



Improving cash logistics in bank branches by coupling machine learning and robust optimization



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ABSTRACT

This paper describes how Machine Learning and Robust Optimization techniques can greatly improve cash logistics operations. Specifically, we seek to optimize the logistics followed by the different branches of a given bank. Machine Learning is used to forecast cash demands for each of the branches, taking into account past demands and calendar effects. These demand predictions are forwarded to a Robust Optimization model, whose outputs are the cash transports that each branch should request. These transports guarantee that demand is fulfilled up to the desired confidence level, while also satisfying additional constraints arising in this particular domain.

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1. Introduction

For those unfamiliar with the topic, we start by explaining how the cash chain and its agents are organized, as well as what rules apply. Once this is understood, we detail what particular problem is solved in this paper. We also outline the approach followed in the rest of the paper.

1.1. Cash chain and its regulation

Cash logistics is one of the key operations a bank has to deal with. In logistic terms, the cash chain can be considered as a supply chain with only one product involved (cash). There are usually four agents involved in this chain: (1) the central bank, which supervises the whole chain, guarantees the circulating cash is valid, and is the only agent authorized to generate new cash from scratch if needed, (2) cash-in-transit (CIT) companies, which store and transport cash between the central bank and commercial banks (in both directions) using their fleets of armored trucks, (3) commercial banks, which dispense cash to customers (be it face-to-face through bank clerks or remotely through ATMs), and (4) customers, who are the final recipients of cash. Customers can also deposit

cash in commercial banks, and this deposited cash recirculates along the chain as long as it follows the central bank standards.

Commercial banks service customers in physical offices called branches, located in different regions so that the whole territory is covered. Each branch must keep enough cash to meet its customers withdrawals, while it must also handle the additional cash that these customers may deposit. If a particular branch receives more money than what it has to dispense, it asks its CIT company for an armored truck, so that the excess of cash is taken away. Conversely, if it dispenses more money than what customers deposit, then it orders an incoming transportation that supplies as much cash as required. Any commercial bank signs agreements with at least one CIT carrier that provides (or takes away) cash for every single branch that requires so, regardless of its location.

In order to guarantee these transportation services, a CIT company (also called carrier) owns regional warehouses (vaults), where it stores the cash bound to or coming from all branches in that particular region. If the carrier finds it convenient to fulfill branch requirements, it can transport cash from one of its vaults to another one. This scheme is depicted in Fig. 1. At the bottom level we have the bank branches b_{ij} . Each branch is associated with a unique vault v_i from the total of V vaults the CIT company is assumed to have. As the arrows make clear, branches cannot send or receive cash from other branches, or from any other vault different than their assigned one. Thus, the only possibility for one branch to transfer money to another branch is going through the carrier's vault both branches must share (actually, it is the CIT

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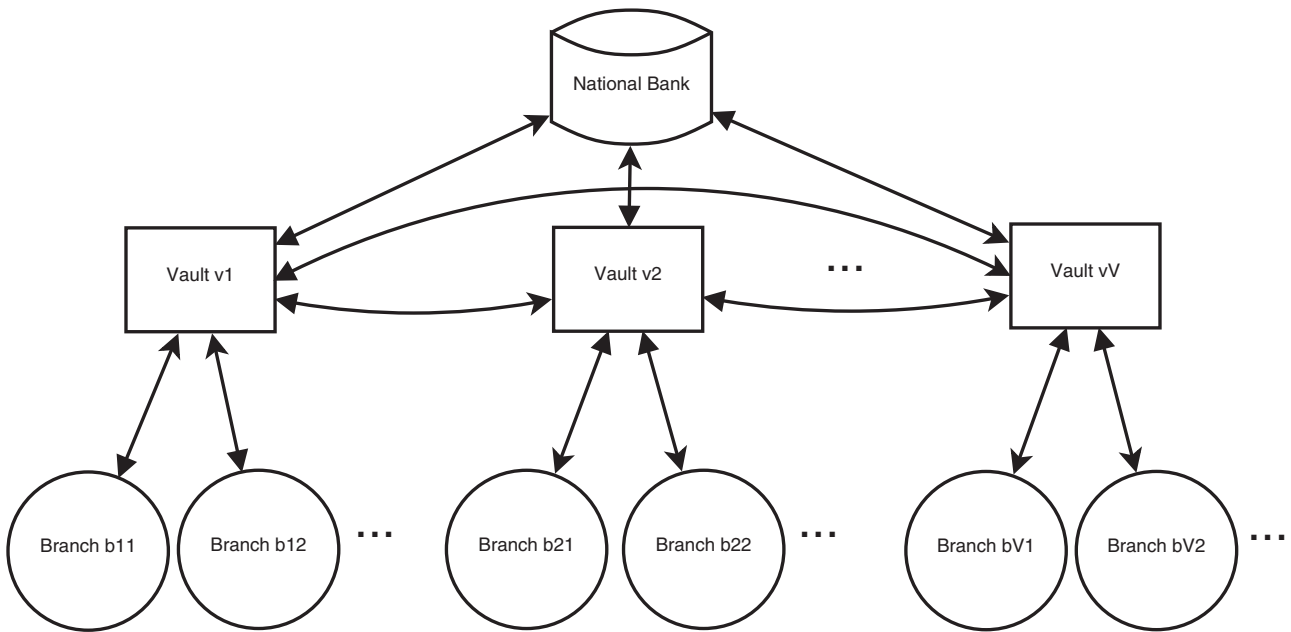


Fig. 1. Depiction of the structure and cash flows in the cash supply chain.

company that does this). Vaults on the other hand are allowed to request transports to receive or send cash to other vaults. Each of the vaults can also send cash to the central bank (from now on called national bank, as we are in a country context), as well as receive cash from it.

The way customers can interact in branches is either through desks (only when branches are open, because these operations depend on bank clerks) or ATMs (usually at all times, since they are electronic). Either way, they can choose to deposit cash or withdraw it. However, three kinds of cash need to be distinguished according to its quality and fitness, and some operations are restricted:

- **Certified cash:** this is brand-new cash that fully complies with the standards of the national bank and can be used for any operation. Incoming cash brought from vaults is always certified, as the CIT company guarantees that its cash comes untouched from the national bank. ATMs can only be loaded with certified cash.
- **Uncertified/common cash:** this is cash which is not fully compliant with national bank standards and cannot be used by branches in ATMs, but may still be used for deposits and desk withdrawals. In particular, cash deposited by customers is assumed to be always uncertified (even if it looks new), so it can be reused by the branch for subsequent withdrawals, but not for replenishing ATMs.
- **Unfit cash:** cash which does not comply with the standards, and whose condition is too bad to be recirculated. Thus, it cannot be used for any operation and must be immediately discarded by the branch to be taken away by the carrier.

Finally, the national bank must ensure that there is always enough cash to service bank branches using the carriers as intermediaries. Not only is it the sole agent that can generate certified cash, but it is also the only one who can destroy unfit cash and dispose it from the cash chain, so CIT companies must make sure to collect all unfit cash from branches and deliver it eventually to the national bank for destruction.

1.2. Problem to solve

To keep things simple enough, in this work we keep ourselves restricted to the bottom layer of Fig. 1. We do not model operations neither among vaults nor between them and the national bank, but only operations within branches and transports from these branches to their respective vaults (or the other way round, from the vaults to the associated branches). It is assumed that vaults have enough capacity to store all incoming trucks from the branches. Likewise, vaults are assumed to be infinite sources of cash: whenever a branch needs cash from its vault, this amount of cash is assumed to be immediately available for transportation. The reason for this is that we take the role of the specific commercial bank that encouraged this study. This bank's desire was to optimize its branches logistics in the best possible way, while making sure that their customers are adequately served and abiding with the above regulation. Therefore, the agents above branches in the cash pyramid of Fig. 1 (CIT companies and national bank) are assumed to be always available for supplying or taking away as much cash as needed, if asked so. The internal logistics of CIT companies and the national bank are beyond the scope of our study (it is tacitly assumed that they organize themselves in an optimal way).

Although some of the cash deposited by customers is indeed unfit (for instance, scratched coins or torn bills), we also decided to ignore its existence and just keep track of certified and uncertified cash. Note that this does not have important consequences: the volume of unfit cash is small compared to the total volume of cash handled by a branch. Besides, a branch can easily discard unfit cash by adding it to our suggested outgoing transport services. Note as well that we do not consider the case of deposits being made in ATMs, but our formulations are very easily generalizable to include them.

ATMs have been used traditionally for withdrawals, but not for deposits. Modern infrastructure allows ATM deposits with machinery that automatically splits fit and unfit cash, but this particular bank still has not deployed such ATMs across the nation. Therefore, from the 4 possible operations between customers and branches, we will only consider the following 3:

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