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# A SYSTEM DYNAMICS APPROACH FOR POULTRY OPERATION TO ACHIEVE ADDITIONAL BENEFITS

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## ABSTRACT

Poultry generates various wastes such as litter, reject and broken eggs, intestines, waste feeds, feather and culled birds. Most of the farm owners do not utlize these wastes for further by-product generation. Without profitability, farmers do not reuse their waste. System dynamics along with simulation is a tool that can be used to forecast the feasibility of waste and by-products generation. In this paper, we present a poultry model grounded on system dynamics to determine the interaction among factors in the system using a software package, Vensim. A case poultry industy in the city of Chittagong, Bangladesh was selected to conduct the study. The objectives of this paper are twofold. First, it develops a qualitative model on poultry operation. Second, it constructs a simulation model to explore possible opportunities available by recycling poultry wastes within the same poultry operation.

## 1 INTRODUCTION

Bangladesh is considered one of the suitable countries in the world for poultry rearing (Shamsuddoha and Sohel 2008). It is because of cheap labor, easy access to the community, available indigenous items and increasing demands. Its appropriateness can be justified due to employment creation, entrepreneur development and social and economic changes in rural, urban and sub-urban areas (Shamsuddoha, Quaddus, and Klass 2013). Applications of system dynamic concepts and simulation can easily guide farmers towards scientific farming with better profitability and sustainability (Shamsuddoha, Quaddus, and Klass 2013; Shamsuddoha, Quaddus, and Klass 2013). It is important to develop a mental model along with the stakeholders linkages in system dynamics (SD) modeling (Forrester 1961; Forrester 1994). System dynamics is a vibrant methodology based on developing simulation models to improve decision making, forecasting or problem solving performance (Vennix, Akkermans, and Rouwette 1996; Vennix and Vennix 1996; Vennix 1996; Andersen, Richardson, and Vennix 1997; Golnam et al. 2011). Such models can serve to develop policies that improve problem situations or provide potential solutions aimed at improving the situation (Vennix, Akkermans, and Rouwette 1996; Vennix and Vennix 1996; Vennix 1996; Andersen, Richardson, and Vennix 1997). Constructing a system dynamic model based on realistic information can model the reality more systematically (Lane and Oliva 1998). Manufacturing operation is quite complicated as it deals with environment, social and economic matters during different stages of production (Corbett and Kleindorfer 2003; Seuring and Muller 2008). Constructing a system dynamic model based on realistic information can model the reality more systematically (Lane and Oliva 1998). Manufacturing operation is quite complicated as it deals with environment, social and economic matters during different stages of production (Corbett and Kleindorfer 2003; Seuring and Muller 2008).

It is difficult and challenging to preserve undamaged environment, have zero impact on society and provide consistent economic gains within manufacturing process that extend over long periods of time. In this situation, effective supply chain (SC) can result in efficient production (McAuley 1972), smooth supply (Fisher 1997), waste reuse, return and recycle (Saysel and Barlas 2001; Prahinski and Kocabasoglu 2006; Kocabasoglu, Prahinski, and Klassen 2007), and increase social benefits (Shamsuddoha 2011). The focus of this study confined on building poultry process model, later fit the model into the simulation environment in the computer. Then the simulation model replicates almost the real poultry process so that output of main products and wastes can be measured. Quantity of various wastes can help to take a decision whether recycling and reprocessing of poultry wastes will be profitable or not. This model also extended version from the real practices of the case industry in aspect of reversing wastes to the processing unit. Practically, some portion of the wastes reuse at the farm level and rest of the share used to supply towards third party as raw materials or dumped as final wastes. Such practices can be opened new opportunity for the existing and small business entrepreneurs.

## 2 LITERATURE

### 2.1 Bangladesh Poultry

Over 73% people lives in the rural areas and are highly dependent on agriculture and livestock system in Bangladesh. The contribution of the livestock sub-sector to GDP and the agriculture sector as a whole is currently 3.2% and 10.11% respectively (Discovery 2009). The Poultry industry is one of the major industries in the livestock sub-sector. Approximately 20% of the protein consumed in Bangladesh originates from poultry. Among poultry species, the chicken population is dominant over others, at almost 90%, followed by ducks (8%) and a small number of quail, pigeons and geese (Discovery 2009). To implement reverse supply chain (RSC) concepts in Bangladesh and within the poultry industry, there seems to be a low chances of product retrieval, return or reconditioning in the reality sense, as most chicken products are perishable. However, there are immense opportunities to reuse or recycle poultry wastage. By reusing poultry wastage, industries can make valuable products like fertilizers, bio-gas, pillows, charcoal, and bakery items. This kind of wastage conversion will help to maintain our environment and will add value at the customer end of the product cycle (Shamsuddoha 2011). Sustainability, Environment and RSC in the poultry industry have not yet received proper consideration by researchers. There are huge opportunities to conduct researches to develop the existing poultry operation in light of achieving organized supply chain, sustainability, profitability and optimality.

### 2.2 Poultry Wastes

There is huge quantity of various poultry wastes generated from the poultry operation. Unfortunately these wastes are dumped into vacant land and rivers and it caused severe environmental damage (Shamsuddoha 2011a, Shamsuddoha 2011b). Neglected wastes create environmental problems. Environmental problems spread various diseases, contaminate river or canal water, and spread odor to name a few. There are four different kind of poultry wastes, namely, litter (Burak Aksoy 2008), manure/compost (combination of poultry litter) (Rivera-Cruz et al. 2008), feathers (Shih 1993), broken eggs and intestines (Burns and Stickney 1980). Poultry litter can be the source of fertilizer (Gupta and Charles 1999), bio gas (Bala 1991), artificial charcoal and fish feed (Burns and Stickney 1980); feathers can be raw materials for the Bed industry (Shamsuddoha 2011b), broken eggs for the bakery and intestines for the fish farms (Shamsuddoha 2011b).

### 2.3 System Dynamics Model and its Application in the Poultry Operation

System dynamics was familiarized by Jay Forrester in the 1960s as a modeling and simulation methodology for long-term decision-making and supply management and waste management (Chaerul, Tanaka, and Shekdar 2008). Such models are easy to control, link variables, and trace the changes through causal feedback loop system (Sterman 2000; Dyson and Chang 2005; Sterman 2006). The chicken industry supply chain (Minegishi and Thiel 2000), and its impact over environmental issues on product supply chain and product recovery (Georgiadis and Vlachos 2004), and waste management (Sudhir, Srinivasan, and Muraleedharan 1997; Karavezyris, Timpe, and Marzi 2002; Ulli-Beer 2003; Dyson and Chang 2005) have been studied using system dynamics and simulation modeling. A system dynamics model has also been proposed by Ulli-Beer (2003) to analyze the divergent local policy initiatives in solid waste recycling. The literature review showed no evidence of research on this current issue of poultry process in developing country like Bangladesh. Research gaps remain in the theory and practice of the poultry industry. No evidence was found of supply chain issues being considered in the light of the poultry industry in Bangladesh. This research gap motivated this study to enrich the literature and improve modern practices.

## 3 METHODOLOGY

Sometime after Forrester (1961) introduced system dynamics, Sterman (2000) conducted a number of studies to popularize it in the industrial world. Today, people are using system dynamics concepts to analyze their individual problems all over the world. For example the paper recycling industry (Spengler and Schröter 2003), poultry industry (Shamsuddoha, Quaddus, and Klass 2011b), business process reengineering (Sterman 1989) and Meadows's ''hog cycle'' (Meadows 1970) were developed on the basis of supply chains. The supply chain of an industry is the key to analyze situations through system dynamic modeling. Total supply chain consists of forward and reverse supply chain of a business process. Forward supply chain received priority over the reverse chains in academia (Aghalaya, Elias and Pati 2012). Systems dynamic deals with the dynamic behavior of a supply chains operation. Dynamic behavior depends on associated loop of a particular variable. A real life experience provides us with ideas that help us to conceptualizes and construct mental model. Table 1 shows how to construct model from a case industry through mental modeling and behavior. Richardson and Pugh (1981) developed a seven steps SD modeling process that begins with identification of the problem and system conceptualization of key variables and the relationships between them (Tarski 1983).

The methodological approach of this study is based on the systems dynamic methodology (Maani and Cavana 2007) with two phases of qualitative and quantitative approaches (Sterman 2000) shown in Table 1. In the first phase, system conceptualization was followed by constructing a mental model through business process observation over time. For structuring the problem systemically, a behavior-over-time information and chart was developed. In the second phase, a causal loop model was developed using a rigorous simulation package called Vensim DSS with version 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 sample respondents from the poultry case industry. This research used in-depth interviews and observations to gain insights and develop a case poultry supply chain model. The total respondents included the top ten executives and case farm owners. 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. For this study, the design science methodology was chosen to extend the model (way of reuse or recycle wastes) to achieve goals (Simon 1969). The simulation package was used as a tool to analyze the poultry supply chain process in order to investigate the research objectives.

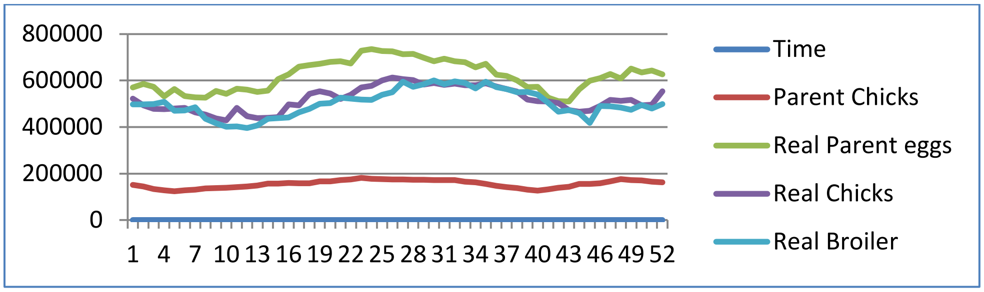


Figure 1: Historical graph of realistic data for key variable over time.

### 3.1 Problem Structuring

Historical behavior-over-time graphs (BOT) were developed based on key variables used to structure the problem. Variable performance over time was used to conceptualize the business trend and provide give appropriate input parameters to the system (Aghalaya, Elias, and Pati 2012). Historic information can provide parameters to represents present and future trends that show the behavior of growth, decline, and oscillations (Aghalaya, Elias, and Pati 2012). In this study, reference graph were drawn (Figure 1) to capture the historical output (behavior) of key variables of parent chicks, real parent eggs and real chicks. The data input in the graph contained 52 weeks (one year) and observed that all the key variables fluctuates number of time over mentioned time.

## 4 CAUSAL MODEL BUILDING

Causal loop diagramming (Sterman 2000; Sterman 2006) is an important part of a system dynamic model. Positive and negative feedback loops indicate the dynamic relationship among or between the key variables (Richardson 1986).

A causal loop diagram also visualizes how interrelated variables affect one another. The diagram consists of a set of nodes representing the variables connected together (Maani and Cavana 2007, Aghalaya, Elias, and Pati 2012). The relationships between variables, represented by arrows, can be labeled as positive or negative. Positive (+) sign means increase (or decrease) in a variable causes a corresponding increase (or decrease) in a corresponding variable. If an increase in the causal variable caused a decrease in the affected variable, a negative (-) sign is placed near the head of the arrow (Aghalaya, Elias, and Pati 2012). According to Figure 2, there are numbers of loops displayed in this mental/qualitative/causal model. For examples:

Positive Feedback loop between ‘Mature Parent and Parent Eggs’: If mature parent supply increases then parent eggs will increase. Nevertheless, when parent eggs production escalates, mature parent will also increase to maintain consistent supply.

Negative feedback loop between ‘Parent Chicks and ‘Mature Parent’: If parent chicks supply increases then mature parent will increase. However, when mature parent increases, parent chicks will be reduced due to parent chicks maturing as parents.

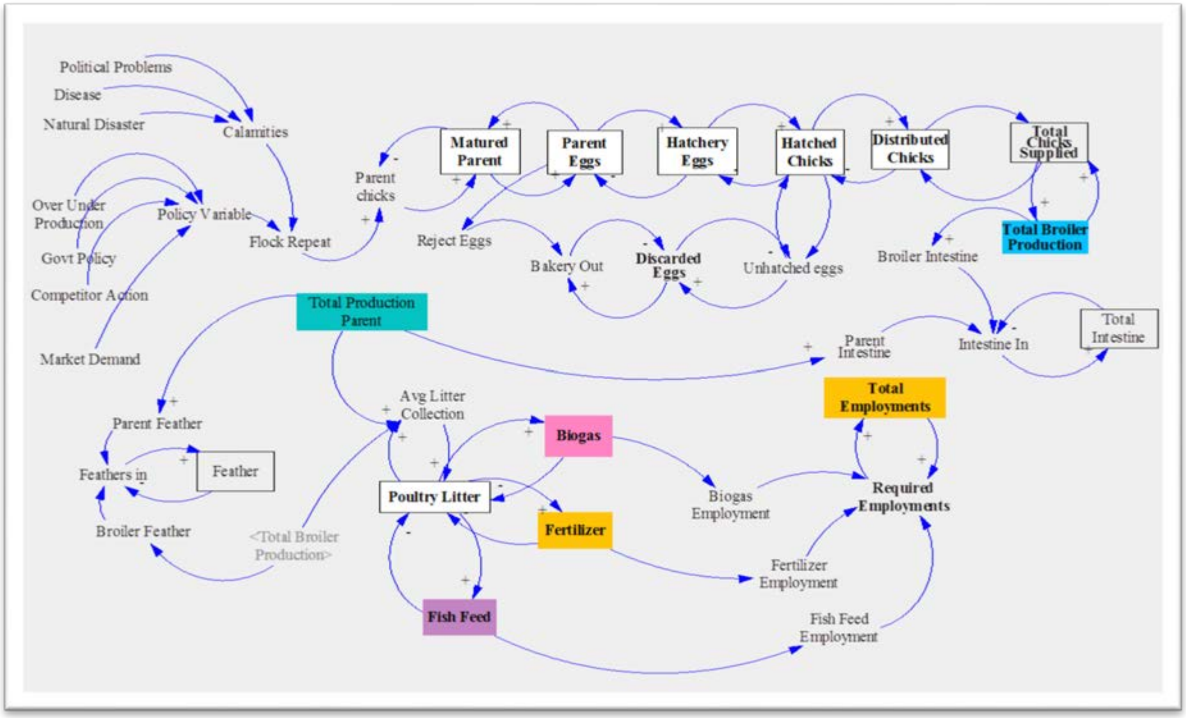


Figure 2: Causal diagram of poultry reverse supply chain.

## 5 QUANTITATIVE (STOCK AND FLOW) SIMULATION MODEL

Qualitative modeling helps to construct a quantitative model, which consists of stocks, flows and diagrams. Figure 3 was developed using the qualitative model displaying in figure 2 which also known as causal model. All the square boxes represented here as level or stock variable. These level variables are associated with the constant and auxiliary variables. The values of different variables were given input values based on the practical experience of respondents.

The model begins with "Broiler Chicks Lookup" variable of real data from the case industry using the last 52 weeks. This is the only input taken from reality and all outputs generated from simulation run by the Vensim package. This stock and flow diagram developed from the causal qualitative model of Figure 3 by determining appropriate rate, constant, auxiliary and level/stock variable. Stock variables are often changed using the determined value of associated constant and auxiliary variable. Most of the values were determined from primary sources of the case industry. This information was converted as mathematical values and equation for all connecting loops and variables. Some of the data was taken from standard practices from the case industry. When model development done, simulation run was conducted to see how it behaves. To get aggregate view of the whole model, synthesim run is an effective way to view it in the Vensim. Synthesim mode shows the graphical representation of levels and auxiliary variables. Constant variables are shown as side bar so that policy makers or modeler can experiment on it by increase or decrease the values instantly.

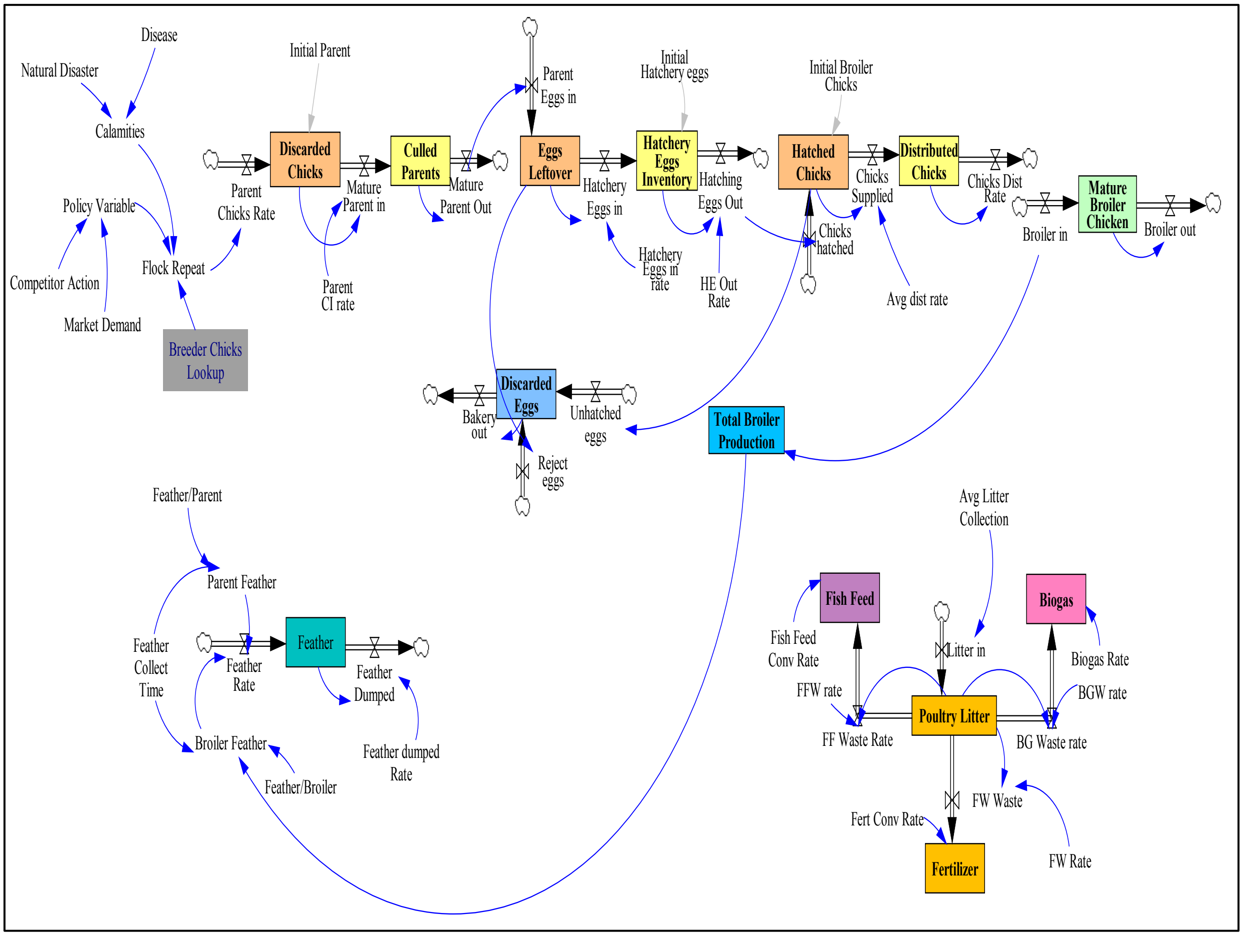


Figure 3: Poultry simulation model.

## 6 RELIABILITY OF THE MODEL

It is an integral part of a research study to check for validity and reliability. Validity and reliability tests are the prerequisites to builds confidence in system dynamics models (Forrester and Senge 1980; Barlas 1996). Reliability test can be done through comparing the simulated data with the real data. If it does not show any unusual behavior then it seems that model is reliable.

The blue and red lines are marked as simulated result and real life data respectively. Figure 5 clearly demonstrated key variables along with comparison of simulated and real data. For example, fish feed, biogas, fertilizers variables in figure 4 behaved perfectly except few sudden ups and down. Still this increase/ups (or decrease/down) are in acceptance range of 10 percent variation. It is observed that red and blue lines are very close with each other with minimum fluctuation. The simulation was been run for 156 weeks (3 years) whether real data available for 52 weeks only. This prediction will help the entrepreneurs to gain knowledge on future scenario. Therefore, the model is reliable as it behaves consistently with the time and real data.

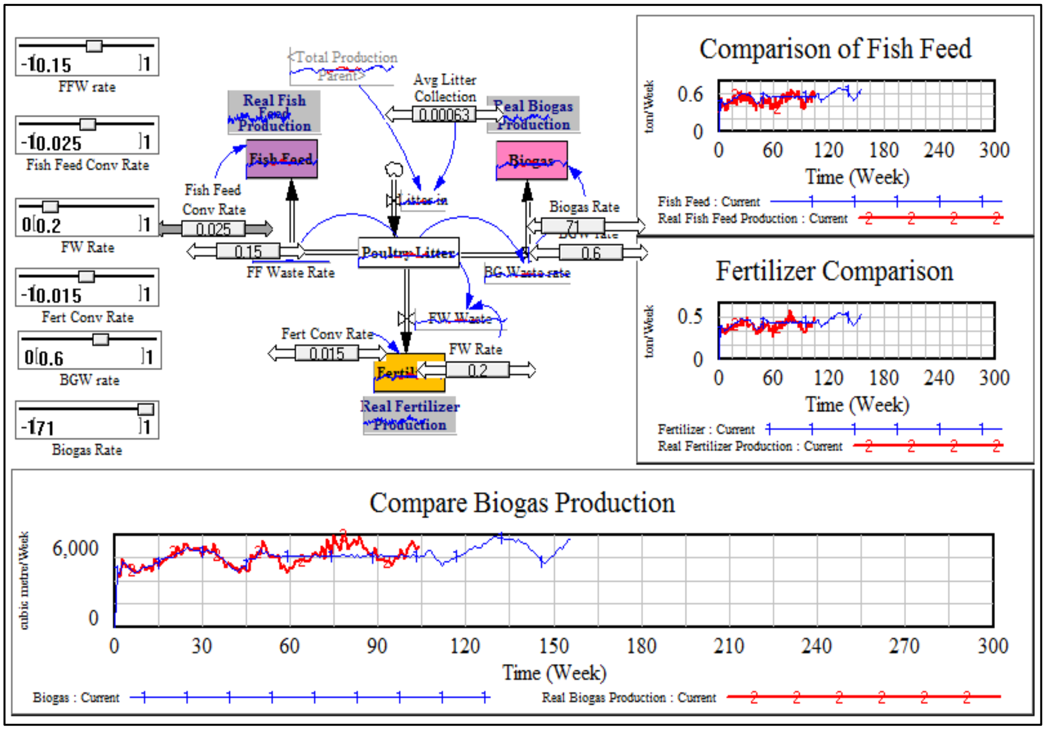


Figure 4: Few tests for reliability test.

## 7 EXTREME CONDITION TEST (VALIDITY)

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). This model was tested in various way of changing policy and constant variable, but it behaves as par expectation and trends. Finally, the model was tested based on policy implication by the policy makers. For example (in figure 5), policy maker want to reduce the poultry parent chicks 140,000 to 1,00000, increase weekly minimum egg production of 3.9 eggs/week to 4eggs/week, increase maximum eggs production 3.97 eggs/week to 4.294 eggs/weeks and the likes. Therefore, the model fulfills the criterion to be valid.

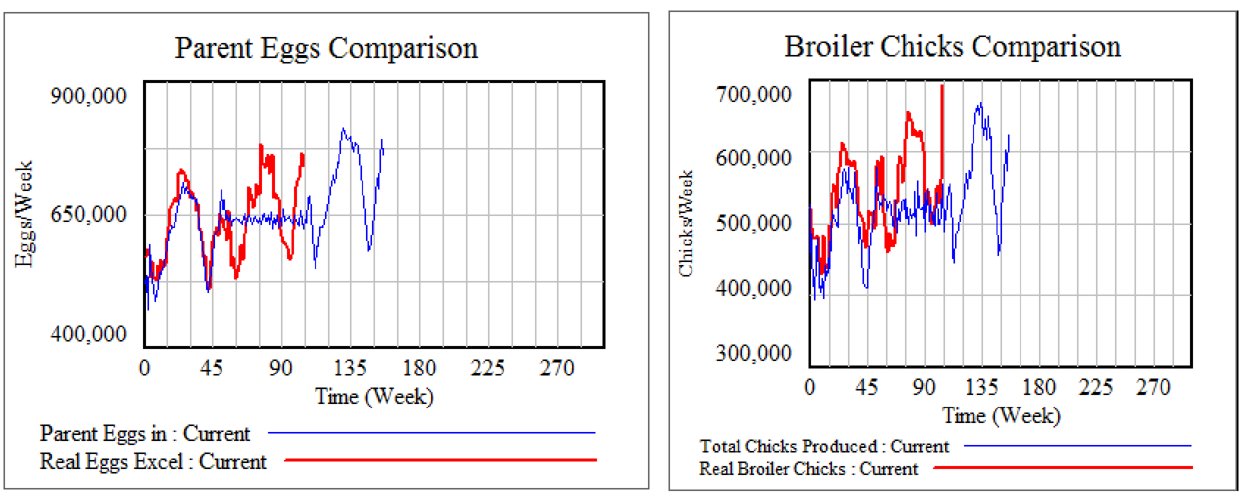


Figure 5: Extreme condition test of key variables.

## 8 MODEL RESULT AND DISCUSSION

Poultry leading countries on poultry farming have adopted many latest technology and concepts in their operation. Consequently, they have gained significant success in poultry rearing and processing, demand, supply mitigating, and wastes management. These innovations have yet to be adopted in developing countries like Bangladesh because of factors that include financial strength, technological inability, inconsistent power supply, land scarcity, failed to predict futuristic scenario, improper disease management, unsure about the market demand, natural disaster and government irresponsiveness. This study has developed such a model, which is one of the major contributions in light of poultry process in Bangladesh. Such model can be experimented by the poultry owners and policymakers' in various ways before implementing a dynamic decision. Dynamic decisions can be based on poultry flock size, waste procurement, employment requirements, demand and supply situation, price, profit and the likes. In figure 3, dynamic relationship between main variables was diagramed in a causal model. At the same time stock and flow model sketched based on causal model, which is almost similar to practical poultry process. This virtual process can able to see 'what if' situations within the process. For example, what quantity of poultry wastes can be generated if particular input was given to the system? Obviously, this model can save the time and practical experiments for the farmers, which save time and money. The model also explored numbers of opportunities within the poultry operation specially in reversing poultry wastes. The model also depicted various by-products (mainly, biogas, fish product and fertilizers) procurement from existing poultry wastes. This study also reveals the opportunity of using unused wastes like poultry feathers and intestines as many countries are making valuable products from them. For example, poultry soft feathers are using for making mattress, pillow and other bedding materials. All the results were reliable based on reliability test and checked the validity using extreme condition test in figure 5. All the figures demonstrated desired results, which is a good sign for the poultry stakeholders. The researchers also believe that this model can be used at any environment to measure poultry wastes and generate by-products from them. Moreover, it will help the farmers and policymakers to integrate forward and reverse supply chain to be more productive poultry industry.

## 9 CONCLUSIONS

In brief, the idea of system dynamics simulation modeling are using in so many sectors all over the world. The great benefit of this methodology is its capability of providing futuristic behavior that helps the decision makers to prepare themselves to act on time. It is now presents a great opportunity considerable idea for the poultry entrepreneurs to utilize their potentiality to gain maximum benefits. Proper poultry management can help to achieve economic, social and environmental benefits. It can also create more employment opportunities, increase the scope of introducing small and medium scale of industry, help to achieve social benefits and help to keep our environment clean and hygiene. There are also many benefits associated with sustainable poultry farming. The output from the model, in addition to being able to measure quantity but also associated consequences, which help the poultry stakeholders to make the right decision in a particular situation. Future research can extend to meticulous particulars of the total industry operation and its optimality.

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