

Research on Constraints of Fresh Fruit Logistics Development Based on Structural Equation Model

Taking Xinjiang as an example

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Abstract—Xinjiang, as one of six biggest fresh fruit production areas in the world, is recognized as a major fresh fruit production base in China and honored as “home of melon and fruit”. With its suitable ecological environment, unique climate conditions, and good location, Xinjiang sells its fruits well all over the world. However, with the development of fruit market outside the autonomous region, the advantages of fruit in Xinjiang nowadays are not so obvious than before. From the perspective of fruit logistics, this paper, based on the data collected and organized from questionnaires and related researches on modern fruit logistics, builds a evaluation indicator system for the constraints of fruit logistics development in Xinjiang, determines the critical factors, and develops structural equation path diagrams. It was found that 9 constraint factors are ranked in the following sequence in view of their influencing power on the development of fruit logistics in Xinjiang, that is, transportation time, transportation cost, preservation technology, storage cost, squeeze and decay loss, handling loss, packing technology, and packing cost. Finally, scientific and reasonable suggestions and recommendations are put forwards to help realize the efficient development of modern fruit logistics in Xinjiang.

Keywords—modern fruit logistics; structural equation model (SEM); constraint; evaluation indicator system; Xinjiang

I. INTRODUCTION

Xinjiang covers a vast geographical area and has abundant resources, which determines that the development of Xinjiang depends largely on high-speed and convenient transportation or the development level of

logistics.^[1] The statistic data shows that well-developed areas of fruit industry in Xinjiang include Kashi Prefecture, Akesu Prefecture, Production and Construction Corps, and Bayingolin Mongol Autonomous Prefecture, where the logistics industry development lags behind, which is a primary reason for low efficiency of fruit industry development.

Modern fruit logistics patterns include modern logistics distribution, supermarket, auction, and e-commerce. Traditional logistics pattern with poor efficiency and simplicity no longer meets the requirements of modern logistics, so we should pay attention to setting up technical fruit distribution center (DC), and developing chain delivery and cold-chain delivery. In other words, improving transportation efficiency is the top priority for the development of modern fruit logistics system in Xinjiang.^[2]

There is an obvious discrepancy between the development of fruit logistics industry and the fruit cultivated area and aggregate output of the fruit in Xinjiang. The backward logistics technology and high logistics cost result in low effectiveness and efficiency of fruit logistics, which in turn has a strong negative impact on the further development of fruit industry in Xinjiang.

Fruit logistics abroad developed relatively well than that at home, which reflects from three aspects. From the perspective of fruit preservation technology, Xie Tiyu introduced such fruit preservation technology and methods as edible fruit preservative, plastic moisture-penetrability film, and low tension preservation storage.^[3] Liu Beichen proved that developed countries with strong economic

power take leading position in preservation technology.^[4] As for packing technology, Gao Hongjun held the idea that preservation and freshness of agricultural products is an important step in agriculture processing.^[5] Chen Kewei, et al. introduced a preservation assistant—postharvest green preserving.^[6] As to refrigerated transport, Xie Ruhe proposed that different transport modes need transportation facilities with different structures and requirements.^[7] There are a lot of research achievements in the respect of fruit logistics. Zhangyan, taking citrus for example, came up with policy suggestions for fruit transportation model construction on the basis of supply chain management.^[8] Yan Ying brought forward network strategies such as social net site (SNS) marketing strategy, regional guiding strategy, and product guiding strategy to improve fruit chain logistics.^[9] Tian Baolong analyzed adverse conditions for fruit transaction information construction, and built a Xinjiang featured fruit transaction informatization platform.^[10] Zhang Xiaoliu found the problems in fruit logistics system in Xinjiang on the basis of comparison with developed countries having advanced fruit logistics system like America, Netherlands, and Japan.^[11] The previous research and studies on fruit logistics mainly focus on qualitative analysis and there are few quantitative studies on fruit logistics industry especially on the development of fruit logistics industry in Xinjiang. In this case, this paper expands the present research methods.

Section II describes the current situation of fruit industry and fruit logistics industry in Xinjiang, which provides foundation for evaluation indication selection and model building. In Section III, the evaluation indicator system for fruit logistics and the structural equation model for the fruit logistics in Xinjiang are established. Section IV, based on the results gotten from the model, some suggestions and recommendations are proposed for further development of modern fruit logistics in Xinjiang. From the perspective of theory, this paper introduces modern advanced logistics management concept to the development of fruit logistics in Xinjiang and enriches the application of SEM. From the perspective of practice, improving storage and preservation technology from the fruits' harvest to sales and improving hardware facilities of fruit logistics will realize low logistics cost and maximize economic benefits and social benefits.

II. CURRENT DEVELOPMENT SITUATION OF MODERN FRUIT INDUSTRY AND ITS LOGISTICS IN XINJIANG

A. Current Development Situation of Modern Fruit Industry

TABLE I. CULTIVATED AREAS OF FOUR FRUITS IN XINJIANG FROM 2009 TO 2013

Year	Apple (hektare)	Pear (hektare)	Peach (hektare)	Grape (hektare)
2009	38.5	73.1	11.7	108.8
2010	55.3	69.5	12.8	114.7
2011	55.3	69.5	12.8	114.7
2012	73.3	68.8	14.6	125.3
2013	83.3	69.9	12.9	135.5

This paper collects specific data of the cultivated area and output of main fruits in Xinjiang, namely, apple, pear, peach, and grape. It should be noticed that melon, apricot, and pomegranate are excluded because of lack of information and effective data. The cultivated area and output of the fruits with complete data are drawn in a broken line graph, and the development trend is marked, in order to reveal the current development situation of modern fruit industry in Xinjiang.

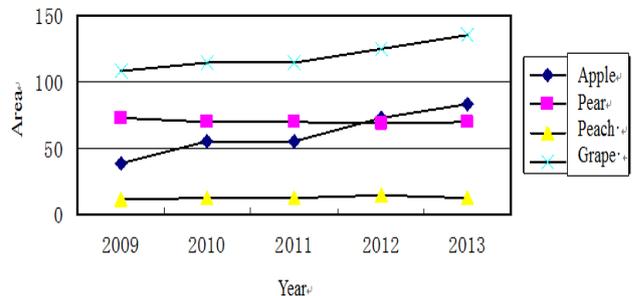


Figure 1. A broken line diagram for cultivation area of fruits in Xinjiang from 2009 to 2013

It can be shown from fig.1 that the cultivated area of apple and grape tends to increase year by year, and the cultivated area growth of pear and peach becomes stable during 5 years, only with slight growth fluctuation. Table 2 shows the output of main fruits in Xinjiang, the data of which comes from Xinjiang Statistics Yearbook.

TABLE II. ANNUAL OUTPUT OF FRUITS IN XINJIANG FROM 2009 TO 2013

Year	Apple (ton)	Pear (ton)	Pear (ton)	Grape (ton)	Grape (ton)
2009	435392	692831	61447	1648718	131413
2010	535058	874988	109212	1754725	1057983
2011	535058	874988	96306	1932157	289950
2012	658728	1052854	104713	1965695	627319
2013	715136	605730	109212	1754725	1057983

According to the Table 2, a broken line diagram for the annual output fruits is drawn to show the changing trend of the fruits' output in Xinjiang. It is clearly shown in Fig. 2 that the output of apple increases by years; the output of date drops sharply in 2010 and then recovers in the following 3 years; the output of grape increases at the first years and reaches peak in 2011 but decreases in 2012; the output of pear increases between 2010 and 2011 but declines in 2013; and the output of peach stays almost unchanged for 5 years.

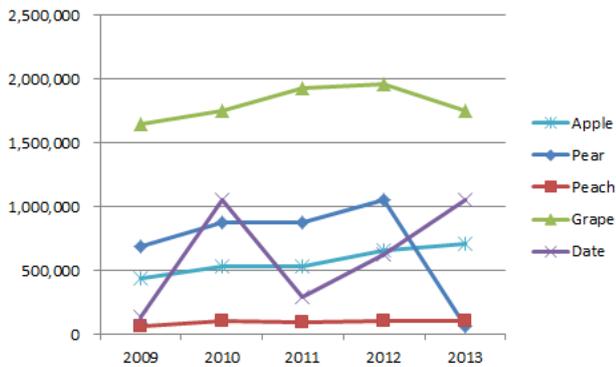


Figure 2. A broken line diagram for cultivation area of fruits in Xinjiang from 2009 to 2013

It is also seem that the cultivated area of fruit in Xinjiang has increased by 274, 300 hectare, 38% in terms of percentage, and the output in 2013 increases 5,442,185 ton that that of 2009, 66% in terms of percentage. The data shows the overall cultivated area and annual output increase every year, so the fruit industry in Xinjiang has a large development room and it is one of the industries driving the economic development of Xinjiang.

B. Current Development Situation of Modern Fruit Logistics Industry

The total mileage of highway in Xinjiang has reached 86,637 kilometers (included 24,306 kilometers from Production and Construction corps), in which express way accounts for 431 kilometers, first-level highway 437 kilometers, second-level highway 6,631 kilometers, and third-level highway and below takes up 54,832 kilometers. Civil cars in Xinjiang are about 500,000 sets, in which commercial passenger and cargo vehicles accounts for 180,000 sets. Among four common transportation modes, highway transportation undertakes 95% of whole passenger transport and 83% of freight transport, both of which are far higher than the average level 91% and 75% respectively. 15 highway border ports and 53 international passenger and freight multi-model transport lines are set up to connect with neighborhood nations. The entry passenger traffic reaches 186,000 person - time, and freight transport volume is 1,432,000 tons.^[12]

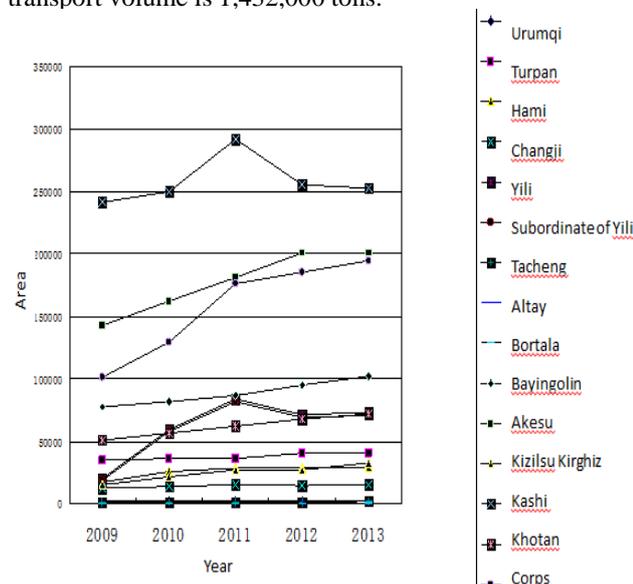


Figure 3. Cultivated area of fruit in different prefectures, states and cities in Xinjiang from 2009 to 2013

It is shown clearly that the top four areas with large cultivated area are Kasi Prefecture, Akes Prefecture, Production and Construction Corps, and Bayingolin Mongol Autonomous Prefecture. It is interesting that most of the areas with large output volume have backward logistics facilities.

III. CONSTRAINTS INDICATOR SYSTEM BUILDING

A. Constraints Indicators

There are various factors influencing the development of fruit industry in Xinjiang. This paper choose three dominants aspects, namely logistics efficiency, logistics technology, and logistics cost and establishes an indicator system for constraints of the development of fruit technology in Xinjiang.

The development of modern logistics in Xinjiang is an endogenous variables and a set with multiple factors. Logistics efficiency, technology level and logistics cost are three exogenous variables which are influenced and reflected by other sub-level exogenous variables. Therefore, three first-level indicators and 9 second-level indicators are selected as the research variables, which are shown in the following table 3.

TABLE III. EVALUATION INDICATOR SYSTEM FOR FRUIT LOGISTICS IN XINJIANG

	First-level indicators	Second-level indicators
Evaluation indicators for fruit logistics	logistics efficiency	transportation time
		handling loss
		squeeze and delay loss
	technology level	packing technology
		preservation technology
		transportation equipment technology
	logistics cost	packing cost
		storage cost
		transportation cost

Based on the above table, four hypotheses are made as following.

Hypothesis 1. The higher the logistics efficiency, the more significant the influence on the development of fruit logistics is.

Hypothesis 2. The higher the technology level, the more significant the influence on the development of fruit logistics is.

Hypothesis 3. The lower the logistics cost, the more significant the influence on the development of fruit logistics is.

Hypothesis 4. The logistics efficiency can be represented by transportation time, handling loss, and squeeze and decay loss; the technology level can be represented by packing technology, preservation technology and transportation equipment technology; logistics cost can be represented by packing cost, storage cost and transportation cost.

TABLE IV. KMO AND BARTLETT'S TESTING

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.673
Bartlett's Test of Sphericity	Approx. Chi-Square	316.794
	Df	82
	Sig.	.000

B. Data Selection

The data chosen in this paper is collected by questionnaires and interviews. The investigation subjects come from four relatively developed areas for fruit planting, Kashi Prefecture, Akesu Prefecture, Production and Construction Corps, and Bayingolin Mongol Autonomous Prefecture. The questionnaire divides the grade into 5 levels, namely, very insignificant, insignificant, significant, relatively significant, and very significant, which are corresponded with 5 marks, 1, 2, 3, 4, and 5. The total number of questionnaires sent is 240, and 203 are returned back. 6 ones that cannot meet the requirement are recognized as invalid and excluded. Finally, 197 questionnaires are gotten, which means the returning back of questionnaires is 82.1%.

C. Reliability and Validity Analysis

Reliability refers to the possibility that the same observation results will be gotten for the same subjects with the same observation methods. Only one measurement method has higher reliability, can the results gotten from the method have reference significance. Cronbach's α coefficient is used for reliability analysis, and the calculation equation is as following.

$$\alpha = \frac{K}{K-1} \left(1 - \frac{\sum S_i^2}{S_x^2} \right) \quad (1)$$

SPSS17.0 is used to analyze the reliability of the data collected. After the examination, Cronbach's α coefficient is 0.8453, which proves the high reliability of the measuring table.

Validity refers to the effectiveness of data measuring table, that is, the tool can measure the property of subjects correctly, genuinely, and objectively. The validity of measuring table is judged by KMO parameter test and Bartlett test to prove if the sample is suitable for factor analysis. SPSS17.0 is used for validity analysis of research data.

Computational equation for KMO statistics is as following.

$$KMO = \frac{\sum_{i \neq j} r_{ij}^2}{\left(\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} p_{ij}^2 \right)}, \quad (2)$$

where K is the number of measured questions, S_i^2 is the variation number of the grade of a question, and S_x^2 is the variation number of sum of the measurement.^[13]

Factor analysis method is used for testing the validity, and the method drawing common factor derives from principal component analysis (PCA) in which factor rotation satisfies variance maximization. The range of KMO is between 0 and 1. The closer the KMO is to 1, the more suitable for factor analysis, vice versa.

The validity results are shown in table 4. After testing, the value of KMO is 0.673, which means the scale is suitable for factor or component analysis. Given the significant level is 0.05, the value of Approx. Chi-Square

is large and the value of p is less than 0.05, which passes Bartlett's test.

It can be seen from the table 5 variance contribution rate that 3 principle components before rotation can explain 35.42%, 20.219% and 14.53% of total variance of 9 original exogenous testing, and cumulative variance contribution rate reach 72.633% which can reflect most of information of the original variables. The cumulative variance does not change after factor rotation, but the variance which is used for explanation of original variables is reallocated and the variance distribution of each factor is changed for practical explanation.

TABLE V. VARIANCE CONTRIBUTION RATE

Component ^o	Extraction Sums of Squared Loadings ^o			Rotation Sums of Squared Loadings ^o		
	Total ^o	% of Variance ^o	Cumulative % ^o	Total ^o	% of Variance ^o	Cumulative % ^o
1 ^o	2.841 ^o	35.472 ^o	35.472 ^o	2.606 ^o	32.538 ^o	32.538 ^o
2 ^o	1.547 ^o	20.219 ^o	56.670 ^o	1.845 ^o	26.139 ^o	57.221 ^o
3 ^o	1.102 ^o	14.538 ^o	72.633 ^o	1.260 ^o	20.717 ^o	76.482 ^o

The characteristic value below change slowly, so omitted.^o

IV. CONSTRAINTS ANALYSIS BASED ON SEM

A. SEM Model

Structural equation modeling (SEM), as a kind of linear statistics modeling technology, is widely used in the field of management for data analysis and hypothesis testing. In simple words, the mathematic modeling of SEM is composed by two parts: measurement equation and structural equation.^[14] The former describes the relationship between latent variable and observational variable, while the latter describes the relationship between latent variable. The measuring equation and structure are list as follows.

$$\mathbf{X} = \mathbf{A} \boldsymbol{\xi} + \boldsymbol{\delta} \quad (3)$$

$$\mathbf{Y} = \mathbf{B} \boldsymbol{\eta} + \boldsymbol{\varepsilon} \quad (4)$$

$$\boldsymbol{\eta} = \mathbf{B} \boldsymbol{\eta} + \mathbf{\Gamma} \boldsymbol{\xi} + \boldsymbol{\zeta} \quad (5)$$

where \mathbf{X} denotes the exogenous measuring variable vector, \mathbf{Y} the endogenous variable, $\mathbf{A} \boldsymbol{\xi}$ the relationship between exogenous latent variable and their observational variable, $\mathbf{B} \boldsymbol{\eta}$ the relationship between endogenous latent variable and their observational variable, $\boldsymbol{\xi}$ exogenous variable, $\boldsymbol{\eta}$ endogenous variable, $\boldsymbol{\delta}$ the difference of endogenous measuring variables, and $\boldsymbol{\varepsilon}$ the difference of exogenous measuring variables. \mathbf{B} represents the regression coefficient of endogenous latent variable, $\mathbf{\Gamma}$ the influences of endogenous latent variable towards exogenous latent variable, and $\boldsymbol{\eta}$ the part which cannot be explained in the equation.

The SEM is built following four steps. The first one is model building. SEM is used for analyzing the relationship

of variables. A theoretical model is built in accordance with professional knowledge and research objectives, and the rationality of the model is tested on the basis of information and data which cover the relationship between observational variable and latent variable, the interrelationship between latent variable, and the numerical value and relationship of parameters limiting factor weigh or relation coefficient. The second step is model fitting. The model fitting in SEM analysis aims to approximate the implied covariance matrix of the model, also called regeneration matrix, with the sample covariance matrix as far as possible. The frequently used parameter estimation methods include un-weighted least square method, generalized least squares method, maximum likelihood method, general weighted least square method, opposite angles general weighted least square method, among which this paper adopts the mostly widely-used parameter estimation method. The third one is model evaluation. The tasks for evaluating a newly built or modified model are to examine (1) whether the solution of the structural model is appropriate, including the convergence of iteration estimation and the reasonable range of the value of parameter estimation; (2) the relationship between parameter and preset model; (3) global fit index for different types. The last step is model modification, which is composed of the tasks below. Firstly, one or several prior models are proposed according to theories and related hypotheses. Secondly, examine the relationship between the latent variables and indicators, and establish a measurement equation model. Thirdly, if there are multiple components in the model, two components are selected to be examined, and all components are integrated into the preset prior model when part of the two components examine results are verified reasonable. Fourthly, standard error, standardized residual, modified index, parameter expectation value alternation, χ^2 and other fitness indicators are examined for each model, based on which the medication is conducted.

B. Constraints SEM Model Building

Constraints SEM model building for modern industry logistics in Xinjiang is to determine the weight of 9 constraints according to the data gotten from the questionnaire. The 9 constraints are regarded as the variables for the model. The SEM path diagram is built by using AMO 4.0, as is shown in fig. 4.

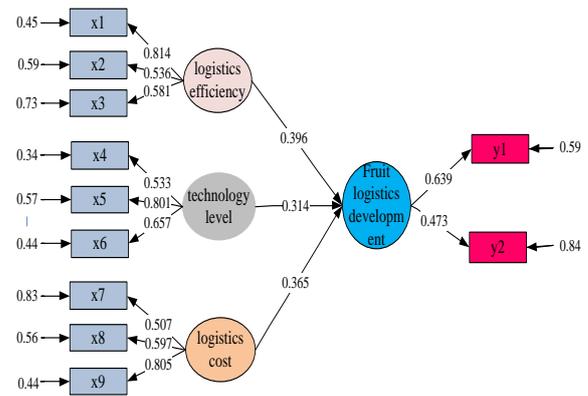


Figure 4. Constraint SEM for the development of modern fruit logistics industry in Xinjiang

According to the fitness result of the structural equation, the four propositions put forward in section 3 are verified and discussed.

Verification for Hypothesis 1. It can be seen from fig. 4 that the path coefficient of logistics efficiency is 0.396, the value of t is 2.674 which is larger than reference value 2, and there is a significant effect. In this case, hypothesis 1 is verified that the high logistics efficiency will improve the development of modern fruit logistics in Xinjiang.

Verification for Hypothesis 2. It is shown in fig. 4 that the path coefficient of technology level is 0.314, the value of t is 3.541, which is larger than reference value 2, and there is a significant effect. In this case, hypothesis 2 is verified that the improvement of technology level will improve the development of modern fruit logistics in Xinjiang.

Verification for Hypothesis 3. It is gotten from fig. 4 that the path coefficient of logistics cost is 0.365, the value of t is 3.207, which is larger than reference value 2, and there is a significant effect. In this case, hypothesis 3 is verified that the reduction of logistics cost will improve the development of modern fruit logistics in Xinjiang.

Verification for Hypothesis 4. The value of t corresponding with path coefficient between latent variable and observational variable is larger than reference value 2 except packing cost, which reveals that the 90% of the relationship between latent variable and observational variable is significant in terms of reliability, which in turn proves it is reasonable and feasible to reveal latent variable by means of the observational variable.

The output results show the relationship between the variables.

The path coefficient of influencing factors for the development of modern fruit logistics in Xinjiang is listed in order as following: logistics efficiency, logistics cost, and technology level.

The path coefficient of influencing factors for modern fruit logistics efficiency is listed in order as following: transportation time, handling loss, and squeeze and decay loss.

The path coefficient of influencing factors for modern fruit logistics technology level is listed in order as following: preservation technology, transportation equipment technology and packing technology.

The path coefficient of influencing factors for modern fruit logistics cost is listed in order as following: transportation cost, storage cost and packing cost.

V. SUGGESTIONS AND RECOMMENDATION FOR THE DEVELOPMENT OF MODERN FRUIT LOGISTICS INDUSTRY

In accordance with SEM results, this paper put forward suggestions and recommendations for the development of modern fruit logistics industry in Xinjiang mainly from such three aspects as logistics efficiency, technology level and logistics level.

- The influence of logistics efficiency on the whole development level is most significant. Therefore, logistics efficiency improvement should be put in the priority, followed by logistics cost. The most critical factor in the improvement of modern fruit logistics industry is logistics efficiency, and transportation time plays the most significant role in logistics efficiency improvement. The transition time should be shortened, and fruit logistics pattern should be normalized to improve the efficiency of fruit logistics, in order to realize the substantial development of fruit logistics industry in Xinjiang. The improvement of logistics efficiency can be realized by formulating a unified standard for fruit logistics. Highly-efficient logistics process should be supported by standardized logistics operation. The fruit logistics has the characteristics of long processing, large batch, and repetitive picking and handling. If the processing of grading, packing and tagging, storing and transporting is standardized, the efficiency of fruit logistics will be improved significantly. For example, update the logistics equipment. Backward trolley and manual tricycle should be replaced gradually by such mechanized and automated handling machines as forklifts, conveyor belt. Trays used for fruit logistics can be allowed to go along with fruits, which is convenient for handling and transportation. Another way to increase efficiency is packing standardization including size and material standardization. Bar code can be printed on the surface of packing to reduce counting time and make real-time tracking. In view of prevalent grade specification made by farmers or vendors, the specification methods can be standardized to reduce the time spending on site selection.
- Technology level is also an important influencing factor for the overall development of modern fruit logistics in Xinjiang. Modern fruit logistics should be supported by informationization. The information sharing between logistics participants can eliminate uncertain factors resulted from information amplification. With the development of Social Network Service (SNS), many information platforms with good service quality are emerging, such as micro-blog, WeChat. Those information platforms have large quantities of users and strong push function. It is urgent to upgrade preservation technology especially for those fruits decaying easily. With the help of information technology, farmers and vendors can

make up virtual alliances and cooperate with each other to complete the transportation and distribution operation. On one hand, logistics participants at the same level can adopt common transport, storage and packaging, which can realize scale development. On the other hand, logistics participants at the upstream and downstream can make a clear labor division, for example, farmers divide the fruits into different grades and specifications when picking and wholesalers conduct sample testing, which can reduce logistics time.

- As for the logistics cost reduction, logistics cost cut is an important influencing factor. Therefore, the logistics path should be optimized with consideration of the choice of packing material and packing patterns. Firstly, The standardized logistics processing and the do's and don'ts can be printed and sent out to logistics participants to reduce the training expenditure, and avoid unnecessary losses caused by human factors. Secondly, third party logistics suppliers can be encouraged to provide specialized service for fruit logistics. In this way, farmers, wholesalers, retailers can get good logistics service with low cost and reduce their investment on logistics equipment and technology. Thirdly, a logistics centers based on the areas of origin can be built. The centers can provide one package or whole-sale service to suppliers including preservation, storage, packing, and transportation services, as is shown in fig.5.^[15]

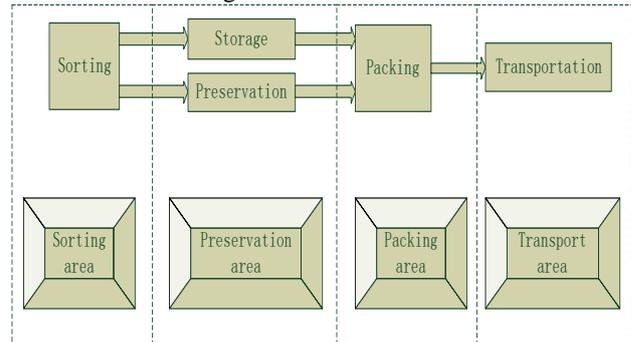


Figure 5. The Flow of Logistics Service in Origin area of Wholesale Market Logistics Center

VI. CONCLUSIONS

From the perspective of modern fruit industry development, this paper collects data, and proves that both the reliability and validity are appropriate for component analysis. On this basis, a structural equation path diagram is drawn. In accordance the path coefficient, 9 constraints influencing the development of modern fruit logistics industry in Xinjiang are determined in order as following: transportation time, transportation technology, transportation equipment technology, storage cost, squeeze and decay loss, handling loss, packing technology, and packing cost. Finally, scientific and constructive recommendations and suggestions are proposed for further development of modern fruit logistics industry.

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