CHAPTER 2

The complexity of cash replenishment in retail banking

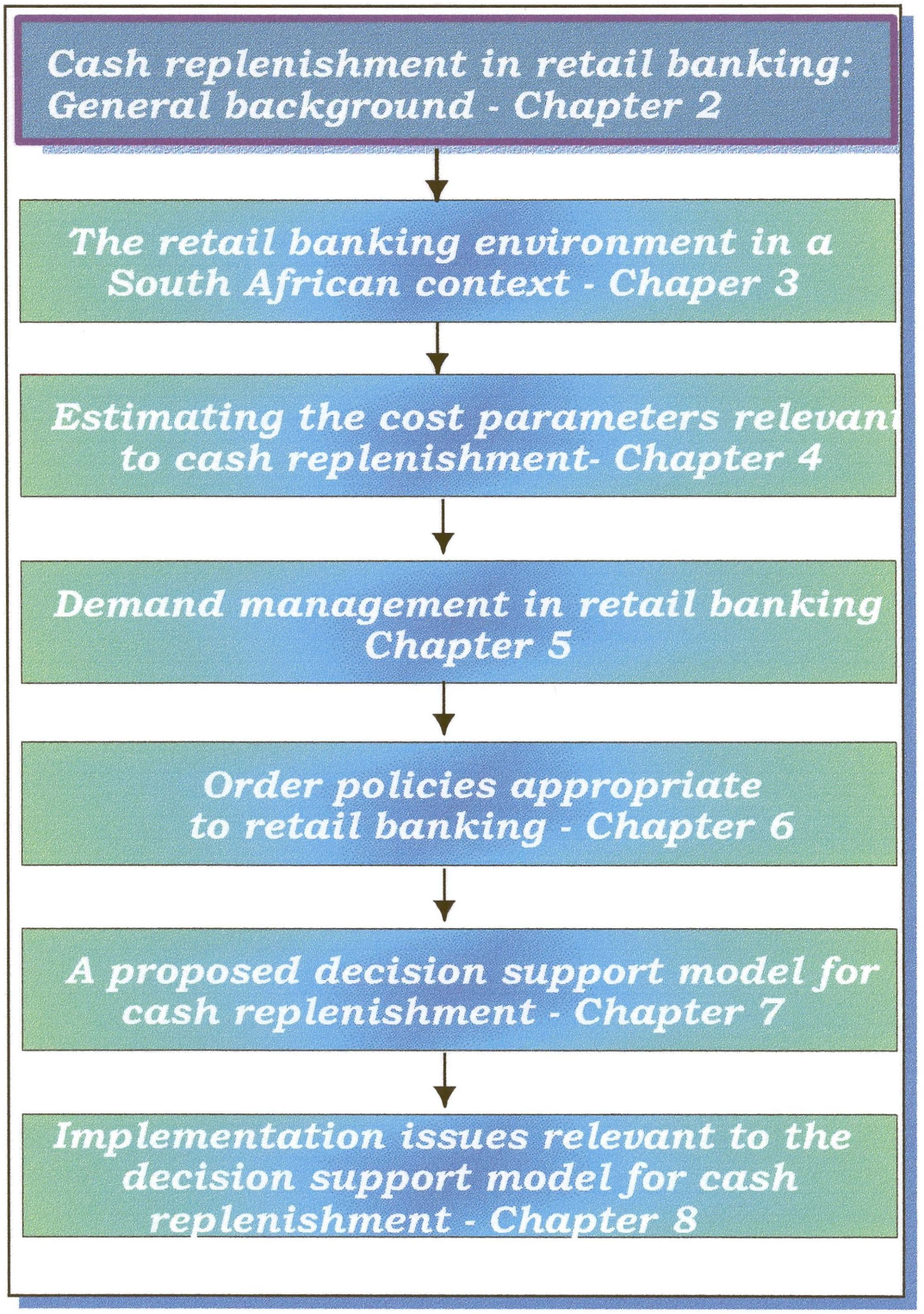
2.1 Introduction

Research commissioned by De La Rue (*s.a.*:2) indicates that any cash handling strategy must be built on individual national environments, bank business mixes together with an understanding of the industry (such as the role of monetary authorities and competition in the industry), an understanding of customer needs, an understanding of the costs involved in cash handling and taking a systems view of the problem.

In this chapter, the complexity of cash replenishment in retail banking is discussed at length. The characteristics of the problem which are discussed include the nature of the mix of cash withdrawals and deposits, factors influencing the demand for cash, the perspective of the customer in respect of good service with specific reference to cash availability, the specifics of cash handling from the point of view of a retail bank, the cost elements involved in cash handling and the effect of the planning or scheduling period. Figure 2.1 shows the relevance to this chapter as regards the subsequent chapter s included in this report.

Figure 2.1

The structure of the report indicating the relevance of Chapter 2



2.2 Problem description

2.2.1 Preamble

A part of the business conducted in retail banking concerns the provision and receipt of cash as required by the customers in turn to conduct their business, whether it is private or commercial in nature. A driving force in the continued high usage of cash despite the development of various other methods of payment is the immediacy and convenience of cash for the individual (De La Rue *s.a.*:5). In studying the cash replenishment problem in retail banking, the specific characteristics of the situation determine the nature of the problem.

In the South African banking system cash replenishment at branches, agencies and automated teller machines (ATM's) of retail banks, takes place on a daily basis within the following framework:

- Cash replenishment occurs by means of a single delivery per day at the normal reorder cost. An interim delivery is possible, but the order cost is significantly higher in such a case. (Refer to paragraph 2.3.2.3 in this regard.)

- Fourteen different denominations (coin and notes) represent the South African currency in circulation. (Refer to paragraph 3.3.1 for circulation figures.)

- A shortage situation is highly unacceptable at a branch or agency, due to the perception formed in the mind of the customer and the ripple effect this may have. At an ATM, a shortage may occur, and is tolerated by the customer, since it is accepted that an ATM may run out of cash from time to time (especially when the location is remote from a branch or agency). Often the customer is unaware of the exact reason for a transaction not being processed at an ATM and therefore accepts a shortage situation.

Cash balances held in branches, agencies and ATM's of a bank represent a sizable amount of unproductive capital and it is therefore in the interest of the bank to reduce such amounts to as low a level as is practical and possible. As stated by Derwa (1978:111):

> *The problem is part of the general class of stock problem. The question is one of determining the amounts to be delivered and the delivery dates that will minimise the total cost, which is the weighted sum of the costs of storage, supply and shortage.*

Johnson (1994:31-33) makes the following statement when describing the traditional bankers' approach to cash: *"Cash is certainly an expensive commodity, but most bankers contend that it is an inevitable expense in the current system."* Wagner (1969:786-787) provides an apt description of the insensitivity in business to the relevance of inventory management, which indeed is the case in retail banking. The employees in this environment in South Africa show an ignorance of the scientific approach to inventory management when cash balances are discussed. Not only is ignorance evident, an unwillingness exists to treat cash as an inventory item. As Miller & Orr (1967:133) state: *"It may be a little startling at first to think of your firm's cash balance as just another inventory – an inventory of dollars so to speak – but is it really so farfetched?"*

Some of the features of the problem require further elucidation.

2.2.2 Cash mix: deposits versus withdrawals

An important complication with regard to cash provision, is the mismatch both in terms of location and timing of cash needs (De La Rue *s.a.*:2). If deposits and withdrawals are compared, there is a significant difference in the mix in terms of denominations. The result of this difference may lead to a situation where on a particular day, the total amount of cash available may be sufficient to provide for the expected demand, but the mix is incorrect. A situation may therefore

result where the amount of cash ordered equals the amount returned to the depot, but the composition differs, necessitating a denomination switch.

Johnson (1994:31-33) claims that most of the cash received by a bank is cash on deposit. The customer base of a particular branch will therefore have an effect on the nature of the deposits received. If the customer base is largely retail, huge amounts of cash will be deposited, whereas a predominantly household/private individual customer base will lead to a different deposit pattern.

In addition, some substitution exists between some of the denominations. For example, should a customer request a withdrawal in R100 notes, if unavailable, the customer would most probably accept either R50 notes or R200 notes. It may be assumed that a natural barrier exists with regard to substitution between R5 coin and R10 notes.

There are indeed limits with regard to legal currency in any transaction. The maximum amounts concerned are R50 when coins of denominations of R1 and higher are presented; R5 when coins of denominations 10c to 50c are presented and fifty cents when coins of denominations 5c or less are presented (Falkena *et al.* 1999:53). Substitution however implies a reduced service level, since the customer is not receiving exactly what is required. The issue of the customer's perspective with regard to service level is addressed in paragraph 2.2.4.

2.2.3 Factors influencing the demand for and supply of cash

Various studies have been conducted in the United States of America to determine customer preferences in bank selection. The factors quoted most frequently included the convenience of branch location in relation to both home and work location, the bank's reputation, the bank's financial strength, the completeness of service as well as the quality of service provided by the bank. As a result of these studies, it was concluded that banking to a large extent is seen as a *"convenience good"*, implying that retail customers largely believe

"...that all banks are alike" (Reich 1977:12-16). A criticism of many of these studies is that the research focussed mainly on demand deposit balances, and not the full line of services provided by the bank. In respect of the demand for and supply of cash, a number of other factors are relevant.

Cash demand patterns vary according to numerous factors, for example the occurrence of month ends, public holidays, school holidays, unusual occurrences (such as a special sporting occasion taking place in the vicinity of the branch, agency or ATM), the end of the financial year as well as any other random event which might play a role.

At the individual level, a factor such as socio-economic grouping also has an impact on cash usage (De La Rue *s.a.*:5). Demand patterns are therefore also dependent on the physical location of the branch, agency or ATM which will impact on the composition of the customer base. The demand patterns at a branch located in the country or a rural area will differ significantly from the demand patterns experienced at a city or urban branch. Inherent differences also occur between the demand patterns at either of the aforementioned and a suburban branch or a branch in an industrial area. As Derwa (1978:111) aptly states: *"There is no way of knowing with any degree of certainty how much in cash balances a branch will need."*

A concept which is relevant at this point, is the so-called service area. In determining the cash demand patterns, it is necessary to establish the service area for that particular branch, agency or ATM. Hansen as quoted in Reich (1977:24) uses the concept of trading area rather than service area. The trading area is defined as *"... a geographically delineated region, containing potential customers for whom there exists a probability greater than zero of their purchasing a given class of products or services offered for sale by a particular firm or by a particular agglomeration of firms."* This definition implies that competition in a particular trading area will have an impact on the volume of business conducted.

Reich (1977:51) further states that rather than categorise a branch according to its location (*i.e.* urban, city, commercial and so forth), this could be done using the volume of expected branch transactions and their distribution by transaction type (for example cashed cheques, cheque account deposits, savings account deposits, *etcetera*). Obviously the total demand at a particular cash point is of importance, but what is stressed by the above statement is the cost implication of having a cash point where numerous small transactions are performed in contrast to a branch with fewer transactions but greater amounts per transaction.

At the *Societe Generale de Banque* the following facts relating to cash demand patterns have been established (Derwa 1978:111):

- The cash requirements follow a symmetrical distribution. In conformity with statistical tests, fitting the normal curve is acceptable.
- The parameters of this distribution vary from one branch to another and for any individual branch, between one day of the week and another.

In the approach discussed above, the model applied was made more realistic by taking other factors such as the mix of denominations into account (Derwa 1978:111).

According to Naddor (1982:22) the probability distribution $P(x)$ is used to designate the demand distribution. The following equation then holds:

$$\sum_{x=x_{min}}^{x_{max}} P(x)=1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}1)$$

where x_{max} denotes the maximum demand, and x_{min} the minimum demand.

For the system under review, the following holds for the demand x:

$$x=\sum_{i=i}^{14} Q_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}2)$$

where Q_i denotes the demand for the i^{th} denomination available in the South African economy.

2.2.4 The perspective of the customer

One of the greatest challenges in providing retail financial services is to determine how to operationally achieve such a detailed understanding of the customer to be able to target products and services in such a way to effectively meet real needs (De La Rue *s.a.*:5). Relationship banking is the phrase used in retail banking to describe strategies that bankers follow in an attempt to retain customers. Despite these attempts, studies have shown that banking scores *"second only to insurance as the industry perceived least responsive to customers"* (Violano & Van Collie 1992: 9).

A feature of the banking industry is a proliferation of new services provided to customers, while existing services which are of greater importance to customers and are used more frequently, have been neglected (Beatty & Gup 1989:15-16). As mentioned in an earlier paragraph, it is important to establish the customer's view of cash handling. In an environment where many customers perceive banks as being *"all alike"* (refer to paragraph 2.2.3), providing superior service is a way of distinguishing the service provided from that rendered by the next bank (Goodman *et al.* 1989:15). As Gray & Harvey (1992:61) quote: *"Quality service is one of the few ways a financial institution can differentiate itself sufficiently in the marketplace to achieve exceptional business growth and earnings performance."*

This statement is confirmed by an international research programme conducted by KPMG's Financial Sector Consulting Group. The research study confirmed that *"most banks identified quality of customer service as the probable key differentiator between retail financial service organisations in the future"* (KPMG *s.a.*:4). From work reported on by Clavert (1990:54), the following quote confirms the above: *"..... that service quality must be considered as a vital factor in*

performance improvement in order to meet the challenges of the changing financial service industry". The KPMG study however found that the relationship between the customer and the retail financial service organisation is currently typically defined by the product used, rather than the existence of a relationship (KPMG *s.a.*:4).

Quality in banking consists of three components: Internal excellence, effectiveness and efficiency; superior customer service; and an organisation structure that is designed explicitly to support the quality orientation (Gray & Harvey 1992:62). From this it is obvious that the cash handling problem could result from an internal problem (i.e. the incorrect amount and/or mix of cash ordered), leading to a reduction in customer service.

In the preamble to this chapter, reference was made to the necessity of avoiding a cash shortage at a branch or agency. The impact of word-of-mouth in this regard is significant. A customer who is dissatisfied with the way a bank has handled a request for assistance will tell an average of 16 people about the experience, while a satisfied customer will tell an average of eight people about the positive experience (Goodman *et al.* 1989:16). A study quoted in the ABA Banking Journal confirms this: *"Dissatisfied customers tell far more people about their experience than do routinely satisfied customers"* (Anonymous 1997:73-74).

First American Corporation (FAC), a regional bank holding company in Tennessee, USA, began a customer satisfaction survey of all its banks in 1989 to focus on retail customer perceptions of the banks' overall level of service provided. The specific objectives of the survey, which is repeated once a year, are the following (Calvert 1990:57):

- To measure overall customer satisfaction with FAC;
- to measure satisfaction with individual branches;
- to identify positive and negative customer experiences;
- to assess customers' willingness to recommend FAC; and

- to determine customer intention to increase business with FAC.

Obviously the way in which FAC manages its cash availability and denomination mix will impact on more than one of these objectives.

2.3 Managing cash balances in a retail bank

2.3.1 The cash handling process

Johnson (1994:31-33) provides an apt description of the cash handling process at a retail bank:

> *As any bank teller will tell you, cash can be a great deal of bother. Handling it is a menial and tedious job. It has to be sorted, counted, stacked into bundles in which all the bills face the same way. It's heavy, it gives you paper cuts, and it turns your hands black. When it's stored, it has to be locked into a vault or bolted into an impenetrable bank machine. When it's moved, it has to be accompanied by armed guards with shotguns and shipped across country in armoured trucks.*

From this description it is obvious that the handling costs are significant due to the equipment involved and the labour-intensive nature of the process.

Figure 2.2 provides a graphic representation of the cash replenishment process. The various elements of the process are described in greater detail in the later chapters of this thesis. In representing the steps involved in the process of cash replenishment, the generic process rather than the typical South African process is described. The process shown in Figure 2.2 does not allow for cash movement between branches. It only allows for replenishment from a central cash centre. This characteristic holds for the South African situation and may be different in other countries.

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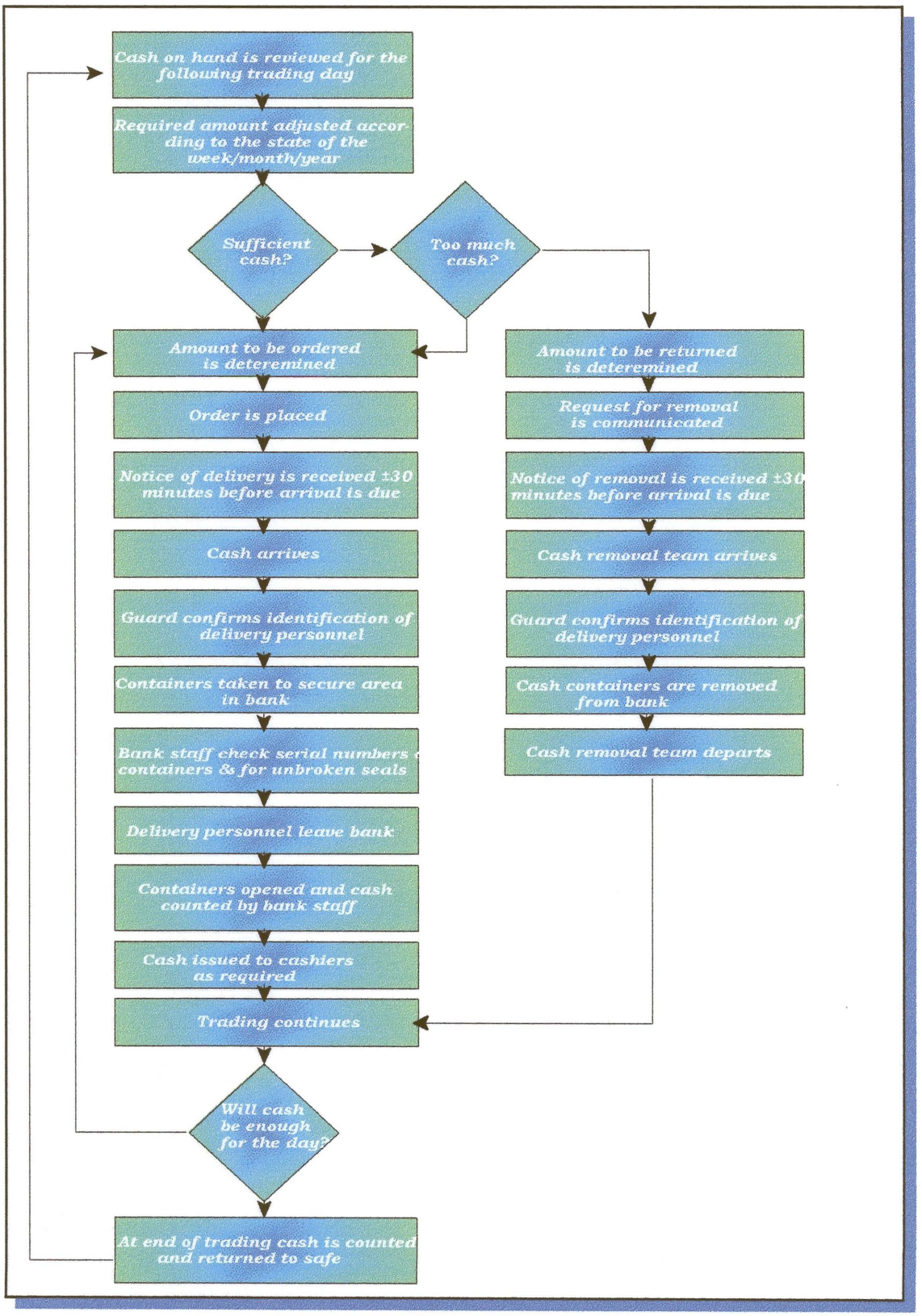
Figure 2.2

The cash replenishment process



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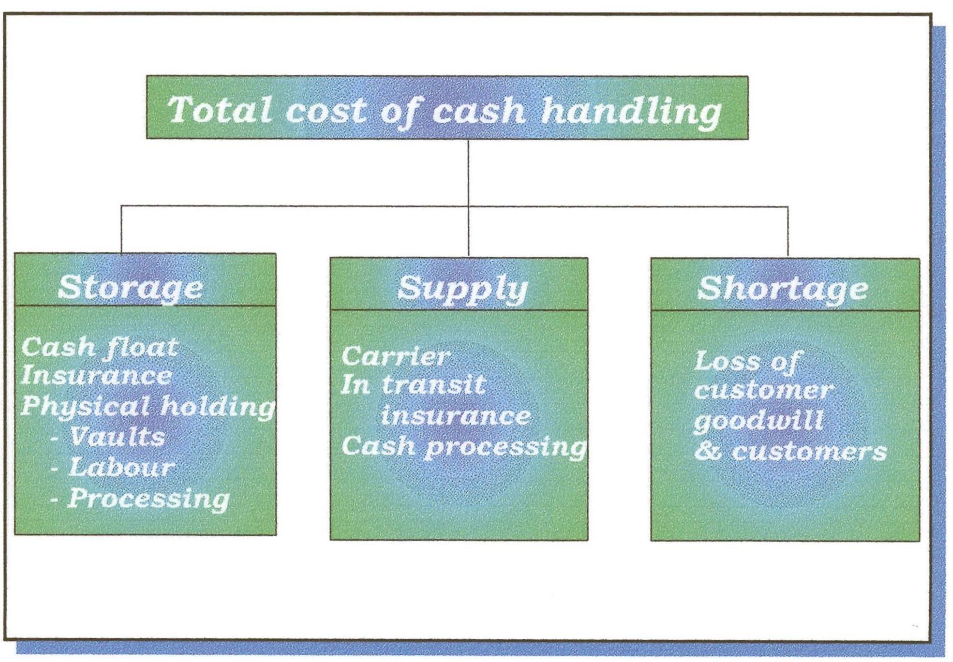
2.3.2 The cost elements involved in cash handling

According to a study commissioned by De La Rue Payment Systems Division, part of De La Rue PLC, the cost of handling cash is substantial. The estimated cost of handling cash reported by the study in 1995, was £3 billion per annum in the United Kingdom, Fr 55 billion per annum in France and DM 15 billion in Germany. These figures do not take interest into account (Anonymous 1995:10-11). The figures are staggering if the fact is considered that these are developed countries where the use of electronic payment methods is common.

As stated in paragraph 2.2.1, the aim in determining the amounts to be delivered or deposited, is to minimise the total cost, which is the weighted sum of the costs of storage, supply and shortage (Derwa 1978:111). Figure 2.3 illustrates the cost components involved in the handling of cash.

Figure 2.3

The cost components of cash handling



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It may therefore be said that the following equation holds:

Total cost of cash handling (C) = Storage cost (C_1) + Shortage cost (C_2) + Supply cost (C_3)

The dimensions of each of these measures (C, C_1, C_2 and C_3) are [R]/[T].

The components of C_1, C_2 and C_3 are discussed in greater detail in the following paragraphs. In developing the mathematical formulation of the model representing the cost of cash handling, notation used by Naddor (1982) in describing the variables is adhered to as far as possible.

2.3.2.1 Storage cost (C_1)

In classical inventory theory, storage cost is referred to as inventory holding cost. This is in fact the principal factor which limits the order quantity when considering the number of physical items to keep in stock. As Wagner (1969:789) states: *"Keeping items in stock is costly because inventories tie up capital that might otherwise be profitably employed."* It is indeed no different when the inventory items are various denominations of cash, ready to be supplied to the customer in the correct amount and mix as required.

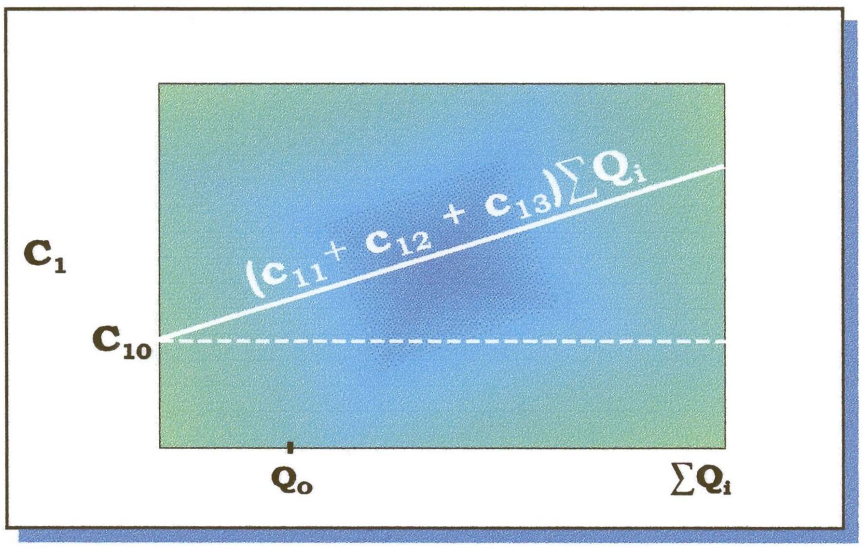
As indicated in Figure 2.3, the storage cost elements include cash float, insurance and the physical holding costs such as the provision of vaults, the labour required and the processing equipment. Figure 2.4 shows the typical behaviour of storage or holding cost as a function of the cash amount. The vertical axis represents the storage cost in Rand per period, whereas the horizontal axis shows the amount of cash held with the amount Q_O indicating the expected demand for the current scheduling period in units. Q_O would, for example, be the total amount of cash required from the bank per trading day (withdrawals), whereas ΣQ_i would represent the final amount carried on that day.

The offset from the origin on the vertical axis in the graph (C_{10}) in the figure above indicates the fixed component of holding the cash – vaults and processing equipment have to be in place. The other elements of holding cost, for example insurance and labour, have a linear relationship with the amount of cash held – for each additional Rand held, the cost is incurred. The cash float cost (c_{11}) is the opportunity cost or interest forgone for every Rand held at the branch, agency or ATM, and therefore also represents a linear relationship with the amount of cash held (De La Rue 1997:7). The insurance cost per unit is represented by c_{12}, while the labour cost per unit is represented by c_{13}. Therefore the total storage cost (C_1) for any amount of cash consisting of a mix of 14 denominations is:

$$C_1(Q_i) = C_{10} + (c_{11} + c_{12} + c_{13})\left(\sum_{i=1}^{14} Q_i\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}3)$$

Figure 2.4

The storage cost element (C_1) of the total cost of handling cash



An aspect of the system under review which has not yet been addressed, concerns the limited storage space. Providing the appropriate storage space for a branch or agency is definitely a concern, and may become a constraint should large quantities of cash need to be carried. Clearly, limited storage space is a constraint when replenishing an ATM. In addition, the storage space of a branch or agency is not only limited, but is explicitly dedicated to the storage of cash.

In practice, a limit is set by head office on the amount of cash carried in a particular branch during any scheduling period. Although this does not represent a physical limit to the amount of cash carried, it does represent a constraint when optimising the amount of cash to be ordered for the next scheduling period.

2.3.2.2 Shortage cost (C_2)

The shortage cost (C_2) of handling cash has two components, *i.e.* loss of customer goodwill and loss of customers. The impact of not fulfilling customer expectations and the effect of word-of-mouth communication amongst customers were touched upon in paragraph 2.2.4. However, the most important aspect in this regard is the effect that a cash shortage at a branch will have. It is said that the penalty for running out of cash is largely loss of goodwill, the perception of a poorly run and probably of an unstable financial institution (De La Rue 1997:7).

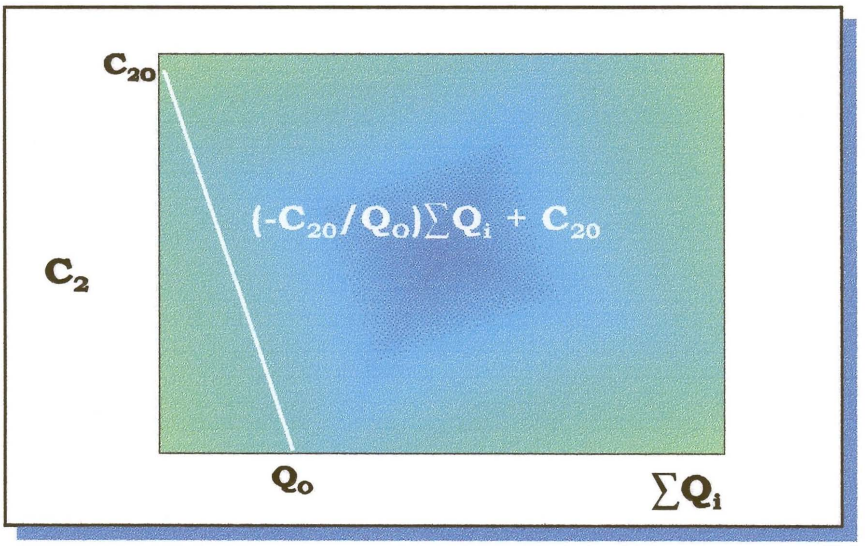
Shortage cost is indeed extremely difficult to measure, but cannot be ignored. The effect of a cash shortage at a branch, differs significantly from that at an ATM or agency. One element of shortage cost which is quantifiable, is the cost incurred by a bank when its ATM has run out of cash forcing a customer to make use of a competitor's ATM. This, however, represents only a small part of the total shortage cost.

Due to the difficulty in quantifying the shortage cost, a qualitative method such as a customer survey, would be a first step in determining the extent of the

shortage cost. In addition, expert opinion may be solicited from sources internal to the bank to place a value on shortage cost. Figure 2.5 shows the behaviour of shortage cost in respect of the amount of cash carried. The variable C_{20} represents the intercept on the vertical axis and all variables are as defined before.

Figure 2.5

The shortage cost element (C_2) of the cost of handling cash



The function which describes the behaviour of shortage cost is also dependent on the amount of cash held.

For $\sum Q_i < Q_O$

$$C_2(Q_i) = -\frac{C_{20}}{Q_O}\sum_{i=1}^{14} Q_i + C_{20} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}4)$$

For $\sum Q_i \geq Q_O$

$$C_2(Q_i) = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}5)$$

2.3.2.3 Supply cost (C_3)

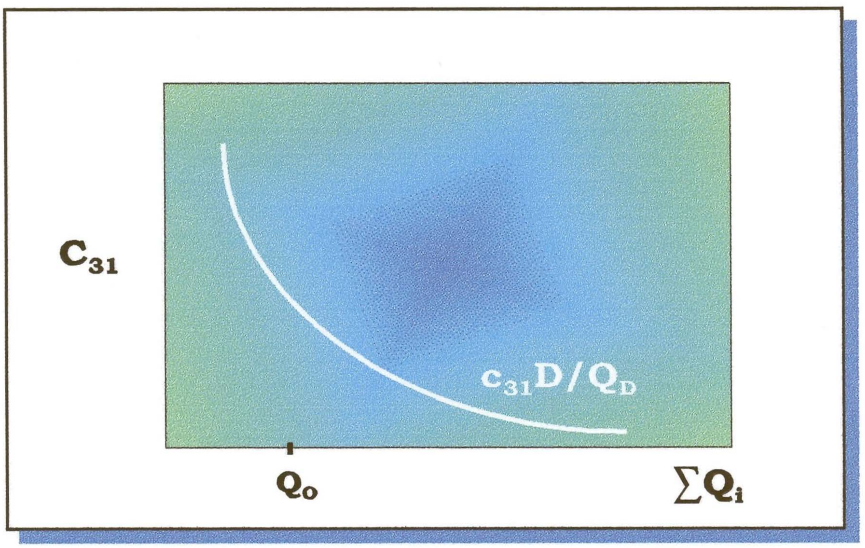
The third group of cost elements contributing to the total cost of handling cash (as shown in Figure 2.3) refers to the supply cost, or as according to the classical inventory theory, the replenishing cost. Naddor (1982:39) describes replenishing cost (C_3) for items that are sourced from an agency outside the organisation under review as *"...the costs associated with the unit cost of replenishment (and) may include clerical and administrative costs, transportation costs, unloading costs and other costs."* From the retail banking perspective this would include the carrier or transportation cost, the in-transit insurance as well as the processing cost (*i.e.* counting, packing, handling and administration performed by the carrier and bank). Figures 2.6 to 2.9 describe the four elements of supply cost relevant to retail banking.

Figure 2.6 illustrates the order cost per period (C_{31}) which represents the cost that would be incurred to replenish cash irrespective of the size of the order. It does not include the cost of cash processing, the carrier or transportation cost or in-transit insurance. It therefore represents all other preparation costs (administrative and clerical), particularly incurred internally by the bank necessary to activate a cash delivery.

Since the unit replenishment cost, c_{31}, is constant per order, the order cost per period, C_{31}, is dependent on the total demand (D) during the planning period, as well as the quantity ordered (Q_D). The latter is a function of the amount of cash held during the previous scheduling period, the demand during that period as well as the expected demand for the current scheduling period.

Figure 2.6

The order cost element (C_{31}) of the supply cost of handling cash



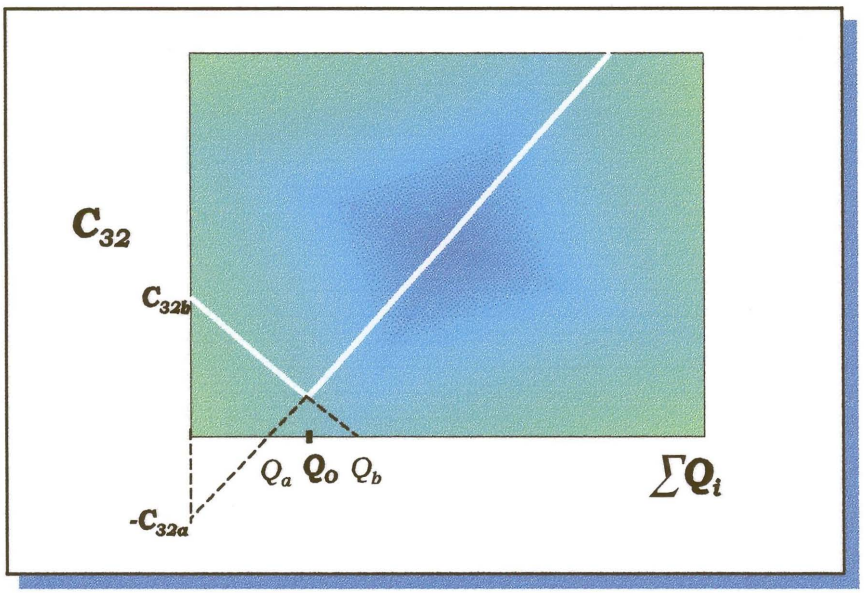
From the above, the equation for the order cost (C_{31}) is as follows:

$$C_{31}(Q_i) = c_{31}\frac{D}{Q_D} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}6)$$

Figure 2.7 shows the cash processing cost (C_{32}), the second element of the supply cost. If the actual demand for a particular day exceeds the expected demand for that day (Q_O), cash processing costs are incurred to obtain additional cash from the cash distribution centre, whereas if the actual demand is less than the expected demand (Q_O), cash processing costs are incurred when returning the surplus cash to the cash distribution centre. Even if a branch holds exactly the correct amount of cash for a particular day, the cost will not equal zero, since some counting and packaging will take place. The probability of having the exact amount and mix of denominations for the following planning period is remote, therefore it may be assumed that C_{32} will always be greater than 0. Once again this is a cost element internal to the branch.

Figure 2.7

The cash processing cost element (C_{32}) of the supply cost of handling cash



In the figure above, the cash processing cost is represented by two linear equations depending on whether the amount of cash held is less than or greater than the expected demand (Q_O). The following two equations describe the relationship:

For $\sum Q_i < Q_O$

$$C_{32}(Q_i) = -\frac{C_{32b}}{Q_b}\left(\sum_{i=1}^{14} Q_i\right) + C_{32b} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}7)$$

For $\sum Q_i \geq Q_O$

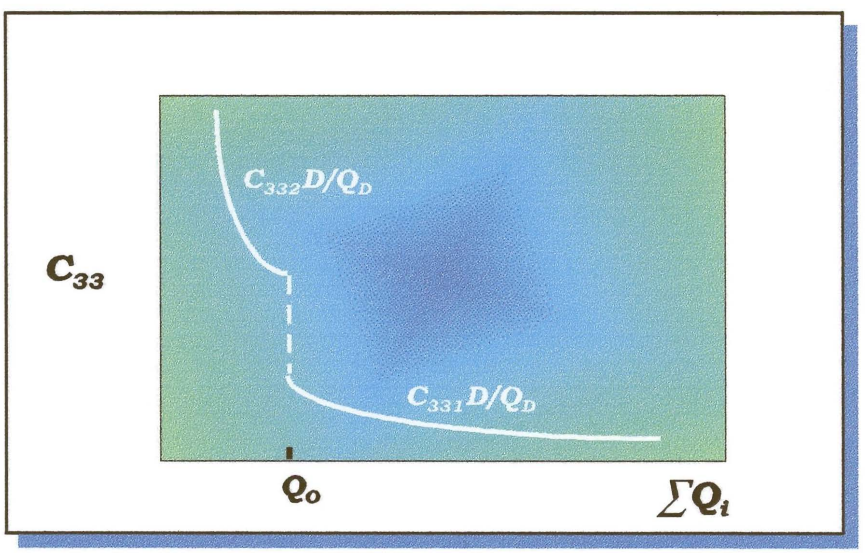
$$C_{32}(Q_i) = \frac{C_{32a}}{Q_a}\left(\sum_{i=1}^{14} Q_i\right) - C_{32a} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}8)$$

All variables are as defined before, with C_{32b} and C_{32a} representing the offsets for the two straight line functions describing the cash processing cost below and above Q_0.

Figure 2.8 represents the carrier or transportation cost element (C_{33}) of the supply cost of handling cash. In the South African retail banking environment replenishment occurs on a daily basis at the normal cost. (Refer to paragraph 2.3.3 for further comments in this regard.) Should a branch require an interim delivery resulting from a projected shortage, the delivery cost is increased substantially. If this penalty cost did not apply, the transportation cost would remain constant per trip. As a result the transportation cost is described by a step function consisting of two hyperbolas. The derivation of the transportation cost per period (C_{33}) is analogous to the derivation of the order cost per period (C_{31}) shown earlier.

Figure 2.8

The transportation cost element (C_{33}) of the supply cost of handling cash



For $\sum Q_i < Q_O$

$$C_{33}(Q_i) = c_{332}\frac{D}{Q_D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}9)$$

For $\sum Q_i \geq Q_O$

$$C_{33}(Q_i) = c_{331}\frac{D}{Q_D} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}10)$$

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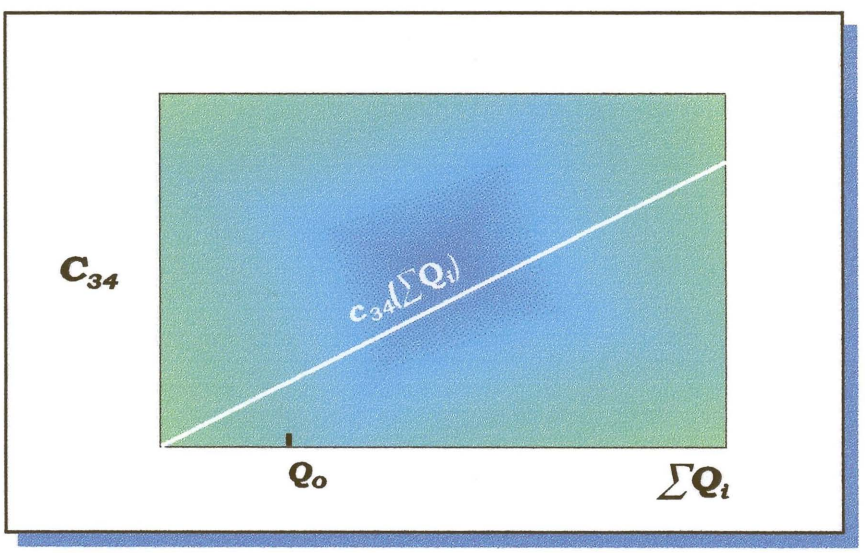
The last cost component of supply cost results form the in-transit insurance cost (C_{34}) required per trip. This is indeed extremely necessary in a South African context due to the high incidence of in-transit robberies. (Refer to paragraph 3.5.1 in this regard). The relationship in this instance is of a linear nature as shown in Figure 2.9.

Figure 2.9

The in-transit insurance cost element (C_{34}) of the supply cost of handling cash



The equation describing the in-transit insurance cost is as follows:

$$C_{34}(Q_i) = c_{34}(\sum_{i=1}^{14} Q_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}11)$$

The total supply cost is therefore

$$C_3(Q_i) = C_{31}(Q_i) + C_{32}(Q_i) + C_{33}(Q_i) + C_{34}(Q_i)$$

which is described by two mutually exclusive equations, depending on whether $\sum Q_i < Q_O$ or $Q_O \leq \sum Q_i$.

For $\sum Q_i < Q_O$, the following holds:

$$C_3(Q_i) = c_{31}\frac{D}{Q_D} - \frac{C_{32b}}{Q_b}\left(\sum_{i=1}^{14} Q_i\right) + C_{32b} + c_{332}\frac{D}{Q_D} + c_{34}\left(\sum_{i=1}^{14} Q_i\right) \quad \ldots\ldots\ldots \quad (2\text{-}12)$$

For $Q_O \leq \sum Q_i$, the following holds:

$$C_3(Q_i) = c_{31}\frac{D}{Q_D} + \frac{C_{32a}}{Q_a}\left(\sum_{i=1}^{14} Q_i\right) - C_{32a} + c_{331}\frac{D}{Q_D} + c_{34}\left(\sum_{i=1}^{14} Q_i\right) \quad \ldots\ldots\ldots \quad (2\text{-}13)$$

2.3.2.4 Conceptual mathematical model of the total cost of handling cash

Based on the deductions in the preceding paragraphs, it is possible to construct a conceptual mathematical model for the total cost of handling cash in a branch, agency or ATM of a retail bank. The model is dependent on whether the amount of cash held during the particular planning or scheduling period is greater than or less than the demand for cash which indeed materialises. The model is as follows:

For $\sum Q_i < Q_O$, the following holds:

$$C(Q_i) =$$

$$C_{10} + (c_{11} + c_{12} + c_{13})\sum_{i=1}^{14} Q_i - \frac{C_{20}}{Q_O}\left(\sum_{i=1}^{14} Q_i\right) + C_{20} + c_{31}\frac{D}{Q_D} - \frac{C_{32b}}{Q_b}\left(\sum_{i=1}^{14} Q_i\right) + C_{32b} + c_{332}\frac{D}{Q_D} + c_{34}\left(\sum_{i=1}^{14} Q_i\right)$$

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}14)$$

For $Q_O \leq \sum Q_i$, the following holds:

$$C(Q_j) = C_{10}+(c_{11}+c_{12}+c_{13})\sum_{i=1}^{14} Q_i+c_{31}\frac{D}{Q_D}+\frac{C_{32a}}{Q_a}(\sum_{i=1}^{14} Q_j)-C_{32a}+c_{331}\frac{D}{Q_D}+c_{34}(\sum_{i=1}^{14} Q_j)$$

. . . . . (2-15)

It must be stressed that the above merely represents a conceptual model for which the various cost parameters need to be determined. Once the parameters are known, it will be possible to investigate the model in depth to establish the optimum of the problem to, for example, interim deliveries. At present in South African banking circles, it is assumed that a single daily delivery provides the optimum solution to the cash replenishment problems of a branch, agency or ATM.

2.3.2.5 Conclusion

Oosthuysen (1995:33) points out that the need for better costing information is critical for South African banks because of the increasingly competitive environment in which they operate. The result is a need for sound decision-making to ensure long-term survival based on accurate information. As Oosthuysen (1995: 36) aptly states: *"Banks are forced to shift the focus from growth in interest income to an increase in operating revenue and/ or a reduction in operating expenses"*. This will only be possible if the true nature and extent of the cost of handling cash is established to facilitate the decision-making process.

2.3.3 The scheduling period and the effect of lead time

The scheduling period is the length of time between consecutive decisions with respect to replenishments and the lead time is the length of time between the scheduling of a replenishment and its actual addition to stock (Naddor 1982:26). In the South African retail banking industry the scheduling period, by popular

conviction, is presumed fixed at one day, with the replenishment of cash or the removal of surplus cash taking place on a daily basis. The scheduling period in this inventory system is therefore constant. It is referred to as a prescribed scheduling period and is denoted by t_p (Naddor 1982:27).

The incentive for adhering to this scheduling period, is embodied in the transportation cost element (C_{33}) of the supply cost of handling cash as illustrated earlier in Figure 2.7. A problem arises however with regard to the lead time. Under the assumption and enforcement of a prescribed scheduling period, it is crucial that the lead time should also be prescribed and constant. However this is not the case. The lead time is denoted by L_j, where j = 1,2,...N and j denotes subsequent scheduling periods.. The adherence to a t_p = 1 trading day, is acceptable if $L_j \leq t_p$. However, as soon as $L_j > t_p$, a cash shortage becomes a possibility. It is precisely this occurrence in the present approach to cash replenishment in retail banking which leads to branches carrying more cash than is necessary as protection against a shortage.

In an attempt to optimise the amount of cash carried in a branch, agency or ATM, it would therefore be required to establish the lead time probability distribution. Once this has been established, the replenishment policy may be formulated to make provision for the demand during the lead time.

Initially, it may be hypothesized that the cash replenishment process is a Poisson process with a negative exponential lead time distribution. If λ = average arrival rate of the cash replenishment process and $1/\lambda$ = the average time between arrivals, then the lead time probability density function is given by the following equation:

$$f(L)=\lambda e^{-\lambda L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}16)$$

The cumulative distribution is given by:

$$F(L) = \int_0^L f(t)dt = 1 - e^{-\lambda L} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2\text{-}17)$$

The validity of the assumptions regarding the lead time distribution will be investigated thoroughly in a later chapter. It would also be prudent to propose that the adherence to a prescribed scheduling period be investigated.

2.3.4 Summary of inventory system characteristics

Having proposed a conceptual model to describe the inventory system used to manage cash holdings in retail banking services in South Africa, it is appropriate to summarise the characteristics of the system. The following has been postulated:

- The demand for (and supply of) cash is described by a probability distribution, which could be approximated by the normal curve, but the parameters of the distribution will vary between cash points (branches, agencies and ATM's). It is therefore an inventory system with probabilistic demand.

- The system is subject to two mutually exclusive conditions, *i.e.* cash held at the cash point for a specific scheduling period may be greater than or less than the demand which finally materialises during that period. The occurrence of each of these conditions will have an impact on the cost equation describing the total cost of handling cash. The cost parameters have yet to be determined.

- The scheduling period is prescribed, but the lead time varies according to a probability distribution, the specific nature thereof as yet unknown.

The system may therefore be described as a (z,q) system according to the notation used by Naddor (1982).

2.4 Conclusion

The aim of Chapter 2 was to highlight the attendant problems of cash replenishment in retail banking. It described the problems relating to the discrepancy in deposit and withdrawal mix and the factors which influence the demand for and supply of cash at a cash point (be it a branch, agency or ATM). The perspective of the customer on good service specifically related to the provision of cash was discussed. The bulk of the chapter was devoted to the development of a mathematical model to describe the costs involved in handling cash from the perspective of the branch, agency or ATM. In addition the impact of the scheduling period and the replenishment lead time were also discussed.

Chapter 3 focuses on the retail banking environment in South Africa, specifically those characteristics that impact on cash handling.