The Location of a Cash Logistics Service Center in Downtown Chengdu, China[1]

Nan Zhu[*1], Long Wang[1, 2], Reginald D. Smith[3] and Les Foulds[4]

[1]Southwestern University of Finance and Economics, Chengdu 610074, China;
[2] Chengdu Branch of People's Bank of China, Chengdu 610041, China;
[3]ITT Corporation, Seneca Falls, NY 13148, USA
[4]Federal University of Goiás, Goiania, GO 74610-130, Brazil
e-mail: zhunan@swufe.edu.cn; hi_ruok@126.com; rsmith@sloan.mit.edu; lesfoulds@gmail.com

Abstract

Using the knowledge of supply chain management and a facility location model, the location of a cash logistics service center in downtown Chengdu, China, is discussed. The purpose is to promote security and efficiency in the issuance of Chinese currency and its circulation management in a way that meets the demands of its cash customers.

Keywords: Facility Location, Banking Industry of China, Chengdu, Cash Logistics.

1. Introduction

Since the founding of the People's Republic of China in 1949 and under the influence of a planned economy, the People's Bank of China (PBOC), China's central bank, has been the center of China's banking industry and the institution responsible for the issuance and circulation management of the Chinese currency: the Renminbi (RMB). Before 1996, almost every Chinese bank operated its own banking vaults and was responsible for the secure transportation of its cash. In some banks, the personnel responsible for storing cash, guarding the vaults and transporting cash was up to a third of all personnel working for the bank [26]. Large varieties of business locations were covered by the networks of many commercial banks and daily they handled large volumes of cash deposits and withdrawals. But each bank's armored trucks were only for its own use, these trucks were often idle, generated no revenue for the bank, and wasted the human and operational capital of the bank.

* Corresponding author

Since 1996, China's banking industry has begun reforms on the issuance and circulation management of the RMB. One aspect of the reforms was to allow the formation of armored transport companies to provide cash security and transport services to the banking industry in Shanghai, Beijing, Shenzhen and other large and medium-sized cities in China. However, outside these areas, especially in the countryside, Chinese commercial banks and similar banking institutions (for example, local rural credit unions) still have to provide their own armored transportation and storage of their cash. Despite this, the plan of China's banking industry to transform the cash issuance and circulation management in accordance with economics principles is still active. In April of 2009, Delun Ma, Deputy Governor of the PBOC, suggested that China should encourage and support the innovation of currency issuance and cash services, at the same time actively exploring cash management models that are suitable for Chinese conditions [14].

In present digital economy, cash is still largely a physical medium of exchange. The cash operation problem appeared from currency issuance and circulation management is a practical but very important problem in finance. However, in China, scholars usually discuss the problems of monetary policy, money supply, money velocity and similar policy matters in terms of macroeconomics. The microeconomic perspective of the RMB issuance and circulation management has rarely been explored. Chen is the first scholar known to us to have addressed Chinese cash operations in practice [3]. Chinese scholars in [18, 25] engaged in the description and qualitative analysis of the circulation management of the RMB.

Supply Chain Management (SCM) involves firms collaborating to leverage strategic positioning and to improve operating efficiency. See [2]. Recently, SCM has been applied to study currency issuance and circulation management in the field of banking industry. Rajamani et. al analyzed cash supply chains in United States [19]. Zhu and Wang provided a framework to study the cash supply chain in China and suggested that a new cash logistics management model should be established in China's banking industry [26]. After that, Zhu et. al further discussed China's nationwide logistics network and its basic structure for the issuance and circulation management of RMB [28]. Recently, Zhu and Wang studied the Chinese cash distribution issue by using the theory of economics [27].

In SCM, the facility location of a logistics center refers to a planning process for selecting an appropriate location and setting up a logistics center in an economic region that has multiple supply and demand points. Facility location is a well established research area within Operations Research and Management Science (OR/MS). See [16]. For example, Hakimi studied the best place to locate police stations on a highway network [11]. Min and Melachrinoudis discussed a practical case study involving the re-location of a combined manufacturing and distribution (warehousing) facility [15]. Gunnarsson et. al

considered a combined terminal location and ship routing problem in Sweden [10]. Facility location can also be used to promote the service strategy of a commercial bank. For example, Davis applied facility location methods to the financial sector [9]. In China, some Chinese scholars developed facility location models for banking offices or bank ATM networks. See [23, 13, 24].

Using the knowledge of SCM and building on some of the work previously referred to in the present paper, we present a study of the location of a cash logistics service center (CLSC) in downtown Chengdu, China. The remainder of the paper is organized as follows. In Section 2, we analyze the current economic situation in Chengdu and its RMB cash issuance and withdrawal history. In Section 3, we discuss the CLSC and its location by using a facility location model. In Section 4, we conduct an analysis on the selection of the location of the CLSC. Finally, in Section 5, we present some conclusions that follow from the results of our research.

2. Chengdu: Its Economy and Renminbi Cash Issuance and Withdrawal

2.1 Chengdu's Economy and Finance

Chengdu, located in central Sichuan province, is the provincial capital of Sichuan covering roughly 12,390 km^2. At the end of 2007, Chengdu's total population was 11.1 million with five million living downtown, making it the fourth most populous city in China following Beijing, Shanghai, and Chongqing (Chengdu Statistics Bureau, 2008). Chengdu contains nine districts, four smaller cities, and six counties. Within these, there are six districts in downtown Chengdu: Wuhou (node B), Jinniu (node C), Chenghua (node D), Jinjiang (node E), Qingyang (node F), and the High-Tech (node G) districts. A map of the downtown Chengdu, with these six districts, is given in Figure 1 (Chengdu municipal government is represented by node A).

With the beginning of China's economic reforms in 1978, Chengdu's importance began to grow markedly. In 1993, China's State Council selected Chengdu as the center of technology, business and finance and a transportation and communication hub for Southwest China. In 2007, the State Council approved Chengdu as one of the regions for the overall planning of urban and rural development.

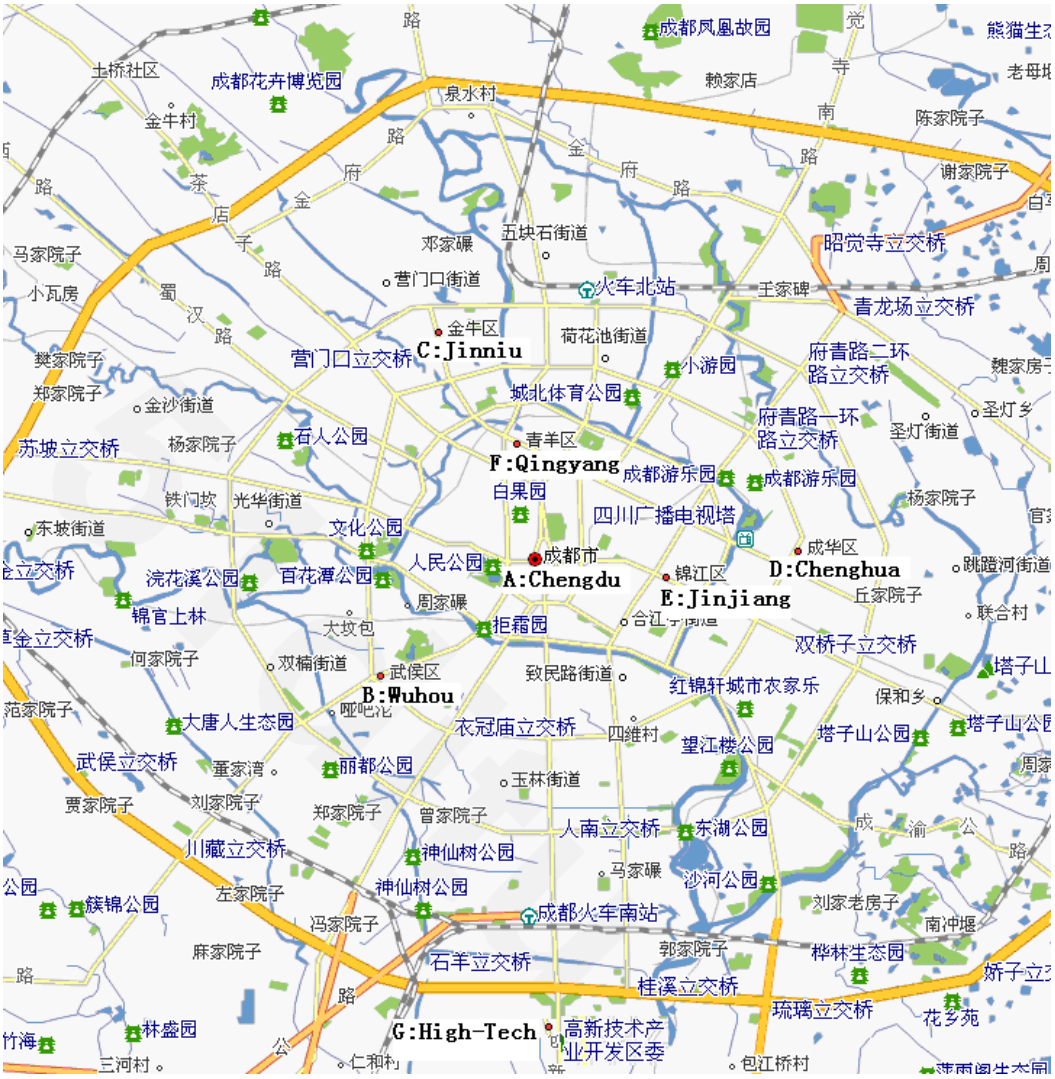

Figure 1: Downtown Chengdu

Web source：http://www.seobar.cn/homegift/ditu.htm

Among all the cities in the Southwest regions of China, Chengdu is home to the most banks. In the first half of 2009, Chengdu had eight branches of the five largest state-owned commercial banks and three policy banks, 12 branches of 11 national joint-stock commercial banks and a national postal savings bank, four branches of city commercial banks whose headquarters are in some other cities, seven branches of foreign banks and two representative offices of foreign banks. Chengdu also has two banking financial institutions owned by local corporations: Chengdu Commercial Bank and Chengdu Rural

Credit Union. In addition, Chengdu has five rural banks as well as a small loan company. 15 financial back-office service centers of commercial banks have already signed agreements with the local government and established themselves in Chengdu. Chengdu is rapidly becoming the financial center for Southwest China [5].

2.2 The Distribution of Business Districts in Downtown Chengdu

Chengdu has over 2,300 years of history and is Sichuan's business and trade center. It is also Southwest China's most important production and distribution center. From ancient times to the present, its role as a business and trade hub has played a prominent part in Chengdu's economic development. The birth of *jiaozi* (paper money) in Chengdu 1,000 years ago in the Northern Song Dynasty represents China's and the world's oldest paper money [8]. The emergence of *jiaozi* allowed business people to save cash, reduce expenses, and enable the growth of trade and commerce. It was the forerunner of the banknotes people use throughout the world today.

The historical prosperous business districts are still Chengdu's modern business centers. The intersection of Chunxi Road and Yanshikou has served as the traditional business center of Chengdu and has assumed an important function in the flow of commerce. In 2006, Chengdu planned that the area consisting of Chunxi Road, Yanshikou and Dacishi (approximately 1 square kilometer) should become the city-level business center.

As shown in Figure 1, the city-level and district-level business centers are located close to the corresponding Chengdu municipal government offices and related local government offices. Besides being areas related to the historical development of business, they have a significant impact on China's planned economy. Each government level has significant distribution power but traditionally, Chinese cities lacked a clear regional development plan. Consequently, in order to conserve resources and minimize government transaction costs, businesses often located themselves near government institutions. As a result, related trade, restaurants, apartments, traffic, and other businesses sprang up nearby. This often caused residents to organize their lives around these areas, so gradually they became business centers. Being the most concentrated areas for cash circulation, the business centers led banking institutions in Chengdu to concentrate their branches, sub-branches, banking offices and ATMs in these areas.

2.3 Analysis of Chengdu's Cash Issuance and Withdrawal

Against the backdrop of a rapidly increasing cash supply, Chengdu's cash issuance (also called cash expenditure) and cash withdrawal (also called cash income) have rapidly increased. In 2008, cash issuance was RMB 660 billion, an increase of 47444% since 1978. Cash withdrawals were RMB 684 billion, an increase of 47400% since 1978.

Except for 1988, in annual net amounts of cash, Chengdu has had a net withdrawal of RMB from circulation. In 2008, RMB 23.2 billion net was withdrawn, an increase of 46188% since 1978. The statistics on cash issuance and withdrawal from 1978 to 2008 are given in Figure 2.

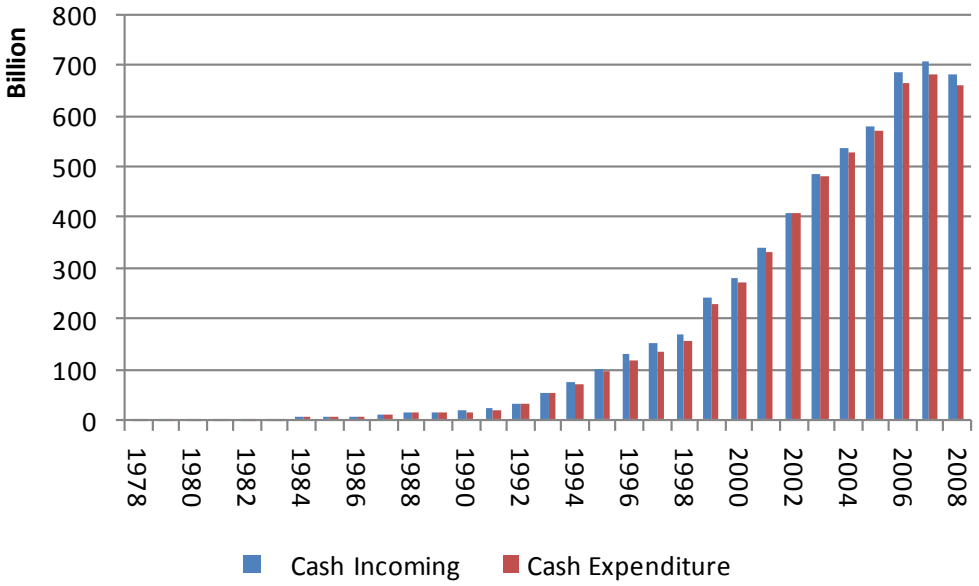

Figure 2: Chengdu cash issuance and withdrawal (1978～2008)

Data source: Chengdu Statistics Bureau (2009)

In the middle of the 1990's, The PBOC established a cash handling center in Chengdu and concentrated cash handling there. The China Industrial Commercial Bank, China Agricultural Bank, and China Construction Bank's Sichuan branches, as well as other commercial banks, established cash centers to protect and consolidate cash. In April 2002, the Chengdu Security Service Company established an armored transport company to provide protection and transport services to the commercial banks in downtown Chengdu. This step has had a beneficial effect on downtown Chengdu's cash transportation management.

However, currently in China the armored transport companies provide mainly armored trucks and guards to protect clients' vaults and to transport their cash. They are not responsible for further cash handling activities such as the packaging, cleaning and sorting of withdrawn cash. Banks still must be responsible for managing their physical banknotes and coins, which causes many problems. The key problems such as cash

customer service, inventory levels, transportation and storage security were discussed by [26, 28], see also [7]. The reforms of recent years have not yet changed the fact that China's armored transporters are still a security service and have not become a cash logistics service. Chengdu traditionally acts as a "cash sink" city and is now facing a rapid rise of withdrawn money in the coming years, along with increasing problems involving the distribution cost, security, cleaning and destruction of money and counterfeiting.

3. Cash Logistics Service Center and its location

3.1. CLSC

At present, the actual infrastructure for the printing/minting of Chinese currency is carried about by China Banknote Printing and Minting (CBPMC), which is controlled by the PBOC and produces banknotes/coins for subsequent distribution to the PBOC's vaults (bond facilities), then to the vaults of commercial banks and similar banking institutions, and finally to the bank customers across China. The current framework of the RMB supply chain as a closed-loop supply chain where both forward distribution and reverse logistics was provided in detail by [28] based on the work of [3, 26]. The simplified framework is in Figure 3, [27]. The solid lines in the figure designate the flow of fit cash destined for and within market circulation. The dotted lines represent unfit cash which is damaged and is eventually removed from circulation by the PBOC.

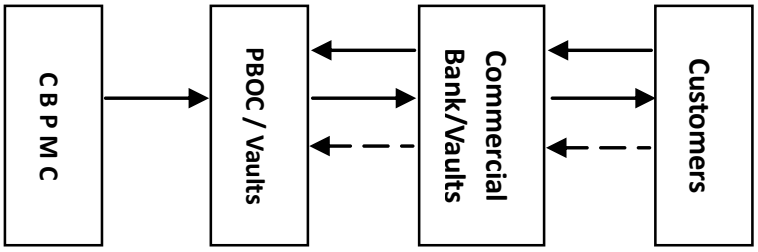

Figure 3: The current framework of the RMB supply chain

The core businesses of the PBOC's currency issuance and circulation are RMB issuing, unfit cash destroying and anti-counterfeiting. The core businesses of the Chinese commercial banks are industrial and commercial deposits, loans and intermediary businesses, etc, for earning profits. Zhu and Wang suggested that in order for these banks to focus on their own core businesses, both the PBOC and commercial banks should arrange for cash logistics, including armored transport, storage, cleaning, packaging, sorting and security, all to be done by an outsourced third-party logistics (3PL) provider

[26]. In order to reduce the responsibility of the PBOC and commercial banks with regard to cash logistics management, it is necessary to establish and develop a cash 3PL organization that manages the above mentioned operations of the cash handling centers and armored transport companies. Zhu and Wang pointed out that the moral hazard, caused by the present Chinese centralized cash distribution model and the difference between the managerial objective of the PBOC and operational objective of the Chinese commercial bank, is the main reason for the big risk, low efficiency and high cost of the present RMB distribution management [27].

Following the work of [26, 27], that a cash 3PL corporation should be established within the current RMB supply chain, combining cash distribution, inventory, processing, armored transport and other cash services using a CLSC, is proposed. In the RMB supply chain, this corporation would be a service located between the PBOC and commercial bank, see Figure 4, [27]. The corporation would be directed by the PBOC. The shareholders would be the banks and relevant financial institutions, traffic companies and other related corporations.

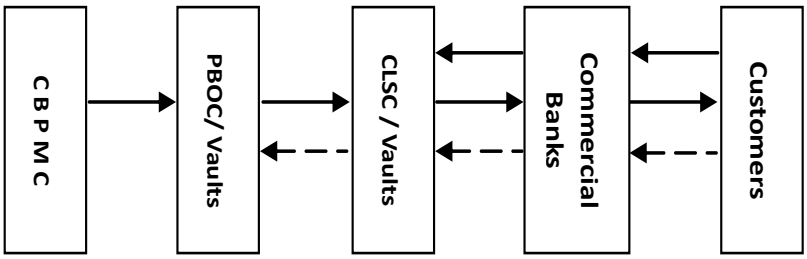

Figure 4: The suggested framework of the RMB supply chain

The CLSC would consolidate the current inventory, handling, and distribution functions currently handled by the PBOC and commercial banks and the transportation currently handled by the armored transport companies. The CLSC would require personnel with banking, OR/MS and management experience. The CLSC should be well equipped with modern equipment (such as an automatic multi-level warehouse, high quality currency sorting machines and armored trucks) and information technology (including the Internet of things and decision support systems) for dealing with the huge amount of various denominations of banknotes and coins safely, effectively and economically.

In a given region, the CLSC would implement cash operational management to meet the demands of its local cash customers.

3.2. The CLSC Site and the Center of Gravity Method

With regard to RMB issuance and circulation management, in order to protect against the risks of criminal activities and external disruptions, selecting the location of and setting up a CLSC should be based on successful foreign experiences (such as the cash management of the Bank of England under the Note Circulation Scheme since 2001). China's "Banking Vaults" industry standard issued by the PBOC (2000) and the techniques of SCM may also prove to be useful. We believe that the location of the CLSC should revolve around the following four location selection principles:

1) The security principle: The CLSC should be set up taking into account the various regional activities such as business operations, geological faults, natural disasters and fire and the surrounding social conditions that all have the potential to put the CLSC at risk.

2) The applicability principle: The CLSC should provide excellent service for local outlets of commercial banks and their customers. It should consider existing traffic conditions and future transportation scenarios to ensure that the local infrastructure is appropriate.

3) The economics principle: The CLSC should be set up on the basis of analyzing future cash logistics activities, the construction and daily running expenses of the facility and the consequent transportation costs.

4) The strategy principle: The location selection of the CLSC should be based on long-term planning, taking into account the cash logistics service needs of the clients and the region's development strategy.

There are various existing facility location methods available to determine satisfactory locations for logistics centers. Among these are the center of gravity (COG) method, mixed integer linear programming, simulation and brainstorming. See, for example, [2, 12, 20].

The COG method is a well-established quantitative technique for finding the location of a new facility that will have traffic with a number of existing facility with the aim of minimizing total transportation costs. In fact, this method was originally developed for the so-called Weber problem, that is, to determine the coordinates of a single facility such that the sum of the weighted distances to given demand points is minimized [12]. As the COG method can be used for the modeling of both forward and reverse logistics combined it is a feasible method for the problem of locating the CLSC discussed above. As the data concerning the cash logistics activities of Chinese banks and armored transport companies are not available, we consider that the COG method to be the most

appropriate for determining the location of the CLSC at present research stage. Consequently, it is used to determine the location of the CLSC in this paper.

Note that the RMB supply chain is a closed loop supply chain. Every morning before business hours, armored trucks of the CLSC would transport cash to each commercial bank in a forward logistics flow. Similarly, every evening after closing time the trucks would return cash back to the CLSC from the commercial banks in a reverse logistics flow. Obviously, the COG method can also be used to model both the forward and reverse logistics by treating the banks both as cash sinks and cash sources with regard to the CLSC.

In the following, the COG method is used to find the location of the CLSC in a given region with the aim of minimizing total transportation costs of all forward a reverse logistics flows. The corresponding model is:

$$\text{Min TC} = \sum_i V_i R_i d_i \quad (1)$$

Where, *TC* is the total transportation cost to and from the CLSC to all of the banks; *n* is the the number of banks, i.e., *i*=1,2, …, *n*; V_i is the total cash transported to and from CLSC to the i^{th} bank which is located in (X_i, Y_i) of a plane; R_i is the freight rate per unit distance between the CLSC and the *i*th bank, and d_i is the distance between the CLSC and the i^{th} bank.

Suppose that the CLSC is located in (X_0, Y_0). If d_i can be measured as the Euclidean distance:

$d_i = \sqrt{(X_i - X_0)^2 + (Y_i - Y_0)^2}$, for all *i*=1,2, …, *n*; then the optimal location (X_0^*, Y_0^*) of the CLSC can be expressed as:

$$X_0^* = \frac{\sum_i V_i R_i X_i / d_i}{\sum_i V_i R_i / d_i}, Y_0^* = \frac{\sum_i V_i R_i Y_i / d_i}{\sum_i V_i R_i / d_i} \quad (2)$$

In practice, a gradient-like search method is used for finding an approximate solution (X_0', Y_0') to (X_0^*, Y_0^*). Suppose ε is a given arbitrarily small positive number. The search method has the following steps：

Step 1. For given （X_i, Y_i） , V_i and R_i (*i*=1,2, …, *n*), let the initial X_0 and Y_0 of the CLSC be

$$X_0 = \frac{\sum_i V_i R_i X_i}{\sum_i V_i R_i}, Y_0 = \frac{\sum_i V_i R_i Y_i}{\sum_i V_i R_i}$$

Go to Step 2.

Step 2. Use the X_0 and Y_0 to calculate initial d_i values (i=1,2, …, n). Go to Step 3.

Step 3. Use the d_i's found in Step 2 to calculate the total transportation cost:

TC = $\sum_i V_i R_i d_i$

and a modified $X_0^{'}$ and $Y_0^{'}$:

$$\acute{X}_0 = \frac{\sum_i V_i R_i X_i / d_i}{\sum_i V_i R_i / d_i}, \acute{Y}_0 = \frac{\sum_i V_i R_i Y_i / d_i}{\sum_i V_i R_i / d_i}$$

Go to Step 4.

Step 4. Use the modified $X_0^{'}$ and $Y_0^{'}$ to calculate modified $d_i^{'}$'s, (i=1,2, …, n). Go to Step 5.

Step 5. Use the modified $d_i^{'}$'s to calculate the modified total transportation cost: TC = $\sum_i V_i R_i d_i$. Go to Step 6.

Step 6. If $\left|\acute{TC} - TC\right| > \in$, let X_0=$X_0^{'}$ and Y_0=$Y_0^{'}$, go to Step 2. This means that the transportation cost needs to be improved further. Otherwise, stop. That is to say, if $\left|\acute{TC} - TC\right| \leq \in$, the best approximate location of the CLSC that the COG method can find is ($X_0^{'}$, $Y_0^{'}$).

4. Location Selection for the Chengdu Cash Logistics Service Center

In this section, the COG method is used to select and analyze a possible CLSC location in downtown Chengdu.

4.1. Model Assumptions

1）The addresses of the Chengdu municipal government office and its six administrative districts' government offices in downtown Chengdu can be regarded as seven big business centers in downtown Chengdu.

2）The capital cost needed for the CLSC's construction and other costs (e.g., labor, public utilities cost) need not be considered and the factors of politics, society, nature and geography, have the same impact on all the banks, and they do not influence the CLSC's location selection.

3）The cash demand amounts of each bank is the same: $V_1 = V_2 = \cdots = V_7$. Assume that the freight rate per unit distance to and from the CLSC to each bank is the same: $R_1 = R_2 = \cdots = R_7$.

4.2. Model Solutions

Following the map of downtown Chengdu (Figure 1), whose lower left corner is designated as point (0, 0), we can model the seven downtown banks as seven coordinate points now termed nodes. The government offices of Chengdu municipal government, Wuhou district, Jinniu district, Chenghua district, Jinjiang district, Qingyang district and the High-Tech district are assumed to represent seven bank nodes respectively: A (10.3, 9.9), B (7.2, 7.6), C (8.4, 14.2), D (15.3, 10), E (12.7, 9.5), F (9.8, 12) and G (10.7, 0.7). See Figure 5.

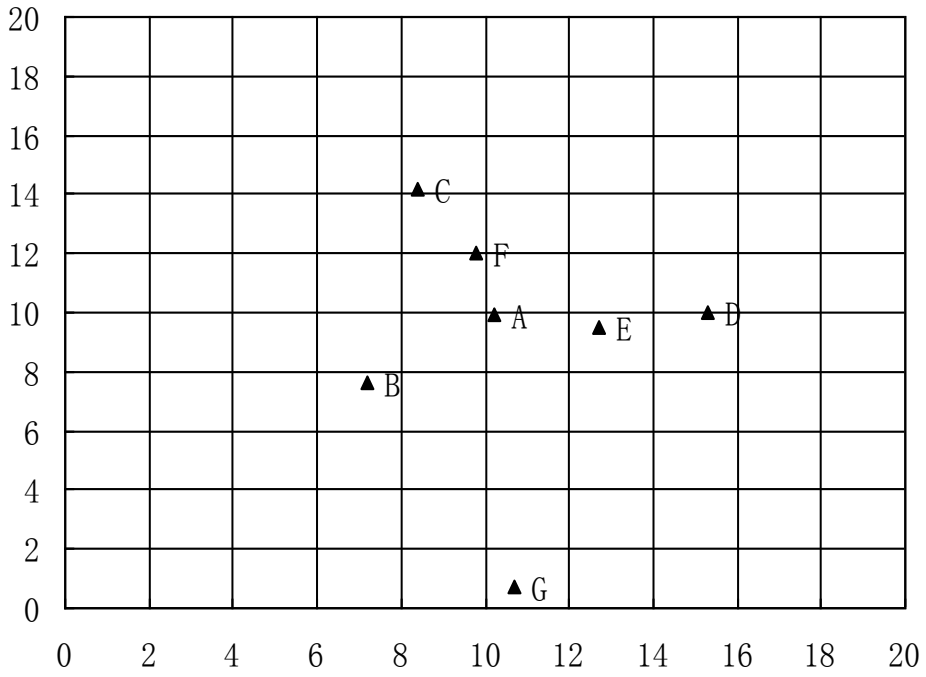

Figure 5: Cash demand locations in downtown Chengdu

Following the aforementioned assumptions, we conducted a computer analysis of the COG method to determine the location for the CLSC in downtown Chengdu. Let ε=0.0001. After 18 iterations, we obtained the location solution of the CLSC: ($X_0^{'}$, $Y_0^{'}$) =(10.2, 9.9) with the total transportation cost of 27.43, see Figure 6.

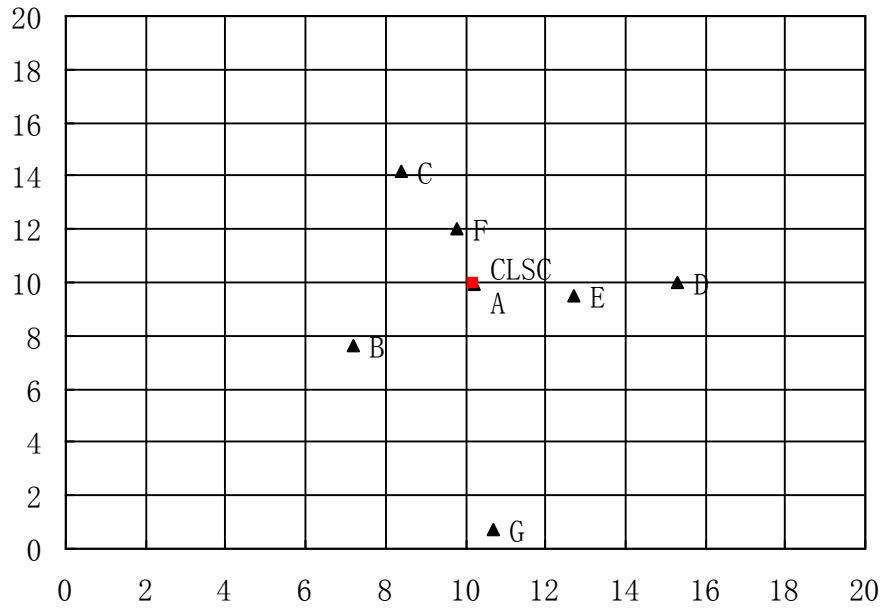

Figure 6: Approximate location for the CLSC in downtown Chengdu

4.3. Solution Analysis

From Figure 6 it is apparent that the required location solution of the CLSC is near point A, the location of Chengdu municipal government office. This point (10.2, 9.9) is within Chengdu's city-level business center – the Chunxi Road-Yanshikou-Dacishi commercial circle.

Chunxi Road, named in 1924, is recognized as Chengdu's "Golden Street". There are many prominent department stores in Chengdu's city-level commercial center, such as Xiwu Department Store, Wangfujin Department Store, Pacific Department Store, Itoyokado Store, Isetan Department Store, Parkson Store, Taiwan Quanguang Department Store, Moore Parkson, Hualian Buliding, Renhe Chuntian, Carrefour, Kowloon Clothing Wholesale City, People's Department Store and many others. The average daily visitor count there exceeds 200,000, and can surpass 500,000 in the holidays. The convergence of merchants and thousands of customers lead to frequent cash transactions and a large flow of cash. Interestingly, Dongdajie Street – the birthplace of the *Jiaozi* is also located in the area of the city-level business center. Nowadays, the periphery of Dongdajie Street already has 56 domestic banking branches and sub-branches, six branches of foreign banks as well as two representative offices of foreign banks. Chengdu has decided to develop Dongdajie Street as Chengdu's "Financial Street" (China Finance Net, 2008),

and to make it play an important role in the process of developing the financial center of Southwest China.

Therefore, by locating the CLSC at point（10.2, 9.9）of Chengdu's city-level business center, theoretically, the total transportation cost could be reduced while more efficiently serving customers than before by assuming that the government offices of Chengdu municipal government and its six districts in downtown Chengdu represent seven bank nodes and using the COG model.

5. Conclusions

For promoting efficiency in the Chinese currency issuance and circulation management, that a cash 3PL corporation with its CLSC should be established along the current RMB supply chain combining cash distribution, inventory, processing, armored transport and other cash services, are proposed. Using the downtown Chengdu as a case, the problems of why, how and where to set up a CLSC are discussed. A possible CLSC and its location selection are also studied by using the knowledge of SCM. A facility location model – the COG method is programmed to find the location of a CLSC that minimizes total transportation costs.

The location selection of the CLSC is based on assumed conditions, assumptions and the COG method. Further research could be conducted by collecting actual data, by using simulated data, by adopting more realistic conditions, by relaxing certain of the assumptions or by using more advanced facility location models. For the downtown Chengdu case, one study could be undertaken where the actual characteristics of downtown Chengdu are considered, such as the role of transportation ring-radial and rectilinear metrics, additional performance measures and different levels of cash demand now and in the future.

It is one of our wishes that this paper could be used as a reference for Chinese decision-makers and managers who are responsible for RMB issuance and circulation management. National policy, regional development, the public security situation, utilization of land resources and social needs would all have to be taken into consideration. Also, operational factors, such as the human cost, operational conditions, service levels, finance and logistics standards, information technology and the business environment should not be ignored.

[1] **Acknowledgement:** The research reported in this paper was supported by a grant from the "Project 211 (Phase 3)" of the Southwestern University of Finance and Economics.

References:

[1] Bank of England Website: "Banknote distribution, circulation & destruction", http://www.bankofengland.co.uk/banknotes/about/distribution_circulation.htm.

[2] Bowersox, D.J., Closs, D.J. and Cooper, M.B., 2002, Supply Chain Logistics Management, Beijing, McGraw-Hill Education (Asia) Co. and China Machine Press.

[3] Chen, B., 1994, Introduction to Cash Operations (Version 1), Beijing, China Financial Publishing House (in Chinese).

[4] Chengdu Municipal Government, 2006, The development planning of Chengdu business network points (in Chinese).

[5] Chengdu Statistics Bureau, 2009, Chengdu Statistics Yearbook 2009, Beijing, China Statistics Press (in Chinese).

[6] China Finance Net, 2008, Jinjiang: Constructing the West China's finance center, http://active.zgjrw.com/News/20081222/index/463665438600.html (in Chinese).

[7] Currency News, 2010, Case study: China–Managing the world's largest cash volumes, Currency News, **2**, 4–5.

[8] Currency News, 2006, Banknote of the month: Chinese Yuan – 1,000 years of history, Currency News, **4**, 10.

[9] Davis, E.P., 1990, International Financial Centers–An Industrial Analysis, Bank of England Discussion Paper, **51**,1–23.

[10] Gunnarsson, H., Rönnqvist, M. and Carlsson, D. , 2006, A combined terminal location and ship routing problem, *Journal of the Operational Research Society*, **57**, 928–938.

[11] Hakimi, S.L., 1964, Optimum locations of switching centers and the absolute centers and medians of a graph, *Operations Research*, **12**, 450–459.

[12] Klose, A. and Drexl, A., 2005, Facility location models for distribution system design, *European Journal of Operational Research*, **162**, 4–29.

[13] Liu, Z. and Mao, Y., 2004, On location selection methods of commercial bank outlets based on GIS and neural networks, *Business Economics and Administration*, **9**, 55–59 (in Chinese).

[14] Ma, D., 2009, Accomplishing currency issuing and cash services, *Shanghai Financial News*, (in Chinese).

[15] Min, H. and Melachrinoudis, E., 1999, The relocation of a hybrid manufacturing / distribution facility from supply chain perspectives: a case study, *Omega*, **27**, 75-85.

[16] Melo, M.T., Nickel, S. and Saldanha da Gama, F., 2007, Facility Location and Supply Chain Management–A comprehensive review, Berichte des Fraunhofer ITWM, Nr. 130.

[17] The People's Bank of China, *Banking Vaults* (JR-T0003-2000), 4 July 2000 (in Chinese).

[18] Ren, W., 2005, Vpower Security Company starts a new model of finance logistics, *China Logistics & Purchasing*, **9**, 32–35 (in Chinese).

[19] Rajamani, D., Geismar, H.N. and Sriskandarajah, C., 2006, A framework to analyze cash supply chains, *Production and Operations Management*, **4**, 1–9.

[20] ReVelle, C.S. and Eiselt, H.A., 2005, Location analysis: A synthesis and survey, *European Journal of Operational Research*, 165, 1–19.

[21] Smith, R., Zhu, N. and Wang, L., 2010, China's Renminbi currency logistics network: a brief introduction, *The ICFAI University Journal of Supply Chain Management*, **3**, 27-39.

[22] Wang Z., 2003, On Renminbi logistics structure, *China Finance*, **14**, 37–38 (in Chinese).

[23] Yang X., 2003, GIS assisted location of financial network node location selection applied to China Agricultural Bank location in Guangzhou, Northeast Normal University Research Report, Shenyang, China (in Chinese).

[24] Ye B., 2006, Analytic Hierarchy Process and applications of the location selection of ATM network points, *Science Information (academic version)*, **7**, 1–4 (in Chinese).

[25] Zhang L., 2005, An analysis of the current state of China's currency logistics, *Logistics & Materials Handling*, **3**, 92–95 (in Chinese).

[26] Zhu N. and Wang L., 2007, A basic investigation of China's banking industry cash logistics management, *Modernization of Management*, **6**, 18–20 (in Chinese).

[27] Zhu N. and Wang L., 2011, Chinese Cash distribution model innovation－RMB supply chain governance structure & incentive mechanism, *International Commercial Cash Operations Seminar Asia*，Hong Kong, 2011.

[28] Zhu N., Wang L. and Smith R., 2010, The currency supply chain in the PRC, *The 4th Asian Cash Handling Seminar*, Beijing, China, 2009. See also: "Case study: China–Managing the world's largest cash volumes", Currency News, **2,** 4–5.