ATM Location Problem and Cash Management in Automated Teller Machines

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Abstract—Automated Teller Machines (ATMs) can be considered among one of the most important service facilities in the banking industry. The investment in ATMs and the impact on the banking industry is growing steadily in every part of the world. The banks take into consideration many factors like safety, convenience, visibility, and cost in order to determine the optimum locations of ATMs. Today, ATMs are not only available in bank branches but also at retail locations. Another important factor is the cash management in ATMs. A cash demand model for every ATM is needed in order to have an efficient cash management system. This forecasting model is based on historical cash demand data which is highly related to the ATMs location. So, the location and the cash management problem should be considered together. This paper provides a general review on studies, efforts and development in ATMs location and cash management problem.

Keywords—ATM location problem, cash management problem, ATM cash replenishment problem, literature review in ATMs.

I. INTRODUCTION

OVER the past two decades, service operations have been given a significant amount of attention in the literature. However, financial services have not been discussed as much as other service industries such as transportation, health care, entertainment, and hospitality [1]. Moreover, when we go deep in the literature related with banking although there are quite a few researches about operations management processes such as; product design and offerings, campaign management, client relationship management, general cash management, lending operations, technology management, operational risk management, call center management and branch management, the scarcity of the studies about Automatic Teller Machines' (ATMs) management problems can be easily seen. In the literature ATMs are also referred as "Automated Teller Machines" or "Auto Teller Machines".

ATM management is very crucial subject for the banks in this competitive environment and that is why banks have started to give extra attention to this issue. There are many reasons that make ATMs one of the most important alternative delivery channels for the banks;
- Most of the banking transactions are served in the ATMs,
- It is easier to deploy ATMs compared to branches and cost efficient,

- Transactional costs are lower in ATMs compared to branches due to employee cost,
- It is a faster way to give service in shorter time without queues,
- It is a way to serve customers out of working hours,
- It is a way to serve customers in a larger area not just in the neighborhoods where are the branches are settled.

Other alternative delivery channels have their substitution, for example; it is possible to make the banking transactions via internet banking that are made via telephone banking. However, ATMs are the only way for cash related transactions after branches and this truth will not change unless people stop to use cash for survival. Therefore, ATMs are one of the most important alternative delivery channels for banks and it is continually keeps growing. According to the data presented by the Interbank Card Center number of the ATMs in Turkey has increased 91% in the last five years, almost doubled. On the other hand, management of ATMs is a very complex issue for the banks as the process is related with a great deal of agents and variables. ATM management process involves several sub-processes such as deployment, cash management, security management, remote monitoring and maintenance. Here, we choose to deal with ATM deployment and cash management issues that we think they are the most important ones and these two management problems are linked together.

There are mainly two types of ATMs on-site and off-site and ATM management problem should be investigated by considering these two types as the partners of the process and the variables that should be considered changes based on this. On-site ATMs are located frontage of the branches or in the branch lobby while off-site ATMs are placed in the locations where there are not any branches.

II. ATM LOCATION PROBLEM

Different departments of the headquarters, branches, outsource companies and customers are involved in the ATM Management process. Table I presents the responsibilities of the agencies that are involved in the process. Locating an ATM into the right place is very important, because moving or redeploying the machine because of bad performance may be perceived by the customers as there are problems with the financial institution and may cause bad reputation [2].

According to [3], there are various criteria that are needed to be taken into account while deciding locations for ATMs. Foot traffic per hour, drive-time traffic and heaviest traffic locations, physical security, proximity of an ATM within a certain radius, the type of neighborhood, traffic counts, customer counts, and volume of fuel purchased counts and

number of hotel rooms are some of these criteria.

Adams [2] adds convenience as the pivotal factor for the most customers therefore in order to increase accessibility of the ATM. Moreover, he indicates that safety is the one of the most important concern while determining the best location for ATMs. This diversification illustrates how challenging it can be to solve an ATM placement problem [3].

TABLE I
ALLOCATION OF THE RESPONSIBILITIES

	Cash Management	Deployment
ATM Management Department	• monitoring the profitability of the ATMs as a means of their efficiencies	• determining which ATM should be given to which branch or Group Transport Centre • deciding the locations for ATM deployment • deciding the ATMs that are needed to move and redeploy to the location that has a higher potential
Group Transport Centers	• ensuring communication with the outsource company; in order to supply the cash needs of the branches and off-site ATMs, pick up the cash from the branches and off-site ATMs and collect the cash in their locations before distributing it to the branches or to the Central Bank	
Construction and Real Estate Group		• deploying the ATMs
Outsource Carrier Company	• picking up the cash from the group transport centers, branches and off-site ATMs, distributing cash to the branches, group transport centers and off-site ATMs	
Branch	• loading money to on-site ATM if it is needed during the day and at the end of the day • loading the idle balance that is in the cash register to the ATM at the end of the day	• aiding the headquarter in the decision of off-site ATM deployment location

III. LITERATURE REVIEW ABOUT FACILITY LOCATION AND ATM LOCATION PROBLEMS

Facility location problems are classical optimization problems which has wide variety of applications especially in the service industry. These applications include health care units, warehouses, gas stations, police stations, power plants and bank branches. The aim of solving these types of problems is to decide the minimum cost of locations of a set of facilities to cover all customer demands [4].

There are many facility location models and algorithms in the literature and several of them are related with service industry and banking which are summarized below.

Berman et al. [5] classify ATMs, gasoline stations and convenience stores in the same group which they called "discretionary service facilities". They emphasize that these kinds of facilities should be located along paths of customer flow due to preplanned trips rather than in an area where the residences and work places exist. They use greedy heuristic to solve their model in order to find minimal number of facilities.

Boufounou [6] published a paper that presents a model to help management in setting branch goals, evaluating branch performance and planning new locations. He classifies the relevant factors of decision making with respect to branch location into four categories. These categories are; location features, trade area characteristics, competitive situation features and internal branch characteristics. Additionally, he reviews Analog Models and Gravitational Models as location models and compares them. Boufounou's study may be utilized in locating ATM problems in some aspects.

According to [7], location allocation of commercial banking facilities involves three layers of services (automatic teller machines, branch bank offices, and main banks). They refer ATMs as the lowest layer, branch bank offices as the next level and the main banks as the highest level and they remark that the variety of services grow up respectively. They point out that the location of higher level facilities may affect the usage of lower level facilities by the customers. Therefore, they propose a capacitated three-hierarchical location-allocation model that is suitable for the successive establishment of banking facilities. Moreover, the model is based on a chance-constrained goal program.

Jayaraman, Gupta and Pirkul [8] have a study about hierarchical model for the location of service facilities and in the research they also cover the operational issues related with managing such facilities. They consider banking facilities and postal facilities as hierarchical in terms of levels of services being offered. They indicate banking facilities as three levels (automatic teller machines or drive-in banks, branch offices and main bank offices) whilst indicated postal facilities as two levels (post boxes and post offices). Jayaraman, Gupta and Pirkul [8] develop an integer linear programming model for locating facilities that offer several layer of service. Furthermore, they use a combination of a lagrangian relaxation methodology and heuristic method in order to solve their model.

Zhang and Rushton [9] present a multi-site location-allocation model for selecting locations in competitive service systems. In their model; the objective function is to maximize a measure of spatial utility of customers and constraints are waiting time of the customers and the budget of the multi-site facility owner. Their aim is to assist multi-site facility owner in the decisions about locating new sites or closing current sites in the presence of one or more competitors. They base their model on the problem of locating bank branches. However, in their research they do not solve the model but they suggest Genetic Algorithm for solving the model. Moreover, besides of the general facility location problems related with service industry and banking, it is hard to find researches that are specialized in Automatic Teller Machines'

(ATMs) location problems.

Adams [2] has a detailed research about choosing a prime site for an ATM. He investigates the issues that need to be considered while making the choice for a site such as; school district(s), future expansion/building plans, property values (cost per square foot), quality of roads and metropolitan hubs. He also adds that population density, traffic flow, ability to get in and out of the location, safety, visibility and demographics are important.

Adams [2] lists the steps that can be traced in ATM placement as below:

1. Identifying the patterns of traffic flow of the members, the places they live and they work and the main roads they use can be the first thing to do. (The information about the places where the members live and work is obtainable from credit union's database.)
2. Surveying the members is also a way to get detailed information about the roads they most frequently travel.
3. After determining the heavily travelled arteries, in-out capabilities of these roads should be identified. (For using ATMs people will get off the road and get back on to it and in most heavily roads it is difficult.)
4. Obtaining the information about traffic flows from the municipality that is related with the interested area. (The number of cars travel both ways daily, the scheduled or projected changes in the route, the plans about the business expansion/residential buildings, the heaviest traffic times can be attained).

Li et al. [10] propose a mathematical model which is combined with geographic information system (GIS) technology for the ATM site selection problem and solve it by the Particle Swarm Optimization (PSO) algorithm. Their model use the knowledge of the machines already installed in order to select a location for installing the new machine. Besides, they assume that all locations are the same which means all ATMs are same in type, price, cost of installation and so on. We recognized that Particle Swarm Optimization algorithm also utilized "Locating Charging Stations for Electric Vehicles" problems in the research that is conducted by [11] and this bring to mind that ATM location problem and charging station location problem for electric vehicles may be similar somehow.

Quadrei and Habib [3] mention the similarity between ATM deployment problems and file server placement that is known to be NP-complete problem. They formulate the ATM allocation problem as an optimization problem and use custom made genetic algorithm for the best possible placement of ATMs with the least cost. There are seven inputs involved in the problem, i.e., ATM types, possible locations, maximum number of ATMs per location, distances between locations, cost of distance unit, maximum delay time, and weights. Moreover, they code the algorithm in C-Sharp (C#) and emphasize that their proposed method can produce solutions in less than 15 minutes on a desktop computer.

IV. ATM CASH MANAGEMENT PROBLEM

Cash or liquidity management is one of the main concerns of a bank and the problem is to determine the amount that will be placed in the ATM to satisfy the uncertain demand. If the demand is higher than the amount that is placed in the ATM, the bank will have to endure the costs due to refilling tasks that are performed by external companies. Therefore, locations of warehouses where the money is kept and costs related with transportations are unimportant for the banks. Moreover, in practice money transportation companies offer two types of policies. In the first policy, the bank pays a substantial fixed fee (e.g., 50€) for the refilling that is independent from the amount and small extra fee for each fraction of a certain amount of money transported (e.g., 0,59€ for each fraction of 10.000€). Whilst, in the second policy; the fixed fee is small (e.g., 20€) and the staircase costs are substantial (e.g., 30€ for each fraction of 6.000€) [12].

Some banks keep 40% more cash at their ATMs than they needed where many experts note that keeping surplus cash of 15% to 20% to be sufficient. Moreover, cash-related cost constitutes 35-60% of the total cost of running an ATM. Banks can decrease their operational expenses and improve the return on their cash assets by optimizing the cash in their ATMs. Moreover, this can be achieved by an intelligent cash management system [13].

The main element of an efficient ATM cash management system is a cash demand model for every ATM and usually this forecasting model is developed based on historical cash demand data. Cash demand depends on trends which follow weekly, monthly and annual cycles. For instance; people draw more cash before Christmas while they draw less cash in August and during the summer holidays, the drawings boost on Fridays and Saturdays in ATMs that are located in shopping centers. Therefore, while developing a forecasting model, a variety of input variables such as the changing behavior of people and the trends should be considered. The basic idea behind the cash demand forecasting model is determining the optimum cash amount for each ATM by calculating the transportation and money uploading costs against interest rates. The cash management system has to assure the availability of cash in the ATM network, estimate the optimal amount of stocked money and manage the daily cash handling and transportation efficiently by reducing the overall cost (transportation and servicing costs) [13].

Distribution of cash causes substantial cost to banks. Although banks try to recompense this cost with different fees and tariffs, the net return from cash is apparently negative. Moreover, the use of cash reduces deposits; therefore it decreases banks' interest income. On the other hand, if a bank had not have any ATM, the bank's customers would use other banks instead and this would diminish the bank's profits as well as market share [14]. Consequently, predicting the demand as accurate as possible and adjusting the cash stock according to this estimate is critical for the banks [15].

In some banks ATM cash management and optimization is performed manually, according to corporate policies and personnel experience while some banks use excel data sheets or commercial softwares. Moreover, there are some drawbacks of the commercial software solutions for ATM cash

management. In these automated solutions; forecasting is based on linear regression models with seasonality coefficients customized for each ATM which makes parameterization time consuming. In addition to this, model parameters are static and this makes online cash optimization impossible [15].

V. LITERATURE REVIEW ABOUT ATM CASH MANAGEMENT

It is a strategic decision for a bank to determine where to locate its one of the most important distribution channel: ATM. However, after placing an ATM the bank should also determine the amount of cash money that will be put into the machine.

Managing inventory of cash money in ATMs is a vital subject in banking business. Money should be ordered and each ATM should be replenished in a specified period of time beforehand according to the forecasts. If forecasts are too high than the actual demand then there will be unused money which means cost for the bank and if the forecasts are too low than the actual demand, ATMs will run out of cash and customers those who are not able to withdraw money will be unsatisfied [16]. Therefore, making accurate forecasts and managing inventory in the right way is a very important problem. However, when we look back to the researches that have been carried out in the literature, the source about ATM cash management is very limited.

Simutis et al. [17] present an approach that based on artificial neural network (ANN) to forecast a daily cash demand for every ATM in the network and they introduce an optimization procedure for cash load of ATMs. They study for eliminating the common drawbacks of the most known cash management systems for ATM network and investigate ATM network which consists of 1.225 ATMs. In their optimization procedure; they consider the most important factors for ATMs maintenance such as cost of cash, cost of uploading and cost of daily services. Their researches show that in case of higher interest rate (cost of cash) and lower cost of money uploading their optimization procedure reduces the ATMs maintenance costs around 15-20%. However, they point out that further experimental investigations are required for the practical implementation of their procedure.

Simutis et al. [13] investigate two different methods to forecast the daily cash demand for ATMs. The first method was based on flexible artificial neural network (ANN) whilst the second one was based on support vector regression (SPR) algorithm. They start out from the common drawbacks of the most known cash management systems for ATM network and they tried to improve these drawbacks in their methods. Simutis et al. [13] perform simulation and experimental tests to see the performance of these two methods and they use the data from 15 real ATMs that were recorded for 2 years. They conclude that flexible ANN performed better than SPR despite the general beliefs about SPR capabilities. Besides, they use the results of their study as an input to improve the professional cash management software ASOMIS, developed by JSC Group.

Laukaitis [18] applies functional autoregressive models as predictor of the cash flow and intensity of transactions in electronic payment channels (ATM: auto teller machine and POS: point of sale) as the continuous-time stochastic process on an entire time-interval. He focuses on two linear wavelet methods; regularized wavelet-vaguelette estimators and projection method in their research. Moreover, he uses Lithuania credit cards payment market data in the model application phase. Laukaitis [18] infers that these two models give very close prediction in means of MISE (Mean Integrated Squared Error).

Castro [12] focuses on two subjects related with cash management; cash management in ATMs and in the compensation of credit card transactions where a decision must be taken according to future customer demand that is uncertain. In his study, stochastic programming models are utilized for these two cases. Two short-term models which consider one single refilling and one mid-term model which regards more than one filling, with fixed and staircase costs for ATMs were presented. MILP equivalent deterministic formulations are adopted in the study. AMPL modeling language and the solver CPLEX 9.1 are used for solving the problem and finding the optimal or near optimal solutions.

Snellman and Viren [14] have a research that analyzed how the market structure affects choice of payment and cash demand. Their empirical analysis shows that the number of ATMs depends on competitiveness in the banking sector. Moreover, they conclude that there is a strong relationship between the number of ATM networks and the number of ATMs and they state that cash demand depends on the number of ATMs and ATM networks.

According to [15] there are some researches that attempt to optimize the cash by modeling and forecasting the demand, however due to high variance and non-stationary of the underlying stochastic process can have negative effect on the reliability of these approaches. Based on this argument they propose the application of genetic algorithms for searching and finding optimal upload strategies in the time horizon up to 2 months. They apply this approach for both individual ATMs and grouped ATMs. They claim that their approach minimize the daily cash balance in the ATM and also assure cash dispensing service availability.

Brentnall et al. [19] develop a system for predicting the daily amounts withdrawn from automated teller machines (ATMs). They use data from 190 ATMs in the United Kingdom that is obtained for a two-year period. They utilize from different models such as linear models, autoregressive models, structural time series models and Markov-switching models and compared these models. Moreover, they choose different model for each ATM and they also use a logarithmic scoring rule in order to decide the most appropriate seasonal and distributional assumptions for each ATM. They mention that by using different models for each ATM, they had a chance to see the strengths and weaknesses of the models. In their study; the total number of ATMs chosen for each model is regarded as the overall performance indicator. In another research, [20] uses random-effects model to predict how much individuals withdraw at a single cash machine visit. Multinomial distribution was used for the distribution of

amounts and the Dirichlet distribution and empirical distribution was used to model the random effects. They execute various tests on a sample of 5.000 UK bank accounts to see the performance of their models. As a result of their study, they conclude that the empirical distribution of random effects performs well with 5.000 accounts but they also remark that generally there are millions of accounts in banks.

Teddy and Ng [16] suggest using a novel local learning model of the pseudo self-evolving cerebellar model articulation controller (PSECMAC) associative memory network to produce accurate forecasts of ATM cash demands. They use a set of data which is comprised of 111 empirical daily ATM cash withdrawal series and they do not consider seasonality in their model. They demonstrate their model performance by comparing it with local and global learning based models. Ben Taieb et al. [21] considered the effects of seasonality, input variable selection, and forecast combination.

Acuña et al. [22] conduct a comparative study between NARX and NARMAX models developed with ANN (Artificial Neural Networks) and SVM (Support Vector Machine) in order to forecast cash demand for ATM. NARMA and NARMAX are nonlinear autoregressive moving average models and the difference between them is NARMAX includes exogenous variables. They consider ATM location, seasonal factors such as weekends, holidays, etc. and historical data from the ATM as variables in their research and test their models with a horizon of 100 days. They conclude that there are no significant differences between NARX and NARMAX for both ANN and SVM. However, they recommend NARX-ANN models as they give best results and they are more user-friendly and simpler tools.

Van Anholt et al. [23] solved an inventory-routing problem with pickups and deliveries for replenishing demands of ATMs in a bank at Netherlands. They formulated the problem as a mixed-integer linear programming model, and proposed an exact branch-and-cut algorithm for its resolution. Chotayakul et al. [24] determined the amount of money to place in ATMs and cash centers for each period over a given time horizon. They also formulated the problem as a Mixed Integer Program (MIP) and developed an approach based on reformulating the model as a shortest path formulation for finding a near-optimal solution of the problem.

All of these studies assume the demand as given or known. They do not perform demand forecasting part. To the best of our knowledge, [25] was the only study that integrates the cash demand forecast into replenishment decision making. Finally, [26] proposes grouping ATMs into nearby-location clusters and also optimizing the aggregates of daily cash withdraws in the forecasting process. Example studies show that this integrated forecasting and optimization procedure performs better for an objective in minimizing costs of replenishing cash, cash-interest charge and potential customer dissatisfaction.

VI. CONCLUSION

The aim of this study is to propose an integrated decision support system for ATM management which will aid management team in banking services and make decision making easier with a scientific methodology in a trustworthy way. As mentioned earlier, there is a scarcity of studies and researches about ATM management. Moreover, considering we have not come across a study that handles both topics together, this study will just fill the gap in the literature and practice as well.

We intend to have two stage solution procedures; first stage is site selection and the second stage is cash management as these two problems are linked together. We believe that cash management policy should be established preemptively according to the ATMs locations.

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