CHAPTER 5

Discussions and Conclusions

5.1 Discussions

5.1.1 Dataset Description Period November 2014 to October 2015

1) Poultry Movement

Almost half of poultry movements were chicken movements. This could be associated with the high demand of chicken meat as the leading source of protein in Indonesia which consists of approximately 84 % of total meat consumption (BPS, 2014). DOC had the highest quantity and singing birds had the longest distance. Singing birds had the longest distance although numbers were low. Songbirds are mainly transported by air, mainly to Java where, keeping singing birds as a hobby is very popular.

2) Cattle Movement

During the period of study, the number of cattle movements was almost half the poultry movements. DGLAHS in Indonesia have regulation of animal health control (Regulation Number 47 of 2014), in animal translocation for domestic and international, animal movement must have animal health certificate from province and district origin, document of recommendation of destination of province and laboratory result, the type of disease should be tested in laboratory depend on destination of province, however traceability of livestock in Indonesia is not supported by a unique identification for each animal, therefore trace back of individual animals is difficult to achieve, this similar problem also was found in Thailand, which there is registration of cattle dealer at the cattle market (Kengwa et al., 2017), an animal trace back system is

useful to provide information on the origin of infectious disease so that preventive and control measure can be applied (Caporale et al., 2001), thus we suggest official authorities to established traceability system in livestock movement.

5.1.2 Social Network Analysis

1) Centrality Parameter of Combined Poultry Network

The network combined poultry showed majority districts with high out-degree also tend to have high betweenness, this district majority were located in Central Java Province. Chicken network had significant in and out degree and in and out going contact chain other than other type of poultry, this suggest chicken play role in the network by connecting other districts. Districts with high level of out-degree had potential risk for spreading infectious disease widely to other districts. Study in epidemic simulation shown removing 1 % of nodes with the highest out-degree values could afford to reduce 88 % in the number of infection nodes (Natale et al., 2009).

Betweenness provides an indication of the extent to which a node facilitates the flow of what is transmitted by the links amongst members of the network (Borgatti., 1999). By removing or intervention districts with high betweenness, the network can be broken down into fragments then will reduce disease transmission and prevalence infectious livestock disease (Kiss et al., 2006; Rautureau et al., 2012*).* Districts with high level of in-degree mostly located in the big city in Java, Kalimantan and Sumatera Island. This high score presumably links with high broiler meat demand in the major cities, including: Semarang, Banjarmasin, Medan, and Bandar Lampung, in the Province less densely the broiler meat obtained from another Province. Location with frequent in-degree conduces high probability to acquire infected poultry and most likely in a large city the poultry takes place in collector yard or live bird market, therefore these places were important for surveillance.

The correlation between in-degree and out-degree in poultry were significant and positive, there is a district large purchaser also large seller or small purchaser also small in selling activity, in this condition high correlation districts more likely to become infected and spread pathogens to other districts. In-degree and out-

degree is used to identify which district more number of recipients and providing poultry or cattle from other districts, however the indirect contact will not calculate. The contact chain capture information of indirect contact, our result showed that contact chain and degree did not always consistent, some districts with a few direct contacts but large indirect contacts, study similar result were reported in Büttner et al. (2013) and Nöremark et al. (2011), using degree parameter could be useful to identify districts with many direct contact, however the indirect contacts will not be known, this is where the contact chain has additional value. Study in Sweden (J. Frössling et al., 2012) showed there was an association between disease occurrence and number in-degree and ingoing contact chain, this parameter can be useful to increase sensitivity of surveillance.

2) Centrality Parameter of Cattle Network

Similar to poultry network, districts with high out-degree in cattle network also had high of betweenness, the five districts with relatively high out-degree and betweenness were all located in Central Java Province, this Province have highest of cattle markets with a total 12 cattle markets, which may explain why this Province important in cattle movement from district to another district.

Districts with high in-degree were located in capital city of Indonesia, Jakarta and surrounding area (Bogor, Bekasi and Depok) probably related as the highest average daily consumption of protein per capita, with 62.89 protein grams (BPS., 2014).

3) Monthly Centrality Parameter of Combined Poultry Network

An increase of centrality parameter in poultry network was observed in two peaks, the first peak occurs in June during Ramadhan and July at the time of Idul Fitri, the second peak which higher than the first peak occurs in September, during Idul Adha, and followed in October. Seasonal pattern also found in several studies in Asia, such as Chinese New Year in China (Magallanes et al., 2012) and Khmer New Year in Cambodia (Van Kerkhove et al., 2009).

4) Monthly Centrality Parameter of Cattle Network

There were increasing degree and contact chain, the increase began before Idul Adha festival (July to August) by one-fold and reached is peaked during Idul Adha (September) about four-fold. Due to increase of poultry and cattle movement at the time approaching and during Idul Fitri and Idul Adha festival, would have the potential risk to spread infectious diseases between districts in Indonesia, temporal trends also was found in other country, in Argentina identified degree scores increase during autumn and winter compared summer and spring (Aznar, et al., 2011).

5) Topology of Combined Poultry Network

The out-degree centralization index was greater than in-degree centralization and density of poultry network was small reflecting that this network comprised of a relatively small district as supplier poultry to multiple districts, with other link between districts, the same pattern also found in all type of poultry, in this condition high correlation districts more likely to become infected and spread pathogens to other districts.

The cluster coefficient higher compared to study of live poultry network in New Zealand (cluster coefficient 0.064) with similar average geodesic distance (3) (Lockhart et al., 2010). Small world properties characterized by a short average geodesic distance and large cluster coefficient, if an outbreak occur, the possibility for outbreak spread from any districts to other districts in the network takes of around 3 steps, step in here does not account for geographical distance between districts, but instead connection of movement. The high level of clustering implies that most infection occurs locally to district connected with the district which had high score of centrality (Watts and Strogatz., 1998).

In this study, the exponent in-degree distribution was >3, indicate no presence of a power-law degree distribution, however the out-degree distribution shows significant scale-free properties with exponent 2, indicate existence power law distribution, display heterogenicity in score of out-degree, a few districts sending poultry to numerous districts, but most districts have only supply poultry to few districts, its

means at the time of outbreak in district with high score out-degree, could spread to many others.

The maximum GSC in poultry network contains 18 % (42) districts and the largest GWC was all districts, chicken network had the largest GSC compared to other type of poultry.

6) Topology of Cattle Network

The cattle network showed same pattern with poultry network, out-degree centralization was higher than in-degree centralization and the network demonstrated small world properties, with cluster coefficient (0.08) higher compare to study cattle network in Thailand and Cambodia, the cluster coefficient was 0,002 (Poolkhet., 2016) and 0.009 (Noopataya et al.,2015), respectively.

The analysis topology of cattle network showed scale free properties for in-degree and out-degree, the exponent in-degree was 2 and 2.5 for out-degree, the acceptable value for scale free between 2 to 3, this result concurs with earlier study of cattle network in Denmark, where exponent in-degree and out degree was 2.18 and 2.03, respectively (Mweu et al., 2013), another study in France showed for in-degree 2 and out-degree was 2,03 (Rautureau., 2012).

Comparing to combined poultry network, the scale free properties present for in-degree and out-degree cattle network, many districts have a small number of sending or receiving of cattle, while a few have significant more link as supplier or purchaser districts. Scale free network was formed through adding node (district) to a network, each new node that is added to the network connects preferentially to districts that already a large number of contacts, some districts in the network will end up with many more links than most of the other node and formed extreme level heterogenicity. (Albert et al. 1999). The impact of heterogeneity is interesting, having high score in-degree means that in outbreak situation, district is greater at risk of infected, therefore may make these highly in-degree district important to risk based surveillance (Natale et al., 2009). High score out-degree means once outbreak occurs in high score of out-degree, can transmitted too many districts. Epidemic simulations showed withdrawing

out-degree of movement correlated with reduction of infected nodes (Natale et al., 2009). Kiss et al. (2006) also demonstrated that targeting control of highly connected nodes is effective to controlling disease.

Disease spreads within the network will vary depend on distribution of contact pattern in the network, simulation study showed the comparison network with the same number of node and link but differ of level heterogeneity. Scale free network demonstrated the fastest rate of disease spread and reached the largest size compare to all network, even at probability of infection was to low to produce an epidemic in other type of network, the scale free network could produce epidemic (Shirley and Rushton., 2005). In this study, compare to combine poultry network with only have scale properties for out degree, cattle network has scale free properties for both, in-degree and out-degree, therefore the epidemic spread of cattle network faster than combine poultry network.

During a 12 months period, there are 8% (10) districts in the GSC of cattle network, less than a combined poultry network, however the GWC were similar, contain all districts. The GSC has been suggested to measure the lower limit of the potential epidemic, assuming in the absence of intervention, while GWC is an estimate of its upper-bound (Kao et al., 2006). However,their usefulness in providing reliable estimates of epidemic sizes may not be the best measure, because in the strong component there should be requirement that the source of livestock operation or districts, after delivery, a trace back to the source operation or districts should be considered in disease spreading, for example animal movement from farm A, which uninfected when deliver to farm B, which infected before received animal from farm A, the owner farm A use their truck to deliver animal from farm to farm, in this situation, truck at farm B could let infection spread to farm A. The infection chains of farms in the GSC can cross outside the boundaries of the GSC, using its size will not represent the lower bound properly. Also, calculate the sequence of delivery in time will lead to infection chains, smaller than the number of nodes included in the GWC (Dubé et al., 2011). Therefore, GSC and GWC may not reflect the actual infection chain of node in the network. However, several authors reported the size of component in livestock network, study in France reported the largest size of GSC around 0.34% (35) holdings and GWC including 95% (9,523) holdings in the network (Rautureau., 2012), in the study of cattle movement in Uruguay

a there were 18% (820) farm in the largest component and 73% (33,288 farm) (VanderWaal et al., 2015).

Studies on the theoretical network identified targeted removal node which had the highest ranked out-degree is more effective in reducing the size of GSC than random removal of the node (Kiss et al., 2006), furthermore, studies network of Danish cattle in Denmark found removing market in the network causing disappearance GSC (Mweu et al., 2013).

7) Monthly Topology of Combined Poultry Network

Analysis combined poultry network in time-scale monthly revealed small world properties in May, broiler breeders usually harvest chicken at age 30-35 days with live weight between 1.5-2.0 kg per chicken, the presence of this properties coincided with one month before Ramadhan, at this month demand of chicken was increasing, and therefore the price also is starting increase until Idul Fitri. Breeder farm tends to supply more DOC to the growing chicken farmer, at this month number of node in DOC network was also high. The GSC was largest in September and October, which is also coincidence with the second big festival, Idul Adha.

8) Monthly Topology of Cattle Network

The small world properties and highest GSC of cattle network was observed in September, during Idul Adha. As the beef meat is more expensive, it is not as popular as poultry, and therefore mostly only consumed during major religious festivals such as the Idul Adha.

By taking temporal analysis of topology network provided information of efficiency in control measure at a critical period of time, however due to constraints in the data analysis only provided 12 months study period and available at district level, further study in depth analysis at premise level (market, production type of farm, market, and slaughter house) and longer of study period could improve prediction of disease transmission and disease control strategies.

In this study, data analysis only available at district level and one step from origin district to destination district, further study in depth analysis at premise level, identify number of steps, also the association between high centrality district, also time period of festival and disease occurrence are need to be calculated to improve disease control in outbreak situation. The cattle and poultry movement are very dynamic and could change based on the supply/demand and prices between two district or region, data movement in this day may not picture for tomorrow, therefore network analysis in poultry and cattle movement are needed to be update continuously

5.2 Conclusions

Cattle and poultry network analysis during the period November 2014 to October 2015 identified districts with high out-degree and betweenness scores which were concentrated in Central Java Province. These districts could have a higher impact in spreading outbreaks within the network. Districts with high in-degree score were mainly concentrated in large cities and act as mainly as receivers of movements (sink). The cattle network was characterized by the scale free network for both in-degree and out-degree, combine poultry network only showed scale free network for out-degree and marked by small world properties one month during Idul Fitri in combined poultry network and during Idul Adha in cattle network, further study to understanding association period of time and disease occurrence are needed.

Studies of livestock movement in Indonesia by using diary based study or complete data in lower level (premises) could improve understanding how infection spread and effective disease control.