POULTRY SUPPLY CHAIN: A SYSTEM APPROACH

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ABSTRACT
Supply chains of individual farms linked with final market via intermediate companies are becoming a normal business phenomenon. Yet at present, it is not clear how such supply chain networks can achieve stability/sustainability in terms of structured network to gain benefits, meeting demand and supply and achieving highest productivity. This quantitative study investigates these questions using a production process simulation model of a poultry parent stock farm and its forward and reverse chains. The model was developed in a system dynamics simulation environment using a design science methodology. Model analysis shows that intricate poultry supply chains behave inconsistently over time to meet market demands. This paper also focuses on poultry unused wastages. The objectives of this study are to find out social, economic and environmental benefits through forward and reverse poultry supply chains.
Keywords: Reverse logistics, Systems thinking, Poultry, Bangladesh

INTRODUCTION

Bangladesh poultry plays an important economic role for 73% of rural people who lives in rural areas (Reneta 2005). The poultry industry gained more than 200 percent growth in the last 5 years with a number of identified problems (Shamsuddoha and Sohel 2004). Bangladesh Poultry is dominated by backyard local chickens (Desi or local) in scavenger system (Nielsen 2007) followed by commercial farming. Poultry helps the livelihood of many and contribute towards improving the family diet with eggs and meat (Das et al. 2008) and is a cheap source of animal protein in terms of meat and eggs (Shamsuddoha 2010a). Poultry meat alone contributes 37% of the total meat production in the country and 22 to 27% of total animal protein (Ahmed 1988, Haque 1992) producing 11500 metric tonnes of chicken meat (FAO 2003). Availability of poultry meat in Bangladesh is only 16.5 gram/day (Amin 2005), whereas world per capita consumption is 30.14 gram/day and 95.89 gram/day for USA (Farrell 2003). Nutritional deficiency is very severe among the rural people due to the scarcity of animal protein. To reduce poverty and improve nutritional status, poultry can play a significant role in the subsistence economy of rural people as it provides self-employment for unemployed people (Hai et al. 2008). There is significant scope to establish and produce more poultry meat and chicks to balance the protein supply and intake.

Recent turbulent business environments pushed the business-owners to collaborate with various forward and reverse chains and as well as with individual companies. This is a smarter way of getting sufficient strength to compete and sustain existing competitive market. Often, these kinds of collaboration and networks are very successful, or at least as successful as their vertically integrated counterparts (Coase 1937, Williamson 1975). This study considers a Bangladeshi poultry case industry with forward and reverse chains. Multiple chains generate various individual small-medium business of poultry parent stock and diversified products of day old chicks (DOC), mature chicken, eggs, and different kind of by-products. Adapting or controlling multiple chains is purely market-driven. This network begins from raw material collection to final products and includes parties like producers, processor, distributor, supplier and retailers. According to the owner of the case industry and other stakeholder companies stated their frustration on understanding market mechanism. Market mechanism consist of proper policy adaptation, uncertain calamities, seasonal demand and supply variability, disease, government inability to take action, cultural constraints and the likes (Rahman 2013, Mannan 2013). Inabilities to projection of market variability in terms of supply-demand and proper wastes management are the main problem of this industry.

The first objective of this research is to model poultry forward and reverse supply chain. Second objective is to use various poultry wastes for making valuable by-products and integrate with the main supply chain for the sake of achieving social, economic and environmental benefits. There are numbers of poultry wastes generated in the poultry operation and thrown into vacant land and rivers which then cause severe environmental damage (Shamsuddoha 2011a, b). In this study, the researcher identifies the benefits from reversing poultry wastes to the addition production process of by-products. This by-products processing brings social, economic and environmental benefits to the society. The supply-demand issue in poultry is a complex cycle in Bangladesh. There are a number of calamities and policy constraints involves with the poultry supply chain, namely disease, natural disaster, political unrest, government policy, finance and over/under production. These all happen due to an unorganized supply chain as different people are involved in different part of the chain. There is no proper coordination so farmers and producers lose opportunities to do business. Given this, the final objective of this paper is to develop a model which has a smooth supply chain by combining all the processors in one frame. A simulation supply chain poultry model was developed based on the in-depth interview with experience poultry businessmen and executives. Both forward and reverse supply chain have been incorporated in the model. The motive of this research was to find out the solution of the mentioned objectives by simulating a poultry production process. To validate the simulation findings, an empirical example is presented and compare with the model output.

LITERATURE

Poultry Industry in Bangladesh

Bangladesh has a long history of poultry rearing under traditional backyard farming practices (Reneta 2005). Poultry is dominated by backyard local chickens (Desi or local), which mostly survive through a natural scavenger system (Nielsen 2007). Livestock sub-sector of Poultry in Bangladesh is playing important role to its economy in light of growing small business, cheap sources of protein supply (Shamsuddoha 2010b), and providing a livelihood for millions of people (Shamsuddoha and Sohel 2008). But practically, this industry was unsuccessful in adapting the latest technology for poultry processing and procuring in a sustainable way (Corbett and Kleindorfer 2003). The poultry supply chain is a deep rooted connection among raw material supplier, breeder, broiler farmers, processor, distributor and final consumers. Though Bangladesh poultry has invested and trades in millions of dollars, it does not have a structured supply chain (Shamsuddoha 2012). Accordingly, this industry is missing the opportunity to do better business than what they are currently doing. Bangladesh poultry need an effective structured supply chain model that practices sustainability, efficient supply chain processes, environmental issues, profitability and optimality concepts (Shamsuddoha 2012).

Forward Supply Chain

The forward Supply chain (FSC) is the process that starts from raw materials collection to the final consumption of the finished product (Cox, Blackstone, and Spencer 1995). It also links together the internal and external partners of suppliers, carriers, investors, policymakers, intermediaries companies and information systems providers. A key point in supply chain management is that the entire process must be viewed as one system (Lummus and Vokurka, 1999). In summary, the forward supply chain is a step by step process of converting raw

materials to finished goods (Kocabasoglu, Prahinski, and Klassen 2007). In the same way, the poultry forward chain start with collecting parent stock breed followed by collecting hatcheable eggs from parent breeder, hatch the eggs in the hatchery, distribute it to farmers through middlemen, rearing them for certain time by the ultimate farmers and selling meat and eggs to the ultimate customers. The smoother the supply flow is, the more benefits start to come to relevant companies to achieve sustainability.

Reverse Supply Chain

Recently, supply chain (RSC) was a step towards integrating the issues of disposal, recycling; and remanufacturing of reject wastages or products (Kocabasoglu, Prahinski, and Klassen 2007). It includes the consideration of product re-design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, and recovery processes at end-of-life (Linton, Klassen, and Jayaraman 2007). Experts are calling it a reverse supply chain which has become an area of academics over the last two decades (Tibben-Lembke and Rogers 2002, Stock and Mulki 2009). An inspiring review work in the supply chain was published in the early nineties by the Council of Logistics Management (Stock 1992), while Carter and Elram (1998) have traced indications of scientific interest in the field to the early seventies. Reverse Logistics (RL) is associated with a holistic set of activities like recycling, repair, reuse and reprocessing, as well as collection, disassembly and the processing of used products, components and/or materials (Kokkinaki et al. 2001). It is evident in the literature on the automobile industries, electronic goods (such as cell phone), paper recycling, sand recycling and even carpet recycling industries, all of which display high percentages of product return and hence room for optimal and eco-efficient policies (Aghalaya, Elias, and Pati 2012). Like the above industries, poultry industry generates tonnes of wastes like litter, waste feed, feather, reject eggs, intestines etc. (Shamsuddoha 2011a). There is little literature dealing with poultry wastes reusing or recycling. This research demonstrates the benefits of further usage of poultry wastes which farmers used were dumped into river water and vacant land.

Combined Forward and Reverse Supply Chain

The authors interviewed case poultry farm owner and through that came to an understanding of Bangladesh poultry forward and reverse supply chain. In forward chains, Bangladesh poultry starts from rearing grandparent breed followed by parent stock farm or breeder farm, hatchery, distributor, broiler/layer farms (day old chicks' consumers), wholesaler, retailer and processor. Day old broiler chicks (DOC) are supplied to the distributors to distribute towards ultimate farmers who produce meat and eggs for mass people. DOC becomes mature chickens which are ready for supply to the open market, restaurants and processing units. In this whole process, a number of issues can be accommodated such as economic, social and environmental issues. Each of the issue covers number of concerns; for example, employment generation under social issue. The reverse supply chain is a relatively new concept to deal with product return, recycle, reuse to keep the environment by using industry wastes (Shamsuddoha 2011a). Realistically, poultry industries have no chances of product retrieval, return or reconditioning due to its perishable nature. However, there are immense opportunities to reuse or recycle poultry wastes. By reusing poultry wastage, industries can make valuable products like fertilizers, biogas, pillows, charcoal, and bakery items (Shamsuddoha 2011a). It was also evident from the in-depth interview that various kinds of

poultry wastes are generated in the poultry process namely litter, feed waste, feathers, broken eggs, rejected eggs and intestines. Poultry litter can be used for producing organic fertilizer, bio gas, artificial charcoal and fish feed; feathers can be used as raw materials for the bed industry; reject eggs can be used for the bakery industry; and broken eggs and intestines can be used for fish feed (Shamsuddoha 2011b, Shamsuddoha, Quaddus, and Klass 2011a). The above review of early studies showed that there was little evidence of research on combined poultry forward and reverse supply chains for social, economic and environmental benefits for the society.

SYSTEMS THINKING AND MODELLING METHODOLOGY

System thinking is an understanding of how a particular system works with number of influences. Initially, Forrester (1961) defined the Systems approach and its complexities related to managing supply chains in the mid-1900s. The majority of research touched on forward supply chain and only a few conducted research on reverse chains (Aghalaya, Elias, and Pati 2012). Systems modelling approaches can be useful for the analysis of relevant dynamic simulations of such feedback loops in a system. Examples of the applications of system dynamic modelling touched in the automobile industry (Sterman 2000), the paper recycling industry (Spengler and Schröter 2003), the poultry industry (Shamsuddoha, Klass, and Quaddus 2011, Shamsuddoha, Quaddus, and Klass 2013, Shamsuddoha, Uddin, and Nasir 2013, Aghalaya, Elias, and Pati 2012, Shamsuddoha 2011a, b, c, Shamsuddoha, Quaddus, and Klass 2011a, b) to the name of few. There is an immense scope for utilising systems thinking in this research effort, which also incorporates economic, social and social aspects in forward and reverse supply chains. Forrester's (1961) famous "Beer Game" (Sterman 1989) and Meadows's ''hog cycle'' (Meadows 1970) were developed on the basis of mentioned problems that have been dominant in our understanding of amplification effects in supply chains. Methodologically, system dynamics has the ability to deal with complex dynamics systems. That is, due to the complicated factors and non-linearity behaviour among variables and the dynamic behaviour of complex systems are difficult to predict from a description of their static structure. Hence, simulation modelling and analysis is essential for robust policy design (Sterman 2000).

Phases	Steps
Problem Structuring (Aghalaya, Elias, and Pati 2012, Maani and Cavana 2007)	Behaviour over time graph development
Identify Variables (Aghalaya, Elias, and Pati 2012, Maani and Cavana 2007)	In-depth interview
Causal Loop Modelling (Wolstenholme 1990, Sterman 2000)	Variable identification and Causal loop model development
Draw Quantitative Simulation Model with rate, level and constant variables (Wolstenholme 1990, Sterman 2000)	Sketch the model based on relationship among variables
Run Simulation	Entered real life data once with starting variable
Validation and Reliability (Barlas 1996)	Examine structural validity and assess the data reliability in different phase
Test Extreme Condition (Barlas 1996)	considerable Changes of key variable values to observe output reliability
Forecasting Future	Model run for 300 weeks whether it has only 104 weeks data to compare with the reality.

Table 1: Methodological Framework

The methodological approach of this study is based on the Systems Thinking and Modelling methodology (Maani and Cavana 2007). The two phases of this methodology used in this study follow a qualitative approach through depicting causal relationship among variables (Sterman 2000), as shown in Table 1. In the first phase, the complex problem related to product returns in the poultry industry was structured systemically. For structuring the problem systemically, a behaviour-over-time information and chart was developed. In the second phase, a causal loop model was developed using a rigorous simulation package of Vensim DSS 6.01b.

Both primary and secondary information was used in this study. Primary information was collected in September 2012 mainly through in-depth interviews with the sample respondents from the poultry case industry. This research used in-depth interviews and observations to gain insights to help develop a poultry supply chain model. The total respondents included the top five executives and case farm owners who were interviewed. Secondary information was collected from various books, referral journals, conference papers, statistical yearbooks and company record and reports. This study adopted a positivist ontology, empirical epistemology and quantitative methodology based on real supply chain cases of poultry processes. The design science methodology was chosen for this study as models were developed with relevant variables to attain goals (Simon 1969) and it can be hard and soft to meet particular objectives (Venable 2006a, b). A simulation package of Vensim DSS 6.01b was used as a tool to analyse poultry processes in order to investigate the research objectives.

Supply Chain Modelling

Poultry supply chain in Bangladesh is suffering due to improper forecasting of demand and supply (Rahman 2013). Policymakers and farmers have failed to incorporate market driven knowledge into production or process level of action. Calamities and policy related matters are untraceable for the poultry producer. Management science for a long while has considered supply chains as an undesirable real-world abnormality, rather than a successful business model (Thomas and Griffin 1996). In this situation, mathematical analysis like simulations can show future projection based on historical abnormality in supply chains, where actors will strive to optimize their performance from a central position (Thomas and Griffin 1996, Sarmiento and Nagi 1999, Akkermans 2001). Few writings have investigated optimal policies for supply chains as a result of these chains proving successful (Cachon 1999, Gavirneni, Kapuscinski, and Tayur 1999, Lee and Whang 1999, Chen et al. 2000). We suggest that the poultry industry should be operated and evaluated based on separate supply chain to enable that the policy makers to design future production, demand and supply effectively.

Problem Structuring

In the problem structuring phase, a behaviour-over-time graph and table was developed for the case industry. Developing a ‘reference graph’ or historical trend graph is one of the tools used in systems thinking (Aghalaya, Elias, and Pati 2012) to show the real life patterns of the main variables in a system over an extended period of time. Typically, the data or information can be taken for several months to several years. The more historical data gathered, the better the extrapolation of future trends can be predicted. Such patterns can indicate the variations and trends in the variable of interest, for example, growth, decline, oscillations, or a combination thereof. The important elements captured by a graph are the

overall trends, directions and variations, not the numerical value of the variable (Aghalaya, Elias, and Pati 2012).

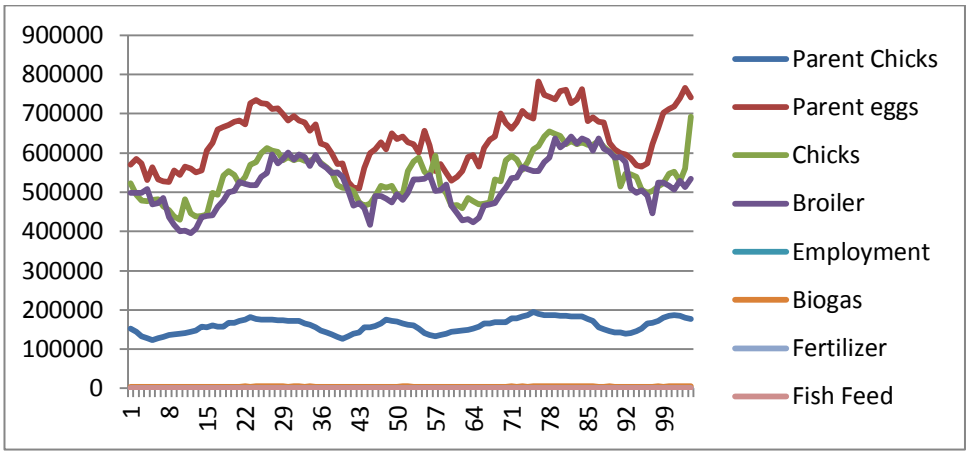

Figure 1: Draw graph of key variable output over time with realistic data

In this study, reference graphs were drawn (figure 1) to capture the historical output (behaviour) of key variables. Selected key variables were parent chicks enter, mature parent, parent eggs produced, employment created, fertilizers and biogas produced, number of farmers, broiler chicks consumed, and final broiler production. The data input in the graph covered 104 weeks. It is mentionable that poultry chicks' production and distribution are run through weekly cycle. The fluctuation in the individual graph line denotes the variation of production and distribution over time. For example, parent eggs line fluctuate a number of times in 104 weeks. Lots of ups and downs can be found in one line (random fluctuation) whereas drastic fall and rise means either collapse or sudden rise of the market and represent fluctuations of business caused by demand-supply gap, over-under production, calamities, and policy barriers. This research focused on discovering these problems through predicted/simulated future results to take appropriate measures.

CAUSAL MODEL BUILDING

Recently, causal loop diagramming formed an important part of a system dynamics model. Positive and negative feedback loops are the building blocks of system dynamics and causal diagram led to the conceptualized a prospective model (Richardson 1986). A causal loop diagram also provided the visualization of how interrelated variables affect one another. The diagram consists of a set of nodes representing the variables connected together (Aghalaya, Elias, and Pati 2012, Maani and Cavana 2007). The relationships between variables, represented by arrows, can be labelled as positive or negative. To generate a directed arrow, a positive (+) sign near the head of the arrow indicates that an increase (or decrease) in a variable at the tail of an arrow caused a corresponding increase (or decrease) in a variable at the head of the arrow. If an increase in the causal variable caused a decrease in the affected variable, a negative (-) sign was placed near the head of the arrow (Aghalaya, Elias, and Pati 2012).

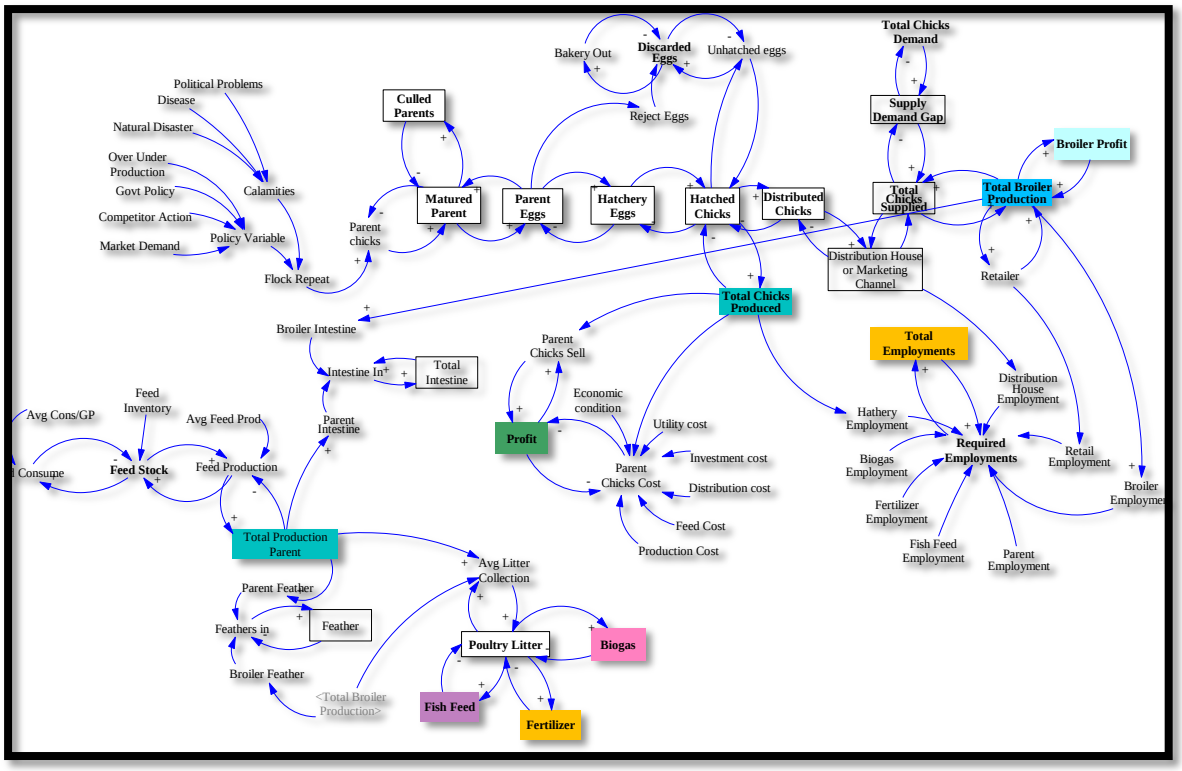

Figure 2: Causal Diagram of Poultry Supply Chain Model

The above figure shows the relationship or link between/among key variables that reflects reality includes only the key variables that are influential and have an impact on the outcome. Figure 2 show a numbers of loops in this qualitative/causal model. These loops includes:

Negative Feedback loop 'Parent Chicks' and 'Mature Parents': If parent chicks supply increases then mature parent will increase as well. But when mature chicks' increases, parent chicks will decreases for the time being until flock finish its cycle.

Positive feedback loop 'Required Employment' and 'Total Employments': If required employment increases, total employment will increase. Again, when total employment increases, required employment will go up as well.

Positive feedback loop 'Total Chicks Supplied" and "Total Broiler Production": These two have the positive relation with others to increase based on other variable.

QUANTITATIVE SIMULATION MODEL

The model below was developed based on a causal diagram and the relationships found among or between variables. This complete model incorporates input, output and process information for individual constants, auxiliaries and level variables. The model also consist number of reference variable and excels lookup to compare and contrast it with real life output. This is shown in a different graph provided below.

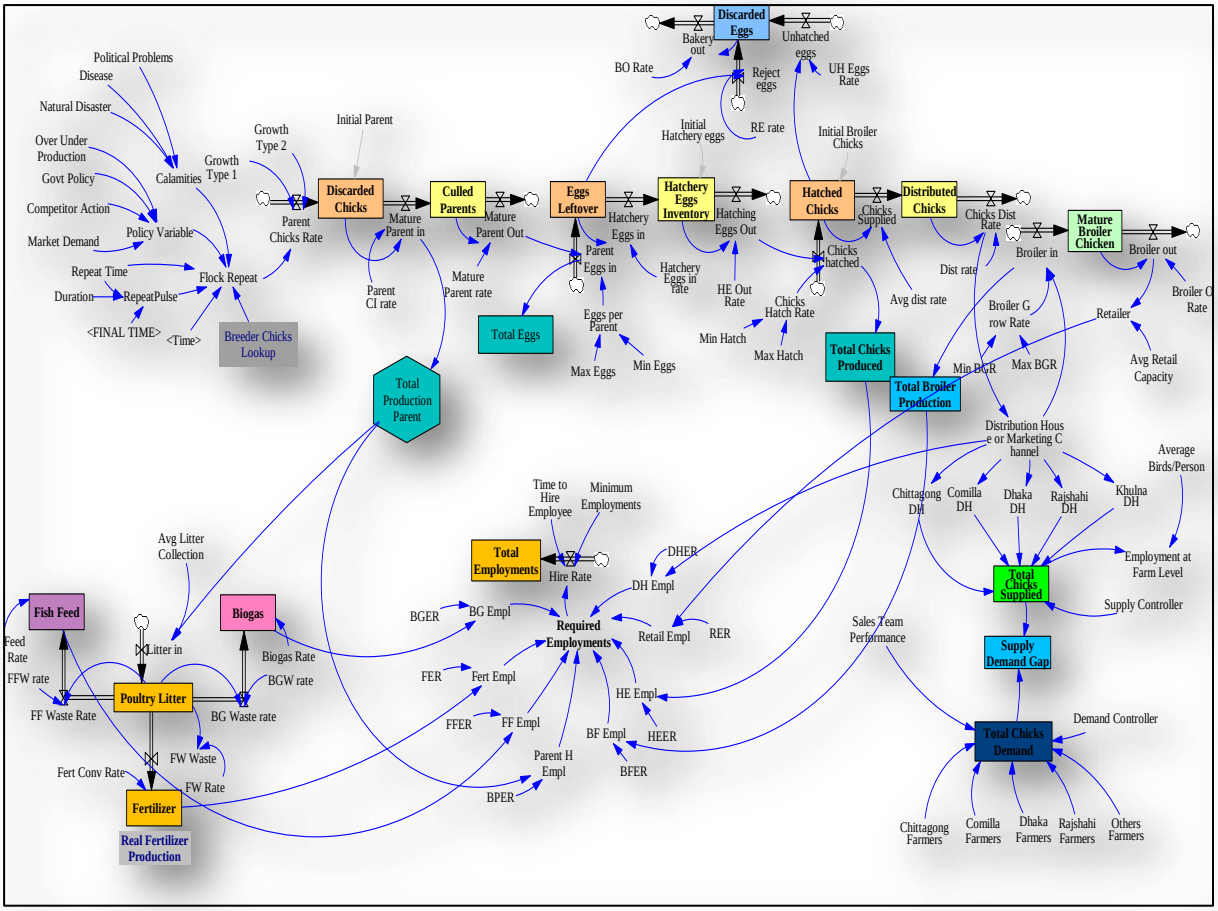

Figure 3: Poultry Supply Chain Simulation Model

Model starts from the "Broiler Chicks Lookup" variable where policy maker/farmers decide how many breeders can be reared in their whole process as a flock. All square boxes denotes level variable which plays an important role in the poultry supply chain. This breeder chick's lookup is the only information given as input which was taken from the case farm.

RESULTS

Validity and Reliability

Validity and reliability tests builds confidence in system dynamics models (Barlas 1996, Forrester and Senge 1980) as part of the behavioural validation. The models of this study were tested and validated based on the formal criteria by Barlas (1996) and Forrester and Senge (1980), which involved three major stages: structure validity; behaviour validity and tests of policy implications. Basically, structure validity tests purposes at assessing model structure and parameters without examining relationships between structure and behaviour. Structure validity comprises a structure-verification test, extreme-condition test, dimensional consistency test (Barlas 1996). Structure validity has been checked by "Check Model" and "Check Units" option of the research tool. The authors compared this with the real life variable structure formation and with model objects. In behaviour validity tests, we look at

whether the model variables behave with each other consistently or not. In addition, it examines uneven behaviour in extreme or unusual condition (figure 5). This model was tested using various changing policies. The model was also tested using various policies by the policy makers. For example, policy makers want to get a growth of 30% instead of 20% due to demand increase. This change was made to see the immediate effect on other variable as well as whole model as a result of the change. Figure 4 presents an example of the reliability check by comparing model result with actual result. Most of the results are within the acceptance level.

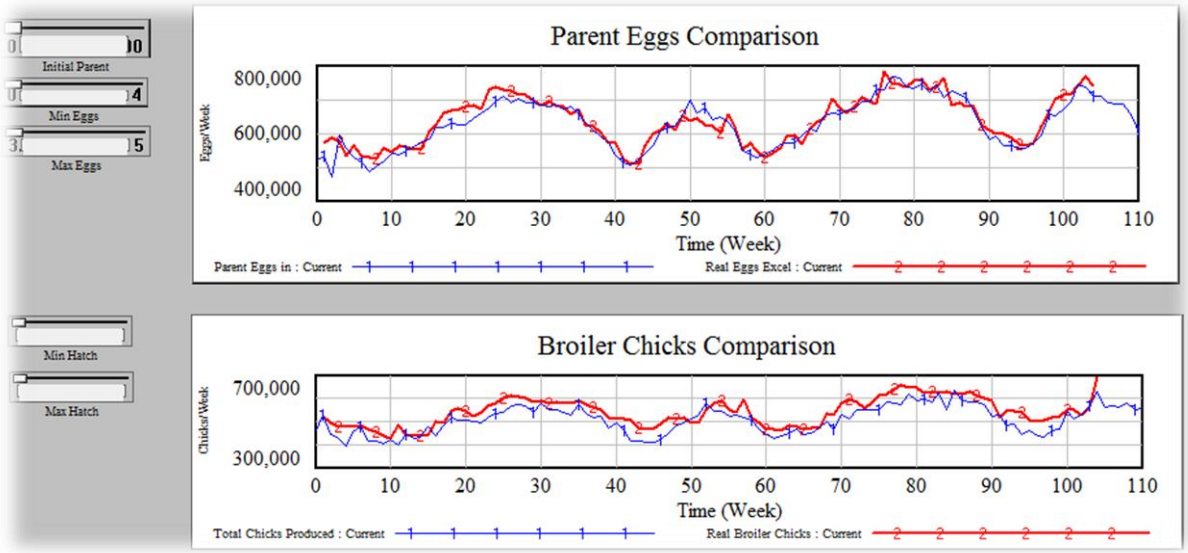

Figure 4: Few tests summarizes for reliability test.

Figure 4 shows the simulated output of seven key variables in the poultry industry. The blue lines are marked as simulated result and red line marked as real life data. It shows that various lines are almost matched with each other having around ten percent fluctuation. The simulation was used to predict the next four additional years result/output based on historical business wave. This could allow producer and policymakers to make predicts a policy and

decision they used for certain change.

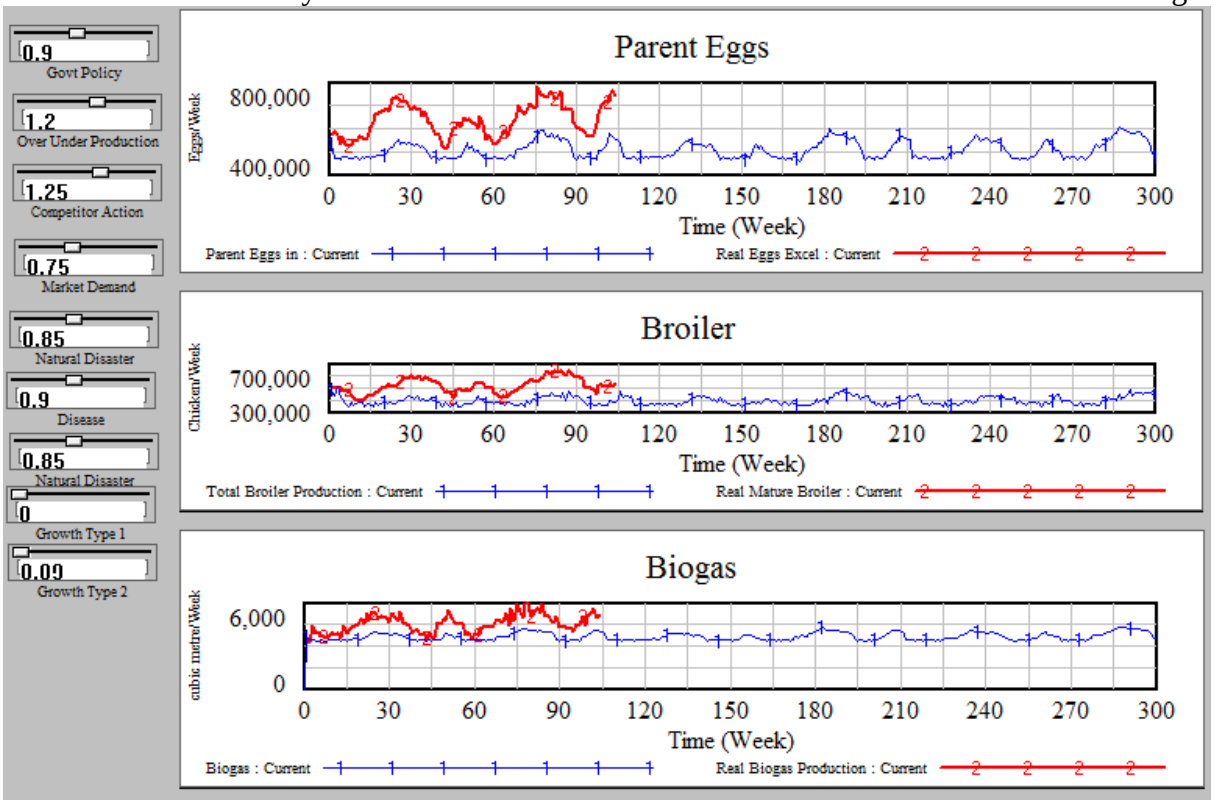

Figure 5: Extreme Condition test of key variables

Validity of model equations under extreme conditions resulting values beyond the projection/anticipation of what would happen under a similar condition in real life (Forrester and Senge 1980). Figure five demonstrates the extreme condition test of the simulation model. So far the results fluctuates based on extreme conditions (such as 10% decrease of Government policy, 25% of increase of competitors action and 15% decrease of natural disaster, demand fall 25%, 10% decrease for poultry disease etc.) are not showing abnormality. The model behaves perfectly based on changes of policy and constant variable.

Forecast and Variable values

The main problem in the Bangladesh poultry industry is in its inability to forecast or predict existing and future demand of the market. Demand-supply forecast mostly rely on uneven/uncertain calamities of disease, natural disaster (flood, cyclone, etc.) and finance. Figure 5 to 8 shows the forecasted output for supply demand gap, employment creation, and benefits from reverse supply chain. Biogas, fertilizer and fish feed are the main by-products coming from the reverse chain using existing poultry wastes. As a starting position, no calamities and policy problems were included. There were adjusted variable as a part of the analysis. For example, in figure 5, natural disaster slide down to 0.85 from 1, which means production process, has lost 36% business due to natural disaster. And more importantly, maximum and minimum value has set for this natural disaster variable is 1 and 0 respectively which is logical too.

Employment Generation through Forward Supply Chain

When an industry operates successfully, it creates so many opportunities for the people who engage directly or indirectly. Owner, employee, stakeholders are benefited through successful operation of business. The same applies to the poultry industry as well. Farmers, employees, distributors, wholesalers, retailers, food processor, transporter are achieving economic benefits from more transaction chicken, eggs and value added chicken products. Figure 6 compares the simulated output with the real life employment figures over the time of 104 weeks. The graph shows red and green lines that represents model generated employments and real employment. Both these lines are almost following each other which mean that the model generated outputs is almost similar to actual outputs. The bottom line is that the more bird transacted, the more employment will be created. At the same time, social, economic and environmental benefits will be achieved as a result of this.

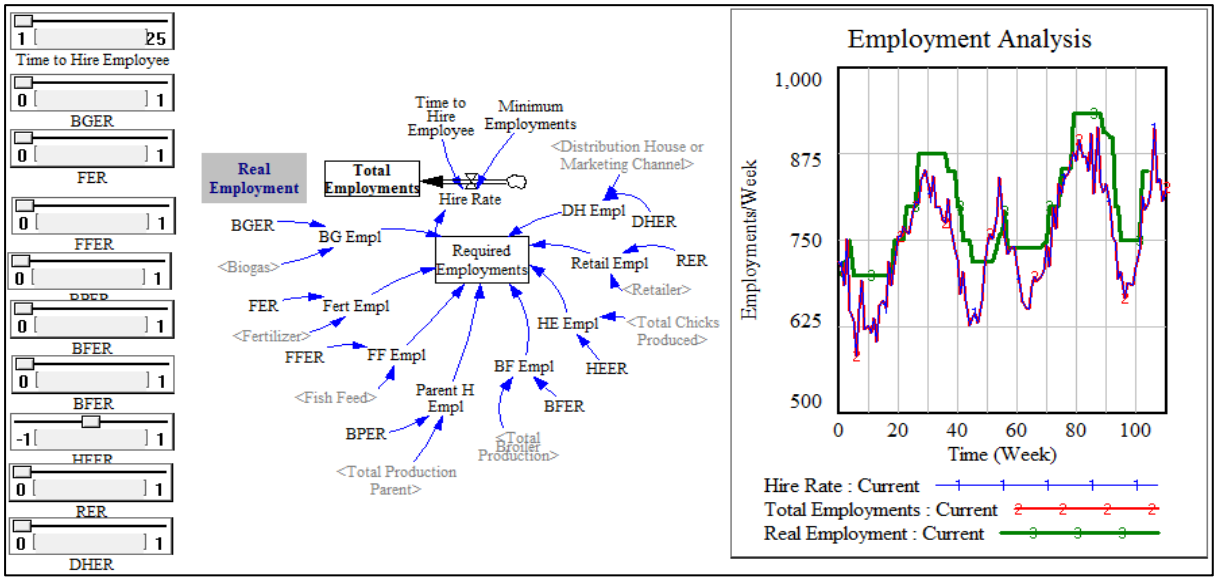

Figure 6: Realistic and projected employment generation in simulated model

Poultry Chicks Supply Demand Gap

Figure 7 show how day old chicks' demand comes from authorized dealer of different zone of the country. Model includes the name of major zones of Chittagong, Dhaka, Comilla, Rajshahi and Khulna. Under each individual zone, there are numbers of dealers and sub-

dealers appointed. All of them controlled from the central head office marketing unit.

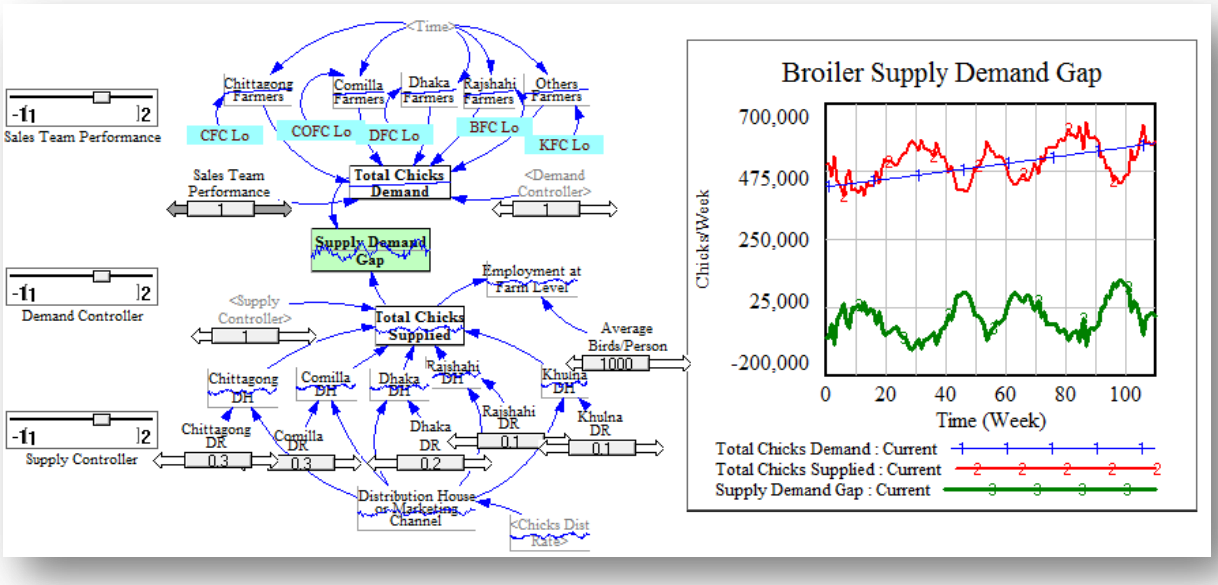

Figure 7: Supply Demand gap analysis for poultry meat

Reversing Poultry Wastes for Producing By-Products

Figure 8 shows the process of by-products coming from poultry wastes through reverse chain. The figure shows the output of biogas, fish feed and fertilizers. It is important to mention that there are few other poultry wastes generated in the poultry process namely, intestines, feathers. Intestine can be used for making fish feed and feather can be used for pillow-bed and for the sophisticated plastic making industry. This area is a key for generating more economic, social and environmental benefits for farmers, processors, distributors, society in particular and country in general.

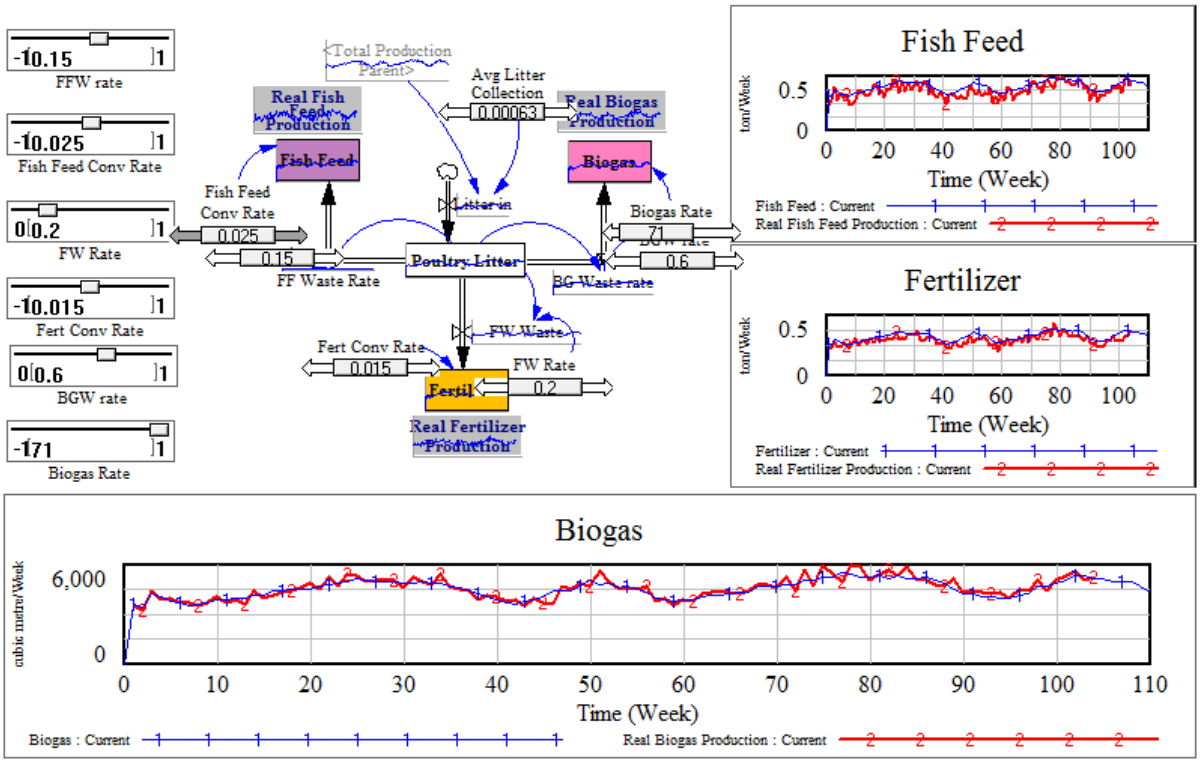

Figure 8: Poultry reverse chain

CONCLUSIONS

Most of the poultry industries in Bangladesh are medium in size having unorganized supply chain network with lack of coordination among stakeholders. Industries are always concerned about the high cost of deployment associated with forward and reverse supply chains. Dynamic process, technology, infrastructures and whole supply chain network management involves huge financial capital which is almost unbearable to achieve in Bangladesh. Bangladesh poultry can integrate complete supply chain network so that they can compete with the local and global market and also reduce their operation cost. The model in this research shows the way of the integrating forward and reverse supply chains. It is evident from the model that reversing poultry wastes for processing by-products can give number of benefits to the industry, society and environment. Integrated forward and reverse processing brings more economic (monetary), social (employments, new business) and environmental (free from pollution) benefits to the relevant society of Bangladesh. Policy variables in the models are the switches and indicators to study the impact those will have a poultry operation including various processing. This research is also contributes theoretically in the field of the commercial poultry sub-sector of Bangladesh. It shows the effective integration of the forward and reverse supply chains that can be used as a direction or guide for the poultry producers and related stakeholders. Future research can focus on the different variables and study its individual impacts on the poultry industry in Bangladesh.

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