compactly stored items are shown by circulation system records instead of updates to library catalogs, then a large number of records may be added to absence files for an indefinite time. The penalties of creating a special absence file for storage items, or of enlarging existing files, may become crucial when file storage and processing costs or system response times are significantly increased.

To exercise R^1 control requires accessing absence records by locational keys of missing items—in the example of Figure 1, by finding records through call number lookups.

To have R^2 control requires that each absence record be periodically retrieved and processed according to its age and membership within a given absence category. When an absence record is created, some time factor such as current date or transaction due date is usually recorded. Within each category records may therefore be subcategorized according to their time factor associations, or ages. Thus at any point in time each subcategory may be scheduled for a unique processing action: some students receive first overdue notices while others receive second notices; some missing books are declared lost and are reordered, while others are simply searched for again.

Because it is generally expected that absent items can be returned or found, the circulation system may actively seek these returns by periodically retrieving and processing absence records through such actions as these. Multiple processing phases are generally prescribed for each absence category, on the order of: (1) first record retrieval and processing phase (e.g., first overdue notice, first follow-up search for a missing item, first interdepartmental notice to preservations department about an item sent there for repair, etc.); (2) one or more

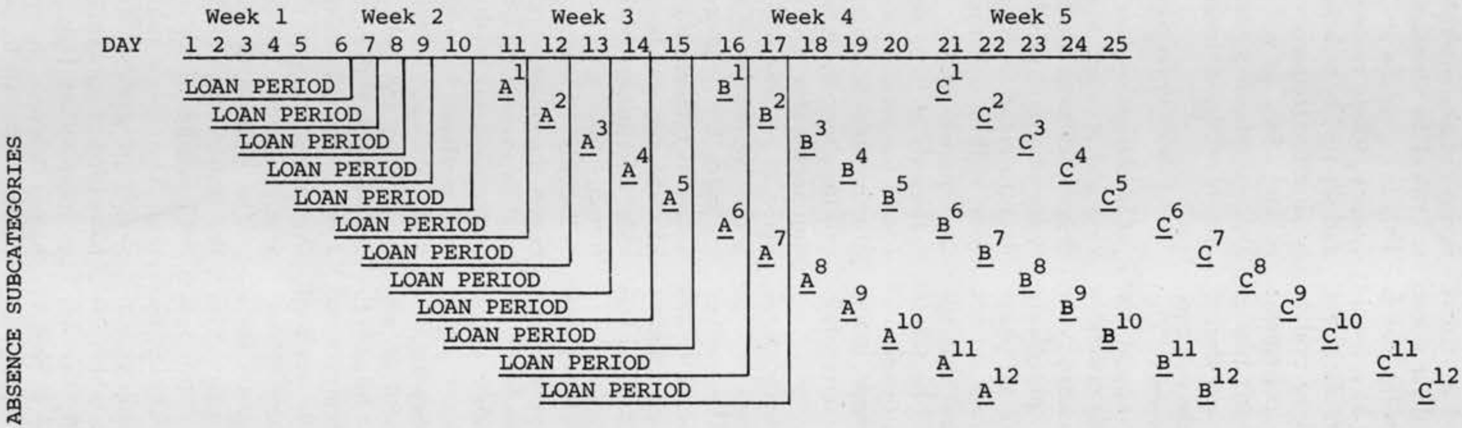
Some Possible Absence Categories*

- Controlled (by absence records accessible through call number)
  - circulation system R¹ file
    - non-charges
      - lost items
      - reordered, lost items
      - missing items being traced
    - charges
      - to individuals
        - 1-day loans
        - overnight loans
        - student loans
        - faculty loans
        - loans of reserved items
      - to nonindividuals
        - photoduplication
        - binding
        - interlibrary loan
        - acquisitions
        - cataloging
        - reserve department
  - other files
    - compact storage files
    - binding records for items in process
- Uncontrolled (not represented by records accessible through call number
  - undetected missing items
    - stolen items
    - misshelved items
    - uncharged items in use within library
    - discharged items which have not been reshelved
  - specially located items whose whereabouts are not shown by library catalogs
    - folios
    - microfilm
    - new books on display

* These examples illustrate possible absences, and are not intended to represent those of any specific library.

Fig. 1

Given: 1. A category of absences for "regular loans," which are made daily and fall due exactly one week from given charge dates.
2. A five-day week.
3. A series of R^2 processing phases (A,B,C) for items not returned by their scheduled due dates, the first phase of which occurs one week after a given item's due date, and the other phases of which occur at one-week intervals thereafter.



The number of subcategories extant within a single absence category depends upon the maximum length of each absence subcategory (in this case 21 days), and the intervals at which new subcategories are begun (here the intervals all equal 1 day). It can be shown for this case that the maximum number of absence subcategories is the length (21 days) divided by the interval (1 day), plus 1. Thus at any time after day 21, twenty-two absence subcategories may be extant. Each subcategory goes through three processing phases (A,B,C), so that daily after day 21, three separate R^2 retrievals must be made to process one absence subcategory each through one of three phases.

Fig. 2

Absence Subcategories and Processing Phases subsequent phases (e.g., send a second overdue notice and then a bill for a lost book, conduct a second follow-up search for missing item, etc.); and (3) a terminal phase (e.g., order a replacement copy for an unreturned item, or update library catalogs to show its permanent loss). The number of processing phases and the nature of actions taken during each depend of course upon the category of absence records being processed. The point is that items become absent for different reasons, and that the processes necessary to secure their returns vary accordingly. Enforcing a processing schedule and especially a terminal phase will ensure that absence records do not remain in files indefinitely, and that appropriate remedial action will be taken. This benefits delinquent borrowers and those with reserves on absence items, and may simplify and reduce circulation system R^2 activities.

Within a given absence category each absence subcategory undergoes its own series of processing phases. The number of subcategories is not necessarily related to the number of processing phases prescribed for a category. Figure 2 illustrates this.

Specifications of absence categories and subcategories and processing phases give a basic definition of circulation R^2 requirements, since the number of required R^2 retrieval categories is equal to or greater than the maximum number of absence subcategories extant at any time. That is, the system must be able to retrieve and process each subcategory of absent records. It should be realized that the number of processing phases and the number of subcategories for a single absence category may vary through time. Their dynamic nature may be attributed to changing library use patterns and circulation policies, increased processing loads, etc., which emphasize the importance of flexible system R^2 capabilities. How or if present and future R^2 requirements for a specified set of absence categories can be met is critical to circulation system design. This is especially important for manual systems, where record encoding methods and file review techniques may effectively limit the frequency of retrieval passes on large files, as well as the number of absence subcategories which can be separately retrieved during a single file pass.

Circulation System Records

Circulation system records are created and accessed to control users' privileges and item absences. Two general types of users' privileges are the privilege to enter the library and restricted areas within, and the privilege to initiate transactions.

Records of item absences may be accessed for several purposes. Accesses by primary item identification key (usually call number) are made to satisfy R^1 requirements for locational information. Periodic retrievals of absence subcategories by attributes such as due dates are made for R^2 processing. Accesses by a user identification key such as name or identification number are needed to provide information about specified users' transactions.

Records of charge transactions between the library and its users are created by combining user data, item data, and time data. Media (source records) and methods by which user data and item data may be initially presented to the system are indicated by Figures 3 and 4, which distinguish between the active participation of users in making their identifications, and the passive nature of items is being identified.

The process of identifying users to the system may be designed for different levels and qualities of user participation. The user's role may range from simply presenting an identification card to writing or speaking varying quantities of information (e.g., full data such as name, address, telephone number; or partial data such as an identification

Possible Methods of User Identification

- identification card
  - alphanumeric data
    - embossed/debossed
    - printed data that are also machine-readable
      - optically readable fonts
      - magnetic-ink character recognition fonts
  - machine-readable coded data
    - punched
    - optically readable bar coded
    - optically readable (mark-sense) codes
    - magnetically readable
  - various combinations of alphanumeric and coded data
- no identification card
  - unverified user stipulation of identity
  - user stipulation of identity and system confirmation (e.g., use of passwords)
  - staff recognition
  - emerging machine-aided identification systems
    - fingerprint recognition
    - voice recognition

Except for "staff recognition," each of these methods of user identification requires initial or responsive user action. It is important to recognize which user card data may or may not be visually readable or otherwise meaningful to users.

Fig. 3

Methods of Item Identification

- item cards
  - machine-readable
    - punched
    - magnetically coded
    - optically readable
      - mark sense codes
      - readable fonts
  - machine-aided replication of item record data
    - reprographic transfer
    - embossed/debossed transfers
  - removal of manual item card(s) for duration of item absence
- no item card
  - machine readable item/label
    - magnetically coded
    - optically readable
  - reprographic transfer of item/label information
    - photocopying
    - quick copying (e.g., xerography)
  - manual transfer of item/label information

Item identifications are passive, in the sense that items do not initiate or enact their own identifications. Users or library employees must therefore do the implied tasks. Item card data may not be visually readable, since the same data may be printed elsewhere inside or outside the item.

Fig. 4

number). What the user must do to identify himself is critical to the sensitive user-system interface, and may significantly influence system performance.

Similarly, the complementary roles of user and system in making item identifications can be variously designed for minimal user participation (e.g., present a book for charging) to extensive participation (e.g., fill out a transaction form). It is thus important to evaluate the method and ease with which item data can be transferred, and the extent of the user's participation beyond simply designating wanted material.

Time Data

Time factor data are made part of a transaction record to associate it with some point in time such as a transaction date or due date, or a time clock reading. There are two basic types of time data for lending transactions: fixed time data, which are the same for all charges within a given time frame (e.g., all books charged today are due in one month); and variable time data, which differ for charges made within a given period, according to particular transaction criteria such as user and item attributes (e.g., student loans, faculty loans, loans of unbound periodicals).

	TRANSACTION ATTRIBUTES						
USER CATEGORY	Faculty	X	X	X			
	Student				X	X	X
ITEM CATEGORY	monograph	X			X		
	bound serial		X			X	
	unbound serial			X			X
LOAN PERIOD	1-day			X		X	X
	2-week		X		X		
	1-month	X					

Fig. 5

Complex Loan Periods in a System Using Variable Time Factor Data

Since variable time data may be determined by either a user's or item's attributes or by a combination of both, a decision-making or computing capability is required that is not needed for fixed time data. Variable time data can thus be distinguished as simple or complex. Simple data are determined by a single transaction criterion such as a single user or item attribute: e.g., two-week student loans, one-month faculty loans, overnight loans of unbound periodicals. Complex data are determined by a combination of transaction criteria, as illustrated by Figure 5.

Transaction Evidence

Evidence of valid charges is required to inspect items that users carry from the library building. This follows from the basic R^2 need for information to control item absences. The proliferation of library security systems in recent years emphasizes the necessity and quality of transaction evidence.

Two types of transaction evidence can be asserted. Simple evidence contains no more user and item data than are input to the system at transaction time, such as user numbers and item call numbers. Complex evidence involves user and item data other than transaction time inputs. For a system to respond with additional data for complex evidence may require special files, processing, and hardware not otherwise needed. This can be particularly demanding in online computerized systems. Consider, for example, the requirements of providing transaction time outputs of full user (e.g., name, address) and item information (e.g., call number, author, title) upon inputs of just user and item identification numbers. Real-time access to files of user and item records would be needed, in addition to terminals that can rapidly display (e.g., printout) the evidence. Think also of security systems that use special book labels or embedded book plates, which are switched and detected to indicate "valid charge" or "no charge."

Transaction evidence usually contains time data to remind borrowers of item return dates. Since time data are typically assigned during the creation of charge records, for both the borrowers' convenience and system R^2 needs, the incidence and quality of these data are not questioned or used to classify types of transaction evidence.

TRANSACTION DATA STORAGE AND TRANSFER

In examining how charge records are created, basic questions are how much transaction information is required in the system, and where data are stored and in what forms. Important factors are the media and data of source records, whether there are pretransaction system-held user or item records, the amount and methods of transaction time data transfers, and the quality of transaction evidence. Table 1 illustrates relationships among data storage and transfer, and requires a somewhat detailed explanation.

Table 1 is concerned first with relative quantities of transaction information—how much data must the system record for a charge, how much identification data are carried by user and item source records (for example, in punched identification and book cards), how much user and item data must be input to the system at transaction time, how much information must transaction evidence contain? We are dealing here with relative amounts of data—partial data and complete data—since the individual requirements of each circulation system specify for it the exact data elements that are needed. When we speak of complete data we mean all the data of a given type—e.g., complete user data. The term partial data is used when only part of the complete data is stored or transferred. It should be realized that what may serve as partial data in one system (e.g., the use of item call numbers to access full descriptive records of books) may be regarded as complete data in another system (e.g., the use of only the call number to describe the item—without citation of author or title).

The table assumes for charge records that enough data (i.e., complete data) about users and items must be held by the system for it to send sufficient descriptions (e.g., telephoned or mailed overdue messages) of unreturned items to delinquent borrowers. In some systems, call numbers alone may suffice as item data, whereas in other systems author, title, and so forth may also be used. Given that the system must hold complete charge information, we can now go back and examine the possible quantities of descriptive data that may be distributed prior to transaction time among users, items (i.e., stored in source records), and system-held files. From here we can see how much data of each type need to be transferred into the system to create a charge record. We also know from this how much data are available for simple transaction evidence, and what further data would be involved in supplying complex evidence.

Looking at Table 1, the first column is headed "Source Record System Types," which are simply reference numbers that are used in following paragraphs to describe prototype systems. The columns headed "Pre-Transaction Data Storage" show where and how much data for each system type are held by user and item source records and by the system, prior to transaction time. The symbol "N" shows that no data are held by a given component. By definition partial data are inadequate for addressing borrower notifications or identifying items, and must therefore be matched to system-held records containing complete data. Examples of source records containing complete data are magnetic user cards and punched item cards that each contain full information.

TABLE 1

Data Storage and Transfer for Charge Transactions

Source Record System Types	Pre-Transaction Data Storage: User Data		Pre-Transaction Data Storage: Item Data		Transaction-Time Transfers		Transaction Evidence		Post-Transaction Sys-Held Chrg Records	
	User-Held	Sys-Held	Item-Held	Sys-Held	User Data	Item Data	Simple	Complex	User Data	Item Data
1	P	C	C	N	P	C	P	C	C	C
2	P	C	P	C	P	P	P	C	C	C
3	C	N	C	N	C	C	C	—	C	C
4	C	P	C	N	C	C	C	—	C	C
5	C	N	N	N	C	C	C	—	C	C
6	N	N	N	N	C	C	C	—	C	C
7	P	C	N	N	P	C	P	—	C	C

Symbols: C: complete; N: none; P: partial; —: either not applicable, or complex evidence is not required to furnish complete data.

Printed user cards could also contain complete data.

The columns headed "Transaction-Time Transfers" show for each system type how much user and item data must be transferred to create a complete charge record. The columns headed "Transaction Evidence" indicate the qualities of possible transaction evidence, using the meanings of partial and complete data, and simple and complex evidence given previously.

The following comments are made to illustrate possible influences of source records upon system design and performance. Type 1 is representative of systems with user cards that contain Hollerith-punched identification numbers, and Hollerith-punched item cards containing complete item information. The only user data contained by simple transaction evidence are the identification numbers, which are regarded as partial data. More user data could be provided by implementing a special system response to furnish complex transaction evidence. Type 2 represents systems in which transaction time inputs of user and item identification numbers are made as links to complete system-held records. Using embossed/debossed cards as source records would yield simple transaction evidence that contains partial data. In an on-line system machine-readable cards or manual keystroking could be used to input identification numbers, and a system response could provide complex transaction evidence containing complete user and item data.

Type 3 suggests a system with magnetic user and item cards encoded with complete data. Another type 3 system is one that quick-copies printed user and item cards to produce a record (perhaps multiply copied to provide simple transaction evidence) containing complete user and item data.

Type 4 represents a system containing partial information for users with invalid privileges, which if matched at transaction time, triggers a system response to prohibit the charge. This feature can be incorporated by manually checking a blacklist, by building this capability into an on-line system, or by adding to any circulation system special negative authorization hardware now used in some commercial applications.

A type 5 system could be one using embossed/debossed user cards to transfer complete data to transaction forms, which are filled in manually with item data. A type 6 system is one in which complete user and item information is transcribed. In a type 7 system a user identification number and full item data could be transcribed to a transaction form, perhaps from a printed user card and the item itself. If the user number were mark-sense coded using a special form, it could be read by an optical reader to access a complete computer-held user record.

File Media and Organization

Absence record media and file organization are mutually influential system characteristics which affect the response times of file-dependent activities such as querying and discharging. They are definitely related to the media and methods of data storage and transfer, as discussed above.

So far the concept of an absence file has been discussed in terms of a single file. It should now be recognized that several differently ordered files or even a single file partitioned into separate sections may actually serve the absence file functions, which are essentially to support R^1 and R^2 processing.

Table 2 illustrates possible combinations of file media, organizations, and functions. Since the R^1 function is viewed as essential to academic library circulation systems, systems which cannot provide locational information for specific, missing items upon request are not considered. This figure does not attempt to give comprehensive descriptions of possible file organizations. Rather, it only illustrates the significance of file characteristics by defining sample types of systems. These are explained below.

Type 1 is representative of systems in which absence records are coded for due date and put into a single manual file ordered by call number. Examples of this are some notched-card and tabbed-card systems. Examples of a type 2 system are traditional double-record (e.g., two book cards, multiple-part transaction forms) systems which have an R^1 file ordered by call number, and a separate R^2 file primarily ordered by date and secondarily ordered by call number. A type 3 system could have a single file like this R^2 file—a call number file partitioned into sections that each contain records with the same date due. Some R^1 call number queries require multiple lookups, but R^2 identifications are simple. A type 4 example is a system with a single machine-held file that supports R^1, R^2, and R^3 functions (R^3 is the optional requirement to provide information about specified users' transac-

TABLE 2

Descriptions of System Types by Absence-File Characteristics

File Characteristics			System Types					
Media	Organizations	Functions	1	2	3	4	5	6
manual records	single file, call number order	R^1		X				
manual records	single file in call number order, with records coded for due dates	R^1	X					
		R^2	X					
manual records	single file by due date, secondary order by call number	R^1			X			
		R^2		X	X			
machine-held sequentially accessible records	single file, ordered by call number	R^1				X		
		R^2				X		
		R^3				X		
machine-held directly accessible records	various files in various orders	R^1					X	X
		R^2					X	X
		R^3					X	X
computer printout	sequential listing in call number order	R^1				X	X	
computer printout	lists of specified users' transactions	R^3				X	X	

tions). R^2 and R^3 outputs are made by automatic, batch processing runs that generate overdue and other notices, and lists of users' transactions. R^1 queries are answered from periodic printouts of the file in call number order. In a type 5 system transaction data are directly processed to update a randomly accessed machine file. Printouts of the file support R^1 querying and R^3 requests, as in the type 4 system. A type 6 system would be one in which R^1, R^2, and R^3 functions are directly performed through on-line, real-time access to computer-held files.

Conclusion

This paper has attempted to explain basic concepts and components common to many types of circulation systems. Classifications of systems according to their source records and files have been given only as illustrations. These are not comprehensive, and other criteria and classifications are possible. To evaluate and design specific kinds of systems such as manual systems and on-line systems will require special considerations beyond the general ones that have been made here. Nevertheless, an understanding of the factors that have been discussed should benefit library managers and system designers alike, who in the process of circulation system development must establish requirements and choose among alternative designs. Once library requirements are known and a system design is well understood, questions of managerial information and costs can then be examined.

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