CHECK PROCESSING AS AN INFORMATION MANAGEMENT ACTIVITY: CRITICAL REVIEW AND RESEARCH AGENDA

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Abstract

Current management science models fail to adequately recognize that treasury management related to check payments has largely become an information management activity. Check processing operations lack the flexibility to capture information which can be used by treasury managers to make the most effective utilization of check-related funds. This argument is developed by examining the fit between management science models and check processing practice in the U.S. banking industry, as well as at the Federal Reserve Bank, in view of the changes that information technology has wrought and the problems it has the potential to solve. We critique models for inbound and outbound check processing and treasury management for checks, and conclude that models which link check processing and treasury management models hold out significant promise for improving management control.

1. Introduction

1.1. The Problem

Rapid advances in the workstation technology used to support institutional treasury management have paved the way for increasing efficiency in short-term financial management. Account balances affected by transactions using electronic funds transfer can now be reviewed and adjusted by the corporate treasurer on a minute-to-minute basis, using highly automated systems provided by commercial banks. The result is improved management of the demand deposit and investment accounts which a corporation or correspondent bank must keep to handle its usual business.

Still, one area stands out as lagging the rest in productivity improvements and new applications of available information systems technology (IT) in treasury management: check processing. Current models fail to adequately recognize that treasury management for checks is rapidly becoming information management. The form and content of information related to check deposits and payments can be an important factor in determining whether a treasury manager is able to successfully manage an account position affected by checks. In this paper, we will argue that current check processing operations lack the flexibility to capture the relevant kinds of information and structure them for treasury managers.

1.2. Issues in Check Processing and Treasury Management

Research on checks has focused on two categories of issues: management of check processing operations and treasury management for checks as cash. Management science has had a major impact in these areas, as evidenced by the many research efforts and papers we will cite in this paper. Most large banks in the U.S. and elsewhere have implemented management science models to guide them in their day-to-day operating and treasury management decisions. However, it would be inaccurate to claim that operating sophistication should be judged by the presence of management science-based approaches. Today, what determines the level of sophistication in banking operations is the technology around which these approaches have been implemented. Since many of the problems that require computer-based modeling solutions have been formulated and solved, the focus has shifted to attacking much larger scale bank operations management problems. Check transit and clearing are among the problems which have grown as the American banking industry is increasingly deregulated and banks begin to expand beyond their traditional operating regions. This changing environment has caused bank operations managers to put a premium on flexibility, so that they can adapt their operations to the customized service requests of clients in different areas.

Meanwhile, most large corporations have implemented ways to more carefully manage check float. The corporate treasury manager has a number of tools to speed or slow the flow of funds through the clearing and collection pipelines, including lock box, remote and controlled disbursement, and payable through drafts. Sophistication in the corporate cash management of checks is based on whether a fully integrated approach, usually through a computer-based decision support system (**DSS**), has been implemented. (See, for example, Srinivasan and Kim (1988).). A DSS reduces the need to take repetitive monitoring and control actions to make the management science models at the heart of the system perform well. In other cases sophisitication has been redefined to eliminate relying on some of the old methods entirely. Hill and Wood (1983), for example, have suggested that the adoption of electronic business data interchange (**EBDI**) changes the "float game" entirely, eliminating the need for checks and providing major cost savings opportunities.

1.3. Outline of the Paper

This paper presents a critical survey of recent research on check processing and cash management for checks. Academic research in both these areas has made a significant impact on management practice in both these areas, and there are several reasons for looking at them together. First, the structure of a bank's check processing operations and its ability to offer the appropriate treasury management services to corporations are inextricably linked. Decisions in one area necessarily affect what is possible in another. Second, the complexity of environment is partly a result of the Federal Reserve Bank's (**FRB**) rules and regulations governing checks processing. This environment affects both banks and corporations in equally important, but different, ways. During the course of our critique we will highlight some of the issues that information technology has the power to solve, and that it creates.

Check processing operations are normally split into inbound and outbound processing activities. *Inbound checks* are those that must be sent from branches to the check processing operation, where they require sorting, encoding, microfilming and then posting to the bank's general ledger and customer accounts. *Outbound checks* are those for which internal bank processing activities have reached a conclusion. Most outbound checks are dispatched back to the bank on which they are drawn, through some clearing or sending arrangement. Section 2 presents an overview of the issues and research related to inbound check processing. Section 3 evaluates recent progress in outbound check processing activities in light of recent technology advances. Section 4 considers the special problems that corporate treasurers face in the corporate cash management of checks. Where it is appropriate in each section, we frame our critique from the perspective of the new capabilities that information technology offers and evaluate how the research relates to these new developments. We also provide suggestions for how some of the models and approaches must be changed to suit the dynamic technological and regulatory environment which characterizes U.S. banking.

2. Inbound Check Processing Research

Inbound check processing consists of four major activities:

- forecasting deposit activity
- scheduling and staffing in check processing operations
- internal check transit
- check sorting

Significant technology-driven developments are now affecting the efficacy of the models and methods check processing managers rely on for operational control. In the discussion which follows, we will define the activities, describe their content in more detail and evaluate what the impacts are.

2.1. Forecasting Deposit Activity

The most basic problem in check processing is the development of an accurate forecast of check volumes. The role of IT in this application is to enable data collection and subsequently store it, and then manipulate it prior to the generation of deposit volume forecasts. This activity has value to bank because of statutory requirements (Regulation E, for example) which require the bank to process all checks it receives, regardless of the geographic location of the receiving branch, in a timely fashion. Although about a decade ago it was standard practice for banks to make their forecasts on the same mainframe computers that were processing transactions, significant changes have occurred as the power of microcomputer technology and econometric forecasting software packages has grown.

Check volumes tend to vary greatly, and may even fluctuate by a factor of two from day to day. Among the first to discuss this problem in the management science literature were Boyd and Mabert (1977), who jointly developed a check deposit volume forecasting technique with Chemical Bank, New York that combined regression and exponential smoothing. They attempted to improve performance over other techniques which were not adapted to the demands of check processing forecasts. Even though the scope of Boyd and Mabert's model was limited to represent specific events like weekdays, holidays in the U.S., months of the year and so on, still they reported that their model's predictive capability was fairly good over time, with errors in the 5% to 7% range.

When banks extend their operations internationally, the problem of forecasting deposit activity becomes increasingly complicated. Some portion of the check processing work conducted by a large international commercial bank will not follow the typical Monday-to-Friday, month-to-month and holiday schedule in the U.S., so this would render the specifics of Boyd and Mabert's model less viable. It lumps into one distribution a set of at least two, if not more, distributions of checks sent for processing. U.S. dollar checks deposited at overseas locations and arriving in the U.S. via "cash letters", for example, will not follow the same distribution. This fact is recognized in practice by most international banks: they sometime organize their check processing operations to represent domestic and international source check deposits.

Other advances (Mabert, Fairhurst and Kilpatricks, 1979; Mabert and Stocco, 1982; and, Davis, Ceto and Rabb, 1982) have centered on more careful estimates of the smoothing constants for each day of the week and measuring the effects of Saturday bank openings on check processing activity. Adjustments also have been made to ensure the models remain robust under the changing conditions that have beset the banking industry. Some of those changes include the shift among check writers to the credit card, increasing use of electronic funds transfer for corporate payments, greater public awareness of cash management using retail electronic banking technologies, and changes in FRB policies which have made the use of checks more and more expensive.

2.2. Scheduling and Staffing of Check Processing Operations

Management science techniques have also been employed in check processing to optimize the scheduling and staffing of check encoding operations. Check encoding involves putting a dollar amount or an account number in magnetic ink at the bottom of each check in preparation for processing through an automated check reader/sorter. The sorter posts checks deposited and drawn to appropriate accounts and then sorts them in preparation for clearing. This staff scheduling problem is often formulated to minimize costs for encoding personnel and check holdover float, subject to constraints on encoding machine capacity and personnel shift schedules. Holdover float occurs when checks miss being sent through the FRB or other clearing mechanisms, causing the depositing bank to miss an investment opportunity. Check volume estimation becomes a sub-problem here.

The role of computers here is in enabling the forecasts and creating solutions for the staff scheduling problems. The reader/sorter is likely to be the single most costly and sophisticated piece of technology in the operation, however, whether it is able to be used effectively is a matter of how well managers are able to staff up to prepare checks flowing to it. Increeasingly powerful microcomputers now have begun to allow managers to run staff scheduling analyses on their desktops. And, when unexpected changes occur in check volume, number of staff on hand, or the availability of functioning encoders, managers can readily revise the assumptions of their staff scheduling models to conduct a sensitivity analysis of the costs associated with a trial staff schedule.

Various techniques have been used to solve for acceptable outcomes. These include linear programming (Krajewski and Ritzman, 1977; Mabert, Fairhurst and Kilpatricks, 1979; and Krajewski, Ritzman and McKenzie, 1980), dynamic programming (Davis and Reutzel, 1981a and 1981b) and heuristic modeling (Mabert and McKenzie, 1980). The different approaches have also varied the constraints used to model the problem, recognizing the need to make the results more realistic and usable. Krajewski, Ritzman and McKenzie (1980), for example, added a one-week time horizon assumption to redefine the staffing constraint. Most firms find it is impractical to reassign workers for periods shorter than one week, and day-to-day temporary help will lack the proper training, causing additional costs for the operation. Mabert (1979) extended the model to handle more uncertain check forecasts. Davis and Reutzel (1981a) added more realism by allowing employee shift lengths and the number of encoding machines to vary in the short run. This work has provided a solid foundation for commercial banks to cost-effectively reduce holdover float once checks have been received in check processing.

The solutions these models propose tend to be based on the assumption of fairly stable interest rates. In a rising interest rate environment, these models understate the value of adding machines and staff to reduce holdover float. With falling interest rates, holdover float becomes somewhat less critical. Fluctuating interest rates, in general reduce the scope of these models: instead of a six-month or longer planning perspective, they provide a very short-term -- perhaps up to one month -- staffing perspective. These models also fail to provide explicit guidance on the marketing impact of a bank's check processing operations. When collection is delayed, holdover float is not the only problem. The opportunity to provide the earliest possible release of funds to clients who demand it also is lost. This seems particularly relevant in view of the efforts that financial services firms have made to increase their responsiveness in their product markets via information systems deployed to boost their competitive advantage.

2.3. Internal Check Transit

Staffing, scheduling and machine use are not the only factors which impact holdover float. A second area of concern arises among banks which have a large number of branches which feed check deposits to a central processing facility. This problem is especially important today as the configuration of a bank's service delivery network changes from fully-staffed branches to non-staffed automated teller machines (ATMs) located throughout a bank's operating region. The problem is how to optimize the bank's internal check transit scheme to reduce holdover float at a minimum cost over an ever larger service network. Encoding staff size, schedules and machine capacities also figure importantly here: if messenger trucks operate at too infrequent intervals, check volume might exceed processing capacity. Too frequent pickups would relieve pressure on the check processing operation, but the cost of the transit system might be prohibitive.

Svestka (1974 and 1976) formulated and solved this problem in the commercial banking context. He constructed a DSS, in cooperation with Cleveland Trust, which consisted of a series of modules describing the physical and policy constraints on different aspects of the process as separate subproblems. The DSS employed algorithms to solve traveling salesman, bottleneck assignment and dynamic programming problems especially formulated for check processing. It also included heuristic routines to generate and evaluate proposed messenger route schedules and a report generator to enable a manager to evaluate the model's results.

The modular structure of the decision support system Svestka constructed adequately handles transit scheme staffing but does not really enable effective cost-benefit comparisons. He limited his study's scope to just two objectives: reducing daily average float and operating expenses due to overtime for the check transit staff. But today, that perspective seems outdated. Float reduction and overtime expenses must also be evaluated with respect to ATM cash stocking and the service perspective of rapid clearing for checks of high value.

A final weakness of this approach is that it cannot handle the variety of branch systems that commercial banks operate today. Svestka assumed that encoding and check proofing were centralized, but not all banks operate in this fashion: many encode at the branch level. They may just run one or two pickups per day. As a result, check processing at bank headquarters need only consolidate and batch checks for clearing.

An appropriate extension of Svestka's model for today's check processing operations is to include the case where branch encoding operations are located at a regional office overseas. Transit is no longer by truck, but by air courier, and messengers' stop schedules are assumed fixed in the short run due to setup difficulties. Staffing and machine requirements remain variable, but a new element enters the picture: the location of the regional check processing center abroad. This problem also has a purely domestic parallel: determining depository ATM versus check processing branch locations in a statewide branch network. And, with deregulation expected to allow more interstate branch banking soon, this problem should eventually have national scope.

More recent work in this area has used heuristic techniques exclusively to simulate the system as a whole (Haas and Zoltners, 1977; Davis and Swanson, 1978; and, Davis, Ceto and Rabb, 1982). Other work involves fine-tuning the way such a system operates over time by allowing more of the components in the system to vary in their values (Heard, Rabb and Hester, 1979).

At present, many banking professionals might suggest that further modeling work in this area would only serve to reduce costs by a small fraction, and this seems to be a reasonable view. But other new opportunities for further savings are yet to be exploited. Information technology has the potential to alter the way decisions are made in this area by providing up-to-the-second information which is increasingly available through branch and ATM automation. This will lead to increasingly frequent cost-benefit analysis for check transit arrangements and subsequent fine-tuning.

2.4. Check Sorting

Another wholly internal check processing operations problem which has been solved is the optimal sorting of very large check volumes in preparation for return via clearing to banks on which they are drawn. Reader/sorter equipment is used to identify transit codes which have been MICR-encoded on checks. Murphy and Stohr (1977) proposed a dynamic programming formulation which minimizes sort costs by determining the optimal structure of a sort tree. The branches represent a priority weighting scheme based on identifying those endpoints with the greatest paper or dollar volume. Processing and throughput since that time have grown tremendously, but check volumes, particularly among banks which operate large intra-state networks, have grown to match. Today's reader/sorters are actually computers in their own right, and have software on board that enables a variety of sort schemes to be used based on historical information about prior checks processed.

3. Outbound Check Processing Research

Another set of check processing problems exists on the "outbound" or clearing side. Most commercial banks attempt to determine the best clearing mechanism from a per check and float cost standpoint. In this section, the literature which models this problem is reviewed and evaluated in terms of the expanding number of alternatives to FRB check clearing. The discussion is broken into four partss:

- FRB actions affecting the U.S. clearing system
- Clearing optimization in light of new clearing techniques
- Clearing optimization and float pricing
- FRB check processing performance

The new clearing methods which became available during the 1980s, including electronic check collection, netting arrangements, direct-send couriers and consortium clearing, urge a re-examination and recasting of previous models. This is also true when some recent FRB actions are considered, and we will evaluate them in more detail shortly.

3.1. FRB Actions Affecting the Clearing System

Prior to 1980, the FRB provided an effectively free check collection transit system to its member banks. Though mandatory reserves were used by the FRB to defray the costs it incurred in operating the system, it made no explicit attempt to price or charge for check clearing. As a result, member banks felt little pressure to carefully control their use of FRB clearing services. Rising interest rates, however, provided the impetus to evaluate the benefits of FRB membership in terms of required reserves. Many members noted that clearing was too slow and sought to improve upon it by implementing alternative clearing mechanisms.

The U.S. Congress passed the Depository Institutions Deregulation and Monetary Control Act in 1980. It set the stage for fundamental changes in the check collection system over the following three to five years. (For example, see the *Federal Reserve Bulletins* listed in bibliography, and Littlewood, Shain and

Co. (1982).) The bill mandated the FRB to begin charging for check clearing and collection services, to work out a mechanism to reduce float within the system and, later, price it explicitly. This is commonly known in the industry as "float pricing". The impetus for float pricing came from the FRB's recognition that transit inefficiencies in clearing were causing it to provide an unintended subsidy to banks clearing checks from or to distant points within the system. In late 1983, the FRB began to implement a new check clearing and collection regime. Under the new regime the cost of FRB float -- float derived from delays within the FRB's own transit system -- was charged back to the depositing bank on a delayed basis.

Currently, the most popular alternatives to FRB clearing are direct-send bank-to-bank couriers and private, typically city-wide consortium clearing arrangements. A number of papers have appeared which address the "clearing mechanism selection problem". The problem has been formulated by adapting the structure of the uncapacitated plant location problem formulation in integer programming (See, for example, Cohen, Maier and Vander Weide (1981) and Nauss and Markland (1983).). But, until recently the size of the problem had always been an obstacle to producing cost-efficient solutions which commercial banks could actually implement on a day-to-day basis. Nauss and Markland (1985a) have been particularly successful in this area. They have used the sparsity of the integer programming formulation advantageously, reducing storage requirements and computation times necessary to solve problem of realistic size. More recently, these authors have further specialized their approach so that it can be implemented on a PC and made available to check processing managers for daily use (Nauss and Markland, 1985b). With the migration of additional computing power to the desktop in the form of 80286 and 80386-based microprocessors, it is becoming increasingly possible to select the appropriate clearing mechanism on an intra-day basis.

3.2. Clearing Optimization and the New Clearing Techniques

Nauss and Markland's modeling approach can be extended to include new, but less well accepted clearing methods. Electronic check collection (ECC), tested by the FRB during the early 1980s, is an important example. ECC truncates the flow of paper checks at the bank of deposit. Electronic messages replace paper checks in clearing, and contribute to reducing costs. At present, even though ECC is not fully operational, astute banking industry observers argue that its development is an indication that the clearing mechanism for paper checks is likely to disappear in advance of the paper itself.

Consortium clearing coupled with direct-send couriers is another new clearing technique which decision support models in this area should address. Consortium clearing uses a shared city-to-city courier through which a group of banks in a city can clear out-of-town checks back to groups of other banks in different cities. This method enables float reduction from FRB standards at a lower cost per check than a two-bank direct send arrangement can provide. These arrangements are unlikely to wholly displace the FRB soon: its large transit system has high volume, short haul routes whose business subsidizes low volume, long haul routes. A related problem that would be worthwhile to model is the consortium clearing arrangement participation decision, since it this would open up another avenue for cost savings to be achieved.

With float pricing implemented by the FRB, electronic bank-to-bank check netting arrangements and negotiated float sharing agreements are likely to gain increasing acceptance. Netting, regardless of whether the FRB is involved, should be accommodated in clearing decision frameworks, since it is basic to the check collection truncation process. As the costs of using FRB clearing services continue to increase, the risks that these new techniques are believed to pose will seem less important.

3.3. Clearing Optimization and Float Pricing

Float pricing is another cost which the clearing selection mechanism models discussed above fail to adequately capture. Delays in FRB transit which led to increased FRB float previously were not charged to the depositing bank. An appropriate refinement of the Nauss-Markland model would involve an additional cost component to represent the bank's policy choice between the fractional and fixed availability compensation schemes now used by the FRB.

A processing bank's choice of clearing mechanism is further complicated by the degree to which it can pass on float compensation charges to its clientele. Float pricing becomes irrelevant if market demand for check processing services is price inelastic. Substantial price elasticity of demand is more likely. In fact, the FRB is not a check clearing monopolist by law; other alternatives are available. As a result, one would expect the solutions to involve a shift away from the use of FRB clearing facilities, if not a decline in the use of checks as an instrument of exchange. In reality, most banks will probably decide to differentially charge subsets of their clientele. Low volume clients won't perceive the charge, but high volume clients will, and will put pressure on their bankers to seek new alternatives besides FRB clearing.

3.4. The FRB's Check Processing Performance

Though interest in using management science methods to solve financial services industry problems has grown over the past decade, the FRB is still the single largest consumer of management science modeling expertise in check processing. Serious analytic efforts have centered on improving the performance of its check processing operations, but only a small portion of the work ever has been reported in journals. For example, there has been a move within the last decade to re-architect the check clearing system, while other projects have been undertaken to maximize the effectiveness of the investments in computer and rationalize the use of Federal Reserve Communicationn System telecommunications resources. Regional Check Processing Centers (**RCPCs**), the new hub-and-spoke transit network, and fractional availability have all been implemented as by-products of the FRB's internal research (Streeter, 1983). Although FRB applications typically offer little generality and require specific knowledge of the details of the FRB's operating environment and policies, the range of operational issues they must consider requires considerable sophistication to pull together workable policy recommendations.

The politics of managing the relationship between the regulator and the regulated also tend to interfere with what the public learns about FRB efforts to streamline check processing and transit operations. A study by Humphrey (1981), for example, showed that diseconomies to scale existed in many FRB check processing operations under the zero price check processing regime in force prior to September 1981. In addition, other studies such as Littlewood, Shain and Co. (1982), and commentaries in the popular press have brought into question the dual role the FRB occupies as competitor and regulator of the American check collection system.

A final study by Hoseman (1972) conducted in the 1970s evaluated the float impact of three electronic funds transfer methods tested in the Atlanta Payments Project: automated bill payments, direct payroll deposits and point-of-sale (**POS**) cash machines. This study developed the mechanics used throughout the commercial banking community today to evaluate the float impact of a wide range of elecrtonic banking services. The techniques it proposed also have enjoyed wide application by corporate treasury managers.

4. Treasury Management for Checks

The two most important issues in corporate treasury management for checks are methods for collection and disbursement. The collection problem a corporation faces is to minimize the float time involved to convert a check into cash, once the bill payer puts it in the mail. The corporate treasurer has just the opposite view about checks: his goal is to maximize the float time for a payee to convert a check into cash. A large number of studies in the management science literature treats collection and disbursement problems. This is especially true for lock box models for check collection; these have been most influential in corporate treasury and check processing operations practice. For example, Fielitz and White (1981) reported that some 1600 - 1800 lock box studies were conducted on behalf of corporations in 1978 and this number has grown through the years. Lock boxes continue to be the most popular collection acceleration tool in use today. In this section we will discuss relevant models from the management science literature and suggest lines along which to extend or refine them to improve their relevance in today's technology-driven treasury management and check processing environments.

4.1. The Lock Box Location Problem for Collections

A lock box is a post office box used to collect the checks of a corporation's bill paying customers. Lock boxes are typically operated by banks on behalf of corporations, city governments and other institutions. Significant reductions in collection float can be achieved when a set of lock boxes is strategically located to serve the geographic regions of a corporation's customers. Lock box arrangements normally result in a one-time transfer of wealth from a company's clients to itself, by reducing the amount of time it takes to turn a check into cash. A significant amount of research has focused on developing techniques to solve for the optimal number and location of lock box accounts. Normally, the models attempt to solve for a lock box network which simultaneously maximizes funds availability on checks deposited and minimizes lock box account operating cost.

Part of the interest that lock box location modeling has received in the management science literature is due tothe mathematical structure of the problem. It is closely related to the uncapacitated plant location problem, which has been of continued interest to operations researchers who wish to improve the computational efficiency of finding satisfactory or optimal solutions to very large problems. One of the best examples of this research is a paper by Cornuejols, Fisher and Nemhauser (1977) which won the Institute of Management Science's Edelman Prize for excellence in management science. (For additional background on location theory which is applicable to lock box deployment, the interested reader should see the survey papers by Tansel, Francis and Lowe (1983) and Revelle, Marks and Liebman (1970).)

4.1.1. The Kraus-Jannsen-McAdams (KJM) Model

One of the early and influential models in the literature was developed in a paper by Kraus, Jannsen and McAdams (1970). (Hereafter we will call this the KJM model.) They proposed an integer program for lock box location with a related linear programming relaxation, to reduce computing costs for implementation. Though the authors formulation guaranteed an optimal solution in most cases, it is important to keep in mind that corporate treasury managers actually demanded far less during the 1970s. Given the interest rate environment, good approximations were sufficient.

The KJM model's primary contribution was to make it possible for a manager to determine the maximum possible deviation from the theoretical optimum for different lock box system configurations. A shortcoming of the KJM model, shared by earlier models including Levy (1966), Stancill (1968) and McAdams (1968), is that it assumed a deterministic level of receivables. The number and location of a corporation's lock boxes depend on a forecast of future accounts receivable. If the forecast is reliable, then the advice that KJM would provide would be quite good. The problem, of course, is that forecasts often fail. So it is more important for managers to know how sensitive a lock box location scheme is to baseline shifts in the pattern of their firms receivables.

KJM, along with Shanker and Zoltners (1972a), made an important tactical assumption which merits further discussion. Check payments sent to a lock box location were subdivided into "homogeneous groups", to include those with similar mail and clearing times with respect to all lock box sites considered. In practice, customers who send checks out of a postal zip code area are considered to be members of a homogeneous group. This simplifying assumption enables the average check to represent every check in a group and so reduces the large number of checks the model has to deal with to make large problems manageable.

Applying this approach, many commercial lock box studies use only the first two digits of the nine-digit postal zip code. This results in a 100-group classification, with each group aggregating 1000 postal zones. The most casual observer is bound to suggest that mail transit time can be expected to vary widely within the arbitrary subdivisions. Remote and controlled disbursement techniques used by corporations also make zip code numbers a less useful indicator of mail transit times. These force a corporation which plans to implement a lock box system to devote resources to careful study of the disbursement practices of bill-paying clients. In addition, many corporations remit payments from multiple locations other than head-quarters.

As a result, the nearest to optimal lock box implementations may remain those where the client base is located in a fairly small region and can be described as "homogeneous" on the basis of more than just the zipcode. The very successful retail lock box systems of the regional power, phone and other utility companies would fall into this category. However, even though the assumptions may appear problematic for lock box networks with less within group homogeneity and greater regional spread, it is important to keep in mind the large savings that lock boxes earn for the corporate treasury. Normally, small refinements can lead to large cost savings.

4.1.2. Extensions of the KJM Model

Management science models also have estimated lock box network costs and benefits when future demand is less certain. Mavrides (1979) and Nauss and Markland (1981), for example, present models which enable parametric analysis to be conducted not just for the number of lock box locations, but also for a range of accounts receivable. This allows a user to estimate how much risk the corporation must bear in its lock box network deployment decision. In practice, some corporations' lock box systems perform very poorly in terms of cost and float savings for just a small distributional shift or reduction in receivables.

A general shortcoming of lock box models, including KJM, still remains an issue today: implementation. Lock box models are difficult to implement in practice since they involve fairly extensive data collection and significant cooperation among banks, corporations and their clients. Unfortunately, much of the data collection has to take place before a corporation has any idea of the actual value of a lock box system. Maier and Vander Weide (1974) presented a structured modeling approach which also addresses the data collection problem. Their multi-stage technique used the fixed charge transportation model, suggested by Shanker and Zoltners (1972a), as the heart of their lock box analysis system.

They separated lock box location into a series of sub-problems. Initially, the concentration bank derives a functional relation between the number and location of lock boxes for a given demand scenario, and the maximum increase in funds availability that will result. Next, the corporate client negotiates the best lock box arrangements by geographic location for all lock box combinations suggested in the previous step. Finally, the bank determines the number of lock boxes for which the net float benefit is maximized. ("Net float" is the difference between the increase in float and the sum of incremental fixed lock box and administration charges.)

4.1.3. Electronic and International Lock Box Systems

Of the models discussed to this point, none has yet been extended into the realm of new banking technology and techniques. For example, intra-firm processing is no longer the sole alternative in lock box collections. An updated version of lock box -- electronic lock box -- serves to eliminate some of the paper flows with electronic messages, speeding cash availability and enabling electronic settlement. But, questions similar to those posed by standard lock box location problem remain, and there are some new ones, too. For example,

- Where should electronic lock box accounts be located?
- What configuration yields the greatest acceleration of funds availability?
- How can a

Current lock box models also fail to consider the problem of designing international lock box networks. These enable faster collection of U.S. dollar checks from foreign locations. In the international collection problem, mail transit times are not the only source of delay. Dollar checks must be relayed to the U.S., the only place they can be converted into cash. This normally requires air couriers to speed the collection process. Although they are more costly, they normally have predictable transit times. Many banks which operate international courier systems largely ignore local mail transit times, though intra-European arrangements are probably an exception. In addition, mail transit time data may be impossible to collect in some countries outside the U.S. and Europe. This is particularly true for Latin America, a zone in which trade flows are almost universally denominated in dollars. Another complication is that couriers can carry other documents besides checks. "Piggybacking", the simultaneous loading of couriers with other time-sensitive documents in addition to checks for collection, reduces overall costs for international check collections.

4.2. Disbursements by Check

Shanker and Zoltners (1972b) were first to model the problem of cost-effectively locating disbursement centers to maximize the time that checks issued remain uncollected. To slow disbursement as much as possible, a bill-paying corporation would issue a check drawn on a bank located the maximum distance, in terms of clearing time, from the creditor's location. This builds "clearing float" into the disbursement process. The check is then mailed from yet another distant location within the U.S., to the creditor. This time distance is measured in terms of postal transit times, the source of "mail float". Overall, this problem is easier to solve than the lock box problem because of the control the bill-payer can effect. The firm disbursing payments actually controls the timing of disbursement, knows the destinations and has relatively smaller set-up costs for a disbursement system.

A related problem involves determination of an optimal account balance over time in a disbursing account. Anvari (1983) examined the question of how an account balance should be managed when check presentments to the account are stochastic. Similar to optimal inventory level models, the problem here is to choose daily account funding levels which minimize idle funds used to cover expected presentments. Anvari proposed a monitoring system which tracks issued checks, using a probabilistic scheme to estimate time of presentment. It assumes the destination, issue date and check amount are the primary factors which affect the schedule of check presentment. He also argued that check cashing experience enables identification of sets of check cashing patterns. This can significantly improve forecast performance. He further suggested guidelines for how to determine "safety balance" levels when overdrafts carry a substantial penalty.

Since the 1970s, the FRB has been working to reduce, and eventually eliminate, float in the system. While it has not taken specific actions to affect corporations' use of mail float to slow disbursements, the FRB frowns upon disbursement schemes which abuse the system. It has issued opinions in its technical bulletins on commercial bank products that lead to improper use of its check clearing system, primarily with instruments like payable through drafts in mind. Payable through drafts builds an extra layer of float into the clearing process. The bank of deposit must obtain confirmation from the bank of issue before clearing can occur.

Meanwhile, corporations have begun to realize that when everyone uses remote disbursement techniques to slow collections, banks offering supporting services may be the only ones to gain. Some firms have responded by setting up mutual periodic payment netting and direct corporation-to-corporation electronic payments.

4.3. The Case for Unified Collection and Disbursement Models

A major shortcoming in cash management research for checks is that most models fail to appropriately unify the collection and disbursement functions. Recently, Srinivasan and Kim (1988) have called for using models which enable "integrated cash management". Their proposal for an integrated cash management system is meant to provide a planning framework for the range of information systems that can be used to drive down the costs of short-term financing.

A study by Maier and Vander Weide (1976) represents a notable exception. The authors examined the problem of deciding where to locate collection and disbursement accounts simultaneously. Their work built upon previous attempts to model a corporation's entire cash flow system, such as those by Calman (1968) and Pogue, Faucett and Bussard (1970). They also included the costs a corporation faces in dealing with clearing and service banks over time. Their work foreshadowed current efforts to implement DSSs which aid in the day-to-day purchase and investment of funds, which lock box collection and disbursement models as their front ends. (For example, see the *Institutional Investor* and *Business Week* articles noted in the References section of this paper.)

Maier and Vander Weide's approach has two aspects which warrant further consideration. First, the authors assumed that all parameters in their model are known with certainty. The parameters include fixed charges for locating and maintaining relationships between a corporation's regional offices and local banks, and disbursement activities at its regional offices. But, this may not be the case in practice: relationship charges often vary directly with transaction volume. Second, the authors assumed that information on the cost associated with individual cash management services is not available. This implies that compensating balances must apply to all services together in one bundle. Having trained their clients well in effective treasury management, bankers now find it increasingly difficult to get them to keep even the minimum balances. As a result many banks have invested in detailed cost reporting and analysis systems which enable specific charges to be made for individual cash management services. Future models may be required to represent these possibilities more explicitly, as the role of IT expands to enable even broader coverage of the product performance.

5. Linking Check Processing and Treasury Management Models

State-of-the-art models for treasury management and check processing operations for checks largely assume that each lies in a separate domain. Besides the work of Srinivasan and Kim (1988) cited earlier, to date few studies have considered the value of linking the two and building integrated models. Yet, the structure of a bank's check processing operations largely determines the kinds of cash management services it can offer for checks. A corporation, meanwhile, is limited to the set of services that its primary clearing bank can support, although this is likely to influence which bank is chosen to receive the bulk of the clearing business. As a result, its check-related cash management optimization models may fail to investigate the full set of alternatives.

5.1. The Need to Consider Institutional Features

Institutional features are partially to blame. Check processing automation in the American banking community has been developed to ensure that check clearing operations through the FRB are conducted on a smooth and error-free basis. The FRB requires member banks to record a substantial amount of information related to every check processed. But, this FRB bias makes much of the information inefficient for use by a treasury manager interested in tracking disbursement and collection.

For example, FRB routing codes which identify the destination of a check and its availability schedule force the check processing manager to program a check reader/sorter with full information about FRB availability schedules for all possible check destinations nationwide. Yet a corporate treasurer may have imperfect information about the details of the FRB availability system. This would make it difficult to classify every check sent for collection as a same, next or two-day cash item. In fact, the treasurer may not even wish to track on a check-by-check or destination-by destination basis for cash balance estimation. But, few banks currently possess the ability to present information on checks processed in a flexible manner. And what information they can deliver through on-line treasury management transaction and balance reporting systems is often not easily used by the treasurer.

A second aspect of the problem is the time orientation of check processing activities. They continue to be biased toward batch processing, conforming with the batch processing environment of the FRB and consortium clearing. Treasury management, however, no longer occurs in a batch environment. The automation present in electronic funds transfers operations makes it very easy for a bank to deliver on-line, continuously updated transaction and balance reporting systems. But, this is not the case for checks. The current structure of most check processing operations does not support timely delivery of cash management information.

5.2. Some Promising Directions for Future Research

Models which link the two areas can overcome these institutional features by considering how information relevant to checks being processed within the FRB is later used by treasury managers. An attractive approach is to explore models which utilize information which is "appropriate" to a treasurer's decision making processes, rather than the "perfect" information provided by the FRB.

Some research we are now conducting examines the role of "aggregates" in check processing and the management of checks as cash. Our approach focuses on making the information provided by the FRB more usable, as opposed to just using FRB information. *Availability aggregates* and *collectibility aggregates* provide a means to squeeze irrelevant regulatory and operating details -- particularly the intricacies of the FRB check clearing system in the U.S. -- out of the treasury management picture. By calculating "weighted average availability" for checks with various endpoints, the check processor can eliminate the need for a treasury manager to keep up-to-date on the details of FRB availability. Availability aggregates can reduce tracking costs for checks deposited and improve a cash manager's ability to predict when funds become available. Collectibility aggregates, on the other hand, address a problem experienced by correspondent banks; they need to know when to release funds on deposited checks to the collecting firm. Our approach involves weight averaging release dates to replace complicated funds release schedules with simpler rules of thumb. This requires very careful modeling, since funds collectibility represents the full dollar value of a check, while funds availability is just the time value of the money the check represents for a short period of time.

A second possible line of attack is to explore models from the literature on risk aversion and insurance for their applicability to the risk-taking behavior that corporate treasurers exhibit when making cash deployment decisions based on "available", but not yet "collected", funds. This would be particularly useful to support development of models which address the check processing concerns of international correspondent banks and corporations, which have even less information about the institutional features of check clearing in the U.S. One of the interesting and recent developments in the market for treasury management services is the recent emergence of treasury management insurance policies which lock in daily cash positions for international treasury managers. Restating the disbursement/collection optimization problem for cases where the treasury manager possesses perfect or imperfect information about the check processing environment would provide guidance to redesign the basic and minimum set of information needed to make effective decisions. It would also suggest ways in which to identify the set of factors influencing a treasury management insurance portfolio held by a cash management bank.[1]

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