Diagnosis of production system of marine frozen products by inventory management theory - A case of blue fins

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Abstract: The purpose of this paper is a characteristic analysis of current production and inventory system for frozen products of blue fins under a fishery instability caused by the warming of the earth and an indiscriminate fishing. For the analysis, a simulation is performed quoted by Vassian’s production management theory. The result of the analysis is that the current system is aimed at minimizing a variation of the inventory at the end of the period.

Keywords: Production and Inventory Planning System, Frozen Processing Industry, Simulation

1. Introduction

This paper proposes a simple diagnosis of current capability of actual production system by an inventory management theory. Objective system is a production system of blue fins frozen products in Japan. The reason is that Japan has the largest fishing and consumptions of them in the world. However a catch of blue fins has been decreased these past few years because of the warming of the earth and an indiscriminate fishing. Also, after 2011 Tohoku earthquake and tsunami, a development of a renewal production model has been required in the area. Applied theory is Vassian’s production management theory (1954) which is one of the traditional and robust theories. It is mainly used to decide a production order with considering an inventory of the product. In this paper, an application of the theory is performed to check a capability of current production system. The challenge of this paper has two meaning. First, a use of the theory will be expanded from a determination of a production order to a diagnosis of a current production system. Second, a convenient method based on a theoretical approach is proposed to an actual production site for an intermediation between an academic field and an industry field.

2. Literature Review

Simon proposed one inventory management models by a servomechanisms theory. One of them is illustrated from Figure 1 (Simon 1952). It is a feedback control system by the block system. The optimum inventory \( \theta_l \) is input data, the actual inventory \( \theta_o \) is output data and the difference between two data \( \varepsilon (=\theta_l - \theta_o) \) is an error. An order \( \theta_1 \) is a disturbance of warehouse \( K_1 \) as a controlled object. An inventory controller \( K_2 \) determines a manipulated variable \( \mu \) to minimize the difference \( \varepsilon \) and supplies to warehouse \( K_1 \).

Figure 1. Inventory Management System (Simon 1952)

There have been researches about the production and inventory planning based on the model. He himself introduced a fixed interval ordering system in which production lead time was adapted to a manipulated variable \( \mu \) of the model (Simon 1952). Vassian (1954) proposed a fixed interval ordering system
proposes a formulation of a production scheduling problem under the condition of the effect by linear programming. However, studies of a marine frozen production order as a matter of course. An idea of this study is Nishijima (1999) developed sub-models of the model, i.e. been spread in recent years. For example, Chiyoma (2013) focuses on the facts and proposes a method to analyze a variation of an indicated production order and the model to minimize a variation of an inventory at the end of the period. It is delivered by Ministry of Agriculture, Forestry and Fisheries in Japan. The object data of this paper are data from 2005 to 2009 before not only a modification of how to survey from 2010 but also the 2011 earthquake off the Pacific coast of Tohoku. A definition of blue fins is followed by the annual report. Namely, the category of blue fins consists of four kinds such as a long-finned tuna, a big eye tuna, a yellow fin tuna and others.

In order to analyze surveyed data, not only basic statistics but also a link relative is calculated to a monthly amount of materials to plants and a monthly amount of products from plants. Values of a link relative are given in the utilization process of a method of a link relative (Persons 1919). It is the ratio of each item at the period of the series to the preceding item, which is item at the period \( t-1 \). A quantification of a change of an annual series’ shape of the two surveyed data will be expected by the indicator.

3.2. STEP2: Construction of Constructed Models

Two constructed models are formulated to grasp the current of the object system. Previously, a performance of a production and inventory planning system is measured by a stability of input and/or output of the system. A representative indicator of the former is a variation of an indicated production order and that of the latter is a variation of an inventory at the end of the period (Nishijima 1999). Watanabe (2013) focuses on the facts and proposes a method to analyze the characteristic of the current system through the comparison among the current system, the model to minimize a variation of an indicated production order and the model to minimize a variation of an inventory at the end of the period. This paper applies to the analysis method too.

3.3. STEP3: Simulation of Production and Inventory System

In the simulation, a monthly amount of materials to plants investigated in Step 1 is considered as input data of two models constructed in Step 2. And an average and a standard deviation of an indicated production order and an inventory at the end of the period are calculated in the simulations by every model. Through the comparisons among current values and the results, a characteristic of the current system is analyzed.

3.4. STEP4: Discussion

Based on the result in the previous steps, the future direction of a production and inventory planning system of frozen blue fins products is discussed.
4. STEP1: Investigation of Statistical Data

4.1. A Monthly Amount of Materials to Plants

Figure 2 shows time series of a monthly amount of materials to plants from 2005 to 2009. It is found that the time series go down year by year. An average of the monthly amounts is 31,545 ton in 2009 which is 88% of 38,322 ton in 2005.

![Figure 2. Time series of monthly amount of materials for frozen blue fins from 2005 to 2009](image)

There are some months which have large variation of the monthly amounts among five years. In particularly, the amounts on April and August in 2009 drop to a lower position than the amounts in 2005 are the most of amounts in five years. From the results, the variation of the monthly amount on each month is very large as shown in Figure 3.

Furthermore, Table 1 indicates link relatives every month among five years. It is found that a change of increase or decrease of the amount at a month against the amount at next month occurs during the investigated years.

Instability of the amount is confirmed based on the above analysis. A realization of maintenance of a capacity of a frozen processing line to overcome the burden will be needed.

4.2. A Monthly Amount of Frozen Products from Plants

Figure 4 show time series of a monthly amount of products from plants from 2005 to 2009. It is found that the time series go down year by year like a monthly amount of materials to plants. An average of the monthly amounts is 38,224 ton in 2009 which is 85% of 32,365 ton in 2005. On the other hand, in comparison with the time series among five years, there is little disturbance of the shape of the time series. From Table 2, it indicates to realize steady supply to the market every year. However, in case of July, a change of increase or decrease of the amount at a month against the amount at next month occurs during the investigated years.

![Figure 4. Time series of monthly amount of frozen blue fins from 2005 to 2009](image)

| Table 1. Link relatives of monthly amount of frozen blue fins from 2005 to 2009 |
|---|---|---|---|---|---|
| Month | 2005 | 2006 | 2007 | 2008 | 2009 |
| 1 | - | 0.80 | 0.72 | 0.77 | 0.85 |
| 2 | 1.00 | 0.96 | 1.06 | 1.05 | 1.20 |
| 3 | 1.28 | 1.36 | 1.27 | 1.22 | 1.02 |
| 4 | 1.06 | 0.93 | 0.86 | 0.95 | 1.05 |
| 5 | 0.84 | 0.84 | 1.23 | 0.94 | 0.92 |
| 6 | 1.09 | 1.14 | 1.11 | 1.24 | 1.37 |
| 7 | 1.09 | 1.19 | 0.94 | 1.07 | 1.01 |
| 8 | 0.92 | 0.80 | 0.88 | 0.67 | 0.73 |
| 9 | 1.00 | 0.93 | 0.97 | 1.20 | 1.03 |
| 10 | 0.96 | 1.17 | 1.05 | 1.00 | 0.99 |
| 11 | 0.95 | 0.91 | 0.98 | 0.85 | 0.96 |
| 12 | 1.06 | 1.08 | 1.05 | 1.04 | 1.04 |

※※：A link relative is less than 1.00 at a year but it is 1.00 and over at the preceding year.

※※：A link relative is 1.00 and over at a year but it is less than 1.00 at the preceding year.

| Table 2. Link relatives of monthly amount of frozen blue fins from 2005 to 2009 |
|---|---|---|---|---|---|
| Month | 2005 | 2006 | 2007 | 2008 | 2009 |
| 1 | - | 0.71 | 0.71 | 0.72 | 0.78 |
| 2 | 1.02 | 1.01 | 1.01 | 1.00 | 0.98 |
| 3 | 1.21 | 1.18 | 1.18 | 1.15 | 1.19 |
| 4 | 1.01 | 1.08 | 1.04 | 1.12 | 1.10 |
| 5 | 0.95 | 0.88 | 0.98 | 0.87 | 0.86 |
| 6 | 1.00 | 1.00 | 1.04 | 1.11 | 1.17 |
| 7 | 1.07 | 0.98 | 1.18 | 0.98 | 1.07 |
| 8 | 0.99 | 0.98 | 0.84 | 0.86 | 0.82 |
| 9 | 0.93 | 0.97 | 0.94 | 0.94 | 0.95 |
| 10 | 1.00 | 1.07 | 1.07 | 1.14 | 1.08 |
| 11 | 1.07 | 0.97 | 0.98 | 0.92 | 0.94 |
| 12 | 1.09 | 1.17 | 1.17 | 1.22 | 1.19 |

※※：A link relative is less than 1.00 at a year but it is 1.00 and over at the preceding year.

※※：A link relative is 1.00 and over at a year but it is less than 1.00 at the preceding year.
In the tendency of quantitative reduction mentioned above, a ratio of a setup time to total processing time will be increased. It is necessary to maintain a productivity of a production system which is equal to the conventional system.

4.3. An Inventory of Products at the End of the Month

Figure 5 shows time series of an inventory of products at the end of the month from 2005 to 2009. It is found that the time series go down year by year like two kinds of the amounts mentioned above. Days of an inventory are illustrated from Figure 3. It is given a monthly amount of the products from plants divided by an inventory of the products at the end of the month. An average of the indicator increases from 1.77 in 2005 to 1.95 in 2009. It seems that a suitable reduction of an inventory of the products has not been performed. Furthermore a variance of the indicator increases from 0.22 in 2005 to 1.95 in 2009. It indicates the instability of the inventory of the products.

6. STEP3: Simulation of Production and Inventory System

6.1. Precondition

In this step, the simulation is performed by the two proposed models. An outline of the simulation is as follows. <Outline of the simulation>

- Input data: Actual data of the monthly amount of materials to plants
- Output data 1: Average and standard deviation of monthly amounts of materials
- Output data 2: Average and standard deviation of inventories at the end of month
- A number of simulation: Five times (from 2005 to 2009)
- Others
  - An inventory at the end of December in the preceding year: Actual data (In case of 2005, 2004’s value is utilized.)
  - A monthly amount of materials to plants at November and December in the preceding year: Actual data (In case of 2005, 2004’s value is utilized.)
  - A monthly amount of frozen products from plants in January and February of the next year: Actual data (In case of 2009, the following equation is utilized.)
    - The amount at January in 2010=The amount at January in 2009×(The amount at January in 2009- The amount at January in 2005)+5
    - The amount at February in 2010=The amount at February in 2009× (The amount at February in 2009- The amount at February in 2005)+5

5. STEP2: Construction of Constructed Models

On the assumption that production lead time is one period, Equation (1) and Equation (2) become Equation (3) and Equation (4). Two models are proposed based on the two equations. In addition, followed by the situation of the object case, \( P_t \) means a monthly amount of materials to plants and \( D_t \) means regarded as a monthly amount of products from plants.

\[ P_t = \hat{D}_{t,i+1} + \hat{D}_{t,j+2} - P_{t-1} - I_t + S \]  \hspace{1cm} (3)

\[ I_t = I_{t-1} + P_{t,i} - D_t \]  \hspace{1cm} (4)

1) In case of a minimization of a variation of an inventory at the end of the period

The assumption that a monthly amount of products of term \( i \) ahead are given at the end of the period \( t \) is installed to Equation (3).

\[ \hat{D}_{t,i+1} = D_{t,i+1} \]  \hspace{1cm} (5)

\[ \hat{D}_{t,j+2} = D_{t,j+2} \]  \hspace{1cm} (6)

2) In case of a minimization of a variation of an indicated production order

The assumption that a monthly amount of products of each period is constant is installed to Equation (3).

\[ P_t = C \]  \hspace{1cm} (7)
6.2. Results

The results of the simulation are illustrated from Table 4, Table 5, Figure 6 and Figure 7. It is found that the current system is nearly a system to minimize a variance of an inventory at the end of the period. However it is considered that the system had a margin for a reduction of an inventory at the end of the period.

### Table 4. Results of the simulation (Materials to plants)

| Year | Minimization of a variance of an inventory at the end of the period | Current system | Minimization of a variance of an amount of materials to plants |
|------|------------------------------------------------------------------|----------------|----------------------------------------------------------------|
|      | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 2005 | 37,166  | 1,211             | 38,322  | 1,021             | 38,224  | 0 |
| 2006 | 33,892  | 1,044             | 35,002  | 1,086             | 34,940  | 0 |
| 2007 | 33,647  | 1,324             | 34,119  | 1,202             | 34,390  | 0 |
| 2008 | 30,850  | 1,236             | 32,147  | 1,214             | 31,990  | 0 |
| 2009 | 31,940  | 1,060             | 31,545  | 1,263             | 32,365  | 0 |

### Table 5. Results of the simulation (Inventory at the end of the period)

| Year | Minimization of a variance of an inventory at the end of the period | Current system | Minimization of a variance of an amount of materials to plants |
|------|------------------------------------------------------------------|----------------|----------------------------------------------------------------|
|      | Average | Standard deviation | Average | Standard deviation | Average | Standard deviation |
| 2005 | 76,966  | 885              | 67,293  | 1,001            | 81,314  | 1,132             |
| 2006 | 70,505  | 583              | 65,212  | 859             | 72,036  | 710               |
| 2007 | 69,703  | 756              | 65,757  | 712             | 73,889  | 1,223             |
| 2008 | 65,313  | 954              | 66,456  | 1,292           | 69,692  | 945               |
| 2009 | 65,098  | 265              | 62,397  | 826             | 62,787  | 1,079             |

7. STEP4: Discussion

From the both results of the survey described in Step 2 and the simulation performed in Step 3, the following four future works are considered.

- Future work 1: Construction of the production system that absorbs an instability of amounts of materials to plants
- Future work 2: Improvement of a flexibility of the production line that corresponds to a reduction of amount of products from plants
- Future work 3: Compression of an inventory that corresponds to a reduction of amount of products from plants
- Future work 4: Equalization of two variances of amount of materials to plants and an inventory at the end of the period

For the first work, the amount of materials to plants is reduced and the expected amount will not be guaranteed on the basis of a stable fish catch. It is related to an excess and a deficiency of production capacity and become factors in an occurrence of opportunity loss and surplus cost. A shift of planned procurement of materials will be needed corresponding to market requirements.

For the second work, as a production scale become down, a ratio of setup time to total processing time will become up. Based on the internet survey about a frozen processing process...
of blue fins, in order to fillet one big blue fin to a shape of rectangles, several cutting process which are from a cutting of helmet-shaped head of blue fins to a removal of dark-colored meat is passed as shown in Figure 8 (Fukuichi Gyogyo 2014). An exchange time of a cutting tool is a stop time of production. It is important to shorten set up time in the process.

For the third work, in the survey of Step 2, a reduction ratio of an inventory at the end of the period is low against a reduction ratio of amount of materials/product to/from plants. Also, it is found that a variance of an inventory at the end of the period is increasing. In general, a surplus of an inventory becomes an increase factor of cost. Accordingly effective management of an inventory in the object system will seem needed.

For the fourth work, Figure 9 shows time series of the monthly amount of materials to plants and an inventory at the end of the period provided from the simulation results described in Step 3. In case of a minimization of a variance of an inventory at the end of the period, a stationary state is kept in an inventory at the end of the period from March to December however transient characteristics are confirmed at January and February. Compared the simulated data with actual data, actual data is equal to or lower than the simulated data. On the other hand, as stated above, a variance of an inventory at the end of the period is increasing year by year. When an amount of materials to plants is checked, equalization of simulation results is better than that of actual data. Based on the results, a control of a variance of materials to plants is needed as one direction of the object system improvement. And a production and inventory system is more stabilized without becoming worse of current level of a variance of an inventory at the end of the period.

8. Concluding Remarks

In this paper, a characteristic analysis of current production and inventory planning system for frozen products of blue fins is performed under the instability of the fishery caused by the warming of the earth and an indiscriminate fishing. For the results, it is found that the current system is aimed at minimizing a variation of the inventory at the end of the period. Also, in order to correspond to the instability of a material procurement, the future works are discussed. For example, it is necessary to control a variance of amount of materials to plants and to reduce setup time, in particular an exchange of cutting tool, in total processing time without becoming worse of current level of a variance of an inventory at the end of the period.

References

[1] Chiyoma, H. and Katayama, H., 2013. “Model Building and Performance Analysis of Forward / Reverse: - Combined Logistics System in Agricultural Industry”, Proceedings of the 8th International Congress on Logistics and SCM Systems (ICLS2013), pp. 281-288, International Conference Center of Waseda University, Tokyo, Japan, 5th-7th August.

[2] Fukuichi Gyogyo Co. Ltd. Homepages, URL: http://www.maguro-fukuboh.jp/ (Access dat: 8th, April, 2014.)

[3] Herbert A. Simon, 1952. “On the Application of Servomechanism Theory in the Study of Production Control”, Econometrica, Vol. 20, No. 2, pp. 247-268.

[4] Herbert J. Vassian, 1954. “Application of Discrete Variable Servo Theory to Inventory Control”, Journal of the Operations Research Society of America, Vol. 3, Iss. 3, pp. 272-282.

[5] Hirakawa Y., Katayama, H., Hoshino K. and Soshiroda M., 2003. “A Hybrid Push/Pull Production Control System for Multistage Manufacturing Environments”, The Journal of The Japan Industrial Management Association, Vol. 45, No. 3, pp. 194-201.

[6] Katayama, H., 1986. “On an Ordering System Using Orthogonal Elements of Moving Average Demand Model”, The Journal of The Japan Industrial Management Association, Vol. 37, No. 2, pp. 73-79.
[7] Katayama, H., Soshiroda M. and Muramatsu R., 1988, “Analysis of Periodic Reordering System with Plural Moving Average Demands”, The Journal of The Japan Industrial Management Association, Vol. 39, No. 4, pp. 218-225.

[8] Nishijima J., Goto M. And Tawara N., 1999, “A Study of Periodical Ordering System to Control the Cost Occurred from Variances”, The Journal of The Japan Industrial Management Association, Vol. 50, No. 4, pp. 207-215.

[9] Ministry of Agriculture, Forestry and Fisheries, 2007. The annual report of statistical data on a distribution of aquatic products (2007), Association of Agriculture and Forestry: Tokyo.

[10] Ministry of Agriculture, Forestry and Fisheries, 2008. The annual report of statistical data on a distribution of aquatic products (2008), Association of Agriculture and Forestry: Tokyo.

[11] Ministry of Agriculture, Forestry and Fisheries, 2009. The annual report of statistical data on a distribution of aquatic products (2009), Association of Agriculture and Forestry: Tokyo.

[12] Ministry of Agriculture, Forestry and Fisheries, 2010. The annual report of statistical data on a distribution of aquatic products (2010), Association of Agriculture and Forestry: Tokyo.

[13] Ministry of Agriculture, Forestry and Fisheries, 2012. The annual report of statistical data on a distribution of aquatic products (2012), Association of Agriculture and Forestry: Tokyo.

[14] Pall J., 1988. “Daily Production Planning in Fish Processing Firms”, European Journal of Operational Research, Vol. 36, pp. 410-415.

[15] Warren M. Persons, 1919. “Indices of Business Conditions”, The Review of Economic Statistics, pp. 18-31.

[16] Watanabe, N., Hwang R. K. and Katayama, H., 2013. “Analysis and Improvement of Production and Inventory Planning System for Process Industry”, Proceedings of The 16th Japan Society of Logistics Systems (JSLS) National Conference, pp. 91-96, Nihon University, Narushino, Chiba, Japan, 11th-12th, May.