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# Pharmaceutical Logistics Forecasting of Beijing: An Exploratory Study

Yanfen Hou[1] and Xiaochun Lu[2]

*[1,2]Beijing Jiaotong University, Beijing, China, 100044*
*13120590@bjtu.edu.cn; xclu@bjtu.edu.cn*

***Abstract***

*Pharmaceutical logistics is closely linked to national economy and people's livelihood. As the national medicine circulation industry development outline (2011-2015) and the new Good Supply Practice's (GSP) promulgation and implementation in China, Beijing's pharmaceutical logistics is facing great challenge. Analyzing the current pharmaceutical logistics service capability and predicting the future medical service demand can help us responding to future changes. In this paper, we have predicted the population of Beijing, analyzing medicine consumption per capita, predicting the demand of pallet spaces of Beijing's pharmaceutical logistics in the future by using the Crystal Ball. We have come to the conclusion: the current storage capability of pharmaceutical logistics enterprises in Beijing can meet 77% demand. In 2020, pharmaceutical logistics enterprises in Beijing require 54, 7700 pallets for storage space, increasing 9,7700 pallets for warehouse to store medicine. We also find that the population has less influence on forecasting model. The logistics technology improvement will cause forecasting model unsuitable for future situation.*

***Keywords:*** *Pharmaceutical Logistics, Warehouse Forecast, Monte Carol Simulation*

## 1. Introduction

China's pharmaceutical industry develops quickly in recent decades. Pharmaceutical logistics is the tie and bridge between medicine and people's livelihood. Pharmaceutical industry's rapid growth make pharmaceutical logistics industry got rapid development.

The national medicine circulation industry development outline (2011-2015) proposed that our country should form one to three annual sales of 10 billion large national pharmaceutical business group and 20 annual sales of billions regional pharmaceutical logistics enterprises by 2015. The first one hundred pharmaceutical wholesale enterprises account for 85% sales of the total pharmaceutical wholesale enterprises. Pharmaceutical retail chain enterprises account for over 60% of the total sales of pharmaceutical retail enterprises. Pharmacy chains increased to more than two-thirds of the total.

On June 1, 2013, China formally implemented the new GSP, which make higher hardware and software requirements on pharmaceutical enterprises, including information system, medicine storage, distribution environment, medicine procurement and *etc.* Under the new GSP management requirements, there are quite a number of pharmaceutical logistics enterprises not meeting the requirements of GSP. For these enterprises, the logistics business must entrust other third party logistics enterprises, which will have a significant impact on Beijing's pharmaceutical logistics industry. Analyzing existing Beijing medical service capability, integrating resources of existing pharmaceutical enterprises and third party medical logistics enterprise, and constructing medical facilities of appropriate scale according to the demand of future medicine can reduce the cost of the medicine and do great help to the development of the medicine circulation.

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In this paper, we analyze medicine consumption per capita and predict the demand of pallet spaces in Beijing's pharmaceutical logistics in the future.

## 2. Literature Review

In recent years, pharmaceutical logistics is developing so rapid. More and more studies begin to focus on medical logistics at home and abroad.

At abroad, Puri, S presented that medicine were not stored and transported the way they ought to be in India. Pharmaceutical companies are facing issues related to choosing and working with the right logistics partners and designing the right system of transportation [1]. Hay, Christian showed us the global identification standards for medicines: from logistics to risk management [2]. Rajeev Narayanapillai put forward a new model based on the evidences from developing country like India to evaluate the inventory management and economic performance of small and medium enterprises [3]. At hom, Yang Jingmei illustrated the importance of logistics industry in the development of pharmaceutical industry in Hebei Province, told us that logistics industry must be first developed before pharmaceutical industry get rapid development [4]. Li Ruifeng showed only the scientific forecast of the supply and demand state of medicine in health service market can improve the medicine supply chain in the pharmaceutical logistics. He optimized the procurement patterns of pharmaceutical logistics enterprises by conducting mixed-strategy solution of medicine procurement in different market states with the matrix game [5]. Zhang Jin studied the genetic algorithm possesses the better optimization quantity and effect in the pharmaceutical logistics distribution routing [6]. Shi Ping did some research on evaluation method of integrated operational performance in medicine logistic, concluding that the customer value and supply chain value are the important indicators of the performance evaluation in pharmaceutical logistics [7]. Zhang Juan gave strategies for pharmaceutical logistics enterprise in China, saying that the pharmaceutical logistics enterprises should take long-term development advice. They should raise their logistics integration to the enterprise strategy management, separate the delivery service from the main business service, and develop the countryside distribution system [8]. Liang Yan focused on the establishment of VMI pattern in medicine storage management and logistics. He compared the traditional ABC analysis method and VMI pattern and brought up a relevant optimization strategy [9]. Cui Linlin studied a case of the pharmaceutical industry in China to show how process-based simulation can be applied to the quantitative studies on the organizational structure reformation. It concluded that the company in the case should improve the specialization of the organizational design, and especially should consider outsourcing the professional logistics service [10]. Shao Lili studied the data of data warehouse and the key technology of designing data warehouse and gave the design scheme of data warehouse model [11].

On the whole, there have a lot of researches about pharmaceutical logistics. We share the common purpose that reduce pharmaceutical logistics cost as much as possible on the premise of meeting the demand. In this paper, we predict the population of Beijing, using the Crystal Ball to analyze medicine consumption per capita, getting storage capability of pharmaceutical logistics enterprises in Beijing, and predicting the demand of pallet spaces of Beijing pharmaceutical logistics in the future.

 

## 3. Modeling Pharmaceutical Logistics Demand in Beijing

In order to forecast pharmaceutical logistics in Beijing, we must know the population in the future and current medicine consumption data. So we investigate 209 pharmaceutical logistics enterprises in Beijing to get survey data.

### 3.1. Population Prediction

The medicine consumption is concern with the population. So our first work is to predict the population in Beijing in the future.

The approach of population prediction can be listed a lot. For example, Malthus population model (also called exponential growth model), the Logistic growth model and power law exponent model are all well-known. Some experiments show that the Logistic model is closer to the statistics data [13-16].

In this paper, the increasing population is described by logistic growth model. It is shown as Equation (1). For Equation (1), by analyzing last 10 years population data of Beijing, we find the population limit *N* is $3.8\times10^7$ properly.

$$N(t)=\frac{N_{\max}}{1+ae^{-bt}} \tag{1}$$

$N_{max}$: the maximum population capacity. In this paper, for Beijing, $N_{\max}$ is set as 38 million persons;

*b*: the population growth rate;

*a*: the constant value;

*N(t)*: population at time *t*. In this paper, t=1,2…20, when *t*=20, the year is 2020.

By the help of SPSS, we do regression analyzing work with the statistics data in Table 1. The regression result is shown in Table 2. From Table 2, we know the R squire of regression is 0.965. The constant $a=6.605\times10^{-5}$, the population growth rate $b=0.83$. All the *p*-value of this regression is less than 0.05. At last, we get the Beijing population growth model as fellow:

$$N(t)=\frac{3.8\times10^{4}}{1+6.605\times10^{-5}e^{-0.83t}} \qquad t=1,2,\ldots20$$

The fitting curve of population growth is shown in Figure 1. From Table 1, we know that the population of Beijing in 2020 will reach 35.857 million, that is $N(t=20)=3.5857\times10^7$ persons.

**Table 1. Beijing's Population (The Statistics and Prediction Value)**

| *t* | *year* | Stat. population ($\times10^3$) | Prediction population ($\times10^3$) | Relative Error |
|---|---|---|---|---|
| 1 | 2001 | 13666 | 12329 | -9.78% |
| 2 | 2002 | 14952 | 13933 | -6.81% |
| 3 | 2003 | 14814 | 15620 | 5.44% |
| 4 | 2004 | 15044 | 17363 | 15.41% |
| 5 | 2005 | 18931 | 19134 | 1.07% |
| 6 | 2006 | 20979 | 20903 | -0.36% |
| 7 | 2007 | 21879 | 22639 | 3.47% |
| 8 | 2008 | 24433 | 24314 | -0.49% |
| 9 | 2009 | 26299 | 25905 | -1.50% |
| 10 | 2010 | 28473 | 27391 | -3.80% |

 

| | | | | |
|---|---|---|---|---|
| 11 | 2011 | 28444 | 28760 | 1.11% |
| 12 | 2012 | | 30003 | |
| 13 | 2013 | | 31119 | |
| 14 | 2014 | | 32111 | |
| 15 | 2015 | | 32982 | |
| 16 | 2016 | | 33741 | |
| 17 | 2017 | | 34398 | |
| 18 | 2018 | | 34963 | |
| 19 | 2019 | | 35446 | |
| 20 | 2020 | | 35857 | |

**Table 2. Significance Testing**

| Equation | Model Summary | | | | Parameter Estimate | |
|---|---|---|---|---|---|---|
| Logistic growth | $R^2$ | F | $df_1$ | $df_2$ | *a* | *b* |
| | 0.965 | 245.434 | 1 | 9 | 6.605E-5 | 0.830 |
| Sig. | 0.00 | | | | 0.00 | 0.00 |

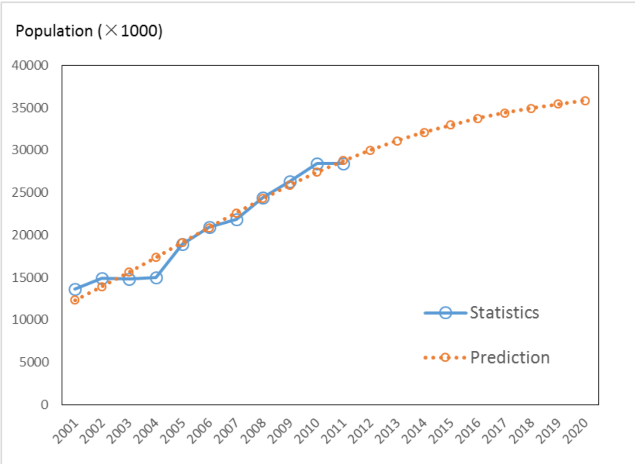


**Figure 1. The Population of Beijing Regression Curve**

### 3.2. The Drugs Consumption for a Person in Beijing Estimation

In order to estimate the pharmaceutical logistics scale of Beijing in 2020, we must know how many medicine bins have been supported in a year. This data can't get directly from survey directly.

We note the drugs consumption for a person as *Y*. Accord Equation (2), we can calculate variable *Y*. In this equation, we note *S* as the total sales revenue for all pharmaceutical logistics enterprises in Beijing. By survey, we get $S_{2012}$= 107.34 RMB billion yuan in 2012. In Equation (2), $N(t=2)$ is the population in 2012. From Table 1, we know that the predicted population of Beijing in 2012 is 30 million.

$$Y = \frac{S_{2012}}{N(t=2) \cdot Prc} \tag{2}$$

*Y*: the random variable about medicine that a person consumed in a year, unit of *Y* is bins/person in a year;

$S_{2012}$: All pharmaceutical logistics enterprises total sales revenue in 2012, unit is RMB/year;

*N(t)* : the population in *t* year in Beijing, unit is persons. When *t*=2, the year is 2012;

*Prc*: the random variable about price of drugs every bin, unit of *Prc* is RMB/bin;

In Equation (2), we note *Prc* as the price of drugs per bin (or per case). It is not a constant value. From survey data we know that the price of drugs every case varies from 8000 yuan/bin to 120 yuan/bin. So *Prc* is a random variable. By analyzing the survey data, the distribution of *Prc* can be get as Table 3 and Figure 2. Obviously it is not uniform distribution or other well-known probability distribution. So we use data in Table 3 as an empirical distribution for random variable *Prc*.

**Table 3. The Distribution of a Medicine Bin Price**

| Drug price of a bin (yuan/bin)-*Prc* | Enterprises | Probability |
|---|---|---|
| 0-1000 | 27 | 0.18 |
| 1000-2000 | 31 | 0.21 |
| 2000-3000 | 20 | 0.14 |
| 3000-4000 | 12 | 0.08 |
| 4000-5000 | 10 | 0.07 |
| 5000-6000 | 15 | 0.10 |
| 6000-10000 | 15 | 0.10 |
| >10000 | 18 | 0.12 |

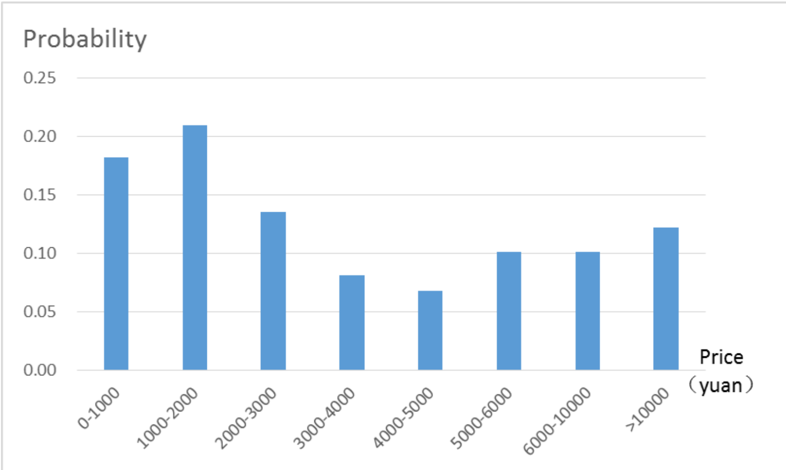


**Figure 2. The Distribution of the Price of Drugs per Bin**

**Table 4. The Probability Distribution of Drugs Consumption for a Person in a Year**

| Drugs Consumption -*Y* (bins/person) | Cumulative probability |
|---|---|
| 0.04 | 0% |
| 0.24 | 10% |
| 0.53 | 20% |
| 0.69 | 30% |
| 0.89 | 40% |
| 1.19 | 50% |
| 1.79 | 60% |
| 2.24 | 70% |
| 2.98 | 80% |
| 5.96 | 90% |
| | 100% |

**Table 5. The Drugs Consumption per Person Simulation Result**

| Statistics | Simulation value |
|---|---|
| Trials | 1,000 |
| Mean | 2.75 |
| Median | 1.26 |
| t value（95% conf.） | 1.96 |
| confidence level | 0.95 |
| confidence interval | 0.28 |
| Mean upper bound | 3.03 |
| Mean lower bound | 2.47 |

Equation (2) is very simple, but we can't calculate *Y* with ordinary method. Because variable *Prc* is uncertainty. So we simulated *Y* by the aid of Crystal Ball (a software of Oracle).

The simulation result of variable *Y* is shown in Table 4, Table 5. From Table 4 and Table 5, we know that for a person the medicine consumption in Beijing is about 2 bins (60%-70% confidence) in 2012.

We assume that the medicine consumption (*Y*) doesn't vary with the time. So the medicine consumption in 2012 is same as in 2020. The *Y* value is the basement we do next work.

### 3.3. The Distribution of Inventory Turnover Time

In order to forecast pharmaceutical logistics in Beijing, we should know the average inventory turnover time and the number of medicine bins loaded on a pallet.

We investigate the turnover time of pharmaceutical logistics enterprises in Beijing. We found that turnover time varies from half of a day to 30 days. The turnover time of distribution is shown in Table 5. We note inventory turnover time as variable *Trn*. From Table 5 we know that the stochastic variable *Trn* does not obey any kinds of distribution. So we set *Trn* as empirical distribution of Table 5 in this paper.

**Table 5. The Distribution of Pharmaceutical Inventory Turnover Time**

| The inventory turnover time-*Trn* (days) | The probability |
|---|---|
| 0-10 | 0.173 |
| 10-20 | 0.162 |
| 20-30 | 0.133 |
| 30-40 | 0.260 |
| 40-50 | 0.064 |
| 50-60 | 0.029 |
| >60 | 0.179 |

### 3.4. The Distribution of Medicine Bins on a Pallet

In order to know how many medicine bins stacked on a pallet in a pharmaceutical logistics enterprise, we investigate survey data. We find that the maximum number of medicine bins stacked on a pallet is 3500 bins. The minimum number is 0.5 bin. The average is 70 bins. Half of the enterprises are less than 20 bins. We note medicine bins on a pallet as *Nbp*. The distribution of *Nbp* is shown as Table 6.

 

**Table 6. The Distribution of the Medicine Bins on a Pallet**

| The number of bins on a pallet -*Nbp*(bins) | Probability |
|---|---|
| 0-10 | 0.22 |
| 10-20 | 0.18 |
| 20-30 | 0.20 |
| 30-40 | 0.15 |
| 40-50 | 0.07 |
| ≥50 | 0.18 |

### 3.5. The Amount of Pallets for Medicine Storage Forecasting

We have predicted the population in Beijing from 2013 to 2020, also have known how many the medicine bins consumed a man in a year as well, and have calculated the distribution of medicine inventory turnover time and the distribution of medicine bins on a pallet.

This section we will calculate the medicine storage space in 2020. Because medicine is stored in bins and stacked on pallets. So if we can get the total number of pallets, the shelves space can be calculated easily and the pharmaceutical logistics demand scale can be estimated.

The formula to calculate the amount of pallets is shown as Equation (3).

$$Plt(t) = \frac{Trn \cdot N(t)}{360 \cdot Nbp} \cdot Y \tag{3}$$

*Trn*: The inventory turnover time, it is random variable, unit is days;
*N*(*t*): the population at time *t*, unit is persons, when *t*=20 , it is 2020 year;
*Y*: the bins that a person consumed in a year, unit is bins/person a year;
*Nbp*: the number of bins stacked on a pallet, unit is bins/pallet;
*Plt*(*t*): the amount of pallets at time *t*, unit is pallets, when t=20, it is 2020 year.

In Equation (3), the variable $N(t=20)$ is got from Equation (1). From 3.1 we know that $N(t=20)= 3.5857\times10^7$. The variable *Y* can be gotten from Table 4, *Trn* can be gotten from Table 5, *Nbp* can be gotten from Table 6.

Then, we run this Equation (3) with Monte Carol Simulation by software Crystal Ball [17-21]. The simulation result about total pallets in 2012 is shown as Figure 3 and Table 7.

**Table 7. The Demand of Total Pallets Simulation Result in 2012**

| Statistic | Simulation values |
|---|---|
| Trials | 1,000 |
| Base Case | 7.45 |
| Mean | $804.5\times10^3$ |
| Median | $109.5\times10^3$ |
| Standard Deviation | $99.4\times10^3$ |
| Mean Std. Error | $83.1\times10^3$ |
| *t* value(95% conf.) | 1.96 |
| confidence interval | $163.1\times10^3$ |
| Mean upper bound | $967.6\times10^3$ |
| Mean lower bound | $641.4\times10^3$ |

The pallets demand simulation mean is $804.5\times10^3$ (varies from $641.4\times10^3$ to $967.6\times10^3$ under 95% confidence). From the simulation result chart, Figure 3, we know that the distribution of pallets demand in 2012 is not normal distribution. Its median value is lower than its mean.

We have surveyed the storage space of pharmaceutical logistics enterprises. The storage space is about is $450\times10^3$ pallets. From Figure 3, we know it just meets the 77% pallets storage space demand in Beijing. Account of the pharmaceutical logistics enterprises actual situation in Beijing, we think this percentage is proper for drugs supply demand. So we set 77% as a standard percentage to judge the simulation of pallets volume (storage space) reasonableness in 2020.

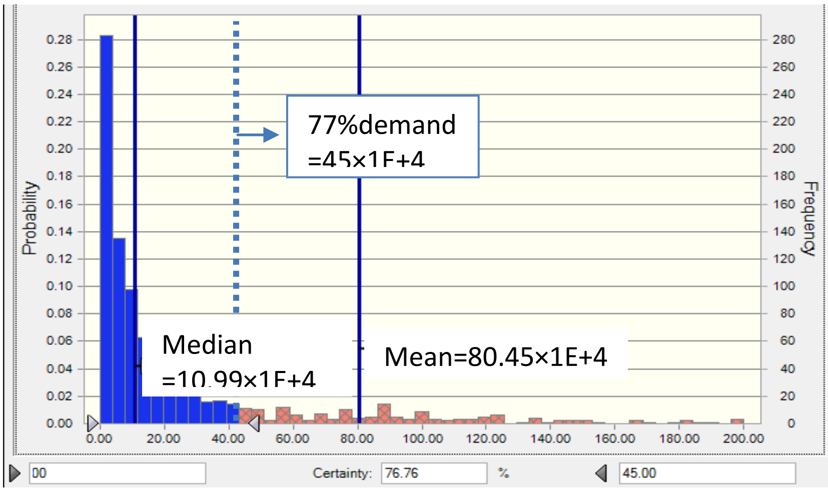


**Figure 3. The Simulation Result of Total Pallets Storage Space Demand in 2012**

Supposing the medicine consumption for every person in Beijing does not vary, that is the variable Y in Equation (3) is constant, we can forecast the pallets storage space demand in the future under 77% certainty. The pallets demand from 2014 to 2020 forecasting result is shown in Table 8. We can see that the pallet spaces demand from 2014 to 2020 in Beijing's pharmaceutical logistics enterprise is growing. When the certainty level is 77%, medicine pallets for storage space in Beijing is 547,700 in 2020, needing 97,700 more than the year of 2012.

**Table 8. The Pallets Storage Space Demand Forecasting from 2014 to 2020 (Under 77% Certainty)**

| year | Pallets( storage space, $\times10^4$) | needing to add more than the year of 2012 ($\times10^4$) |
|---|---|---|
| 2014 | 49.05 | 4.05 |
| 2015 | 50.38 | 5.38 |
| 2016 | 51.54 | 6.54 |
| 2017 | 52.54 | 7.54 |
| 2018 | 53.41 | 8.41 |
| 2019 | 54.14 | 9.14 |
| 2020 | 54.77 | 9.77 |

## 4. Forecasting Model Sensitivity and Reliability Analysis

In the Equation (3), the pallet storage space demand forecasting model, there are four variables influence the calculation result: $Trn$-the inventory turnover time; $N(t)$-the population at time $t$; $Y$-the bins that a person consumed in a year; $Nbp$-the number of bins stacked on a pallet. Because variable $Y$ is calculated from Equation (2), and $Y$ is concern with variable *Prc*- price of drugs every bin, Equation (3) is the model about variables *Trn, N(t), Nbp, Prc*.

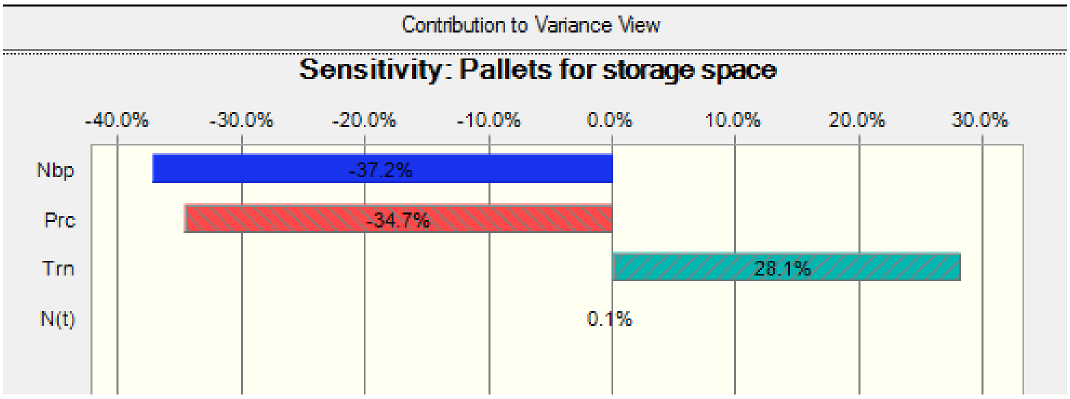


**Figure 4. Forecasting Model Sensitive Analysis**

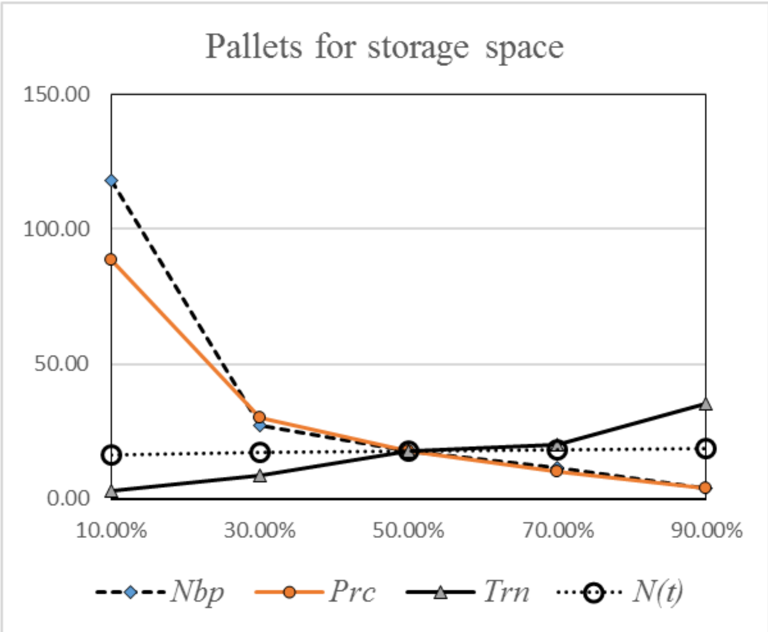


**Figure 5. Total Pallet Spaces Demand Forecast Reliability Analysis**

So we make sensitive analysis of the Equation (3) by Crystal Ball. The result is shown in Figure 4, Figure 5 and Table 9. From Figure 4, we can see the *Nbp* and *Prc* have negative effect on the pallets storage space. These variables have -37.2% and -34.7% contribution to the pallets storage space variance. Whereas the variable *Trn* (the inventory turnover time) have positive Influence. Its contribution to the pallets storage space variance is 28.1%. The population variable *N(t)* growth does not have influence on forecasting model.

From Figure 4, we know that the variable *Nbp* has more influence than *Prc* and *Trn*, so the survey data of medicine bins stacked on a pallet is very important for Equation (3).

The spider charts of variables in Equation (3) is shown in Figure 5, Table 9, Table 10. They are same as Figure 4. From Figure. 4 and Table 9, Table 10, we can get 3 interesting points:

1) When the variable *Nbp* (the bins stacked on a pallet) increases from 10% to 90%, the pallets storage space demand will cut down from 117.43 to 3.84. It tell us that: if in the future, with the logistics storage technology development, more and more bins can stacked on a pallet, the pallets storage space will be saved, and warehouses volume will not be need same as today.
2) The variable *N* (the population) has not the lowest sensitivity ranking on pallets storage space. When population increases form 10% to 90%, the pallets storage space demand increases from 16.31 to 18.79, it is lesser influence. We think the population in Beijing is under strict control, so it will not fluctuate serious and will not impact on pallets storage space demand highly.
3) Table 10 is the variance analysis. The variable *N* explained variation of Equation (3) is less than 1%. It means that we don't need pay more attention to the population issue of Beijing.

**Table 9. Spider Chart Analysis**

| Variable | The pallets storage space demand | | | | |
|---|---|---|---|---|---|
| | 10% | 30% | 50% | 70% | 90% |
| *Nbp* | 117.89 | 27.21 | 17.68 | 11.79 | 3.84 |
| *Prc* | 88.42 | 30.32 | 17.68 | 10.31 | 4.11 |
| *Trn* | 2.95 | 8.84 | 17.68 | 20.04 | 35.37 |
| *N（t）* | 16.31 | 17.29 | 17.68 | 18.32 | 18.79 |

**Table 10. The Variance Analysis**

| | The Pallets for storage space | | | | Input | | |
|---|---|---|---|---|---|---|---|
| Input Variable | Downside | Upside | Range | Explained Variation[1] | Downside | Upside | Base Case |
| *Nbp* | 117.89 | 3.84 | 114.05 | 61.44% | 3.00 | 92.00 | 20.00 |
| *Prc* | 88.42 | 4.11 | 84.31 | 95.01% | 600.00 | 12900.00 | 3000.00 |
| *Trn* | 2.95 | 35.37 | 32.42 | 99.97% | 5.00 | 60.00 | 30.00 |
| *N(t)* | 16.31 | 18.79 | 2.48 | 100.00% | 3,111.90 | 3,585.70 | 3,374.10 |

## 5. Conclusion and Contribution

The paper analyzes Beijing's medicine demand. According to Beijing's population prediction and medicine consumption per capita analysis, the storage capability of pharmaceutical logistics enterprises can meet 77% demand. Basically, it can meet the need of Beijing's pharmaceutical logistics. In 2020, pharmaceutical logistics enterprise in Beijing require 547,700 pallet storage spaces, needing to increase 97,700 new pallets storage spaces compared with 2012.

By sensitive analyzing, the paper finds that the bins number stacked on a pallet is a more important variable, it will influence the forecasting accurate. Another interesting finding is that the population growth rate is less important variable. It has trivial influence on pallets storage space forecasting.

In the future, we will pay more attention on the logistics technology improving. Because it will cause the variable (the bins stacked on a pallets) changing, and will cause the forecasting accurate lower.

 

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