Research on Integration of Livestock Products Supply Chain Based on the Optimal Match Between Supply and Demand

Liang Zhao, Yong Huang[(✉)], Zhusheng Liu, Mingcong Wu, and Lili Jiang

Business School, Sichuan University, Chengdu 610064, People's Republic of China
huangyong_scu@aliyun.com

Abstract. China is a big country on livestock production and Chinese livestock products output value is increased yearly. However, Chinese livestock products are still mainly dominated by self-employed farmer's production mode which leads to imbalance between supply and demand, periodic fluctuations in prices. In this paper an integration of livestock products supply chain is proposed to solve the imbalance problem. A sample of a duck farm is chosen to show the process of the integration. First a discrete-event simulation model is built by the supply chain which is composed of hatching, breeding, and packaging and transporting. Then production plan, transport routes and the number of fixed assets are adjusted to achieve the goal that the mean of supply-demand ratio is close to 1 and the variance is close to 0.

Keywords: Livestock products · Supply chain · Duck farm · Integration · Discrete-event simulation

1 Introduction

China is a big country on livestock production and Chinese livestock products output value is increased yearly. However, the construction of livestock products supply chain (LPSC) is inefficient. At present, Chinese big enterprises in the livestock products market have just started the integration of supply chain, and the livestock products market is still mainly dominated by self-employed farmer's production mode. Farmers neither share their information nor have any plans for production, so it leads to the imbalance between production and market demand. Once a product is sold well, farmers flock to produce it blindly. Then the price will fall, and farmers will switch to produce other products sold well, finally becoming a vicious circle. In addition, the production of livestock products has many shortcomings, such as low levels of automation, decentralized farmers. If we want to integrate the supply chain, the issue that matches supply with demand must be met. When the farmers make production plans, they're faced with the situation that demand is stochastic and production plans must be decided before they know the real demand [1]. From the experience of developed countries

for agricultural development, scale management on livestock products has an incomparable cost advantage. Therefore, this paper considers building integrated livestock products supply chain (ILPSC) to solve the mismatch between supply and demand.

The process of production, cultivation, processing, transportation and sale in LPSC will produce added value. Therefore, the LPSC is a value-added supply chain from upstream to downstream. However, if a peasant-oriented platform is just simply built, the information provided for each other may not be entirely true due to the opportunism between enterprises in supply chain. It is difficult to realize the information sharing in practice and this will cause supply and demand imbalance, eventually to make market price fluctuations. Building the ILPSC and formation of close cooperation are the emphases, which can integrate the information flow in the supply chain. But in the implementation process, there are still many issues to be resolved, such as the determination of the assets number, production planning and transportation routes. This paper builds an ILPSC model with simulation software, aimed at matching supply with demand, and eventually using a sample to prove the effectiveness and feasibility of the ILPSC model.

This paper is organized as follows. In Sect. 2, relevant literatures are reviewed. In Sect. 3 the ILPSC model is shown and analyzed. In Sect. 4, an empirical model of duck supply chain is presented and the supply-demand radio of the model is optimized. Section 5 gives some conclusions.

2   Literature Review

LPSC is a kind of agricultural products supply chain. Chinese research on agricultural supply chain started in 1999, and LPSC was later introduced. Chen and Luo [2] put forward the idea of building a new Chinese LPSC by adding the information agent to provide a scientific decision-making for strengthening the supply chain management of Chinese LPSC. Zhou [15] proposed some conclusions to promote the healthy and stable development of the pig industry. Yu and Li [14] proposed the market operation mode and structure of livestock products were no longer a single entity competition of production, processing and sales. The survival and development of livestock products were more and more dependent on the overall quality and comprehensive strength of the whole industry chain. In the basis of this, the supply chain model of the combination of third-party logistics and livestock products was used to improve the whole efficiency of LPSC. Wang and Huang [12] put forward the SCOR model of agricultural products based on information network, and constructed the agricultural supply chain logistics management mode under the information network environment. Then through the empirical analysis of Shanghai freshwater supply chain logistics management mode, they proved the effectiveness and practicability of agricultural logistics supply chain management mode. Liu, Sun and Wang [4] found that the researches of Chinese agricultural supply chain were mainly concentrated on the traditional mode of operation of agricultural supply chain, fresh

agricultural products at the end of the supply chain supermarket and information technology under the traceability system and e-commerce environment. And he believed that the establishment of a new integrated production and marketing supply chain and circulation system to achieve the circulation of agricultural products and information network management, could make Chinese agricultural products enter further into the global supply chain.

Compared with China, the United States, the Netherlands, the European Union, Japan and other developed countries have been perfect on the development of agricultural supply chain, so there are many researches about LPSC, especially about beef and pork supply chain. Birthal and Pratap [10] proposed that the revolutionary progress in livestock production was demand-driven. The income elasticity of demand was higher compared to most other food commodities. And livestock would have a larger effect on poverty reduction compared to crop sector. Facchioli [3] used a computational simulation system tool to coordinate its flow of matter and information. Piewthongngam [8] developed a system dynamics model as a tool for managers to visualise the movement of the entire production chain. William, Norina and Cassavant [13] thought SCRA was a "production adjustment & consumer-driven" systems. Van Roekel, Kopicki and Broekmans [11] gave the basic four steps in the development of agricultural supply chains. Simchi and Kaminsky [9] pointed out that information sharing and task planning was the key to integrating supply chain. Min and Zhou [5] summarized the methods and applications of integrated supply chain modeling. It provided a reference to establishment of the ILPSC. Pan and Jean [7] analyzed the link between pork supply chain in China and the United States, and put forward that a mechanism of enterprises and peasants, a sound logistics operation system and an information network platform should be established so that the efficiency of Chinese pork processing supply chain could be improved. Robert and Jon [6] used a visual modelling environment to overcome the problems involved in implementing simulation models.

3   Model Description

3.1   Integrated Livestock Products Supply Chain Model

The ILPSC model refers to the integration of all members in the LPSC, based on the common goals, to achieve true sharing of information and integration of supply, production and sale. Figure 1 shows the whole ILPSC model, and there are mainly four parts. The first part is the process of producers which contains capital goods suppliers and flows. Capital goods suppliers weekly produce pups as per production plan which is designed by demand. Then, a collection of several suppliers makes up a flow. The combined production of a flow is kept together when it moves through the model. The second part is the process of manufacturers for a period of breeding activities. The third part is the process of processors where livestock products are processed and packaged. The fourth part is the process of sending products to market.
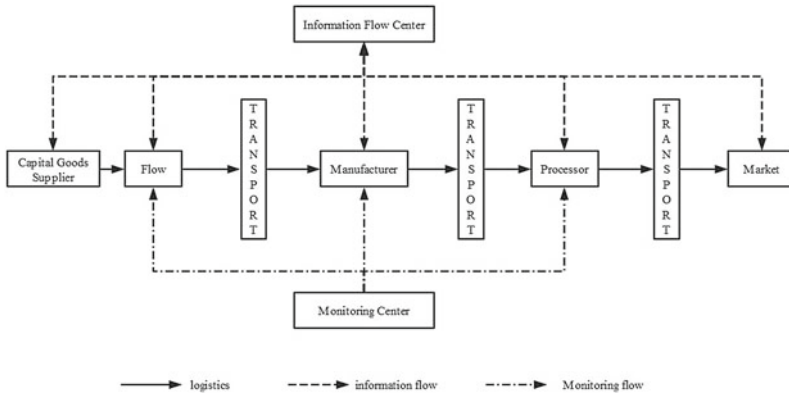
Fig. 1. The integrated livestock products supply chain model

In the whole model, the information flow center makes information flow in the whole supply chain smoothly and shares the information with every part in the model. At the same time, reasonable decisions are made on all links of the supply chain through the integrated information, such as production plan and transportation routes. And early in the supply chain construction, it can determine whether the number of assets to meet the market demand number by the weekly market demand plan. Monitoring center is mainly for flows, manufacturers and processors. Among them, the flows and manufacturers are mainly concerned about the health condition of livestock. What we want to monitor is whether the livestock are sick, whether the disease is contagious and whether the sick livestock are dead. In addition, the weekly sales of processors should be monitored, because the processor needs to sell products to the market weekly. And a batch of products is sent to market several weeks.

The ILPSC model is a two-way driving model. That is, on the one hand, the model needs the production plan of the most upstream companies to push the entire supply chain, on the other hand, it needs the final market demand to pull. Therefore, it's necessary to forecast market demand to pull the production to guarantee the matching of supply and demand information, and then push the production through the production plan. Events in the model take 1 week.

The goal of the model is to strike a balance between the supply of livestock products to market and the demand of the market. The supply-demand ratio can be used to response the situation about balance of supply and demand. Therefore, whether the target is achieved or not can be determined by analyzing the mean and variance of all processors' corresponded supply-demand ratio. If the mean of it is close to 1 and the variance is close to 0, it can be proved that the target is achieved. And a sub-goal may exist, such as the cost. The rule to transport products can be considered, when the transporter works. Distance between different parts in the model is affected by the rule, and the cost is affected by the distance. There are some uncertain factors in the model which is concerned

with the goal of the model. The first one is the uncertainties associated with the health condition of livestock. It includes whether the livestock are diseased, which type of health episodes is caught, whether it has died after the illness and which week after the illness is the time livestock dead. Secondly, the week when the livestock products are sent to the market is also an uncertainty factor. All of them will affect the number transported to the market, through the uncertain production losses for the entire system caused by themselves. In this paper, these uncertainties are solved by simulation model.

The ILPSC model is suitable for livestock products, which mainly refer to livestock and poultry meat, and livestock including pigs, cattle, sheep and so on, poultry including chickens, ducks, geese and other poultry meat and wild birds. The characteristics of livestock products include that the number of production can be counted, production cycle is long, the sickness can result in uncertain production losses, it's easily restricted by the size of the farm, it will be transported between different farms and processing and packaging are needed.

3.2   Model Entities, Variables

To build a discrete-event simulation model, entities and variables must be determined.

Model entities. Livestock, transporters, capital goods suppliers, flows, manufacturers and processors are used in the ILPSC model as model entities.

Model variables. There are 12 variables in the ILPSC model, and the details are shown in Table 1.

3.3   Analysis of Model Process

There are many process in the model, and the processes of health condition and selection of flows to manufacturers are the most important and analyzed.

(1) Health Condition Process
Livestock may get sick during the breeding process, and the type of diseases may be different. The infectivity of different types of diseases is also different. If the disease is infectious, the diseased livestock need to be isolated from other healthy livestock. The flow chart of the process is shown in Fig. 2.

(2) Selection of Flows to Manufacturers Process (based on the shortest distance rule)
When livestock are transported from flows to manufacturers, a transportation rule can be considered such as the shortest distance rule. It is preferable to transport the products to the available manufacturer who is the nearest to the flow. At the same time, the number of livestock transported will be constrained by the capacity of transporters and manufacturer's assets. The flow chart of the process is shown in Fig. 3.

Table 1. Variables of ILPSC model

| Variable name	Variable description	Notes
Transfer week	The number of weeks in the model before to be sent to the market	Updated weekly when the value is 0, it will be sent to the market in the week
Health condition	0 is showed healthy, 1 is showed sick	
Health episode	The type of illnesses, using 1 n as disease 1 disease n	
Sick week	The number of weeks before a sick livestock dead	Updated weekly when the value is 0, it will be dead due to illness
Week	The number of weeks the model runs	
Quarter	The number of quarters the model runs	
Min mile#	The nearest distance between the flow and the nearest available manufacturer	# is the number of flows, $1, 2, \cdots, m$
Supply#	The number of livestock products supplied to markets weekly	# is the number of processors, $1, 2, \cdots, t$
Transporter#	The number of livestock delivered by a transporter	# is the number of flows, $1, 2, \cdots, m$
Ill livestock#	The number of sick livestock per week for each flow	# is the number of flows, $1, 2, \cdots, m$
Rate#	Weekly supply-demand ratio	# is the number of processors, $1, 2, \cdots, t$
SD Rate#	The difference between the mean of the Rate# in the simulation period and 1 the value is closer to 0, the matching rate is higher	# is the number of processors, $1, 2, \cdots, t$
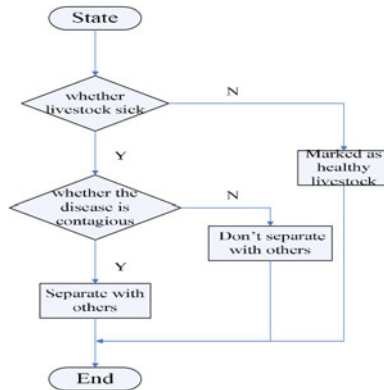
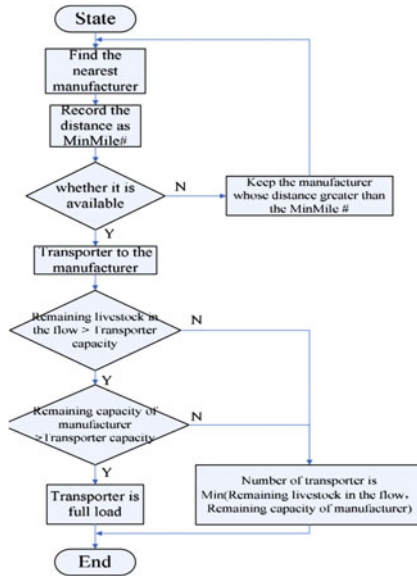**Fig. 2.** The flow chart of the health condition process

Fig. 3. The flow chart of the selection of flows to manufacturers process

3.4   Model Optimization Rules

To achieve the goal, the model needs to be optimized. There are many parts in the supply chain will have an impact on the goal. In this paper, three factors are mainly considered including the asset numbers of manufacturers, production plans and transportation routes.

(1) The asset numbers of manufacturers
It refers to the number of assets in the supply chain where manufacturers breed livestock. Manufacturers are used to breed pups provided by capital goods suppliers, and it's the key to connecting upstream and downstream of the supply chain. Therefore, when the production plans of capital goods suppliers have been decided with the change of the market demand, the asset number of manufacturers should change accordingly. So, whether the asset number of manufacturers is enough must be first determined in the establishment of the model. Only when the number of manufacturers' assets is sufficient can the model continue to be optimized.

(2) The production plans
A production plan is a schedule of the number of pups produced by capital goods suppliers. It directly determines the approximate size of the livestock products that are ultimately sent to the market. Therefore, the sum of livestock products transported to market will be closed to the sum of market demand by optimizing the production plan.

(3) The transportation routes

Transportation routes refer to the routes that transporters deliver livestock between the links of the supply chain. This paper mainly considers the route between manufacturers and processors. Since processors have their corresponding markets, processed livestock products can be distributed evenly by adjusting the routes, when the sum of supply is close to the demand.

4   Empirical Analysis

4.1   Model Overview

The empirical data in this article refers to the competition of the 2016 Arena Simulation Student Competition: Rockwell Duck Farm Supply Chain Optimization. Two schedules will drive the simulation model of the farm system: a market schedule, and a hatching farms schedule.

There are currently about 75 hatching farms in the system which produce a total of approximately 100,000 ducks each week. Hatching farms breed ducks per the hatching farms schedule, and a collection of several hatching farms makes up a flow to move together. The order for transport is carried out in descending order of flows and finds the nearest available growth/finish farms to receive the ducks with the shortest distance rules. Production will be affected by the health condition of ducks. There are four diseases to ducks showing in Table 2. The probability of getting sick in four quarters of every hatching farm and prevalence of the four diseases are based on the data provided in the competition.

Table 2. Four diseases to ducks

Disease types	Requires separation?	Sick weeks (week)	Output loss (%)
DED Exposed ($Disease_1$)	No	4	0.25
DED Naive ($Disease_2$)	No	4	1
DRRS Non-Vaccinated ($Disease_3$)	Yes	8	0.4
DRRS Vaccinated ($Disease_4$)	Yes	8	0.1

There are currently about 230 growth/finish farms in the system. The farms receive the ducks from the hatching farms until it is full. Ducks are breeding 22 weeks in the growth/finish farms. Because disease_3 and disease_4 need to be separated from other ducks, the growth/finish farm_27, growth/finish farm_199, growth/finish farm_1564, growth/finish farm_65, and growth/finish farm_179 are selected to receive the ducks suffering from the two diseases, which are relatively closer to each station.

There are 11 packers/plants in the system. After packaged and processed, ducks are sold for 6 weeks, the proportion shown in Table 3.

Table 3. Proportion of ducks sent to market weekly

Sales week	Sales ratio
Week 1	0.04
Week 2	0.08
Week 3	0.2
Week 4	0.25
Week 5	0.25
Week 6	0.18
Sum	1

Ducks are transported by truck in the system and each truck is loaded with 2,600 ducks. A distance matrix defines the miles between a central point of a flow's location to a particular growth/finish farm. The simulation time is two years or 104 weeks. Figure 4 shows the supply chain model of the duck farms established with visual simulation software. The lower left part of the facility interface is 75 hatching farms, the top part is 230 growth/finish farms and the lower right part is 11 packers/plants.
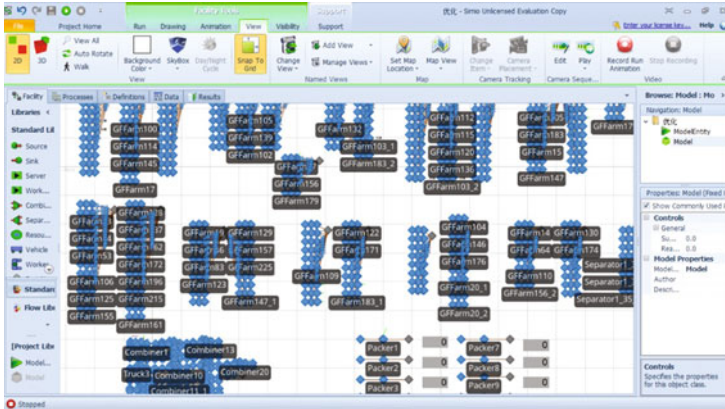

Fig. 4. The ILPSC model of duck farms established with visual simulation software

4.2   Model Optimization

When the model is run, it's found to be incorrect. The number of farms is insufficient to accommodate the duck. Therefore, there need more farms to meet the extra expectations. 16 growth/finish farms near the 16 flows are selected to form a group, three groups added. After running the model again, it's found that the supply of packer/plant$_5$ is zero. Therefore, transportation routes are adjusted per

the results of operations. It's mainly solved through adjusting the corresponding packers/plants of the new three groups to the packers/plants whose supply is obviously insufficient. To find the optimal production plan, an experiment needs setting up. The controlled variable for the experiment is the number of hatchings per week for 75 hatching farms. The target is SD Rate# of 11 packers/plants. SD Rate# in 40 scenarios is shown in Fig. 5.
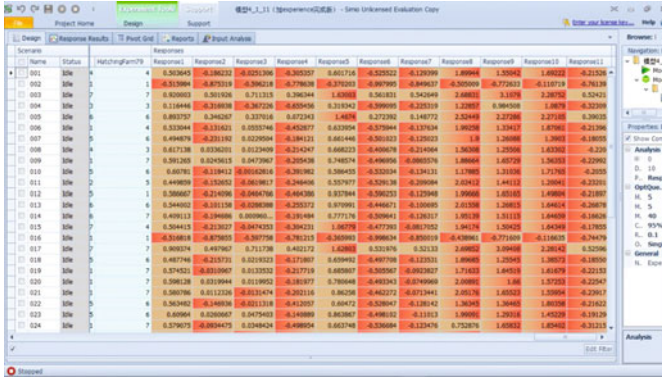

Fig. 5. SD Rate# in 40 scenarios after running experiment

Since the ultimate goal is to achieve the match of supply and demand, it can be achieved by finding a scenario where the supply-demand ratio is closer to 1 and the SD Rate# is closer to 0. Therefore, by comparing the mean and coefficient of variation (CV) of the absolute value of the SD Rate#, the scenario can be found where the mean and CV are closer to 0. It proves that the number of supply and demand is closer. An mean-CV line chart is shown in Fig. 6.
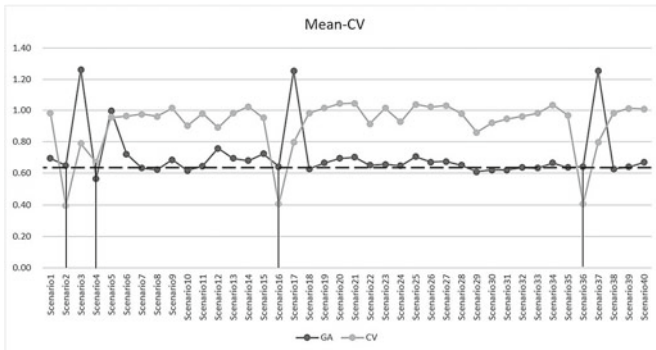

Fig. 6. Mean-CV line chart for 40 scenarios

Table 4. The adjustment scheme based on the result of experiment

Parker 1	Parker 2	Parker 3	Parker 4
G/F farm 15_4	G/F farm 65_4	G/F farm 63_2	G/F farm 54_4
G/F farm 20_4	G/F farm 179_4	G/F farm 20_2	G/F farm 183_4
G/F farm 63_4	G/F farm 224	G/F farm 36	G/F farm 16_4
G/F farm 147_4	G/F farm 178	G/F farm 207_4	G/F farm 76
	G/F farm 205_4	G/F farm 220_4	G/F farm 64
			G/F farm 16_2
			G/F farm 156_1

Parker 6	Parker 7	Parker 8	Parker 10
G/F farm 222	G/F farm 14	G/F farm 66	G/F farm 27_4
G/F farm 211	G/F farm 30	G/F farm 206	G/F farm 199_4
G/F farm 210	G/F farm 145		
G/F farm 209	G/F farm 208		Parker 11
G/F farm 95	G/F farm 34		G/F farm 156_4
G/F farm 213	G/F farm 17		
G/F farm 150	G/F farm 148		

The mean and CV of scenario 2,4,16,36 are all suitable. Finally, the production plan of scenario 4 is selected. Then the model is ran again and the transportation routes from the growth/finish farms to the packers/plants are adjusted based on the results. The adjustment scheme is shown in table 4(G/F farm represents Growth/Finish farm). Since the supplies of packer/plant$_5$ and packer/plant$_9$ are sufficient, they are not shown in Table 4.

The line graphs between the supply and demand of the 11 packaging plants in the original and the optimized model are shown in Fig. 7.

From Fig. 7, it can be seen the fluctuation range of the optimized model's supply is decreased compared with the original model, and supplies of every packer/plant are basically fluctuating up and down in demand. The supply-demand ratio of the original model and the optimized model is compared, as shown in Table 5. And the line chart is shown in Fig. 8.

According to Fig. 8, it can be seen that the overall supply-demand ratio of the 11 packers/plants of the optimized model is close to 1, and the fluctuation is obviously reduced. There are three changes seen from Table 5 the mean of supply-demand ratio of 11 packers/plants is reduced by 0.0836, the standard deviation is reduced by 0.6979 and the variation coefficient is reduced by 0.6478. Although the mean of the original model is also close to 1, the standard deviation is 0.8142 which means it is very volatile. And the standard deviation and the coefficient of variation after optimization is closer to 0, it can be seen that the optimized model can make the match of supply and demand better.

Fig. 7. The line graphs between the supply and demand of the 11 packaging plants in the original and the optimized model during 28-104th weeks

Table 5. The supply-demand ratio of the original model and the optimized model

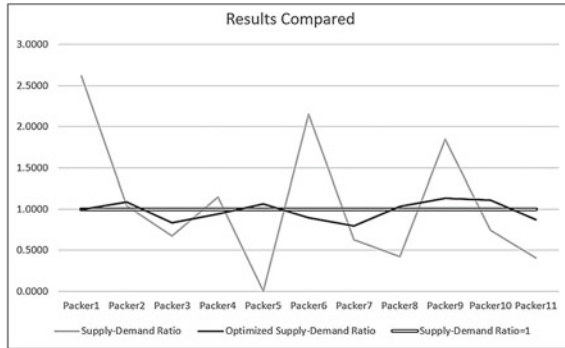| Packer number	1	2	3	4	5	6	7
Supply-demand ratio	2.6161	1.0385	0.6777	1.1512	0	2.1518	0.6294
Optimized supply-demand ratio	0.994	1.0853	0.832	0.9447	1.0613	0.8967	0.7984
Packer number	8	9	10	11	Mean	*SD*	*CV*
Supply-demand ratio	0.4204	1.8445	0.7463	0.4056	1.062	0.8142	0.7667
Optimized supply-demand ratio	1.0332	1.1317	1.1111	0.8735	0.9784	0.1163	0.1189

Fig. 8. The line chart for the supply-demand ratio of the original model and the optimized model

5   Conclusion

This paper establishes an ILPSC to integrate the entire supply chain, which ultimately matches the supply and demand of livestock products. The whole process of the ILPSC from the upstream capital goods suppliers to the downstream market is introduced, including the information flow center and the control center to control the information flows and uncertain factors. Then, an integrated supply chain model for a duck farm is constructed with simulation software. In the example, the number of assets in the growth farms is added, and the production plan of the hatching farms and the transportation routes between the growth farms and the packing plants are optimized. Finally, the mean of supply-demand ratio of the 11 packing plants is reduced by 0.0836, the standard deviation is reduced by 0.6979 and the variation coefficient is reduced by 0.6478. The construction of the ILPSC is a quite complex problem. Though the ILPSC can represent most of the integrated process of livestock products, it also can be extended to other aspects, for example, the question on reduction of transportation costs, and the question on increasing utilization of growth farms.

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