Computers and Electronics in Agriculture 110 (2015) 27–35

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Minimizing the total cost of hen allocation to poultry farms using hybrid Growing Neural Gas approach

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ARTICLE INFO

Article history:
Received 6 January 2014
Received in revised form 30 August 2014
Accepted 5 October 2014

Keywords:
Poultry farms
Hen egg production
Growing Neural Gas
Heuristic algorithm
Total cost

ABSTRACT

In this paper a decision support system to solve the problem of hen allocation to hen houses with the aim of minimizing the total cost is described. The total cost consists of farm utilization cost, hen transportation cost, and loss from mixing hens at different ages in the same hen houses. Clustering of hen houses using the traditional Growing Neural Gas (GNG) was first determined to allocate hens to the hen houses effectively. However, the traditional GNG often solves the clustering problem by considering distance only. Therefore the hybrid Growing Neural Gas (hGNG) considering both the distance from the centroids of the clusters to the hen houses and the weights of hen house sizes was proposed to solve the problem. In the second phase, allocating and determining routes to allocate hens to the hen houses using the nearest neighbor approach were carried out in order to minimize the total distance. The performance of the algorithm was measured using the relative improvement (*RI*), which compares the total costs of the hGNG and GNG algorithms and the current practice. The results obtained from this study show that the hGNG algorithm provides better total cost values than the firm's current practice from 7.92% to 20.83%, and from 5.90% to 17.91% better than the traditional GNG algorithm. The results also demonstrate that the proposed method is useful not only for reducing the total cost, but also for efficient management of a poultry production system. Furthermore, the method used in this research should prove beneficial to other similar agro-food sectors in Thailand and around the world.

1. Introduction

In the egg industry, egg production planning is considered a crucial activity because it may affect production costs. Since egg production planning concerns not only the number of eggs laid by hens over a period of time, but also how to allocate chicks to replace birds with diminishing laying capacity, egg production requires efficient planning for minimizing costs in order to maximize profit generation while meeting customer demand. Supply Chain Management (SCM) is hence one aspect for consideration. Designing and building more effective supply chains and competitiveness are required for all activities.

In egg production, eggs are produced by batches of hens according to production schedules in order to meet high market volumes. A firm generally starts by purchasing chicks from a hatchery. The chicks are then transferred to pullet-raising farms where they stay until they reach a certain age (i.e. about 17 weeks of age). These pullets are then moved to a laying unit (i.e. hen houses), and will remain in the hen house until a certain age (i.e. 75 weeks) and be fed to a prescribed body weight to support egg production. Once the hens have diminishing laying capacity, they are slaughtered at the firm's slaughterhouse (see Fig. 1). Hence, egg production is considered a dynamic production leading to complexity (Gates and Xin, 2008), especially concerning the decision of how to allocate flocks to facilities. Allocation of flocks to facilities in the current period may affect the efficiency of allocation of the flocks in the next period. Currently, the firm has difficulty in obtaining efficient flock allocation due to production complexities. (1) Heterogeneous capacities of facilities depending on the level of investment of contract farms. Even though the firm attempts to allocate flocks to the facility fully, there will be at least one facility partially filled due to imbalance between the flow-in flocks and the capacity of the facilities. The partially filled facilities can still be used for allocating new flocks in the next period if the firm wants to obtain high utilization of these facilities. Hence, mixing of flocks at different ages in the same facility cannot be avoided. (2) Distances between the facility where the flocks are moved out and the facility where

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http://dx.doi.org/10.1016/j.compag.2014.10.006
0168-1699/

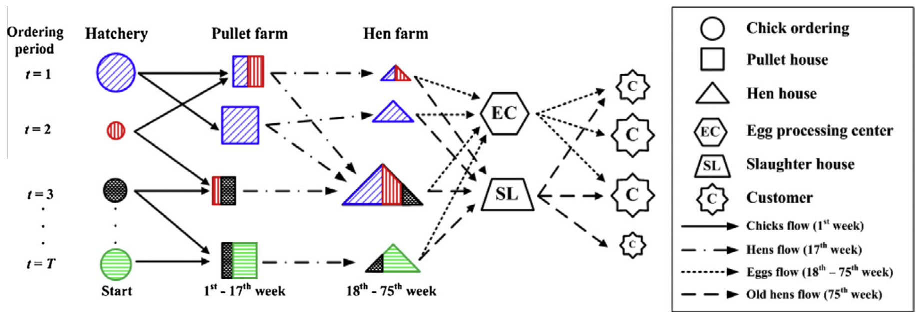

Fig. 1. Flow chart of hen egg production.

the flocks are moved in. (3) The number of chicks purchased and delivered to the industry in each time period may be different due to demand fluctuations. (4) Due to sanitary regulations, pullets or hens must be moved as a whole to the next station.

Based on the nature of egg production, inefficient flock allocation can create unnecessary costs, especially allocation of pullets to hen houses. The costs associated with inefficient chicken allocation decisions and considered in this study are as follows. (1) Higher cost of farm utilization (baht/house/week). This cost can be farm renting from farmers in a contract farming system or operation and depreciation costs for raising hens if the firm owns the farms. It is high if the firm allocates pullets to more hen houses than they should, resulting in some hen houses being partially filled. (2) Higher transportation costs from pullet farms to hen farms. This cost is usually high if the pullets are allocated to the hen houses dispersedly, and the hen houses are partially filled. (3) Loss from the mixing of hens at different ages in the same hen houses. Under this condition and due to sanitary regulations, some hens are sent to the slaughterhouse although they have not reached the right age, resulting in a loss of egg laying opportunities.

To reduce such costs, aligning supply and demand is therefore achieved by matching the flow of pullets with the capacities of the hen houses and determining efficient routes for transferring pullets to hen houses in order to make their egg production systems more flexible, with lower production costs while the demand constraints are met. This research therefore focuses on allocation of pullets to hen houses and determining routes for transferring pullets from pullet houses to hen houses in order to minimize the total cost for given economic constraints and different demand volumes in the planning horizon. The total cost considered consists of three main cost components: cost of farm utilization, transportation cost from pullet farms to hen farms, and loss from mixing hens at different ages in the same hen houses. To solve the problem, a two-phase heuristic algorithm was developed. In the first phase, clustering of hen houses was determined to allocate hens to the hen houses efficiently. The problem of hen allocation to hen houses has many similarities to the Growing Neural Gas algorithm in which groups of similar hen houses are clustered together. Hence, in this paper, the GNG algorithm is firstly applied for the purpose. However, the traditional GNG is often used to determine the clustering problem by considering only the distance. Therefore, the hybrid Growing Neural Gas (hGNG) was proposed in this paper which considers both the distance from the centroids of the clusters to the hen houses and the weights of hen house sizes. The second phase was developed for allocating and determining routes to allocate hens to the hen houses using the nearest neighbor algorithm in order to minimize the total distance. To illustrate the hGNG effectiveness, numerical experimental results were compared with those of the current practice of the egg industry selected as a case study and also with the traditional GNG. In the next section, related literature is reviewed. The methodology used to solve the problem is presented in Section 3. Section 4 presents the case-study application, illustrates numerical examples and performance of the algorithms. Finally, a summary of the main findings is given in Section 5.

2. Literature review

Generally, in egg production, the main expenditures for the laying cycle are divided into fixed costs and variable costs. Fixed costs include feed, vet costs and medicine, and various other expenses (i.e. water, lighting, etc.), while variable costs consist of labor costs incurred to manage birds, rent, building and equipment costs, and general overheads (FAO, 2003). Based on current egg production operations, various studies have been conducted in different areas, especially in the field of methods for monitoring daily production process such as feed and water consumption, ambient temperature, egg sorting and mortality, in order to support day-to-day management on aviary farms for laying hens (see, e.g., Lokhorst and Lamaker, 1996; Patel et al., 1998; Mertens et al., 2008). For the medium-term and long-term production planning of poultry farm in order to reduce production costs, it has also been addressed by various researchers. For example, Mohaddes (2009) studied the determination of productivity level in the poultry industry. The production function used to measure productivity was estimated using cross-sectional data collected from 47 farmers in the Khorasan Razavi province. The results indicated that, to improve profitability, the farmers should use less feed and keep more pullets resulting in reduction of production cost. In 2010, Demircan et al. made a comparison among various sizes of laying hen farms. These farms were compared in terms of performance, including feed consumption, production cost and profitability per chick and egg, and the most profitable farm size was determined. It was found that in the study area, as the farm size increased, production costs per hen decreased and the gross, net and relative returns increased.

Even though some studies have been conducted to improve profitability in the poultry industry, there is still more room for improving the efficiency of poultry production, including cost reduction due to production complexity. Powerful methodologies which lead to effective management, especially concerning the activities of allocation, scheduling and transportation in poultry production are needed (Apantaku, 2006). Recently, there has been some research that has proposed planning processes for proper and efficient management of poultry farm activities in order to minimize production costs. For example, Sethanan et al. (2013a) focuses on determining the appropriate size (capacity) of the pullet and hen houses to yield lower production costs in the long run, within the economic constraints and different demand volumes in a planning horizon. The genetic algorithm and neighborhood search methods were used to determine the number of pullet and hen houses. In the same year, Sethanan et al. (2013b) also conducted another study focusing on multi-period poultry planning. Whitin's algorithm was applied to find the proper number of chicks to replace birds with diminishing laying capacity. A heuristic