Payment System Policies and Intraday Liquidit
in a Real Time Gross Settlement System:
The Colombian Case

September 2005

Joaquin Bernal R. and Carolina Merlano G.
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Payment System policies and intraday liquidity in a real time gross settlement system: the Colombian case

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September 2005

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About the authors

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The views expressed in this paper are the exclusive responsibility of the authors and do not necessarily reflect those of the Banco de la República or its Board of Directors, nor of the World Bank, CEMLA or the WGPS-LAC.
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ABSTRACT

The implementation of a real time gross settlement (RTGS) mechanism for settling operations in a systemically important payments system contributes on a substantial way to the financial stability and the prevention of financial risks, in particular, the systemic risk, but raises significant challenges for the intraday liquidity management.

This paper analyses the intraday liquidity determinants of the Colombian RTGS system and its distribution among banks and other system participants related to their payment needs. The factors that affect the liquidity supply are evaluated, such as the evolution of the reserve requirements, the incidence of tax factors on the composition of the reserve requirements, the intraday and overnight provision of repos, the turnover of available balances at the central bank, the functioning of the money market, the collaterals mobility, the schedule and sequence of operations along the day and others, as well as the liquidity demand factors, among which the exponential growth of the public debt and foreign exchange markets is the most relevant one.

The policy actions taken by the Banco de la República (BRC) aimed at supporting the smooth and faster settlement of payments along the day, with a lower amount of liquidity required in the BRC accounts and at a lower opportunity cost, are also assessed, as well as the cooperation efforts among the different participants, under the BRC leadership, to reach these goals and the reform of the RTGS system pricing scheme implemented as of April 2004, aimed at strengthening the policy signals for incentivizing the faster settlement of operations that inspired the cooperative agreements.

This research is based on a methodology for processing and analyzing the statistics of the intraday operations flow in the RTGS system and of the intraday account balances at the central bank of the different participant which is innovative at the Latin American level and which greatly contributes to visualize more integrally the aforementioned issues and the effect of the policy actions agreed with the participants. The objective is to offer a methodology to evaluate the determinants of the intraday liquidity flows and the impact of the policy decisions aimed to increase the Payment System efficiency and to reduce the opportunity cost of liquidity, which is useful for others central banks, in particular from emerging and developing economies.

Another important aspect of the paper is that it shows the importance of strengthening the interoperability between payments and securities settlement infrastructures on an empirical basis and the relevance of their harmonious development in order to satisfy the needs of the monetary policy, the money and public debt markets, as well as the management of cross-systems risks. These are topics which have been considered critical by the BIS for payment systems development (CPSS, 2005b).
### LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>BIS</td>
<td>Bank for International Settlements (Banco de Pagos Internacionales)</td>
</tr>
<tr>
<td>BRC</td>
<td>Banco de la República (Colombia)</td>
</tr>
<tr>
<td>CB</td>
<td>Central Bank</td>
</tr>
<tr>
<td>MEC</td>
<td>Colombian Electronic Market (managed by Bolsa de Valores)</td>
</tr>
<tr>
<td>COP$</td>
<td>Colombian pesos</td>
</tr>
<tr>
<td>CPM</td>
<td>Collective Portfolio Managers (Pension Funds, Trustees, etc)</td>
</tr>
<tr>
<td>CPSS</td>
<td>Committee on Payment and Settlement Systems - BIS</td>
</tr>
<tr>
<td>CSD</td>
<td>Central Securities Depository (managed by BRC)</td>
</tr>
<tr>
<td>SEN</td>
<td>Electronic Trading System (in public debt securities), managed by BRC</td>
</tr>
<tr>
<td>IR</td>
<td>Intraday “Repo” (Repurchase Agreement)</td>
</tr>
<tr>
<td>NTD</td>
<td>National Treasury Directorate – Ministry of Finance</td>
</tr>
<tr>
<td>OR</td>
<td>Overnight “Repo” (Repurchase Agreement)</td>
</tr>
<tr>
<td>RTGSS</td>
<td>Real Time Gross Settlement System</td>
</tr>
<tr>
<td>PS</td>
<td>Payment System</td>
</tr>
<tr>
<td>SB</td>
<td>Stock Broker</td>
</tr>
</tbody>
</table>
1. INTRODUCTION

In 1998, Colombia adopted a real time gross settlement mechanism for systemically important transactions channeled through the payments system. In this kind of system payments are settled one by one (“gross”), in real time and continuously throughout the day.

The international literature on real time gross settlement systems (RTGSS) recognizes that this type of payments mechanism is very effective in “minimizing and even eliminating the basic inter-bank risks in the process of settlement...by reducing the duration of the credit and liquidity exposures ....and offers a powerful mechanism to reduce the systemic risk” (CPSS, 1997, pp. 10-11). In fact, the sooner finality of payments settlement (in other words, unconditional and irrevocable) takes place, the lesser will be the exposure to financial risks (CPSS, 2005). However, RTGSS are very demanding when it comes to requirements of intraday liquidity since the payments are only accepted by the system when there are sufficient funds in the payer’s transactions account at the Central bank (credit type operation).

As is widely recognized, obtaining and maintaining enough liquidity in the accounts at the central bank (CB) adds an opportunity cost to commercial banks and to the rest of the participants in the Payments System (PS). This cost corresponds to the difference between the rate at which the banks can place resources in the inter-bank market and the remuneration offered by the central bank, which is frequently null or at least lower than the inter-bank rate (Marquardt, 1994).

Therefore, since “mobilizing the required liquidity imposes costs on banks and, all other things being equal, the banks have an incentive to economize on liquidity” and due to the fact that RTGSS are so demanding of liquidity, each individual bank “may prefer to wait for incoming payments before sending their own payments. This can lead to delays and gridlocks, i.e. situations where several payments each await the settlement of others (Bech and Soromäki, 2002).

From the perspective of the PS as a whole and of its individual participants as well, the liquidity in a RTGSS is a function of certain financial markets characteristics such as the functioning of the inter-bank money market, the availability and mobility of collaterals and of CB policies concerning reserve requirements and provision of liquidity (CPSS, 1997, pp. 14-15), besides a number of other elements of operational nature for each participant and for the system as a whole. In the last instance, the benefits, costs and risks that a RTGSS faces “depend critically on the distribution (or concentration)

---

1 A synthesis of the literature and international experiences on the subject can be consulted in: Committee on Payment and Settlement Systems (CPSS), Real-time gross settlement systems, BIS, March 1997, and more recently in CPSS, New developments in large-value payment systems, BIS, May 2005a.

2 A deeper money market facilitates the lending of funds between banks and, thus, the proper functioning of the Payments System. The development of the former will facilitate matters even more to the extent that loans can be backed by adequate guarantees (collateral) and that the supply of collaterals such as public debt bonds and others be sufficient and have a dynamic secondary market. High reserve requirements (so long as the authorities allow their mobilization for inter-bank payments) make the PS more liquid and enable its proper functioning, as explained by Marquardt (1994); however, reserve requirements have the same effect on economic efficiency as an indirect tax, as argued by Fry et al (1998).
of liquidity between banks and other participants in relation to their settlement needs” (CPSS, 1997, p.17).

In the Colombian case the large-value payments system has been facing growing liquidity pressures, stemming from the fact that a significant number of the transactions channeled through it are settled in the late hours of the day, after money markets and the central bank (Banco de la República or BRC) Lombard window have closed, which calls for adequate management so as to prevent potential risks that could affect all participants under certain extreme circumstances.

This document analyses the incidence of different market factors and of the functionality of the Colombian RTGSS on the intraday distribution of transactions and the liquidity of the payments system, as well as the policies adopted by BRC to favor their de-concentration are described. Among these, the following are emphasized: 1) the actions inherent to BRC as the monetary authority and RTGSS administrator, aimed at achieving earlier settlement, with less requirements on banks' account balances at BRC and lower opportunity cost; 2) cooperation efforts among the various participants in the system, under BRC leadership; 3) the adjustment of the RTGSS fee structure, implemented as of April 2004, which aimed at reinforcing the signals that had inspired the collective agreement effort. Among the first group, an additional reference will be made to the analysis of the new functional features of the RTGSS, aimed at promoting earlier settlement and optimizing liquidity management by the implementation of a sophisticated queue release mechanism supported by “off-setting queuing” facilities for gridlock resolution.

This research is based on a methodology for processing and analyzing the statistics on the intraday flow of transactions in the RTGSS and of the intraday balances at the central bank of the different groups of participants, which is an innovative approach in the Latin American context and contributes to visualize in a more integral manner the problems in question, and the effect of policy decisions and cooperative efforts among PS participants. Even though the analysis and the recommendations relate to the particular structure of the Colombian monetary and financial system, and to the local characteristics of its payments settlement needs, the purpose of the document is to offer a methodology for evaluating the determinants of the intraday liquidity flows and the impact of policy decisions aimed at increasing PS efficiency and reducing the opportunity cost of liquidity, which may be useful for other central banks, especially in emerging and developing economies.

Another important aspect of this research is that it illustrates the interaction between the payments and securities settlement infrastructures in a practical case, the relevance of a harmonious coordination of their respective development to satisfy the needs of monetary policy, money markets and public debt, and the management of the cross risks of such infrastructures, topics which have been considered by the Bank of International Settlements as critical elements in the development of payment systems (CPSS, 2005b).

The document consists of nine sections of which this introduction is the first one. The second one analyzes the main stylized facts of the supply and demand of available liquidity, pointing out certain peculiarities of the Colombian case that make it sui-generis in the international context, and the factors of monetary and tax policy that affect aggregate liquidity. The third section studies
the typical behavior of the intraday liquidity cycle prior to April 2004, which is complemented in the fourth section with other liquidity indicators in the RTGSS. The fifth section describes different policies adopted by BRC to improve the intraday liquidity cycle in Colombia before 2004. The sixth section describes the most important reforms to the RTGSS that came into effect in April 2004 to contribute to the improvement of the liquidity cycle and the efficiency of the system, where the changes to the applicable fee structures for the RTGSS and the Central Securities Depository (CSD), as well as another set of measures of an operational nature, are highlighted. The seventh section evaluates the incidence of the above policies on the two target variables: the intraday cycle of balances in the participants’ accounts in the RTGSS and the time schedule for transactions settlement. Finally, section eight consists of the analysis of the new earlier-settlement facilities that will be adopted towards the end of 2005 or beginning of 2006 (queue release mechanisms for gridlock resolution supported by “off-setting queuing”). Section nine summarizes the main conclusions.
2. DETERMINANTS OF SUPPLY AND DEMAND OF AVAILABLE LIQUIDITY IN THE COLOMBIAN RTGSS: STYLIZED FACTS

In 1993 BRC implemented an automated large-value funds transfer system (nowadays called the “Deposit Accounts System” -DAS), which from the beginning operated in direct interface with the CSD\(^3\) for the settlement of securities transactions under the delivery versus payment mechanism.

In 1998, in the midst of one the largest crises in history faced by the Colombian financial sector, BRC, in order to reduce moral hazard risk to itself and prevent systemic risk, adapted the functioning of the DAS to an operating mode of real-time gross settlement (RTGS) by simply activating on-line controls on account balances at BRC to the channeled transactions\(^4\), which significantly increased the liquidity requirements of the system.

The performance of the RTGSS has been determined, on one hand, by certain institutional peculiarities of the Colombian financial markets, and on the other, by monetary and tax policy decisions, as well as by the exponential growth of the public debt market. All of these factors exert structural pressure on the supply and demand of liquidity available to the payments system.

2.1 PARTICULAR INSTITUTIONAL ASPECTS OF THE COLOMBIAN CASE

In this respect, the principal stylized facts are:

1. In Colombia the agents who trade in the capital and money markets have voluntarily agreed (since no official regulation demands it) that the spot transactions agreed upon in the trading systems are to be settled the same day, which contrasts with what occurs in most of the rest of the world, where the settlement occurs in T + 1 or even later. In Colombia, the exchanges close down trading between 13:00 and 15:30 hours and many agents only start to settle after closing.\(^5\)

---

\(^3\) The CSD, managed by BRC, is the securities depository for public debt bonds (dematerialized and fungible) which operates under model 1 of delivery versus payment (according to the classification suggested by BIS), that is, transactions are settled grossly, in real time, and in online interface with BRC's own RTGSS. These, along with external debt bonds, are the only securities accepted by BRC as adequate collateral for its monetary operations. It should be pointed out that 90% of the value of transactions in the Colombian capital markets correspond to secondary market trading in public debt securities, and only 10% to private securities.

\(^4\) From the outset the system was designed with real-time gross settlement facilities, but in practice online controls on account balances were only applied to those intermediaries who were not subject to BRC reserve requirements. In other words, banks and other credit institutions subject to reserve requirements were de facto allowed intraday overdrafts on their reserve accounts at BRC, but at the end of the day the net balance to be settled could not exceed available funds in the BRC reserve account. Online balance controls to avoid intraday overdrafts were extended to all agents in 1998.

\(^5\) Operating hours for the RTGSS and CSD, managed by BRC, extend until 21:00 hours.
2. The range of agents authorized to hold settlement accounts for both money and securities at BRC is wider than in many other countries. It not only includes banks and credit institutions (subject to reserve requirements), but also stock brokers (SB), the private securities depository (DECEVAL) and collective portfolio managers (CPM) comprising fiduciaries, pension fund administrators, insurance companies and others. Neither the SB nor the CPM are subject to required reserves, so they do not have their “own sources” of liquidity, and are also subject to different regulatory constraints that prevent them from taking full advantage of the intraday liquidity facilities offered by BRC, thus depending on the banks for the transfer of liquidity from their current accounts at commercial banks to the RTGSS. Intermediary banks usually begin to execute their clients’ instructions once they have already settled a large volume of their operations on own account. For this reason, the transactions by SB and CPM (together with DECEVAL) are usually the ones that are settled later in the day, frequently only after 16:00 hours or later.

3. The Ministry of Finance – National Treasury Directorate (NTD) operates an account at BRC and until June 2005 acted with total independence in the money market, usually by placing its excess liquidity through “repo” transactions. This was until recently a very important source of injection and withdrawal of system liquidity and during the period 2002-2004 actually exceeded the value of the “repo” transactions for transitory expansion by BRC itself.

2.2 Monetary and Tax Policy Factors and Financial Markets Growth

With regard to the main policy factors that have influenced the availability of intraday liquidity for the payments system, the following stand out from the supply side:

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Footnotes:

6 For a comparative international view see CPSS, The role of Central Bank money in payment systems, BIS, 2003.

7 DECEVAL is the securities depository for private bonds, debt certificates and shares. These securities are not acceptable to BRC as collateral for monetary transactions, except for mortgage-backed securities. However, public debt bonds in sub-custody at DECEVAL are acceptable collateral for BRC.

8 Until 2002 BRC only allowed banks and other credit institutions access to intraday “repos” (backed by public debt bonds as collateral). In 2002 this was extended to SB and CPM. However, on one hand BRC regulations limit the maximum amount of “repos” granted (overnight and intraday) to 15% of liabilities subject to reserve requirements at credit institutions, or to net worth equivalent in the case of SB and CPM, and on the other, prudential regulation forbids the use of securities from portfolios under management in liquidity and “repo” transactions (including intraday).

9 Furthermore, a fair number of intermediaries have not made the investment required for an efficient automated connection between the front office and the back office, which would facilitate the straight-through processing (STP). This also contributes to explain why such a large number of transactions are channeled only at the end of the day.

10 This policy strategy was subject to a profound revision in 2005, aiming at reducing the participation of NTD in the money market. As a result, as of June 2005 NTD began depositing its entire excess liquidity at BCR (as interest-bearing deposits) and suspended its own transactions in the money market. See Section 7.1.
1. Available liquidity for settlement of inter-bank payments has shown a structural tendency to drop as a consequence of the following elements: a) the reduction in the level of required reserves, which decreased from an average of 15.3% in 1994 to 7.3% in 1998 and 5.7% in 2004; b) A sharp change in the composition of the monetary base, as a result of which the share of currency in circulation increased from 48.5% in 1998 to 71.6% in 2004, while reserves (in other words, reserves available at BRC and cash in vault) fell from 51.8% to 28.4% (see figure 1); c) An increase in the share of banknotes held as available reserves from 17% in 1996 to 58.9% in 2004, and a consequent reduction from 83.1% to 41.1% in the balances held as reserves in deposit accounts at BRC (see figure 2).

2. A fundamental determinant of the latter was the introduction in 1998 of a tax on financial transactions, applying to withdrawals and transfers of the accountholders' money in banks, and which induced a strong increase in the demand for banknotes by the public. Another key factor was the drop in the nominal interest rate from 32.6% in 1998 to 12.2% in 2000 and 7.8% in 2004.

At the same time that the supply of available liquidity for meeting transactions in the payments system has been contracting, the demand for it has rapidly increased due to the exponential growth in transactions settled through the RTGSS (Figure 3), which increased from a daily average of COP$ 1.2 trillion in 1996 to COP$5.6 trillion in 2000 and to COP$14.9 trillion in 2004. The number

![Figure 1: Components of the Monetary Base, 1996-2004](chart)

Percentage Share

<table>
<thead>
<tr>
<th>Month</th>
<th>Cash/Monetary Base</th>
<th>Reserves/Monetary Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr. 1996</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Dec. 1997</td>
<td>25%</td>
<td>75%</td>
</tr>
<tr>
<td>Aug. 1998</td>
<td>20%</td>
<td>80%</td>
</tr>
</tbody>
</table>

11 Average calculated as the ratio of the annual average of weekly available reserves to liabilities subject to reserve requirements.
12 Corresponding to the rate paid on 90-day time deposit certificates (CD).
13 Trillion = 1,000,000,000,000.00.
14 The symbol "COP$" represents the Colombian peso.
of daily transactions went from 641 to 2,270 and 6,446 in each of those years. This trend has remained positive during the first semester of 2005, by settling a daily average of 8,340 transactions for total value of COP$ 19.7 trillion.

This is explained mainly by the growth in the market for public debt. Indeed, secondary market trading in public debt securities (sales, repurchase and buy-sellback agreements) carried out through the SEN\(^{15}\) (Electronic Trading System) and MEC\(^ {16}\) (Colombian Electronic Market) systems and in the OTC market, which are settled at the CSD in a delivery versus payment mode, have witnessed exponential growth over the last four years, by increasing from COP$ 1.1 trillion daily in 2001 to COP$ 4.5 trillion in 2004, and to COP$ 8.0 trillion in the first semester of 2005.

Due to the above, the turnover ratio\(^ {17}\) of deposit account balances at BRC went from 3.8 times in a typical day of operation in the year 2000, to 8.7 times in 2004 (and has remained practically unchanged during the first semester of 2005), as can be seen from Table 1.

\(^{15}\) SEN is an electronic trading platform for market-makers in public debt securities administered by BRC.

\(^{16}\) MEC is electronic trading platform for brokers and other intermediaries in the secondary market for equities and fixed-income securities administered by the Colombian Stock Exchange.

\(^{17}\) The turnover ratio is defined as the ratio of the value of transactions settled through the system each day to the aggregate balance on participants' accounts at the end of the day.
Figure 3: Value and Number of Transactions in the RTGSS, 1996-2004

Table 1: Comparative Statistics of the RTGSS, 2000 – 2004

<table>
<thead>
<tr>
<th>RTGSS Statistics</th>
<th>2000</th>
<th>2004</th>
</tr>
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<tbody>
<tr>
<td>Average Balance on Deposit Accounts</td>
<td>COP$1.4 trillion</td>
<td>COP$1.7 trillion</td>
</tr>
<tr>
<td>Number of Daily DAS Payments</td>
<td>2,270</td>
<td>6,446</td>
</tr>
<tr>
<td>Value of DAS Payments</td>
<td>COP$5.6 trillion</td>
<td>COP$14.9 trillion</td>
</tr>
<tr>
<td>Turnover Ratio (Times per Day)</td>
<td>3.8</td>
<td>8.7</td>
</tr>
<tr>
<td>Payments between 08:00 and 18:00 – Value</td>
<td>71.1%</td>
<td>79.8%</td>
</tr>
<tr>
<td>Payments after 18:00 – Value</td>
<td>28.9%</td>
<td>20.2%</td>
</tr>
<tr>
<td>Payments between 08:00 and 18:00 – Number</td>
<td>73.4%</td>
<td>78.8%</td>
</tr>
<tr>
<td>Payments after 18:00 – Number</td>
<td>26.6%</td>
<td>21.2%</td>
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</table>
3. THE INTRADAY CYCLE PRIOR TO APRIL 2004

Figure 4 presents the typical behavior of intraday balances for all participants in the Colombian Payments System up until the first quarter of 2004, clearly showing the stability of balances in the morning hours (due to the low volume of operations) and the pressure on liquidity in the early afternoon, due mainly to the liquidity drainage and subsequent injection effects of NTD and BRC transactions, which reduced the bank's balances.\(^{18}\)

It should also be pointed out that, structurally, the balance at the start and end of the day is practically identical, since it corresponds to the level of required and available reserves, while the intraday balance is higher because banks resort to intraday repos at BRC in order to comply with their obligations during the rest of the daily cycle.\(^{19}\)

Until March 2004, as banks repaid their repos their available balances in BRC accounts fell, while the NTD balance increased. Both the NTD and BRC gradually re-injected liquidity to the system via

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\(^{18}\) The BRC repo auction takes place at 11:00 each day. Up until November 2003 NTD would invest its excess liquidity earlier, through bilateral repo trading. Banks would then have to complete reversion of their repos prior to receiving the corresponding liquidity for the new repos. BRC, as manager of the Central Securities Depository, considered it prudent to allow banks at least two hours from the time of confirmation of the value of assigned repos in which to mobilize their collateral in favor of BRC and NTD. As can be seen in Section 6.2, this changed as from June 2004, allowing banks the freedom to complete reversion of their repos at the time they saw fit.

\(^{19}\) The banks' account balances at BRC are also increased at midday by the freeing of funds originating from the inter-bank check clearance.
new repos as from 15:00 hours. The banks did not begin settling their obligations to other participating agents in the payments system until they had finished complying with their obligations to the Treasury and BRC and had received anew from them the liquidity corresponding to “overnight” expansion repos. The end receivers of the liquidity cycle are the SB, CPM and DECEVAL who, in consequence, only started to settle most of their payments at around 18:00 hours.

Since the payments of certain agents constitute the major source of liquidity to others (receivers) and each individually has an interest in economizing liquidity, the operational and institutional factors mentioned above contribute to explain why liquidity is not distributed in a sufficiently timely manner throughout the day, uniformly between hourly segments and equally among agents, and the motive for which, up until the beginning of 2004, 46% of the DAS operations (both in volume and in value) were settled after 17:00 hours (see figure 5).

In this respect it should be pointed out that, from the moment the Lombard window closes at 16:00 hours each day, BRC does not engage in further monetary expansion operations, and since a sufficiently deep inter-bank intraday money market has not been yet developed in Colombia, the above mentioned concentration of transactions in late hours of the day presents a strong potential for liquidity risks in the RTGSS.

**Figure 5: Time Schedule of Transactions in the RTGSS – 1st Quarter 2004**
Percentage of Daily Average Value and Volume by hourly Segment
4. OTHER LIQUIDITY INDICATORS IN THE RTGSS

Given the fact that growing demand for liquidity in the RTGSS could lead to gridlock in the payments system, policy design should first diagnose whether the available liquidity is sufficient for the system in aggregate, and then proceed to evaluate if its distribution among individual agents is appropriate in relation to their payment needs. If this were not the case, the risk of delays in the channeling of payments would appear which could only be overcome by optimization mechanisms in the management of the available liquidity, such as the clearance of transactions in the queue for settlement, or by external injections of additional liquidity to the system.

The methodology suggested by Bech y Soromäki (2001 and 2002), Koponen y Soromäki (1998) and Leinonen y Soromäki (1999) is particularly relevant in the approach to this problem. The following synthesize some of the main results of a recent study carried out at BRC in this field. The theoretical underpinning is developed in greater detail in Annex 1.

- A first indicator of the liquidity required for the RTGSS corresponds to the value of the maximum overdraft that the system would produce as a consequence of settling the totality of transactions channeled through it on any given day, under the assumption that the deposit account balances at the start of the day would be zero (upper bound indicator, UB, according to the mentioned authors’ methodology). When comparing the daily value of this indicator with the actual aggregate balances on deposit accounts of participants in the Colombian large-value PS (excluding NTD) during the period of analysis, it was found that without exception the latter exceeded the respective UB indicators, at first glance reflecting sufficient aggregate liquidity in the system.

- A similar conclusion is arrived at when evaluating, ex post, the UB indicator at the individual level of each bank entity. This means that the required reserve balance held at the central bank is enough to settle the totality of obligations in the payments system (even exceeding it in a fair number of cases).

- However, due to the fact that the two above-mentioned exercises took as a starting point the ex post time schedule during which the different payment transactions were in fact already settled, but not so the time at which many of these first entered the RTGSS and were rejected due to lack of funds, the exercise was recalculated by replacing the time of actual settlement with that of the first attempted settlement, under the premise that only under this scenario could the initial diagnosis of sufficient liquidity in the system be validated.

- In the above case banks exhibited positive liquidity indicators in the aggregate (total available balances exceeding the UB indicator), but it was found in several individual cases that funds were insufficient at the initial moment of payment order, thus producing delays during  

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20 Work undertaken by Freddy Cepeda and Fabio Ortega, of the BRC Payments Systems Department, and based on the methodology employed in the papers by the cited authors from the Bank of Finland.

21 The current system does not manage queuing, but shall as from early 2006 (see section 8).
which the bank in question rounded up the additional liquidity required to honor it. On the other hand, even at the aggregate liquidity level, shortages were registered for the SB and CPM groups. For example, in the 40 days analyzed, it was found that 101 entities accounting for 68% of total RTGSS participants, experienced delays in settling their payments due to insufficient funds at the time of initial instruction.

In conclusion, the application of this methodology to the Colombian case made it clear that, even if the aggregate liquidity of the payment system can be considered sufficient, under the current operating conditions of the RTGSS, delays occur in the process of settlement due to insufficient funds available in individual participants' accounts. This occurs quite frequently at the SB and CPM level, but also occasionally in the case of certain banks.

The above results suggested at that point the need for BRC to take additional measures to provide for a more timely settlement of payments, at a lower cost to banks in terms of liquidity resources at the central bank.
5. STEPS TAKEN BY BANCO DE LA REPÚBLICA TO IMPROVE THE INTRADAY LIQUIDITY CYCLE PRIOR TO 2004

BRC has adopted many policy measures aimed at improving intraday liquidity in the RTGSS, in keeping with international experience and in accordance with the recommendations of theoretical literature (CPSS, 1997, 2003 y 2005), and has gradually improved multiple operational aspects of the system.

The first and more obvious policy option consisted in revising the sequence of transactions throughout the day for some key players, especially BCR and the NTD, in order that the latter should initiate their payments earlier in the day and speed up the circulation of liquidity to the remaining participants. Mechanisms for injecting “additional” liquidity to the system were then implemented via intraday repos, and some more sophisticated technical and operating mechanisms have been adopted subsequently.

Among the principal measures adopted between 1999 and 2003, the following should be highlighted:

- **Reordering of the sequence of transactions in the RTGSS (1999):** Due to the fact that in August 1999 the funds from the first check clearing session (21:00 hours) were frozen at BRC until the closing of the second session (13:00 hours t + 1), the repayment or reversion of BRC and DTN repos which was executed automatically at 4:00 hours, was moved up to 14:30 in order to provide additional liquidity to the market in the morning hours.

- **BRC Intraday Repos at quasi-zero cost (1999):** BRC intraday repos were introduced en 1998, but it was only in 1999 that their cost was reduced to an almost null level together with a wider set of policy measures to ensure greater and more efficient use.

- **Linking of BRC Repos (2000):** This is an operational facility at the CSD that lessens the impact of withdrawals and injections of liquidity associated with reversion and granting of new repos each day, by clearing one against the other and settling the net differences. Today, between 30% and 35% of BRC and NTD repos are linked.

- **Conversion of the Intraday Repo (IR) to an Overnight Repo (2001):** the use of the IR was very low until April 2001 since BRC penalized the non-repayment of the IR within the day with the loss of the collateral, based on the argument that it was indispensable to maintain a strict control of monetary aggregates. With the dismantling of the exchange rate band and the switch in monetary management towards a policy of “inflation targeting”, BRC authorized conversion of the IR into an overnight repo (OR) without loss of collateral. This transaction

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22 From late 1998 to mid 1999 BRC charged one third of the commercial time deposit rate on intraday repos. Banks practically did not use IRs because they considered this cost to be very high. In fact, internationally very few central banks charge for the use of an IR. In mid 1999 BRC lowered the cost of IRs to the equivalent of an annual rate of 0.1%. Since then their use by banks has accelerated.
has a penalty cost, however, and remains subject to the OR rules from the moment of its reconversion.\textsuperscript{23}

- **Automation of NTD Repos (2003):** This allowed for NTD to make use of an automated facility for trading and placing its repos in BRC's SEN so as to facilitate straight-through processing and linking.

- **Earlier Treasury Payments (2003):** NTD pays suppliers through the BRC's ACH (daily average of COP$ 150 trillion, equivalent to 1.5% of the value of the payments made by the banks through the RTGSS). As of 2003 this payment cycle was moved up from 16:00 hours to 13:00 hours.

Since then the effort has been permanent and new functions and facilities have been introduced, some of which can be consulted in Table 2 (section 6.2). This set of measures contributed to allowing the system to satisfactorily cope with the growing volume of transactions entered and to the increased use of Intraday Repos (COP$ 21 trillion in 2001 to COP$39 trillion en 2002, COP$69 trillion in 2003 and COP$99 trillion in 2004).

\textsuperscript{23} The RO rate is set at the maximum rate charged by BRC on expansion repos, plus 100 basis points (1%). ROs must be repaid before 18:00 hours on day $T+1$. See also footnote 8.
6. THE 2004 REFORMS TO THE RTGSS

Cooperation and public action, together with competition, are the forces that propel the development of payment systems (Padoa-Schioppa, 2004). BRC realized that what was needed was a combination of public and private efforts, together with cooperative incentives with clear and explicit signals, preferably based on prices, regarding the direction in which the central bank thought desirable that market forces should be guided.

Even though, at least since 2001, BRC had worked closely with the NTD and market agents, cooperative efforts to improve the intraday liquidity cycle and to promote a more efficient use of such liquidity had not yet taken shape.

Towards the end of 2003 BRC informed users of its payment, trading and securities settlement services that there would be profound changes in the applicable fees and charges, which would come into effect partially within six months and totally about a year later. As will be seen below, the new fee structure created incentives for an early channeling of payments.

To avoid the financial impact of the new fee structure representing a heavier burden, BRC invited all those concerned to combine efforts and cooperate in jointly achieving the objectives. Finally, after more than six months work, at the beginning of 2004 a collective agreement was reached containing commitments from each of the parties concerned. The content of this agreement is summarized in section 6.2.

6.1 REFORMS TO THE RTGSS FEE STRUCTURE

Following a detailed cost analysis of payment, trading, custodian and securities settlement services provided by BRC, substantial modifications to the fee schedules for each of these systems were approved in 2003 (and came into effect in April 2004) with the objective of: a) partially correcting for “cross subsidies” between the various services; b) fully reflecting costs in the fees charged to participants; c) introducing charges calculated to create incentives towards a more efficient use of these services; d) approaching greater compliance with Principle VIII (efficiency) of the CPSS Basic Principles for Systemically Important Payment Systems; and e) creating fee incentives aimed at attaining payment systems policy goals, thus contributing to a better use of intraday liquidity and to a more uniform distribution of payments, aiming to avoid the concentration of transactions at the end of the day that had been observed in previous years.

With respect to the strict objective of de-concentrating transactions, the main reform consisted in substituting the single ad-valorem rate in effect since 1993 (COP$ 2 per million) by a scheme with incentives for making payment before a given hour, and extending the fee even to payments for transactions with public debt securities (PDS) that were previously exempt and represent one third of all payments settled in the system (excluding repos).

The new scheme has two components: a fixed charge of COP$ 2,000 (approximately USD 0.85) per transaction settled before 18:00 hours and an ad-valorem rate of COP$ 2.5 per million after that.
hour. Only BRC open market operations completed during the first operating-hour window remain exempt from the RTGSS settlement fee.

The basic charge per transaction was fixed at a level comparable to the cost of a transaction settled by check, to avoid promoting the use of a less safe and less efficient payment instrument. The ad-valorem rate penalized larger-value transactions, which was in contradiction with the very nature of the RTGSS. The new flat charge is neutral both with respect to the value of the transactions and to their origin, in other words, whether they are inter-bank transfers, public debt securities, private securities, settlements from other payment systems, etc. 24, but penalizes the payments settled after 18:00 hours.

The effects of this rate change, after eight months of its implementation, will be analyzed in section 7 of this document.

### 6.2 Additional Steps Underway

Table 2 summarizes another set of additional steps agreed between BRC, the NTD and payments system participants to improve the liquidity cycle:

<table>
<thead>
<tr>
<th>Action</th>
<th>Current Schedule</th>
<th>Proposed Schedule</th>
<th>Status</th>
<th>Responsible for action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bring Forward Reversion of BRC NTD Repos</td>
<td>14:00</td>
<td>13:00</td>
<td>Executed</td>
<td>BRC</td>
</tr>
<tr>
<td>Voluntary Reversion of BRC and NTD Repos</td>
<td>13:00</td>
<td>Anytime</td>
<td>Executed</td>
<td>BRC</td>
</tr>
<tr>
<td>Automated Intraday Repo</td>
<td>NA</td>
<td>NA</td>
<td></td>
<td>BRC</td>
</tr>
<tr>
<td>Collateral Substitution at CSD</td>
<td>NA</td>
<td>NA</td>
<td>Executed</td>
<td>BRC</td>
</tr>
<tr>
<td>Securities Borrowing/Lending</td>
<td>NA</td>
<td>NA</td>
<td>Underway</td>
<td>BRC</td>
</tr>
<tr>
<td>Earlier-settlement (gridlock resolution)</td>
<td>NA</td>
<td>NA</td>
<td>Will operate</td>
<td>March/06 BRC</td>
</tr>
<tr>
<td>facility in the PS and for securities at CSD</td>
<td></td>
<td></td>
<td></td>
<td>BRC</td>
</tr>
<tr>
<td>Advances on Tax Payments</td>
<td>14:00</td>
<td>11:00</td>
<td>Executed</td>
<td>NTD and Banks</td>
</tr>
<tr>
<td>Bring Forward Second Check Session</td>
<td>12:30</td>
<td>11:30</td>
<td>Executed</td>
<td>Intermediaries</td>
</tr>
<tr>
<td>Liquidity Distribution to Clients</td>
<td>15:00 – 20:00</td>
<td>13:00 – 18:00</td>
<td>Underway</td>
<td>Intermediaries</td>
</tr>
<tr>
<td>Dividend Payments DECEVAL</td>
<td>20:00</td>
<td>18:00</td>
<td>Pending</td>
<td>Intermediaries</td>
</tr>
<tr>
<td>DVP-DECEVAL Payments</td>
<td>20:00</td>
<td>18:00</td>
<td>Pending</td>
<td>Intermediaries</td>
</tr>
<tr>
<td>Private Debt Investment Decisions</td>
<td>17:00</td>
<td>15:00</td>
<td>Pending</td>
<td>Intermediaries</td>
</tr>
<tr>
<td>Front and back office integration - STP</td>
<td>NA</td>
<td>NA</td>
<td>Underway</td>
<td>Intermediaries</td>
</tr>
</tbody>
</table>

24 In recent years the average value of a transaction settled through the RTGSS was COP$2.3 trillion. Under the previous fee structure the average transaction would have been charged COP$4,600. Under the new scheme the charge is COP$2,000 before 18:00 hours, but the delay will increase its cost to COP$5,750.
The steps related to bringing forward the timetable for reversion of BRC and NTD repos and allowing their voluntary activation, as well as the advances on the tax payments, among others, are aimed at getting intermediaries to see to their obligations with these two entities earlier, since they are higher priority, and then be able to initiate their operations sooner with other participants in the system.

The automated IR seeks to: a) settle delivery versus payment transactions at the CSD where the buyer does not have the funds, by granting an automatic RI guaranteed by the purchased security; and/or b) settle those delivery versus payment transactions at the CSD where the seller possesses the corresponding security pledged to BRC, by its automatic release versus funds received from the buyer.

The option of permitting the substitution of collateral at the CSD aims at promoting the linkage of a higher proportion of BRC and NTD repos, since currently only 35% are linked, given to the entities’ need to cancel past due transactions in order to free collateral pledged to other transactions. This measure contributes to increasing the mobility, and thus the liquidity of the securities, which is also a key aspect for payment system liquidity.

Securities borrowing and lending is another widely used mechanism in more mature markets to increase the liquidity of securities, especially to cover short positions.

In order to optimize the use of liquidity in the RTGSS (deposit account balances) and in the CSD- (public debt securities), two projects are currently underway to implement for both systems a gridlock resolution mechanism based on “off-setting queuing”. This is explained in more detail in section 8 of this document.

Finally, the convenience of settling securities transactions taking place after 13:00 hours on day T + 1, rather than T + 0 as occurs today, has been put to the consideration of the financial community.
7. RTGSS INTRADAY LIQUIDITY FOLLOWING THE 2004 REFORMS

The performance of the RTGSS during the first year of application (2004) of the new fee structure and the implementation of the rest of the actions enumerated above is described under this heading. It shows that their impact on the behavior of liquidity and on the de-concentration of transactions during the intraday cycle was positive.

7.1 INTRADAY BALANCES IN THE RTGSS

The following figures present the intraday balances of the group of agents authorized to maintain deposit accounts at BRC for the period of April-December 2004, compared to their observed level in the first quarter of the same year.

Figure 6: Intraday Balances in the Security Deposit Accounts at BRC – 1st Quarter 2004
Daily Average by Hourly Segment, in COP$ Trillions

First of all it can be seen how the NTD, whose balances rose daily by COP$ 500 trillion between the hours of 14:00 and 15:00 as an effect of the daily reversion of its repos and gradually fell back until 18:00 hours due to the new placement of funds, shows a far more stable behavior as of April 2004. Since then its balance rises by approximately COP$ 200 trillion and the respective process begins (13:00 hours) and ends (15:00 hours) earlier, thus advancing the restoration of liquidity to the market.

The above change can be attributed to the following: a) NTD’s entry to the SEN in order to trade repos with the banks, providing for an earlier investment of its funds; b) the operational adjustments made by BRC in relation to the linking of a portion of its repos and bringing forward by one hour the
time schedule for their reversion; c) earlier payment to suppliers (at 13:00 hours), and d) concerted agreements between the NTD and BRC seeking greater stability in the level of remunerated deposits held by the former at BRC. Also, the volume of these have been growing constantly since June 2004, to the extent that the direct share of the NTD in the money market has been falling, leaving more room for BRC to fulfill its role in this segment.25

Figure 8: Intraday Balances in the Deposit Accounts of NTD at BRC
Daily Average by Hourly Segment 2004, in COP$ Trillions

25 In fact, finally in June 2005, the DTN completely suspended their own operations in the monetary market and since then it deposits the totally amount of it excess in BCR accounts (remunerated), which has contributed to give more stability to the intraday liquidity cycles of the banks and other intermediaries.
For their part, until the first quarter of 2004 the banks' intraday balances would fall substantially between 14:00 and 15:00 hours due to the referred return of resources to the NTD, generating relative inactivity in the RTGSS during the first hours of the afternoon (see Figure 9). It should be noted that, even when the aggregate balances of the group banks seem high (close to COP$ 1 trillion), these funds are concentrated in a small group of entities that are relatively less active in the money and capital markets, and therefore the liquidity they control cannot be used by the system as a whole for the settlement of payments (see Figure 10).
By December of the same year it can be observed how the balances fall by a lesser amount, and how the respective cycle, besides being shorter, starts earlier due to the advancement in meeting banks’ priority transactions and the faster liquidity irrigation by NTD, which at the same time allows banks to make earlier payments and funds transfers to the SB and CPM.

The impact of the above changes in the transaction cycles of the NTD and banks upon the balances of the rest of the market agents (SB and CPM) can be observed in Figure 11. A slight improvement can also be noted, although additional efforts must still be made.

### 7.2 RTGSS Time Distribution of Transactions

As was mentioned above, the set of measures described in sections 5 and 6 had the dual purpose of improving intraday liquidity distribution by hourly segments and among agents, as well as bringing forward the transactions channeled through the RTGSS, with the aim of reducing exposure to liquidity risk for participants in the SP.

As can be seen in Figures 12 and 13, the accumulated daily value of transactions settled through the RTGSS before 18:00 hours, which in the first quarter of 2004 was 73%, increased in the three following quarters to 84%, 82% and 80%; the volume settled rose from 72% in the first quarter, to 83%, 81% and 79% in the next three. In other words, with the set of adopted measures, and especially the incentive provided by the change in the fee structure, a clear improvement in the transactions cycle was obtained in a short lapse of time, by displacing a larger portion of transactions towards the first time-window for rates (until 18:00 hours). In the third and fourth quarters this tendency was partially reverted due to the fast growth in public debt market transactions (see Figure 14).
Figure 12: RTGSS Time Distribution of Transactions in 2004 - Value
Percentage Share by Time Window

<table>
<thead>
<tr>
<th>Quarter</th>
<th>First Window</th>
<th>Second Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Quarter</td>
<td>73%</td>
<td>27%</td>
</tr>
<tr>
<td>Second Quarter</td>
<td>84%</td>
<td>16%</td>
</tr>
<tr>
<td>Third Quarter</td>
<td>82%</td>
<td>18%</td>
</tr>
<tr>
<td>Fourth Quarter</td>
<td>80%</td>
<td>20%</td>
</tr>
</tbody>
</table>

Figure 13: RTGSS Time Distribution of Transactions in 2004 - Volume
Percentage share by time window

<table>
<thead>
<tr>
<th>Quarter</th>
<th>First Window</th>
<th>Second Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Quarter</td>
<td>72%</td>
<td>28%</td>
</tr>
<tr>
<td>Second Quarter</td>
<td>83%</td>
<td>17%</td>
</tr>
<tr>
<td>Third Quarter</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Fourth Quarter</td>
<td>79%</td>
<td>21%</td>
</tr>
</tbody>
</table>

Figure 14: Value and Volume of Transactions in the RTGSS in 2004
In Quarters

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Values</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Quarter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second Quarter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Third Quarter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fourth Quarter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Stock brokers (SB) and collective portfolio managers (CPM), for their part, even by December 2004 continued to settle very high percentages of their transactions after 18:00 hours (close to 45% in value and 33% in volume). This is explained, as has been mentioned before, by the fact that they are not subject to mandatory reserve requirements nor have they developed mechanisms to generate their own liquidity in the RTGSS (due to the opportunity cost involved). Consequently, their basic sources of liquidity are the payments and transfers received from other agents (mainly banks), either as the outcome of securities transactions or by transferring funds deposited in bank checking accounts to the RTGSS.

Table 3: Percentage Distribution of Payments in the RTGSS During the First Fee Window, 2004

<table>
<thead>
<tr>
<th></th>
<th>VALUE</th>
<th>VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1st Quarter</td>
<td>4th Quarter</td>
</tr>
<tr>
<td>NTD</td>
<td>96%</td>
<td>97%</td>
</tr>
<tr>
<td>Banks</td>
<td>80%</td>
<td>86%</td>
</tr>
<tr>
<td>Brokers and CPMs</td>
<td>51%</td>
<td>55%</td>
</tr>
<tr>
<td>Others</td>
<td>76%</td>
<td>75%</td>
</tr>
<tr>
<td>DECEVAL</td>
<td>43%</td>
<td>42%</td>
</tr>
</tbody>
</table>
8. NEW EARLIER-SETTLEMENT FACILITIES AT THE RTGSS AND CSD

Despite the positive results of the measures adopted in 2004 to partially de-concentrate the flow of payments and improve liquidity management in the RTGSS, it may be foreseen that sustained growth in secondary market public debt transactions and in the general level of economic activity could continue to exert pressure on the timeliness of payments via the RTGSS.

Taking as reference the observed evolution in other countries with deeper securities markets and more sophisticated PSL, in 2005 BRC began two projects aimed at implementing earlier-settlement and gridlock resolution mechanisms for both the RTGSS and the CSD through “off-setting queuing” methods. It is expected that these will be fully operational by the beginning of 2006.

It is worth pointing out that both systems will continue to operate under the real time gross settlement model, or in other words, that transactions will continue to be settled in the traditional manner. However, a facility will be introduced that subject to the restriction of funds available in each agent’s account at BCR and considering queued incoming payments from other participants, develops an algorithm that optimizes outgoing payments and settles the overall set of operations gross.

The simulation exercises undertaken with both random and real data in the two systems have resulted in liquidity-saving estimates of close to 65% for the CSD and 85% for the RTGSS. A brief description of the objectives of each project and their main functional features follows.

8.1 EARLIER-SETTLEMENT FACILITIES AT THE RTGSS

Prior to the introduction of these facilities in the RTGSS, BRC implemented a system simulator in which different types of optimization algorithms for the settlement of queued transactions were programmed, in order to identify the more efficient ones in terms of settling the largest number and value of payments subject to the liquidity available in each participant’s account at BCR.

Based on the above exercise, the following operational alternative was identified as the one that best satisfied the objectives pursued: if an individual transaction cannot be settled in real time

26 As the recent CPSS report New developments in large value payments (BIS, 2005) illustrates, a fair number of G-10 countries have already implemented various release facilities. However, is difficult to obtain information relative to the optimization algorithms employed. Initial references for BRC were the documents published by the Bank of Finland, who generously shares its studies on the topic (Koponen and Soromäi, 1998, Leinonen y Soromäki, 1999, Bech y Soromäki, 2001) with the international community. A BRC technical team, with Freddy Cepeda, Fabio Ortega and Omar Silvera, carried out additional studies in this field.
due to lack of funds of the ordering agent at the time, it is sent to be handled by the queuing mechanism. Every so often (pre-defined), the system will set in motion a “fifo bypass” type sweep. Additionally, one or two times a day, the system will submit the transactions accumulating in the queue to an “off-setting”, constrained by the availability of balances on account. The transactions selected as the outcome of this process are finally settled gross.

As will be seen in the next section, it was concluded that individual CSD transactions would not be submitted to queuing in the RTGSS so as not to affect liquidity at the CSD, but would continue to be automatically rejected in the event of lack of funds. However, such transactions would in turn be subject to a similar optimization process at the CSD itself, which would freeze the available funds in the RTGSS for very brief periods of time in order to carry out an “off-setting”, based on the same logic described for the RTGSS, with these funds and with securities linked to the queued transactions. Thus will be selected the transactions from both systems that will finally be settled gross. This service will remain available for other systems that may eventually in the future require a similar settlement of transactions in the RTGSS.

Table 4 shows some of the results obtained from simulation exercises, in terms of the value of queued transactions solved by the application of different optimization algorithms. The algorithm chosen by BRC was that of multilateral clearance with re-inactivation, which basically consists in estimating the account balances required by each participant to settle all queued payments and removing, should it be required, those transactions of entities in deficit that do not generate lack of funds with counterparties, until their funds deficit is eliminated, and evaluating at the end the possibility of again including in the off-setting cycle some of the inactive or previously eliminated transactions.

The percentage reductions shown in the first row of Table 4 correspond to potential reductions in the required balances at the start of the day in deposit accounts at BRC. For example, the last row in the Table indicates that by reducing account balances by 99%, a queue of value COP$2.17 trillion is formed, of which close to COP$1.33 trillion is resolved with the two multilateral off-settling schemes analyzed or COP$0.49 trillion with three different bilateral off-setting alternatives.

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27 Under the FIFO system (“first in – first out) the system tries to complete transactions in the same order in which the ordering agent sends them to the system for settlement. The problem that can arise is that there may be large-value transactions at the head of the queue that are blocking all those behind. The FIFO bypass mechanism consults all transactions in the payment queue and “skips” those at the head which are blocking, looking further down the queue for the first transaction(s) of equal priority that can be settled with the balance available on account.
Table 4: Simulated Solutions for RTGSS Queuing Operations Under Different Optimization Algorithms
Values in Millions

### Real Data

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>1%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>90%</th>
<th>99%</th>
<th>Average Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral FIFO</td>
<td>0</td>
<td>14,735</td>
<td>2,192</td>
<td>48,224</td>
<td>187,002</td>
<td>491,907</td>
<td>9.19%</td>
</tr>
<tr>
<td>Bilateral with Inactivation</td>
<td>0</td>
<td>14,900</td>
<td>2,210</td>
<td>49,300</td>
<td>188,300</td>
<td>496,376</td>
<td>9.29%</td>
</tr>
<tr>
<td>Bilateral Greedy</td>
<td>0</td>
<td>14,800</td>
<td>2,197</td>
<td>48,320</td>
<td>187,620</td>
<td>492,715</td>
<td>9.22%</td>
</tr>
<tr>
<td>Multilateral with Inactivation</td>
<td>2,216</td>
<td>87,524</td>
<td>351,183</td>
<td>627,476</td>
<td>951,797</td>
<td>1,334,344</td>
<td>69.06%</td>
</tr>
<tr>
<td>Multilateral with Re-inactivation</td>
<td>2,216</td>
<td>88,200</td>
<td>367,081</td>
<td>652,609</td>
<td>1,149,954</td>
<td>1,338,926</td>
<td>72.16%</td>
</tr>
<tr>
<td>Average size of queue</td>
<td>6,756</td>
<td>94,632</td>
<td>394,755</td>
<td>692,483</td>
<td>1,978,378</td>
<td>2,178,378</td>
<td></td>
</tr>
</tbody>
</table>

### Random Data

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>1%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>90%</th>
<th>99%</th>
<th>Average Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral FIFO</td>
<td>302,597</td>
<td>3,026,114</td>
<td>16,740,398</td>
<td>52,210,092</td>
<td>108,157,793</td>
<td>125,601,471</td>
<td>31.42%</td>
</tr>
<tr>
<td>Bilateral with Inactivation</td>
<td>302,600</td>
<td>3,223,001</td>
<td>16,800,300</td>
<td>53,740,317</td>
<td>114,353,046</td>
<td>187,946,065</td>
<td>35.23%</td>
</tr>
<tr>
<td>Bilateral Greedy</td>
<td>302,597</td>
<td>3,222,154</td>
<td>16,741,100</td>
<td>53,230,021</td>
<td>108,300,100</td>
<td>125,900,300</td>
<td>31.75%</td>
</tr>
<tr>
<td>Multilateral with Inactivation</td>
<td>4,079,037</td>
<td>19,554,014</td>
<td>43,739,716</td>
<td>92,265,100</td>
<td>173,744,081</td>
<td>324,915,613</td>
<td>66.82%</td>
</tr>
<tr>
<td>Multilateral with Re-inactivation</td>
<td>4,096,370</td>
<td>19,776,510</td>
<td>44,578,653</td>
<td>94,510,034</td>
<td>175,361,139</td>
<td>331,601,462</td>
<td>88.10%</td>
</tr>
<tr>
<td>Average Size of Queue</td>
<td>4,591,179</td>
<td>22,433,852</td>
<td>51,988,314</td>
<td>110,467,079</td>
<td>200,205,241</td>
<td>359,198,709</td>
<td></td>
</tr>
</tbody>
</table>

### 8.2 Earlier-settlement Facilities at the CSD

The off-setting scheme presented in the previous section was extended to cover secondary market electronic trading in public debt securities settled at CSD. However, as mentioned above, for reasons of efficiency it was decided that these should be handled separately and independently from other transactions channeled through the RTGSS.

This is because if such transactions entered the general RTGSS queue, this would imply freezing the respective securities until such time as the settlement of funds and their delivery versus payment were confirmed, which would affect the efficiency of the CSD since around 65% of the transactions which are settled in the RTGSS originate in the CSD. Additionally, the rapid growth in recent years of public debt securities market in Colombia also poses high liquidity demands for this market, requiring the implementation of optimization schemes for the handling of securities.

For this reason, the adopted solution consists in the CSD continuing to attempt individual settlement of its securities transactions in the RTGSS under the traditional mode of real-time gross delivery versus payment, and the latter immediately rejecting those that present insufficient funds, queuing...
them at CSD and periodically subjecting them to a process of re-entry and off-setting with re-inactivation during the day.

The process consists, in detail, of the following: a) the calculation of the required balance in each participant's securities account to settle all queued payments, in order to determine which of them can be settled under the off-setting scheme based on available balances in CSD accounts, applying an optimization algorithm to settle the largest volume and value possible; b) the calculation of required cash balances corresponding to the securities transactions selected during the previous step; c) the comparison of such required balances with the available and frozen balances at that point in time in its BRC cash account; d) in event of lack of funds for the off-setting of the selected transactions, the exclusion for purposes of settling of securities purchase transactions by the entity in deficit, and the recalculation of the positions in securities and cash, until verifying the required availability on both ends; and e) the gross settlement of the transactions finally selected at both the CSD and in the RTGSS, honoring the delivery versus payment scheme currently in operation.
9. CONCLUSIONS

The following conclusions can be drawn from this document:

- The implementation of a RTGSS contributes substantially to financial stability and the prevention of different risks, especially systemic risk, but also poses significant liquidity challenges which can be exacerbated by changes in the instruments and goals of monetary policy. In such circumstances it is of vital interest to the monetary authority to evaluate the interdependence between monetary policy and payment systems policies, and to develop appropriate instruments for a more efficient management of the available liquidity.

- In the Colombian case, the 1998 implementation of a gross settlement scheme with online control of balances in a large-value PS was apparently assimilated rapidly by the participating entities. However, the convergence of a set of monetary, tax and institutional factors, together with accelerated growth in the public debt, exchange and money markets, generated liquidity pressures in the payment system that led to a growing concentration of transactions being met at the end of the day.

- Even though there had long been awareness of the inconvenience of the described situation, and different steps were gradually adopted to improve intraday liquidity in the system, they were still not enough.

- An important process of agreement among the different groups of participants in the RTGSS began in late 2003 as a result of the decision taken by BRC to modify the fee structure of the system and introduce, among other elements, differential rates for settlement by hourly segments. Sector-wide cooperative efforts took shape and actions by each of the participants were agreed in order to improve the intraday liquidity cycle and settle transactions earlier in the day.

- As a result of all of the above, recent empirical evidence shows significant progress in achieving a more uniform distribution of aggregate intraday liquidity, as well as an initial displacement of more than 10% of transactions, both in value and volume, to an earlier settlement during the day. All participants in the payment system contributed to this result and benefited from it. Nevertheless, additional efforts must be made to improve the capacity for a timely settlement of transactions by agents other than credit institutions.

- As a complement to the foregoing, and in the search for more efficient solutions in terms of facilitating the earlier settlement of payments and optimizing the use of available liquidity in the RTGSS and in the central depository for public debt securities (DCV), in early 2005 BRC initiated a project aimed at introducing new queue release facilities based on off-setting techniques, while maintaining the current real time gross settlement mechanism. Such mechanisms will be operational by early 2006.
The Colombian experience demonstrates the importance to central banks of systematically tracking and analyzing in detail the behavior of large-value payment systems and their intraday liquidity, given that their efficiency and effectiveness depend on the capacity of adapting to the changing conditions of financial markets and the overall economy.
10. ANNEX

10.1 METHODOLOGICAL FRAMEWORK FOR THE ANALYSIS OF INTRADAY LIQUIDITY

For the purpose of a more detailed analysis of the behavior of intraday liquidity and the effects derived from the implementation of a queuing mechanism for clearance in the Colombian large-value payment system, a methodology was defined based on the work done by Koponen y Soramäki (1998), which, by use of a RTGSS simulator for Finland, evaluates the advantages and disadvantages of various arrangements for optimizing the use of liquidity.

Koponen y Soramäki evaluate the optimization mechanisms for liquidity management via a range of payment settlement schemes, under the assumption of zero counterparty risk, by means of comparing two variables: liquidity employed and delay in the settlement of transactions.

To this end, the authors elaborate a set of indicators to quantify said variables under schemes that go from immediate settlement – RTGS - to the clearance of payments in a deferred net settlement cycle at a given time -DNS-, with or without the addition of time-critical payments, in other words, payments that must take place before a given time.

Figure A-1, borrowed from the cited research, on the horizontal axis shows the liquidity employed by the system, comprising risk-free resources such as reserves held at the central bank or liquidity obtained from it through repos (or guaranteed or non-guaranteed loans, as the case may be); and on the vertical axis registers the settlement delay, corresponding to the lapse of time between the receipt of the payment order sent by the entity to the system, and the final and irrevocable settlement of payment.

This figure shows how, depending on the settlement scheme used, there is a trade-off between the delay in settling payments and the liquidity employed for such purpose. The coordinates of points A, C and B represent three different combinations of these variables for systems of net end-of-day clearance, real time gross settlement and settlement under the RTGS scheme but with queue management, respectively.

It should be noted that, while at point A (corresponding to the deferred end-of-day netting system) clearance delay is at its maximum and employed liquidity is at its minimum, at point C (RTGS without queuing) the settlement is immediate or the delay zero but the demand on liquidity is at its maximum. Additional liquidity beyond point C is unnecessary, since at this point there are sufficient funds to settle all payments in gross fashion.

Although there is some settlement delay under a RTGS queuing system (point B), the required funds are much less than in a pure RTGS system. The points on Curves AC and BC represent a set of possible combinations of delay and use of liquidity, which should be chosen according to market preferences by evaluating the liquidity costs vis-à-vis the delay costs.

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28 This annex summarizes work developed in greater detail by Cepeda (2005).
The conceptual definition of the set of indicators necessary to quantify the previous variables is as follows:

**a. Theoretical Upper Bound UBt**: refers to the suggested minimum balance at the start of the day for immediate settlement or zero delay (Equation 1, Figure A-1) in a RTGS system without queuing:

\[
UB_{\text{theoretical}} = \min \left[ 0, \min \sum_{i=0}^{T} (P_i^i - P_i^o) \right] \forall t \in [0, T]
\]

Where \( P_i^i \) is the value of incoming payments at time \( i \) and \( P_i^o \) is the value of outgoing payments at time \( i \).

The starting point for the calculation of UBt is a zero balance at the start of day, which is updated at each moment payments enter or exit the system. Figure A-2 shows the balance resulting from the difference between incoming and outgoing payments (taken from real data in a normal day of transactions) in the account of a randomly selected bank in the DAS-RTGS system during an operating day. As can be seen, point UBt is the value of the minimal balance required for settlement to be immediate.

It can be observed in the same Figure how the series in which the initial balance corresponds to the Upper Bound UBt will allow all transactions to be settled immediately, since the balance is at all times positive. In other words, there are sufficient funds to handle the sequence of payments processed in the system in the course of the day. Initial balances lower than defined by UBt will cause some
payment orders be rejected, since under a RTGS scheme it is necessary to have sufficient funds to cover each of the payments sent in.

b. Theoretical Lower Bound (LBt): refers to the suggested minimum balance at the start of the day for the successful settlement of all transactions in a RTGS system with off-setting queuing. When adding an optimization mechanism for queuing release to a RTGS system, participating entities will require lesser availability of funds in return for allowing a delay in the settlement of their payment orders.

Starting from an initial balance equal to zero, the minimum liquidity that a bank needs to settle its payments successfully is equal to the absolute value of the minimum amount of its net payments (outgoing minus incoming payments), accumulated during the day (equation 2).

\[ LB_{\text{theoretical}} = \min \left[ 0, \left( \sum_{i=0}^{T} P_i^i - \sum_{i=0}^{T} P_i^o \right) \right] \]

Where \( P_i^i \): is the value of the incoming payments and \( P_i^o \): is the value of the outgoing payments.

If the resulting liquidity position of a bank is positive throughout the day, its need for external liquidity will be zero, since it receives sufficient liquidity in the form of incoming payments. If its liquidity position is negative, the bank needs to obtain sufficient funds to cover the shortfall in order
to settle of all its payments. In Figure A-2 the path of the intraday balance can also be observed, starting out from an initial balance equal to LBt. It should be stressed that via the process of re-ordering transactions, typical of an off-setting queuing algorithm, all transactions can be successfully completed with less liquidity than that required in a gross settlement system.

29 The data employed in tracing this path was obtained from the Colombian RTGSS (DAS) simulator using a queuing mechanism where resolution is achieved via hybrid algorithms, including FIFO and multilateral and bilateral netting.
## GLOSSARY OF TERMS

**Delivery versus Payment:** A linkage between a securities transfer system and a funds transfer system which guarantees that delivery will only occur if, and only if, payment takes place.

**Gridlock or blockages:** Situations that can arise in a funds or securities transfer system when the non-execution of certain transfer instructions (due to lack of sufficient balances on money or securities account) results in a substantial number of other payment instructions from other participants not being executed.

**Intraday Liquidity:** Funds that can be accessed throughout the working day, usually to enable financial institutions to effect payment in real time.

**Multilateral netting:** The sum of all payment orders received in favor of each participant in a net settlement system over a given period, minus the value of all payment orders originating from said participant in favor of others.

**Real Time Gross Settlement:** Continuous settlement (in real time) of individual transfers of funds or securities, or on an order-by-order basis (without netting).

**Repo:** A contract to sell and subsequently repurchase securities at a specific price and on a specific date.

**Reserve Requirements:** Banks' obligation to maintain balances (bank reserves) at the central bank in proportion to certain types of liabilities. In Colombia, as in other countries, cash in vault is accepted as part of reserves.

**Settlement:** Finalization of a transaction in which the seller transfers securities or financial instruments to the buyer and the buyer transfers funds to the seller.

**Systemic Risk:** The risk that a participant's default on obligations within a transfer system, or in financial markets in general, may result in other participants or financial institutions in turn not being able to comply with their obligations (including settlement obligations within a transfer system) when coming due. Said default could cause significant liquidity or credit problems and, as a result, could threaten the stability of financial markets.
**Systemically Important Payment Systems:** A payment system is systemically important if the disturbances which could arise within it, if it were insufficiently protected against risk, could trigger or transmit greater disturbances to participants or systemic disturbances to the financial sector at large.
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