

DYNAMIC SIMULATION MODEL OF BEEF SUPPLY CHAIN TO FULFILL NATIONAL DEMAND

Erma Suryani^{a*}, Rully Agus Hendrawan^a, Isnaini Muhandhis^a, Lily Puspa Dewi^b

^aInformation Systems Department, Institut Teknologi Sepuluh Nopember, Jalan Raya ITS, Surabaya, 60111, Indonesia

^bDepartment of Informatics, Petra Christian University, Jalan Siwalankerto 121-131, Surabaya, 60236, Indonesia

Article history

Received

3 August 2015

Received in revised form

5 August 2016

Accepted

15 August 2016

*Corresponding author
erma.suryani@gmail.com

Abstract

Sustainable food supply chain is required to mitigate supply chain risks, reinforce long-term supplier relationships and build stakeholder and customer trusts. It has a significant role in social welfare, political stability, and economic growth. In this research, we treated beef as a commodity, based on consideration that the demand of this commodity continues to increase in line with population growth and the needs of processed food industries. On the other hand, the supply of this commodity tends to decline. Currently beef production in Indonesia covers only about 60% of the need, i.e. the rest is imported. The beef supply chain is too long, and the demand surges during Eid festivities causing shortages of beef in the market. There is a need to design a program that is strategic and systematic to anticipate shortages of beef production as importing beef product is unable to resolve the issue. One of the problem-solving efforts that can be done is to improve supply chain management. There is a need to plan, build, and integrate aspects of "production-distribution-consumption" at the national level by identifying the stakeholders including regions and distribution channels. By considering the aforementioned problems, the beef supply chain can be improved with the support of simulation model to assess the existing system and to develop some scenarios to improve the system performance. We utilized system dynamics model to accommodate several key variables or parameters that have significant contribution to strategic sustainable development of food supply chain, such as changes and uncertainties in supply (caused by climate change), demand, distribution, as well as internal and external business factors. The research results show that national demand can be fulfilled through several strategic initiatives.

Keywords: System Dynamics, Beef Supply Chain, Demand, Productivity, Scenario

© 2016 Penerbit UTM Press. All rights reserved

1.0 INTRODUCTION

Food self-sufficiency is a very sensitive issue for the well-being of a nation. To meet the need for food, Indonesia still relies heavily on imports of some basic commodities such as beef, which plays a growing role in national food. Indonesia has experienced a deficit in the beef production as the impact of the decrease in national cattle population, that is not able to keep the domestic beef consumption which continues to increase.

Strong population growth was driving a rapid increase in beef consumption, though from an extremely low base. During the first half of the 1990s, the growth in beef demand outstripped the capacity of Indonesia's cattle herd to supply that beef.

Increasingly, Indonesia resorted to imports of live cattle for subsequent fattening and slaughter, and to imports of frozen boxed beef. Tariffs on imports were set to assist both smallholder producers and company feedlots: there were no tariffs on imported breeder cattle, a 10% tariff on imported live feeder cattle and a 35% tariff on frozen beef. The beef industry in Indonesia is experiencing serious problems. It is characterized by rising prices and demand for beef, declining supplies of beef, as well as increased competition due to competition from imported meat. The supply chain is very dynamic and characterized by huge structural differences in production, live cattle trade, processing and retail. A large number of small cattle producers are facing a growing quantity of imported beef and cattle

finished in Indonesian feedlots based on Australian live cattle imports. At the same time, the retail is consolidating towards supermarkets and the consumer preferences and eating habits for beef are changing. Currently, the Indonesian government is determined to achieve its self-sufficiency goal in future beef supply. Structural weaknesses in Indonesia's traditional beef supply include some issues:

- High transportation costs: production areas are often distant from markets and transportation is inefficient. Transport costs can often exceed the crop value.
- Lack of working capital: farmers tend to sell crops immediately.
- Lack of bargaining power: there are farmers' organizations, but they are not always very effective. Therefore, traders play an important role in traditional agriculture and farmers are relatively isolated from their end markets.

2.0 LITERATURE REVIEW

2.1 Beef Demand and Supply in Indonesia

According to the BAPPENAS (Badan Perencanaan Pembangunan Nasional), the beef demand in Indonesia would continue to increase, due to higher household incomes and changing tastes towards meat quality. In the next three years, the level of meat consumption is expected to increase from 1.6 kg to 2.3 kg / capita / year. In the period 2000-2012 the population growth is higher than the previous period. Beef cattle population development trend shows increasing trend is more positive. This is shown in the period 2005-2012 the average growth of the cattle population reached 6.02% per year. The total cattle population in 2012, was around 16.03 million and beef production was around 505,500 tons. The self-sufficiency policy should continue to be carried out intensively by the government through relevant agencies to increase beef production, and will reduce beef imports nationwide [1]. The increasing population makes the beef demand continues to increase. The projection shows that the number of Indonesian population over the next twenty-five years continuously increased from 238.5 million in 2010 to 305.6 million in 2035 [2].

Strong population growth was driving a rapid increase in beef consumption, though from an extremely low base. During the first half of the 1990s, the growth in beef demand outstripped the capacity of Indonesia's cattle herd to supply that beef. Increasingly, Indonesia resorted to imports of live cattle for subsequent fattening and slaughter, and to imports of frozen boxed beef. Tariffs on imports were set to assist both smallholder producers and company feedlots: there were no tariffs on imported breeder cattle, a 10% tariff on imported live feeder cattle and a 35% tariff on frozen beef. The beef industry in Indonesia is experiencing serious problems.

It is characterized by rising prices and demand for beef, declining supplies of beef, as well as increased competition due to competition from imported meat. The supply chain is very dynamic and characterized by huge structural differences in production, live cattle trade, processing and retail. A large number of small cattle producers are facing a growing quantity of imported beef and cattle finished in Indonesian feedlots based on Australian live cattle imports. At the same time, the retail is consolidating towards supermarkets and the consumer preferences and eating habits for beef are changing.

Indonesia with a large population, need a beef supply in large enough quantities. Domestic livestock so far not been able to meet the national demand. The difference between supply and demand was still high. The Government (Ministry of Agriculture) recognizes the beef cattle business main problem in Indonesia is the supply that is always experiencing a shortage every year. While the growth rate of consumption and population growth are not able to be offset by the growth rate of consumption and population growth are not able to be balanced by the growth rate of beef cattle population. Under these conditions forcing Indonesia to always perform imports, either in the form of live cattle and meat.

To encourage the growth of beef population as well as to repair the genetic quality of cattle, the government has utilized the technology of artificial insemination. However, due to limitations of the government, the range is still limited artificial insemination. From the evaluation of the implementation of artificial insemination of beef cattle in some regions such as Lampung, West Java, and East Java showed that the realization of artificial insemination of beef cattle is still about 30-50 percent of the potential acceptor. In addition to the areas of artificial insemination services, we found that the reproductive efficiency of beef cattle is still relatively low (around 60 per cent of potential reproductive efficiency). This is due to various factors such as delays in diagnosis on the cattle breed, disturbance in reproductive organs, lower feed quality, and technical errors of the inseminator. The low efficiency of reproduction and artificial insemination limited range causes the growth of beef cattle population in Indonesia become low [3]. As a result, the rate of growth in domestic beef production is also relatively slow compared to the growth in demand for beef domestically. This imbalance has contributed to the relatively high price of beef in domestic market.

2.2 Previous Studies

Supply chain networks run physical, operational, and reputational risks as the impact of climate change. Supply chain managers should pay special attention to the impacts of climate change on supply chains and academics should further explore the interrelationships between climate change and supply chain design and operations [4].

According to Gebresenbet and Bosona, a generic list of redesign strategies to facilitate the redesign process and attain sustainable supply chain objectives is as follows [5]:

- Redesign the roles and processes performed in the supply chain (e.g., reduce the number of parties involved, reallocate roles such as inventory control, and eliminate non-value-adding activities such as stock keeping).
- Reduce lead times (e.g., implement information and communication technology (ICT) systems for information exchange and decision support, increase manufacturing flexibility or reallocate facilities).
- Create information transparency (e.g., establish an information exchange infrastructure in the supply chain and exchange information on demand/supply/inventory or work-in-process, standardize product coding).
- Synchronize logistical processes with consumer demand (e.g., increase frequencies of production and delivery processes, decrease lot sizes).
- Coordinate and simplify logistical decisions in the supply chain (e.g., coordinate lot sizes, consolidate goods flows, eliminate human interventions, and introduce product standardization and modularization).
- Emphasis on redesigning processes in order to reduce greenhouse gas emissions and energy consumption

The low population growth of beef in various provinces, partly due to the death of a cow is still at a high rate of calf mortality ranging from 20% - 40% and cows range from 10% - 20%, cutting productive cows, and cutting a cow that does not wait for optimal weight [6].

To speed up the procurement of cattle from within country course requires superior seedlings cow. This calf cow can be met from derived cows as the results of artificial insemination, which there is currently quite a lot in the area of artificial insemination service such as Lampung, Central Java, East Java, and NTB. In addition, imports of parent stock also needs to the Northern Australia [7].

2.3 System Dynamics

System dynamics (SD) is a method to analyze and design a policy for complex system. It can be used as an approach for modeling and simulation of

complex system. Sterman describes system dynamics as an aid to learning and understanding complex systems [8]. He emphasizes how the system dynamics modeling process consists of tools to elicit mental models of systems, procedures to create formal models based on the mental models, computer simulations of the formal models, and applications of the findings of the simulations to improve understanding of the system. SD uses a set of tools that allows its practitioners to visually and succinctly depict interpretations or mental models of systems to increase system understanding.

SD enable us to develop some scenarios by issuing different valued to the parameters and initial variables. By issuing different values for the parameters, alternative forecasts, or scenarios can be easily obtained. In addition, by modifying the parameter values, it will provide a better understanding of the system behavior. These scenarios can provide some future projections to improve the system performance. In developing a system dynamics model, a modeler has to clearly define the model boundary. This boundary contains all component models. A modeler must brainstorm all necessary components of the system.

Some steps are required to develop the model [8]: (a) system understanding, (b) model formulation will define the interactions of state variables and parameters [6]; (c) data collection, (d) base model development, (e) validation and verification of the base model, and (f) scenario development.

3.0 BASE MODEL DEVELOPMENT

As can be seen from Figure 1, in general, we can classify the beef supply chain into two parts, i.e. on farm and off farm. On farm part may cover beef cattle productivity and beef production. On the other hand, off farm part may cover the beef supply chain mechanism, the flow of beef production starting from beef population, Orion (traders), local butcher, slaughterhouse, and local consumers, as well as the distribution flow starting from Orion to beef collector, trader between provinces, destination butcher, destination slaughter house, and destination consumers. The system is described in Causal Loop Diagram (CLD) as in Figure 1.

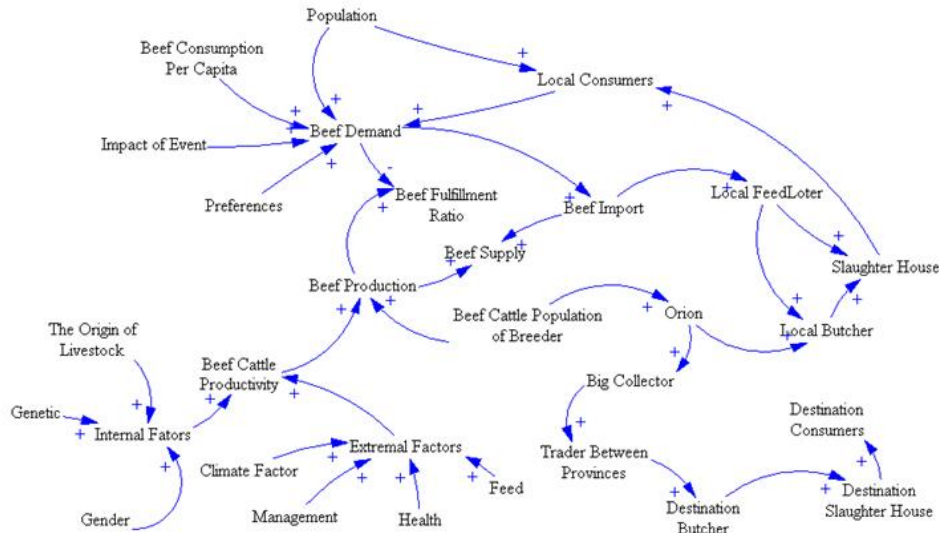


Figure 1 Causal Loop Diagram of Beef Supply Chain

After the causal loop diagram (CLD) was developed, this CLD will use for model development. In developing the model, we need to convert this causal loop diagram into a flow diagram. As the starting point in developing beef supply chain model, we start from the population for each region.

3.1 Population Based on Each Region Sub model

We classify population based on each region to fit with the supply chain of beef production as follows: Java, Sumatera, Kalimantan, Sulawesi, Bali and Nusa Tenggara, as well as Maluku and Papua. The flow diagram of "population based on each region" is depicted in Figure 2.

Java population has grown with the average growth rate of around 1.2%. In the year of 2000, people population in Java area was around 121 Million and reached 145 Million in 2015.

Sumatera population has grown with the average growth rate of around 1.5%, this growth. In the year of 2000, people population in Sumatera area was around 43 Million and reached 55.4 Million in 2015.

Kalimantan population has grown with the average growth rate of around 2%. In the year of 2000, people population in Kalimantan was around 11.3 Million and reached 15.3 Million in 2015.

Sulawesi population has grown with the average growth rate of around 1.5%. In the year of 2000, people population in Sulawesi was around 14.9 Million and reached 18.7 Million in 2015.

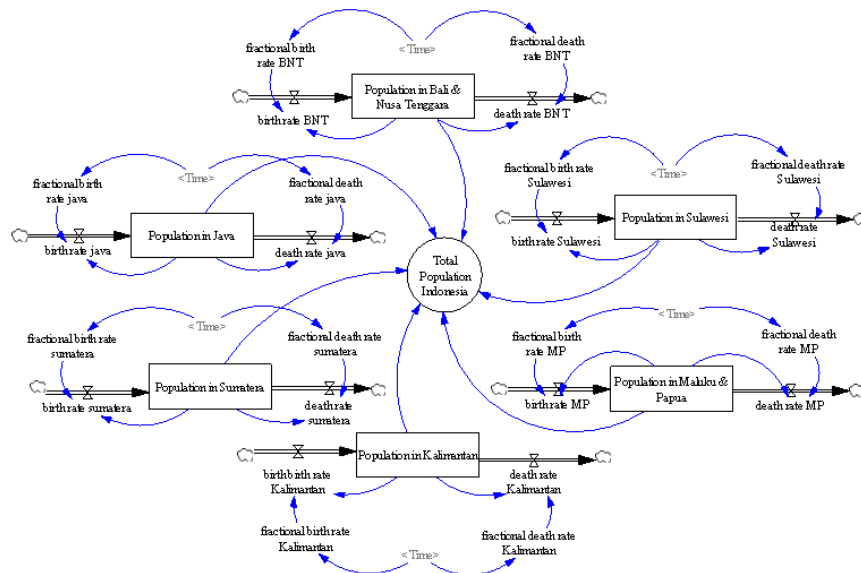


Figure 2 National Population Based on Each Region

The population of Bali and Nusa Tenggara has grown with the average growth rate of around 1.6%. This population growth is shown in Figure 3. In the year of 2000, people population in Sulawesi was around 11.1 Million and reached 14.2 Million in 2015.

Maluku and Papua population has grown with the average growth rate of around 4%. In 2000, the

population in Maluku and Papua was around 4.2 Million and reached 6.7 Million in 2015.

3.2 Beef Demand Sub model

Beef demand per each region depends on Population, Consumption Per Capita and Preferences as seen in Figure 3. Total demand is the summation of the demand for all regions.

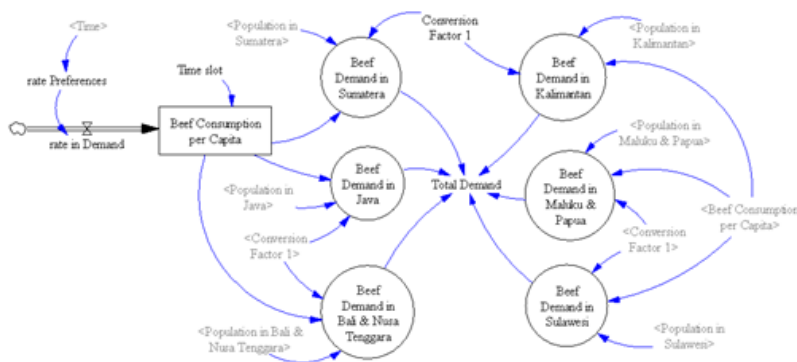


Figure 3 Beef Demand in Indonesia

Beef demand in Java will grow with an average growth rate of around = 4.7% per year. Beef demand in Java was around 340,293 tons in 2015.

Beef demand in Bali and Nusa Tenggara will grow with the average growth rate of around = 5.2% per year. This growth of beef demand in Bali and Nusa Tenggara. Beef demand in Bali and Nusa Tenggara was around 33,328 tons in 2015.

Beef demand in Sumatera will grow with the average growth rate of around = 5.1% per year. Beef demand in Sumatera was around 129,970 tons in 2015.

Beef demand in Sulawesi will grow with the average growth rate of around = 4.9% per year. Beef demand in Sulawesi was around 43,909 tons in 2015.

Beef demand in Kalimantan will grow with the average growth rate of around = 5.5% per year. Beef demand in Kalimantan was around 35,836 tons in 2015.

Beef demand in Maluku and Papua will grow with the average growth rate of around = 6.9% per year. Beef demand in Maluku and Papua was around 15,830 tons in 2015.

Beef demand in Indonesia will grow with the average growth rate of around = 4.93% / year. Total Beef

demand in Indonesia was around 599,215 tons in 2015.

3.3 Beef Production

Beef production depends on the amount of livestock, beef productivity, percentage of meat and a percentage of carcasses. Beef productivity is influenced by internal and external factors. Internal factor depends on genetics, gender and the origin of livestock [9]. External factor depends on feed, management, health, and climate factor [10, 11]. Local beef production in Java, in 2014 was around 218.659 tons.

3.4 Local Beef Supply

Currently, total local supply depends on the supply from each region, those are Java, Sumatera, Kalimantan, Sulawesi, Bali and Nusa Tenggara, as well as Maluku and Papua. This system is shown in Figure 4. Total local supply in Indonesia was around 420,968 tons in 2015. The growth of total local supply for beef in Indonesia is shown in Figure 5.

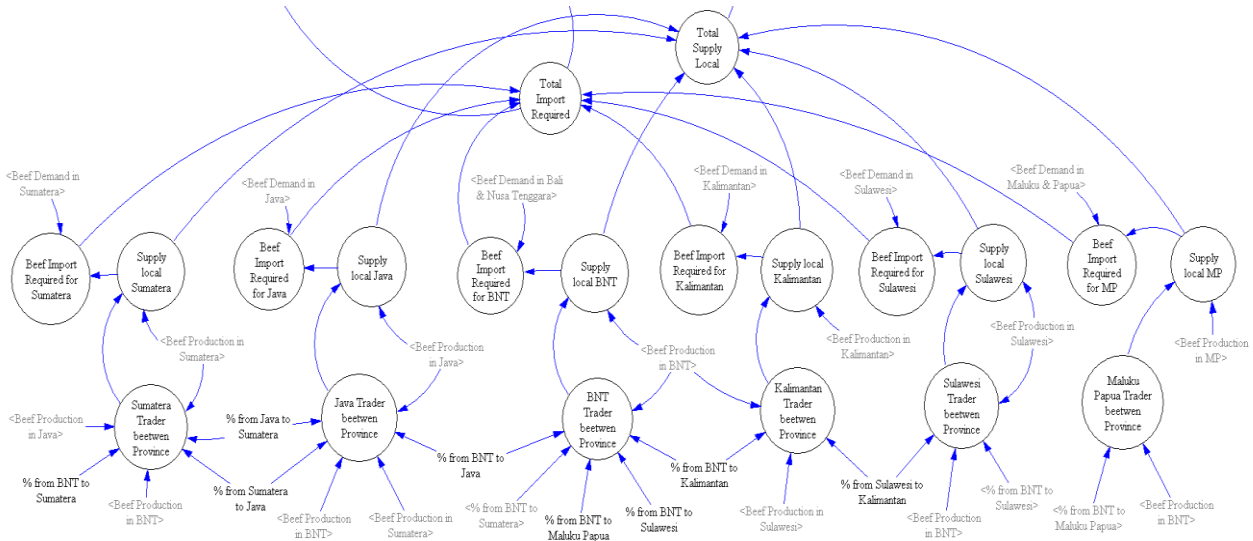


Figure 4 Diagram Flow of Total Local Supply

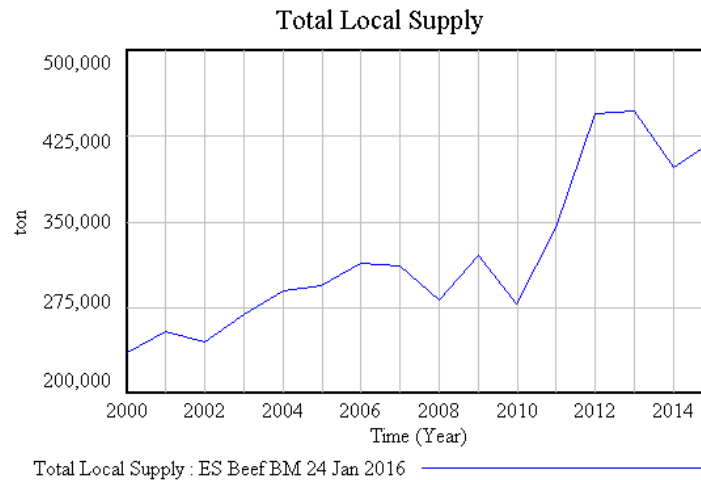


Figure 5 Total Local Supply in Indonesia

4.0 MODEL VALIDATION

Model validation is required to check the model validity. A model will be valid if the error rate is less than 5% and error variance is less than 30% [12]. Error rate and error variance are defined in Eq. (1) and (2):

$$ErrorRate = \frac{|\bar{S} - \bar{A}|}{\bar{A}} \quad (1)$$

$$ErrorVariance = \frac{|Ss - Sa|}{Sa} \quad (2)$$

Where:

\bar{S} = the average rate of simulation

\bar{A} = the average rate of data

Ss = the standard deviation of simulation

Sa = the standard deviation of data

Error rate (E1) of some variables that have significant impact to the model output can be determined as follows:

1. Error rate of "Population"

$$= \frac{[228425959 - 228290502]}{228290502} = 0.000593358$$
2. Error rate of "Beef Demand"

$$= \frac{[431881.050 - 431328.461]}{431328.461} = 0.001281133$$
3. Error rate of "Sumatera Beef Production"

$$= \frac{[75615.8 - 77508.04]}{77508.041} = 0.0244$$
4. Error rate of "Java Beef Production"

$$= \frac{[121995.1474 - 123351.9123]}{123351.9123} = 0.011$$
5. Error rate of "Bali and Nusa Tenggara Beef Production"

$$= \frac{[41893.22396 - 42402.60318]}{42402.60318} = 0.012$$
6. Error rate of "Kalimantan Beef Production"

$$= \frac{[11858.6599 - 37578.54219]}{37578.54219} = 0.022$$

7. Error rate of “Sulawesi Beef Production”

$$= \frac{[37119.5 - 37578.5]}{37578.5} = 0.0122$$

8. Error rate of “Maluku and Papua Beef Production”

$$= \frac{[5323.89 - 5394.1]}{5394.1} = 0.013$$

6. Error variance of “Kalimantan Beef Production”

$$= \frac{[2260.5 - 2295.9]}{2295.9} = 0.016$$

7. Error variance of “Sulawesi Beef Production”

$$= \frac{[7066.6 - 7116.2]}{7116.2} = 0.007$$

8. Error variance of “Maluku and Papua Beef Production”

$$= \frac{[1013.4 - 1021.5]}{1021.5} = 0.008$$

Meanwhile the Error Variance (E2) of some variables that have significant impact to the model output can be determined as follows:

1. Error variance of “Population”

$$= \frac{[14632220.89 - 14577658.75]}{14577658.75} = 0.00374286$$

2. Error variance of “Beef Demand”

$$= \frac{[91993 - 92028]}{92028} = 0.0004$$

3. Error variance of “Sumatera Beef Production”

$$= \frac{[15268.6 - 14677.6]}{14677.6} = 0.04$$

4. Error variance of “Java Beef Production”

$$= \frac{[23091.2 - 23359.1]}{23359.1} = 0.01$$

5. Error variance of “Bali and Nusa Tenggara Beef Production”

$$= \frac{[7869.4 - 8029.7]}{8029.7} = 0.02$$

From the above calculation we can see that all of the errors rate are < 5% and the errors variance are <30%, which means that our model is valid.

5.0 SCENARIO DEVELOPMENT

This scenario is made to meet the needs of national meat through: 1) improvement of maintenance of the cows by providing adequate food and ground for fattening cattle to get increased production by 50% from its original state; 2) the addition of cows; 3) suppression rate of productive female slaughter; 4) an increase in the percentage of productive female pregnancy. The flow diagram of beef productivity improvement scenario can be seen in Figure 6.

From the simulation result of scenario model, it was found that local supply will meet or exceed demand in 2026, as shown in Figure 7. Beef supply is projected to grow of around 12% per year, meanwhile demand is projected to grow of around 3.7% per year.

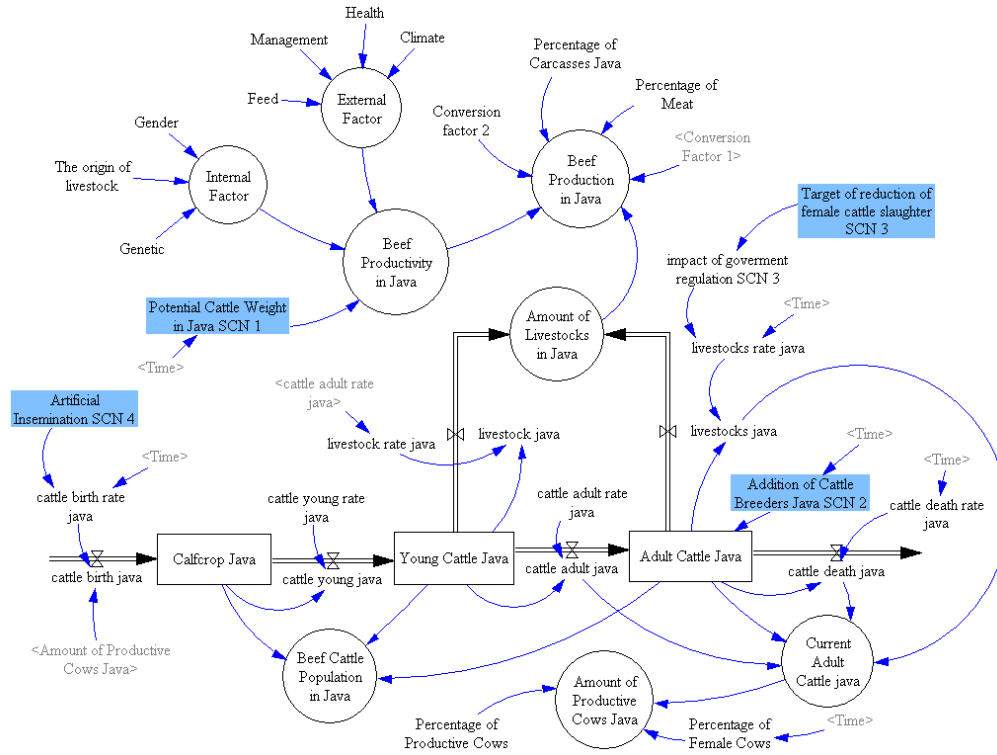


Figure 6 The Flow Diagram of Beef Productivity Improvement

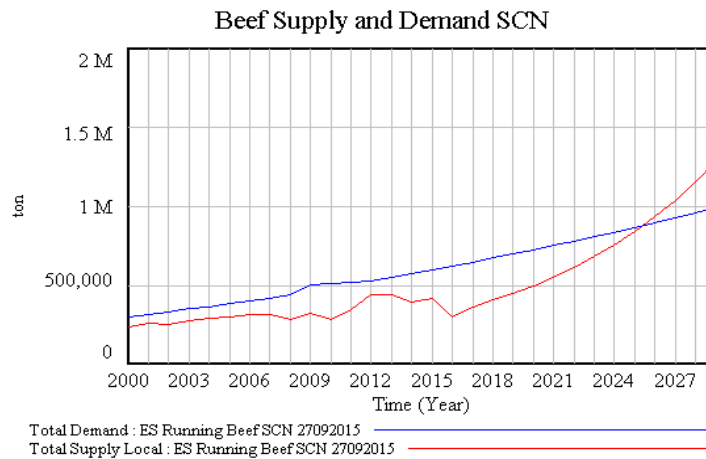


Figure 7 Total Local Supply and National Demand

6.0 CONCLUSION

Beef demand per each region depends on Population, Consumption Per Capita and Preferences. Beef demand in Java will grow with the average growth rate of around = 4.7% per year, Bali and Nusa Tenggara will grow = 5.2 % per year; Sumatera will grow = 5.1 % per year; Sulawesi will grow = 4.9% per year; Kalimantan will grow with = 5.5% per year; Maluku and Papua will grow = 6.9% per year. Based on the growths in each region, total

beef demand in Indonesia will grow with the average growth rate of around = 4.93% / year.

Beef production depends on the amount of livestock, cattle productivity, percentage of meat and percentage of carcasses. Cattle productivity is influenced by internal and external factors. Internal factor depends on genetics, gender, the origin of livestock. External factor depends on feed, management, health, and climate factor.

Beef Distribution in Indonesia is divided into several areas: Java, Sumatera, Bali and Nusa Tenggara, Kalimantan, Sulawesi, as well as Maluku and Papua.

Supply from local (Beef Processing Plant) and import are distributed to traditional market (wet market), supermarket, hotel, restaurant, food processing industry. Local beef supply in 2015 was around 420,968 tons. Local beef supply is expected to meet or exceed demand in 2026.

Acknowledgement

This research is supported by Australia – Indonesia Center (AIC). Through the help and support from all of our team, including: ITS research center, family, friends, please allow us to dedicate our acknowledgment of gratitude toward them. Finally, we sincerely thank to our colleagues, family, and friends, who provide any advice and support. The result of this research would not be possible without all of them.

References

- [1] BAPPENAS. 2013. Beef Demand and Supply in Indonesia.
- [2] Central Bureau of Statistics (2013). Beef Supply in Indonesia.
- [3] Ginting, D. 2013. Challenges and Strategies Agribusiness Beef Cattle.
- [4] Dasaklis, T. K., & Pappis, C. P. 2013. Supply Chain Management In View Of Climate Change: An Overview Of Possible Impacts And The Road Ahead. *Journal of Industrial Engineering and Management*. 6(4): 1139-1161.
- [5] Gebresenbet, G., & Bosona, T. 2012. Logistics and Supply Chains in Agriculture and Food, Pathways to Supply Chain Excellence, Dr. Ales Groznik (Ed.). ISBN: 978-953-51-0367-7, InTech, DOI: 10.5772/25907. Available from: <http://www.intechopen.com/books/pathways-to-supply-chain-excellence/logistics-chains-in-food-and-agriculture-sector>.
- [6] Mahbubi, A. 2014. Optimization of Beef Supply Chain Management from NTT to Jakarta. *Proceeding of Seminar Nasional dan Workshop Optimalisasi Sumberdaya Lokal pada Peternakan Rakyat Berbasis Teknologi-1. Makassar, Indonesia*.
- [7] Pusat Agribisnis. 2013. Challenges and Strategies Agribusiness Company of Cows in the Era of Free Trade.
- [8] Sterman, J. 2010. *Business Dynamics: System Thinking and Modelling for a Complex World*. McGraw-Hill/Irwin, New York.
- [9] Indriatmoko, D. W. 2014. Potensi Genetik Sapi Madura Alami Penurunan? Department of Animal Husbandry, East Java. Available from: <http://disnak.jatimprov.go.id/web/layananpublik/readopini/1097/potensi-genetik-sapi-madura-alami-penurunan>.
- [10] Balai Pengkajian Teknologi Pertanian (BPTP) Jambi. 2007. Beef Feedlot Management. Ministry of Agriculture, Jambi.
- [11] Prasetya, A. 2011. Management of Beef Cattles in BPTP Rambatana, West Sumatera. Bogor Agricultural University, Bogor.
- [12] Barlas, Y. 1996. Formal Aspects of Model Validity and Validation in System Dynamics. *System Dynamics Review*. John Wiley & Sons, Ltd. 12(3): 183-210.