http://ansinet.com/itj

ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (24): 8615-8621, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.8615.8621

Study on the City Planning of Distribution Centers

[1,2]Jing Sun and [1]Shaohua Dong
[1]School of Mechanical Engineering, University of Science and Technology Beijing, Beijing, 100083, China
[2]Department of Industrial Engineering and Logistics, Beijing Union University, Beijing, 100020, China

Abstract: Rapid increasing logistics demands call for high efficiency delivery in cities. Effective city planning of distribution centers is crucial. This paper describes the steps of distribution centers planning in detail including zone definition, shipment volume forecast, productivity forecast and capacity forecast. Based on these data, the author puts forward an effective way to build and evaluate operation models. Proper implementation of the best operation model will be helpful to fulfill the increasing market requirements.

Key words: Logistics, distribution center, planning, location, model

INTRODUCTION

The logistics industry has developed for several decades rapidly in China. With the development of Chinese economy, the demands on the logistics services increase rapidly at home and abroad (Zhang and Wei, 2009). The logistics industry must improve their service level as a result (Zheng and Wang, 2011). In all aspects of customer service, on-time delivery is very critical. The most significant contributor to good delivery performance is the city planning of DCs. Therefore, how to effectively plan the DC locations has become a key issue (Chen, 2010).

OBJECTVES

The objectives of city planning of DCs are:

- To ensure appropriate infrastructure and operation models are in place for key cities
- To ensure service and cost optimization for key cities

ISSUES TO BE SOLVED

Issues to be solved are:

- How many facilities should there be and at what locations?
- Can the existing gateway in these key cities support the business and operations needs?
- How should shipments be routed in the key cities?
- What are the roles and functions (Gateway, DC, Courier Base) of each facility in the key cities?
- How can the immediate operations issues be alleviated in the short or medium term?

SOME DEFINITIONS

Point: A Point is defined as "an individual visit to a customer" (Chi and Li, 2003). The number of points a courier is required to perform defines a courier's capacity rather than the total shipments, total pieces or shipments per point (SPP).

Cycle: A Cycle (Fig. 1) is defined as each period away from the DC.

Time: Outside Time is effectively the total time required to complete the cycle.

Operation Time is the actual time period in which the courier is able to pick up and deliver shipments.

Come Out Time and Come Back Time are dependant on the ability of the courier to select the most optimal way to the first and from the last customer. They are also dependant on the DC's location and traffic patterns.

Other Activities Time is the time taken for other activities (such as: traffic jam, refueling, brakes).

The basic calculations are expressed as Eq. 1-4 (Sun and Dong, 2013):

$$\text{Come out time} = \text{first point time} - \text{depart from DC time} \tag{1}$$

$$\text{Come Back Time} = \text{arrive at DC time} - \text{last point time} \tag{2}$$

$$\text{Operation Time} = \text{last point time} - \text{first point time} \tag{3}$$

$$\text{Outside Time} = \text{Come Out Time} + \text{Operation Time} + \text{Come Back Time} = \text{Total Cycle Time} \tag{4}$$

Corresponding Author: Shaohua Dong, School of Mechanical Engineering, University of Science and Technology Beijing, Beijing, 100083, China

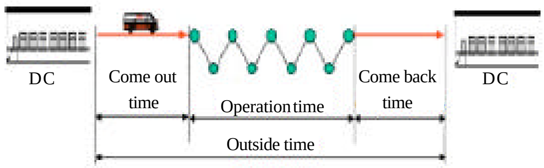

Fig. 1: A simple cycle

Productivity indicator: Points Per Operation Hour (PPOH) is the actual rate of work while performing pickups and deliveries. PPOH is a very powerful tool for evaluating how many points may be achieved for a given productive time (Operation Time). It is different for each operation area and cycle.

Other Activities during the Operation Time should be identified and separated wherever possible to avoid distorting the true rate of work.

The calculation may be expressed as Eq. 5.

$$\text{PPOH} = \text{Total Points} / (\text{Operation Hour} - \text{Other Activities Hour}) \quad (5)$$

ZONE DEFINITION

The definition of service zone is intended to categorize volume forecast and productivity forecast according to the city location, so as to forecast the volume and productivity more accurately and to provide the coordinates for the DC location. Relying on the existing service block boundary and the main roads as auxiliary lines, the logistics service area can be divided into several service zones according to different sales or operation characteristics. To avoid making this planning too complicated, the number of service zones should be restricted within 20.

The output of this phase is:

- A map with zone boundary
- A brief description for each individual zone about its business profile
- A zoning table about how service zones are composed of current blocks

Collect volume data: Minimum 4 weeks of volume data is required.

Choose representative day: The representative day should be selected amongst the days with a total volume slightly higher than average.

Obtain pickup and delivery (PUD) address: The couriers' PUD records on the representative day should be collected in this step which include the addresses we need.

Draw the points and the borders of blocks on the map: According to the address list, plot the PUD points on the city map. Draw the boundary of sample month's blocks on the same map. Mark the current DC and airport location on the map as well.

Plotting techniques generally include:

- Plot all points for the selected day manually on large wall maps to show each individual point (Xuan *et al*., 2006)
- Plot each cycle on separate maps (or plastic overlays)
- Use different color dot for each block
- Identify pickup points from delivery points with different colors

Define zones: There are three steps:

Step 1: Draw zone boundary on the plotted map.

The criteria in zoning are:

- PUD points density showed on the plotted map
- Expansion plan of the service region
- Main types of customers
- Policies and characteristics of different regions
- Structure of the existing blocks
- Natural boundaries (major highways, rivers, etc.,)

Figure 2 shows the service zones of Beijing.

Step 2: Describe the service characteristics of each service zone

Some information is needed to be provided:

- The type of service zone (CBD, industrial area, residential area, village, institution, Free Trade Zone, etc.,)
- The main customer type of the service zone (bank, government department, foreign company, etc.,)
- The estate price
- The traffic condition (such as: special traffic restriction)
- The development planning from the government (local municipal function, major roads in the future, etc.,)

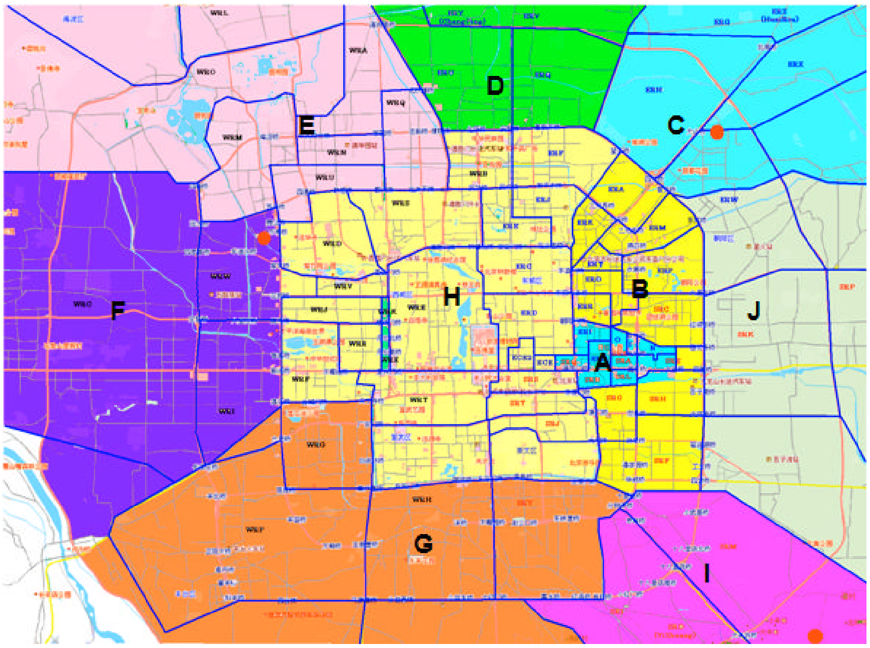

Fig. 2: The service zones of Beijing

Table 1: Blocks in each zone

Zone A	ECC0	ECD0	SRA0	SCD2	...
Zone B	ERI0	SRB0	ECK0	ERH0	...
Zone C	ERF0	ERG1	ERV0	ERW0	...
Zone D	ERE1	ERP0	ERT1	WRA1	...
Zone E	WRL0	WRP1	WRP0	WRL0	...
...	...	...	...	...	...

For example, service zone A can be illustrated as:
"Zone A: located in the core central business district. Major customers include: foreign companies, foreign banks, foreign embassies and government departments. There are heavy traffic jams in this area, especially during the rush hours. The estate price of this region is the highest in Beijing. Currently we have three DCs in this zone. In the future city planning, this region will go on act as the business center and there will be no major changes in the traffic structure. But the situation of traffic jams will be alleviated with the government's road improvement scheme."

Step 3: Assign blocks to each defined zone.

SHIPMENT VOLUME FORECAST

The objective of this phase is to make yearly volume forecast by product and by zone for the next 5 years. This phase ensures operation infrastructures will be deployed at suitable locations with suitable capacity (Wang *et al*., 2012).

Collect and analyze volume data: Collect the current volumes of each block and then convert the raw data from by month and by block to by day and by service zone. This will be the base volume for the forecast.

Analyze market information: Any information about local market that can be referred for the 5-year volume forecast will be collected.

They may include:

- Foreign trade volume and growth
- Economy structure of the city
- GDP growth of the city in recent years
- Business branch of main international user
- Main import and export industrial sectors and commodity
- Present and prospective strategy to local PUD agents
- Long and medium term local economy development plan

Find advantages and disadvantages of competitors: Try to collection information about competitors' facility locations, operation capacity, market share and strategy by market investigation.

Forecast volume by zone: Based on the above information, we can get a more accurate forecast of volume by product and by zone.

Table 2: Volume forecasted

	Shipment day					
Zone A	Y2010	Y2011	Y2012	Y2013	Y2014	Y2015
IB DOX	309	459	502	545	589	623
IB WPX	126	174	208	243	281	316
IB DOM	15	22	25	29	33	38
OB WPXE	109	124	142	156	171	187
OB DOM	13	19	28	38	51	68
TTL	981	1295	1540	1779	2058	2362

Table 2 shows the volume forecasted.

PRODUCTIVITY FORECAST

The PUD productivity may be affected by various changing components:

- Profiles of goods
- Operation arrangements
- Traffic conditions
- Customer characteristics
- Point density

The goal of this phase is to forecast the productivity index in the next 5 years. The outputs of this phase are: A 5-year Operation Hour, PPOH, SPP assumption for each zone.

Step 1: Information should be obtained concerning the current operation arrangements and the time to pick up and deliver goods.

Firstly, write down the time of key activities in daily operations.

Secondly, calculate each current block's Outside Hour based on above operation schedule. Use Eq. (6) to calculate Ideal Operation Hour.

$$\text{Ideal Operation Hour} = \text{Outside Hour} - \text{Come Out Hour} - \text{Come Back Hour} - \text{Other activities Hour} \quad (6)$$

If any block has more than one cycle, the Operation Hour of this block is the sum of each cycle's Operation Hour.

Step 2: The current productivity index should be calculated.

Firstly, list out PPOH and SPP for each current block. If the data is by cycles, combine them. The calculations are expressed as Eq. 7 and 8).

$$\text{PPOH}(\text{A and B}) = [\text{PPOH}(\text{A})\times\text{Operation Hour}(\text{A})+\text{PPOH}(\text{B})\times\text{Operation Hour}(\text{B})]/[\text{Operation Hour}(\text{A})+\text{Operation Hour}(\text{B})] \quad (7)$$

$$\text{SPP}(\text{A and B}) = [\text{SPP}(\text{A})\times\text{PPOH}(\text{A})\times\text{Operation Hour}(\text{A})+\text{SPP}(\text{B})\times\text{PPOH}(\text{B})\times\text{Operation Hour}(\text{B})]/[\text{PPOH}(\text{A})\times\text{Operation Hour}(\text{A})+\text{PPOH}(\text{B})\times\text{Operation Hour}(\text{B})] \quad (8)$$

Secondly, calculate zone-compound PPOH, SPP and Operation Hour.

Example 1: Zone-compound PPOH, SPP, Operation Hour calculation, shown as Eq. 9-11.

Assume Zone C is composed of block ERD0 and block ERJ0:

$$\text{PPOH}(\text{Zone C}) = [\text{PPOH}(\text{ERD0})\times\text{Operation Hour}(\text{ERD0})+\text{PPOH}(\text{ERJ0})\times\text{Operation Hour}(\text{ERJ0})]/[\text{Operation Hour}(\text{ERD0})+\text{Operation Hour}(\text{ERJ0})] \quad (9)$$

$$\text{SPP}(\text{Zone C}) = [\text{SPP}(\text{ERD0})\times\text{PPOH}(\text{ERD0})\times\text{Operation Hour}(\text{ERD0})+\text{SPP}(\text{ERJ0})\times\text{PPOH}(\text{ERJ0})\times\text{Operation Hour}(\text{ERJ0})]/[\text{PPOH}(\text{ERD0})\times\text{Operation Hour}(\text{ERD0})+\text{PPOH}(\text{ERJ0})\times\text{Operation Hour}(\text{ERJ0})] \quad (10)$$

$$\text{Operation Hour} = [\text{Operation Hour}(\text{ERD0})+\text{Operation Hour}(\text{ERJ0})]/\text{number of blocks} \quad (11)$$

Step 3: The future operation arrangements and PUD time should be made.

Identify any possible change to current operation arrangement that can alleviate current operation issues, or is anticipated to bring service and productivity improvement in future.

Make assumptions on each zone's Operation Hours based on predicted change of operation arrangement.

Step 4: The future productivity index could be forecasted by service zone.

In fact, PPOH can be calculated by Product Mix Index (PMI) and Point Density Index (PDI) (shown as Eq. 12).

$$\text{PPOH}_{(\text{Y2013})} = \text{PPOH}_{(\text{Y2012})}\times(\text{PDI}_{(\text{Y2013})}\div\text{PMI}_{(\text{Y2013})}) \quad (12)$$

Different block has different shipment characteristics of the customers, so SPP various from block to block. Forecast SPP based on best knowledge for each zone. Assume SPP to remain if there's no obvious reason that it will change over time.

Table 3: The productivity index forecast

	2010			2011	...		2015		
	PPOH	Operation (h)	SPP	PPOH	Operation (h)	SPP	PPOH	Operation (h)	SPP
Zone A	8.07	5.90	1.1	8.50	5.40	1.2	10.55	5.40	1.4
Zone B	7.74	5.20	1.1	7.76	4.70	1.2	8.69	4.70	1.4
Zone C	7.81	6.52	1.1	7.81	6.02	1.1	8.14	6.02	1.1
Zone D	6.18	6.15	1.1	6.47	5.65	1.1	7.08	5.65	1.1
Zone E	6.23	6.14	1.1	6.57	5.64	1.1	7.90	5.64	1.3
...									

Summarize above assumption in Table 3.

CAPACITY FORECAST

Calculate number of blocks by zone: Calculate number of blocks required for each zone in future years by using Eq. 13:

$$\# BK = SPD / (PPOH \times SPP \times \text{Operation Hour}) \quad (13)$$

#BK: Number of blocks
SPD: Shipment per day
SPP: Shipment per point
PPOH: Points per Operation Hour

Estimate number of DCs: Summarize annual total number of blocks of DC. Divide the total number of blocks by 30 and keep the decimal place (eg., 2.3 DCs) finally to get number of DCs for each year (Table 4).

The number of DCs is only a theoretical reference for facility planning. The number of blocks required should be revised based on the Come Out Time and Come Back Time relative to the locations of the future DCs as described in the next phase.

OPERATION MODELS GENERATION

In this phase, 2 to 3 operation models should be constructed in order to evaluate them in the next phase.

Build a baseline model: Model generation is an iterative process. It is better to iterate in 4 steps until an "Operations Capacity Balance" is achieved.

Step 1: Determine DC location and the overall layout according to the needs of the next 5th year

The following factors should be considered (Dong *et al*., 2013):

- Close to key PUD area where business comes from
- Good accessibility to airport and inter-city highway
- Good traffic condition
- "Reasonable" rental

Table 4: No. Of blocks by zone and no. Of Dcs

Year	Y2012	Y2011	Y2012	Y2013	Y2014	Y2015
Zone A	19.0	23.0	25.0	27.0	29.0	30
Zone B	20.0	24.0	26.0	28.0	30.0	31
Zone C	5.0	7.0	8.0	9.0	10.0	11
Zone D	7.0	9.0	10.0	12.0	13.0	15
Zone E	10.0	14.0	15.0	17.0	19.0	21
Zone F	4.0	5.0	5.0	6.0	7.0	7
Zone G	1.0	1.0	1.0	1.0	2.0	2
Zone H	10.0	12.0	13.0	14.0	15.0	16
Zone I	3.0	5.0	6.0	6.0	7.0	8
Zone J	5.0	6.0	7.0	8.0	9.0	11
Zone K	14.0	17.0	17.0	18.0	18.0	19
Zone L	1.0	2.0	2.0	2.0	2.0	3
Zone M	1.0	2.0	2.0	2.0	3.0	3
Zone N	1.0	2.0	2.0	2.0	3.0	3
Total	102.0	129.0	139.0	152.0	166.0	180
DC no.	3.4	4.3	4.6	5.1	5.5	6

- No major regulatory restrictions (truck access, building structure, etc.)
- Good security
- Good public transportation

In general, we use "Location Assessment Form" to help us to select several zones as DC locations (Table 5). In detail, we must figure out suitability weight and score for each factor of each zone,and then rank the service zones by the weighted score. The zone with highest weighted score should be selected in the first place as the new DC location.

Sometimes, most of the high-rank service zones in the Location Assessment Form are located in one part of the city (e.g., because of low rental cost or fine traffic condition). The geographical unbalance of the whole infrastructure network will come into being.

To avoid the unbalanced infrastructure network, it is necessary to:

- Conform the "Center of Blocks" of the city;
- Build a "Reference Frame" in the "Center of blocks";
- Verify the balance of DC network with the "Reference Frame";
- Adjust the location of DC to get a balanced network under "Reference Frame".

Step 2: Confirm DC coverage

Define the service coverage area for each of the DCs. Assign blocks to each DC and adjust the number of blocks in each DC.

Table 5: Location assessment from

Factor	Weight	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Close to key PUD area	16	4	3	2	4	4	3
Good accessibiltiy to airport inter-city highway	20	4	2	1	2	2	3
Good traffic condition	8	3	3	3	1	3	3
Reasonable rental	16	4	5	5	3	5	5
No vehicle restrictions	12	5	5	5	2	5	5
No regulation against building expansion	4	3	3	3	3	3	3
Good security	8	4	4	4	4	4	4
Good public transportation	4	4	4	3	5	3	3
Availability of suitable warehouse	12	4	4	4	2	5	4
Geographic balance with existing DC/depot	14	5	4	5	3	1	4
Access to good secondary roads	10	3	3	3	3	3	3
No noise restrictions	6	4	4	4	3	4	4
Final weighted score		524	470	444	362	452	486
Rank		1	3	5	6	4	2

Table 6: DC coverage-madel 1

	DC1							DC2							
	Block	Zone	IBSH	OBSH	IBKG	OBKG	Bk eqv	Block	Zone	IBSH	OBSH	IBKG	OBKG	Bk eqv	...
Sum	35	EOC	1012	676.9	3971	31950	40	19	SOC	582.9	510.3	1945	3141	23.097	
1	ECDO	Zone A	0.000	0.503	0	0.502	1.0	SCB0	Zone A	29.87	23.83	122.6	109.8	1.0000	
2	ECE0	Zone A	40.71	28.50	115.1	64.19	1.0	SCB1	Zone A	12.72	8.444	41.49	25.43	1.0000	
3	ECE1	Zone A	30.17	28.90	107.9	62.33	1.0	SCD0	Zone A	29.62	29.66	99.41	60.35	1.0000	
4	ECE2	Zone A	37.20	20.71	63.35	94.15	1.0	SCD1	Zone A	43.92	34.18	129.9	83.07	1.0000	
5	ERN0	Zone A	4.180	25.23	22.13	107.1	1.0	SCD2	Zone A	26.17	26.34	59.31	78.67	1.0000	
6	ERN0	Zone A	37.07	30.16	80.48	161.4	1.0	SCD3	Zone A	25.32	21.31	101.1	85.96	1.0000	
...															

Ways to determine the service area coverage of a new DC are:

- Get the “Year 5 Number of Blocks Equivalent” (Y5NBE) of all the existing blocks
- Size up the service area of new DC 1 by expanding the service area coverage from the centre of the DC outwards
- Distribute and summarize the Y5NBEs of the existing blocks when the service area boundary is enlarged to cover its service areas
- Repeat the above 2 steps until the Y5NBE reaches between 27 to 33 routes
- Repeat the above 4 steps for the remaining of the DCs
- Rebalance the Y5NBE allocations among the DCs to optimize the PUD capacity and service level if necessary

The best location is not at the geographical centre of a zone but “off-set” towards the direction of the gateway or the processing centre.

The “Adjusted” blocks requirement need to be re-calculated based on the “Adjusted” Come Out Time and Come Back Time relative to the locations of the new DCs in “year 5” that has been decided.

Procedures of re-calculating blocks requirement for the new DCs are:

Estimate the new Come Out Time and Come Back Time of the blocks assigned to each DC. Assume the blocks within the same zone have the same Come Out Time and Come Back Time;

Calculate the “Adjusted” number of blocks required for each DC based on the new Come Out Time and Come Back Time.

Step 3: Set the operation functions of DC.

Define the operations roles of each of the facility in proposed ground network by assigning Inbound and Outbound activities to each of the facility.

Design the shuttle network (Inbound and Outbound) to support the inter-facility shipment flow.

Step 4: Calculate the service demands for year 1 to year 4 respectively and make the improvement plan, including new construction, expansion, moving, etc.,

Model 1 is figured in Table 6 as an example.

Build other operation models: Other operation models should be built with the same method because:

- The Baseline model (without Feeders/Sweepers) may not be optimal from cost and productivity standpoints
- Rental cost may be too much to set up a large DC
- A building with the right size and specifications in the right zone for a full DC operation may not be obtained

- It is not feasible to set up a DC because of traffic restriction (e.g. for truck)
- Good and secured hand-over points for Feeder/Sweeper operation are unavailable

Generally, at least one DC with Feeders/Sweepers model and one to two more DC supported by courier depots models should be built.

OPERATIONS MODELS EVALUATION AND SELECTION

By comparison of the investment costs, operation costs and service quality of each operation model, final operating model can be selected (Wu and Shi, 2004).

The flowing costs and index should be considered during this phase:

Fixed cost:

- Machinery and equipment cost
- Decoration cost
- Vehicle cost

Recurring cost:

- Personnel cost
- Facility rental
- Vehicle lease
- Vehicle maintenance
- Vehicle fuel
- Utilities

Three financial index:

- Operation cost per KG
- Operation cost per Move
- Net Presence cost

Two service index:

- Pickup score
- Delivery score

Discuss and rationalize the results and select a final operation model for implementation.

IMPLEMENTATION

The first thing is to put the facility in the right location. The real estate agents may offer more than one option. Select the "best" location site with sufficient floor space. Optimize the floor space utilization to maximize the capacity of the facility in the future.

It might be encountered realistic issues such as not being able to obtain a DC at a preferred location. When it happens, re-rationalize and adjust the plan to make it implementable.

CONCLUSION

It is a very complex project to plan DCs in cities (Jiang and Wang, 2005). This paper goes deep into the detailed steps of the city planning of DCs and provides an effective way to build operation models. It is necessary to do a periodical simulation and evaluation of DCs to respond the changeable market demand.

ACKNOWLEDGMENTS

Jing Sun Author wishes to thank teachers in University of Science and Technology Beijing for their helpful comments and suggestions and thank Ya Sun for her help and support.

REFERENCES

Chen, X.L., 2010. The application of Excel programming solver to facilities location. Ind. Eng. J., 13: 116-118.

Chi, J. and L. Li, 2003. Network's optimize methods of deliver area and deliver paths in logistics. Oper. Res. Manage. Sci., 12: 123-127.

Dong, K.F., H.C. Gan and H.Z. Zhang, 2013. Distribution center location model based on economics and timeliness. J. Univ. Shanghai Sci. Technol., 35: 336-339.

Jiang, Z.Z. and D.W. Wang, 2005. Model and algorithm of location optimization of distribution centers for B2C E-commerce. Control Decision, 20: 1125-1128.

Sun, J. and S.H. Dong, 2013. Study on the delivery area optimization and management. J. Applied Sci., 13: 3730-3735.

Wang, R., Y.Q. Xing and Y. Li, 2012. Distribution prediction and storage space evaluation methods for beverage distribution centers. For. Eng., 28: 107-109.

Wu, J. and Z.K. Shi, 2004. Selection of distribution center's location based on genetic algorithm. J. South China Univ. Technol. (Nat. Sci. Edn.), 32: 71-74.

Xuan, D.D., D.W. Hu and H.L. Lin, 2006. Planning method of city logistics delivery system based on GIS. J. Chang'an Univ. (Nat. Sci. Edn.), 26: 84-87.

Zhang, Y. and J.G. Wei, 2009. Global logistics' situation and Chinese logistics' development. China Bus. Market, 23: 30-33.

Zheng, K. and X.C. Wang, 2011. Location selection of the fruit and vegetable distribution center based on the maximization of service. J. Anhui Agric. Sci., 39: 8760-8763.