SYSTEM APPROACH TO THE MODELLING OF THE PROCESS OF EGG PRODUCTION ON THE FARM

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Abstract

This document presents a dynamics model of producing eggs on a farm using the system approach and methodology of system dynamics. We used system approach because it was about a continuous dynamic process. Our aim was to describe dynamic process of egg production and how production, numbers of hens and eggs stocks are changing after the modification of variables, demand and number of orders. The first part generally describes the process and the direction in which it will be developed. After that the subjects of the process and their role have been pointed out. The next thing was to describe how the process of the production functions in details with all its elements, objects and connections. In the second part we have presented the system flow chart diagram. The information has been obtained from the interview with people who were included in the work on that farm as well as from the observation.

Key words: *system approach, dynamic, egg production*

1. PROCESS OF EGG PRODUCTION

1.1. Introduction

The subject of this research is the process of egg production. The analysis process is based on a systematic-dynamic approach. The process of egg production is a continuous process due to delay[1] in changing the production capacity (number of layers) and a short shelf-life products (eggs) cannot be viewed separately from the production capacities and market. Therefore, the analysis of the process of egg production requires a holistic approach whereby the individual elements of the egg production is placed in the context of the whole system. The basic elements of the system analyzed in this paper are manufacture, supply, demand and the number of hens, which affects the creation of new levels of production.

The production flow within the system is based on modern concepts of the table eggs production. From an economic standpoint, changes in demand in the current business conditions significantly increases costs in the production process. With the previously mentioned characteristics of the process, according to other characteristics it is similar to other manufacturing processes in which market and demand affect the inventory level and production level. Therefore it is necessary to set up a model system based on the feedback to work when the balance changes in demand for products, eggs. Observing the behaviour of the system before and after the change it is necessary to answer the few questions: How the elements of the system responds?, How many delays are in the adjustment of production and demand? What is the amount of stock? What should be the level of production to comply with the requirements of the market in the shortest possible time, but taking into account the specificity of the observed process? How many new layers do we

[1] Roberts Nancy (2001), Introduction to delays

need? Etc. Given answers will provide an easier planning production and contracting new business for selling eggs.

The observed model is a farm of hen for producing eggs. It is smaller to medium size with a capacity about thousand hens average. It is located outside of Split at around 15 km away but the market is oriented to the Split-Dalmatia County, Croatia. Largely represented wholesale from retail. The current way of planning at the farm is ad hoc. There are major suppliers with whom is pre-agreed amount of eggs for delivery so we know how much to produce. Other fluctuations of demand in certain periods of the year are dealing with the accumulation of inventories. Hens that are no longer feasible to hold at the facility, are replacing regularly with new every month, about 10% of them is replaced.

1.2. Defining System

As already mentioned the basic function of the system is production of eggs. The process of producing eggs at the farm begins with production process which is performed by laying hens, and the final products are eggs. Thus produced eggs are stored and create inventories that are specified as condition at the time. The desired level of production is determined on the basis of information about stocks. Production is determined by the number of hens and their fertility. When we multiply these two values we get daily egg production (1).

Production = 'Condition of laying hens' * Productivity (1)

The number of layers is taken as the current situation that exists in the observed time while their productivity is constant that is observed as the average value. It was therefore necessary to measure during their stay in production where they stay until they realize maximum.

The stock of eggs is reduced by delivery to customers. So each new delivery is the output from the stock, while the production is input. This helps maintain a balance that is achieved by a steady demand for eggs. In order to be able deliver eggs there are orders on the basis of which we can do the delivery. The level of demand is determined by the number of orders for our eggs. As the number of orders increases / reduces so does the demand increases / reduces. Information about orders is going to demand. A variable change in demand is defined by several variables (2). Variables affecting the change in demand are: old demand, orders and the grace period of contracts because it is still a continuous dynamic model and needs changes in time.

Change in Expected Demand = ('Order rate'- 'Expected Demand')/'Grace period of delivery of eggs' (2)

Information about the state of demand is going to the desired level of inventories and the desired level of production. Desired inventory level is average condition that we want in stock every day. It is determined by multiplying the demand and numbers of days how much we want to keep covered with stocks (3).

Desired Inventory = 'Expected Demand' * 'Desired duration of stock' (3)

Demand also affects on desired level of production. It is the penultimate step towards the production, and has an indirect influence on it. The desired level of production is determined by the current state of stocks, preferred stocks, demand and the duration of the contract (4).

Desired production rate = 'Expected Demand'+ ('Desired Inventory'-Inventory)/'Duration of the contract' (4)

Desired level of production determines how much we want to produce eggs daily. Since the hens are the main input in the production, the desired production level affects the number of hens. The required number of layers we learn from the desired level of production because it has defined the desired quantity of products, eggs. The required number of layers is obtained by dividing the desired production rate with a yielding capacity of our hens, which average is 1 egg per day (5).

The required number of hens = 'Desired production rate'/ Productivity (5)

Condition of laying hens is required by desired production rate. To achieve that number of laying hens, at first its state must have the necessary information on required number of layers, and that provides the variable required number of layers by an information link. Condition of laying hens increases with procurement of new and reduces with ejection of spent hens from the current production. Acquisition of new is determined by how many of them we have now, the necessary number, how many of them were thrown out of the production and how much time we need to purchase new ones. After a fertile period of hens on the farm is over we throw them out of production.

1.3. Problems of management system of egg production and their causes

Nothing in this world is perfect and so our system, which has curtain problems. The main problem we identified is the existence of certain oscillations during each year. After examining the operation of the observed farms there were found variations in specific periods. During the holidays, especially Easter and Christmas, the demand for eggs increases. Everyone needs eggs to make cakes and biscuits. This causes a sudden increase in orders on which there is no answer.

The causes of problem lie in the inability of short-term increase in capacity. Namely, if we try to answer on that increasing demand and we increase the level of production, then we need to get new hens. Later, when demand returns to previous level we have a surplus of laying hens on the farm that we cannot use or pay off. Then we have to reduce capacity and lose money because we did not pay the acquisition of new layers. Generalization of the problem is according to the general problem of short-term increase in production. Specifically, each laying in average has two years of a fertile period for laying eggs and in that time we need to make revenue. This means that any agreed period which is less than two years presents a problem because it is necessary to intervene in the price of eggs which is extremely low in today's business environment.

It is precisely the application of system dynamics will allow the development of models that should allow the adjustment of the above parameters in order to minimize the deviation of demand and production. *System dynamic believe that the availability of a product, rather than its rate of production, affects the market price and demand. This means that the inventory (or backlog) of a product is a major determinant in setting price and regulating demand.* **(**Economic supply & demand By Joseph Whelan, Kamil Msefer, 2003)

2. DEVELOPMENT OF DYNAMIC SYSTEMS MODEL

2.1. System dynamics

System dynamics is a way of understanding the behavior of complex systems over time. It affects on behavior of the system using feedback loops and time delays. It is created by Jay Wright Forrester[2]. In the second half of the 20th Century, this scientific discipline has developed after appearing more and more complex systems, and when their numbers began to increase. Developing the computer technology increases the possibility of its application by producing simulation. In system dynamics it is important to detect patterns of behavior by observing the interactions of all events. There are four specific types of behavior. The causal loop diagrams with positive and negative feedback loops are describing the systems. Today there are several software packages, system dynamics: Dynamo, Vance and Powersim.

2.2. Modeling the structure of the system

Based on the description of the system from the previous chapters in the following figure shows is the causal diagram of the resulting action between the observed variables.
Arrows indicate the direction of causal effects, while the sign indicates the type of connection between the observed variables[3]. The meaning of FBL abbreviation, in Figure 1, is Feedback loop. Thus the observed

[2] Leslie A. Martin,(1997) „The First Step“
[3] Garača, Ž. (2010), „Business process simulations“, System dynamics, Faculty of economics, University of Split, pp. 13.

structure must be translated into a mathematical computer model. In this paper, we used a computer program Powersim[4]. Powersim is software tool for creating models and running simulations.

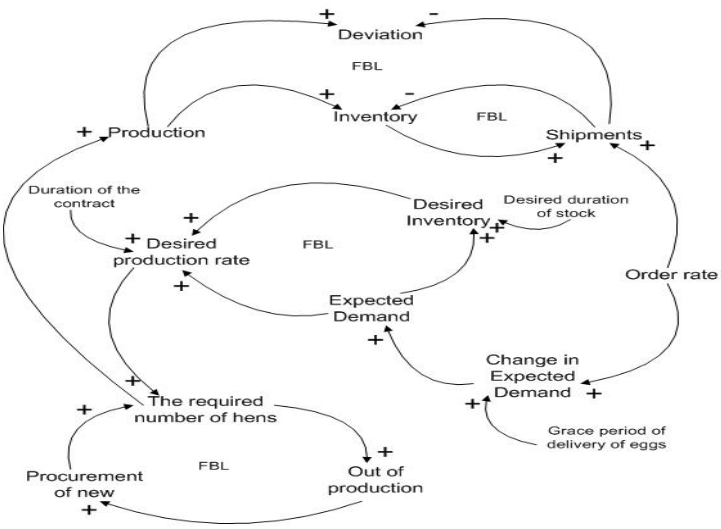


Figure 1 Causal Loop Diagram

2.3. Flowchart

The first step in the software tool is the creation of a flowchart according to the previously described structure. Each of these symbols represents a different element in the system.

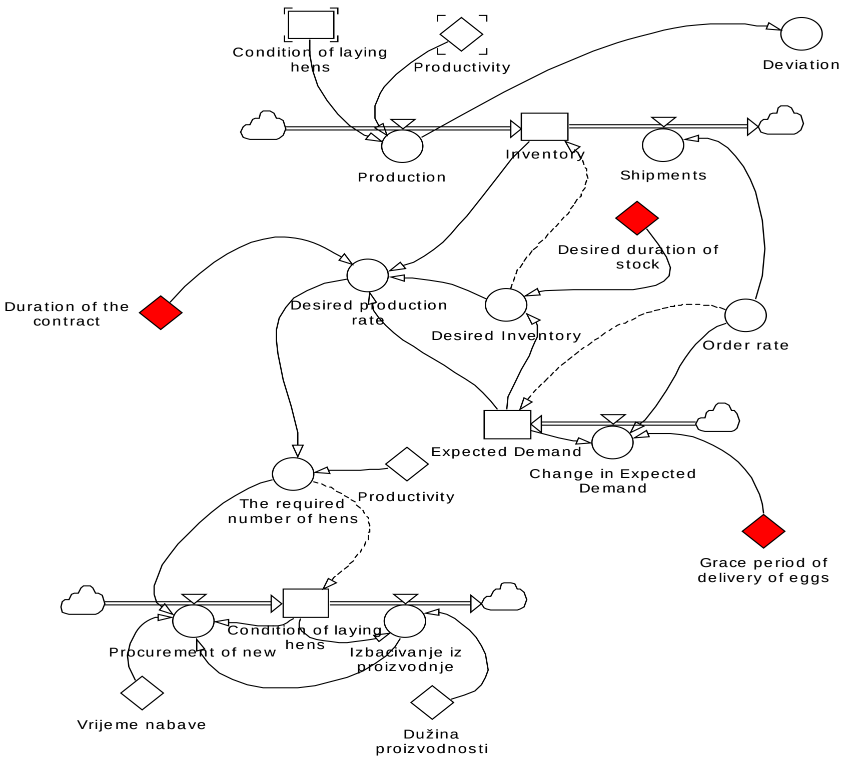


Figure 2 Layout of computer model

[4] http://www.powersim.com/[20/09/10]

Square symbols denote the state of the system and according to mathematical point of view presents a summary function (integration). Circles presented changes of the system in time and they perform mathematical operations that can edit in every particular facility. Rhombs are constants. In order to simplify the presentation of a model we used shortcuts (angular border point symbols). In the reference model for visibility, constants were tinted in order to manipulate the system. Changing their values we observe how the system is changing and how it reacts to various scenarios.

2.4. Basic equations

The mathematical basis of system dynamics involves two basic equations, the system of state and changes. Two types of basic equations: equation of state (6)

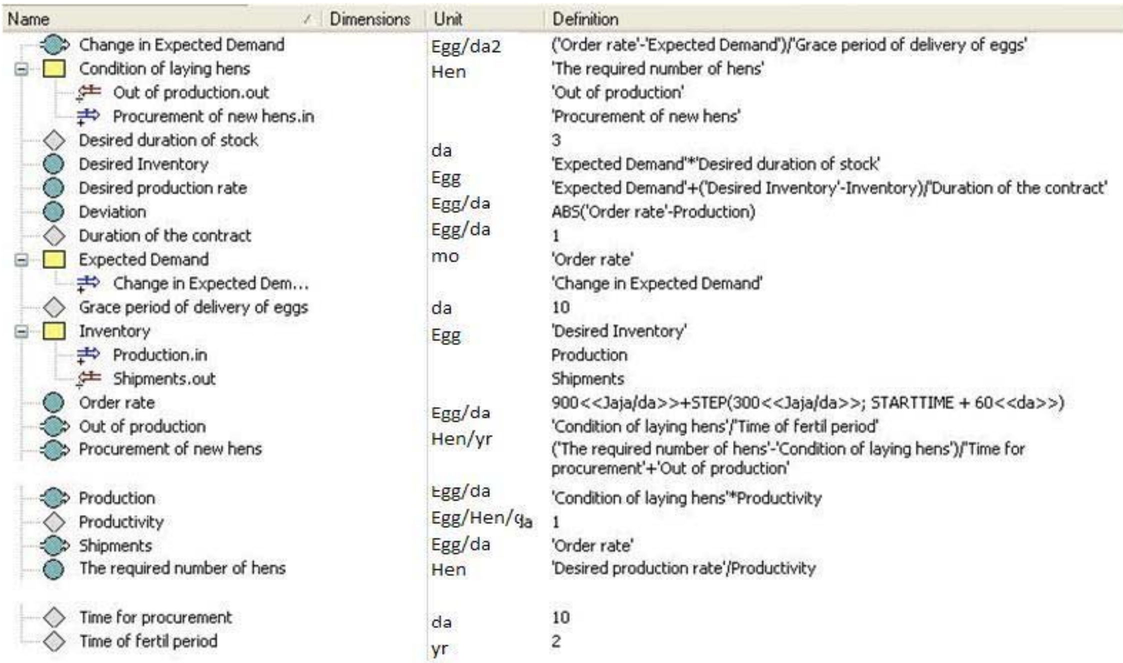
$$\mathit{State\ of\ the\ System}\ (t) = \mathit{Initial\ state} + \int_0^t [\mathit{In}(t) - \mathit{Out}(t)] * dt \qquad (6)$$

and the equation of changes in the conditions which describes the dynamics of state changes in time.

Below is one equation from our model, for example equation state of inventory (7) in the reference period can be described with following equation:

$$\mathit{Inventory}\ (t) = \mathit{Desired\ Inventory} + \int_0^t [\mathit{Production}\ (t) - \mathit{Shipments}\ (t)] * dt \ (7)$$

The table below shows the variable of computer model with the corresponding symbols, names, units and equations.



Name	Dimensions	Unit	Definition
Change in Expected Demand		Egg/da2	('Order rate'-'Expected Demand')/'Grace period of delivery of eggs'
Condition of laying hens		Hen	'The required number of hens'
Out of production.out			'Out of production'
Procurement of new hens.in			'Procurement of new hens'
Desired duration of stock		da	3
Desired Inventory		Egg	'Expected Demand'*'Desired duration of stock'
Desired production rate		Egg/da	'Expected Demand'+('Desired Inventory'-Inventory)/'Duration of the contract'
Deviation		Egg/da	ABS('Order rate'-Production)
Duration of the contract			1
Expected Demand		mo	'Order rate'
Change in Expected Dem...			'Change in Expected Demand'
Grace period of delivery of eggs		da	10
Inventory		Egg	'Desired Inventory'
Production.in			Production
Shipments.out			Shipments
Order rate		Egg/da	900<<Jaja/da>>+STEP(300<<Jaja/da>>; STARTTIME + 60<<da>>)
Out of production		Hen/yr	'Condition of laying hens'/'Time of fertil period'
Procurement of new hens			('The required number of hens'-'Condition of laying hens')/'Time for procurement'+'Out of production'
Production		Egg/da	'Condition of laying hens'*Productivity
Productivity		Egg/Hen/da	1
Shipments		Egg/da	'Order rate'
The required number of hens		Hen	'Desired production rate'/Productivity
Time for procurement		da	10
Time of fertil period		yr	2

Figure 3 Computer model layouts

In the first column there are names of variables with associated symbols. In the third column there are units of measure in which variables are expressed. And in the forth column there are equations which define variables in the computer model.

3. SIMULATION

Upon completion of the model the same one was tested on the basis of historical data. Data were collected from conversations and interviews with the leader of the observed farms. The simulation was conducted in one year with a time step of 7 days. The program is running scenario where changes in product demand increases with 300 units after 60 days. It is necessary to determine how the system adapts and returns to the steady state.

3.1. Scenario 1. : Initial state

The results of the simulation scenarios are shown in Figures no 4th and 5th. The first graph shows the changes in demand and production occurred after the change in quantity of orders.
According to the scenario after 60 days there has been an increasing demand for 300 eggs. It has influenced the change in demand, which reacted with a delay but soon equalized with an order. After that, we can see that the production responds the last and the last began to change and grow rapidly and even exceeds the desired level of production because it has been set to create the stock for three days. Then rapidly falls, but till the end of the second quarter production it has been equated with demand and has been once again able to fulfill all orders. This reaction of production is adverse reaction because as we can see on the curve of production, it has created a high and sharp peak, which causes us problems because of the rapid increase in production and then decrease in the short term.

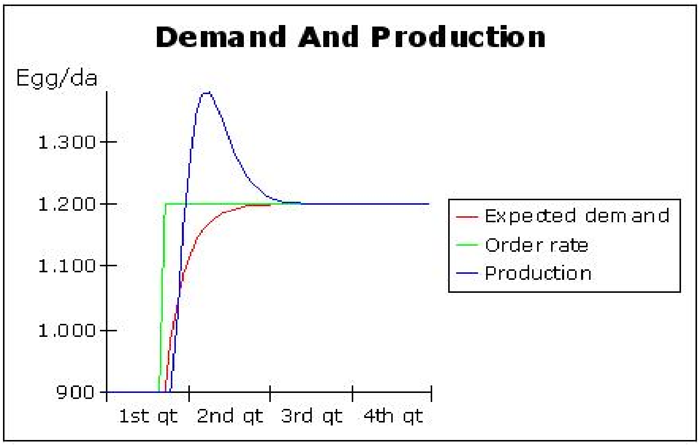


Figure 4 Graph of Demand and Production, initial state

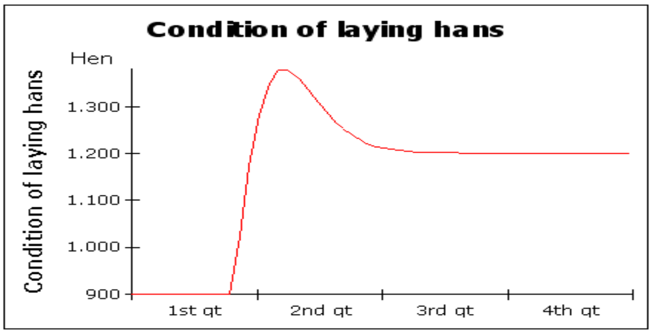


Figure 5 Graph of Condition of laying hens, initial state

On the second graph we have a Condition of laying hens. The number of layers is 900 until a change occurs in a scenario which causes an increase in demand for eggs. Then the number of layers increases rapidly and grows in leaps on 1400 hens to satisfy the need for increased demand. But after a time the number of laying hens decreases on 1200 when is establish a new balance. The curve of Condition of laying hens is equal to the curve of Production, and also has a sharp peak. In practice this could mean that in just one quarter, we should get 500 new layers and then get rid of 200 of them which is an unacceptable because any newly acquired hen should be kept at least for two years to make it worthwhile, and to make our revenues.

3.2. Scenario 2. : Optimized scenario

Possible solution is to change the values that we have in the constants (Duration of the contract, The contract grace period, Desired duration of the stocks). Finding the optimal values of these variables will allow definition of the contract items in order to increase profits. Therefore, we observe deviations of production (depending on the number of layers) and demand. The goal is to minimize the deviation, by balancing mentioned constants. This problem, according to the previous scenario (Duration of the contract is 1 month, the contract grace period 10 days, desired duration of the stocks 3 days) is shown in the graph figure no 6.

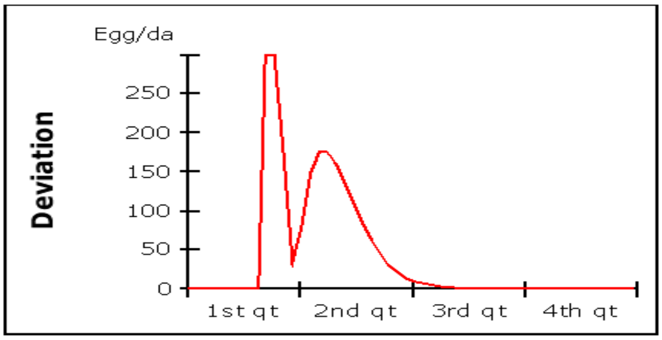


Figure 6 Graph of deviation, before optimization

The simulation shows that the production and delivery will equate only during one quarter. On the curve of deviation, after the initial peak of deviation the curve descends and then rises again and then finally falls. After the implementation of system optimization, we got new values of constants that we should demand from our customers during the future concluding contracts in order to avoid the appearance of sharp peaks. Substituting the calculated (optimized) values (Duration of the contract is 7.6 month, The contract grace period 7.42 days, Desired duration of the stocks 8, 92 days) and starting the simulation we got a new scenario of deviation shown in graph Figure No. 7.

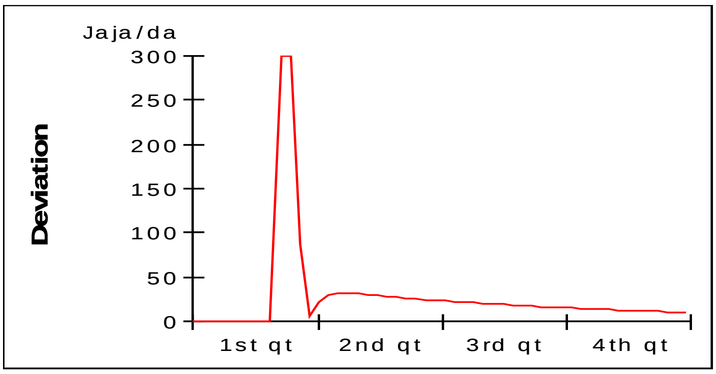


Figure 7 Graph of deviation, after optimization

Comparing these two graphs we can see that the time of the system reaction is decreased for more than one quarter. Initial time response was one and a half quarter and now is less than half a quarter, which is a significant saving of time and improved speed of response. Looking at the variable "Demand", "Production" in the figure no. 8th and "Condition number of laying hens" in the figure no. 9th it is evident that there are no sharp peaks and that the curves are completely straightened and do not show any extreme fluctuations, what was exactly our goal.

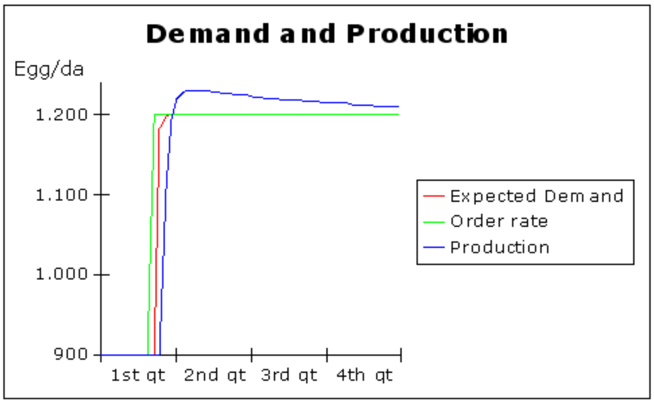


Figure 8 Graph of Demand and Production, after optimization

In this way fluctuations in production capacity are avoided, and thus the need to increase costs caused by non-exploitation of the increased number of layers. Dynamic of increase in the number of hens is shown in Figure No.9.

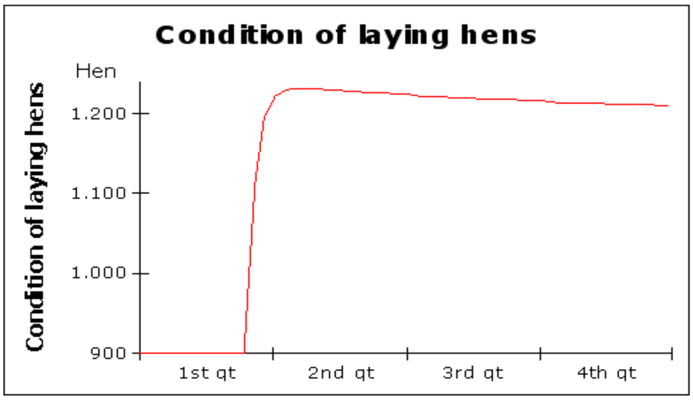


Figure 9 Graph of Condition of laying hens, after optimization

4. CONCLUSION

Looking at the model and analyzing the results after the change of state, we observe the form of model behavior. Construction of the model helped us to predict the behavior of the system and helped us to find the best solutions for the observed problem of the capacity oscillations.

The developed model can improve the simulation of demand (eg, Monte Carlo simulation) and then implement new scenarios. Also, the existing model can be linked to financial indicators of the observed system. This will allow more affordable model for managing the system of egg production.

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