An Integer Programming Approach to Chick Placement at a Broiler Production Company

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***Abstract*—Broilers are a popular meat choice worldwide due to their low cost, high protein content, and fast growth rate. In recent decades, poultry consumption has been increasing, especially in developing countries. Efficient poultry production remains a challenge for many poultry companies. We consider the problem of optimally placing chicks in pens so as to minimize the total cost of a production cycle. We use an Integer Linear Programming Model to minimize costs over a given planning period subject to availability, capacity and cost constraints. A case study was conducted for a specific poultry farm. Planning periods of different lengths were considered to determine which length resulted in the minimum cost when applied over a total of six months of production. For all period lengths, significant decreases in cost were obtained. The minimum cost was obtained using 18-day periods, which resulted in a decrease of 16.7 percent compared to the company's actual costs for the cycle. This represents an increase in profits which can give companies a competitive advantage. This research has applications in poultry supply chain management and can be adapted to other agricultural sub-sectors and industries.**

***Index Terms*—Poultry; Integer Programming; Trinidad and Tobago; Cost Optimization; Chick Allocation; Production Planning**

I. Introduction

Poultry production refers to the raising of domestic fowl species, including chickens, ducks, and turkeys for their meat, eggs or, feathers [1]. Chicken is the second highest consumed meat worldwide, after pork. It provides a good source of protein while being cheap and relatively low in calories and fats, which may account for its popularity [1]. In recent decades, meat production and consumption have increased worldwide, with the poultry industry showing the largest growth [2]. The Central and South American region shows a much higher increase in meat consumption than the global average, due to development in the region [3]. While many countries rely on imports, local poultry production can help improve food security. In Trinidad and Tobago, there is a 40% tariff on imported poultry products, as well as a 15% surcharge, which helps boost the local industry [4].

In Trinidad and Tobago, poultry production accounts for approximately 40% of the gross agricultural production value and is by far the largest contributor to the agricultural sector [4]. The country is self-sufficient in its broiler production. Around 91% of poultry farms in the country produce chicken products, including broiler meat and table eggs, while 9% produce duck meat [5]. About 75 thousand metric tons (MT) of broilers were produced in the country in the year 2024. In contrast, only 16 thousand MT of broilers were imported [6]. Broiler production in the country has greatly increased in recent decades.

The broiler industry has many stages of production. These include hatching, growing, processing, and sales. There are four main broiler production companies and several smaller farms in Trinidad and Tobago, which have varying degrees of vertical integration. Local broiler companies rely on imported eggs from foreign suppliers. At local hatcheries, the eggs are incubated until they hatch, under strictly controlled environmental conditions. Some chicks may be sold to private farms for a profit. Then, chicks are transported from the hatcheries to farms where they are grown until they reach the desired weight. Many materials are needed during the growing process, including feed, litter, and medicine. The company may manufacture its own feed using raw materials. At this stage, the company may sell live broilers to private shops, which provide fresh meat to consumers. Next, the broilers still owned by the company are taken from the farms to processing plants where they are slaughtered and processed to produce different products. They may then be stored or distributed to retailers and customers. At each of these stages, different costs are incurred.

II. Literature Review

Reference [7] provided an overview of simulation optimization of supply chains in the agricultural sector. The papers reviewed included crops, flowers, meat, and several other items as products. A wide range of problems were studied, including sourcing, inventory management, transportation, and scheduling. Recent trends showed that there was a sharp increase in works about optimization in agriculture.

Previous related research considered supply chain management models. Reference [8] developed multi-period lot sizing with supplier selection models to optimize flock coordination in poultry farms. The research considers both deterministic and stochastic treatments of broiler weight. It seeks to maximize the production for each farmer, which minimizes costs. It considers several constraints, including transportation, demand, and period length. This paper does not consider costs directly, since it is assumed that costs on each farm per kilogram of broilers produced are similar. Linear programming and multiobjective programming models were used.

Reference [9] formulated a distribution problem and sought to minimize the total distance covered in transporting poultry products to customers using linear programming and heuristic approaches. Reference [10] developed a deterministic model for minimizing transportation costs between hatcheries, farms, and processing plants. The model considers the same growing time on each farm, and capacity, inventory, and distance constraints. A case study was conducted to determine the distribution network for two hatcheries, three farms, and two processing plants.

Other papers sought to minimize growing costs in the farming stage through means other than chick allocation. Reference [11] considered a mixed-integer linear programming model that sought to minimize costs on a poultry farm. In this case, only one farm was considered, so distribution was not necessary. Linear cost constraints, waste, demand, storage, and capacity constraints were considered. Sensitivity analysis by varying certain parameters in the model by different percentages was also conducted.

Reference [12] developed a general chick placement and broiler harvesting model that maximized profits for poultry farms. Similar constraints to this work were utilized. This model considered various types of chickens. The cost, capacity, and time constraints varied according to the type of chicken rather than with the farm, as is the case in this model. Additionally, some parameters are defined per week while others are defined for the entire growing period.

Reference [13] developed a linear model that minimizes cost while allocating a set of chicks to different farms. Similar to other models, demand, capacity, and cost constraints were considered. This model allowed broilers of different ages to be placed in the same pen. In this case, parameters are also defined per week. The researchers also proposed a stochastic model that allows the number of chicks placed at different farms to vary. This model predicts parameters representing the number of chicks to be placed, which are used in the linear model.

Reference [14] consider a broiler flock sizing, scheduling, and allocation problem to optimize the broiler production supply chain. This model considered the hatchery, farm, and processing plant stages of production. Parameters included estimates of costs or gains under certain circumstances, such as deviation from demand, discarding some eggs, and deviation of a broiler from the target weight. Constraints included egg supply, capacities, allowances for unhatched eggs and broiler mortality, broiler age and weight, and number of farms from which broilers were slaughtered. A mixed-integer linear programming approach and a heuristic approach were formulated. The heuristic approach considered a rolling horizon and was used to reduce the run time and complexity of the problem.

This paper seeks to address an allocation and scheduling problem. While supply constraints were similarly formulated to previous models, this approach considers costs to be related to the farm. This is because each farm is unique in size, location, type, weather conditions, and typical chick treatment. As such, certain costs may be higher on some farms than others. This model also considers costs for the entire growing period, rather than per week or per day. This is because at different times during the growing period, some costs may be more than others. For example, in later weeks, a greater feed cost may be incurred due to the increase in the average size of the broilers. Thus, average costs for the entire period are considered for each farm. Independent periods were used rather than a rolling period since planning takes place after each period was completed. This research can be applied to other agricultural sub-sectors, such as livestock or crop cultivation. Also, problems outside the agriculture sector may arise dealing with multi-period resource allocation, for example, in the provision of perishable items to different centers. This research can be modified to meet the requirements of these cases.

III. Methodology

A. Problem Description

In the production of broilers, eggs are first hatched at hatcheries. The chicks are then transported to farms where they are grown until they reach the desired average weight. Then they are transported to processing plants where they are prepared for sale. Depending on the level of vertical integration of the company, it may be involved in one or more of these stages of production.

Consider a company involved only in the growing stage of production. This company must buy chicks from a hatchery, grow them, and sell them to a processing plant. If this company has multiple farms, a problem arises in how to best allocate the chicks to different farms to maximize the profit for the company.

A given number of chicks must be distributed to a fixed number of pens to meet the placement requirements for each day. This allocation should be done in such a way that the profit is maximized. Profits are calculated by subtracting the total costs from the total revenue. For a poultry company, revenue comes from chicken sales. If the company sells broilers from all farms at the same price, then the revenue is independent of the placement. Thus, profit can be maximized by minimizing total costs.

The poultry company has three types of farming arrangements. Some farms may be completely owned by the company, so the company is responsible for covering all costs. Other farms may be contracted by the company to grow chicks. In this case, an agreement between the company and the contract farmer would dictate which costs are to be covered by whom. In addition, the company would pay the farmer a sum of money for growing the chicks. Thirdly, some farms may be 'buy back' farms, where the farmer sells chicks to a private farmer and buys them back at the end of the growing period. In this case, the company only pays the farmer the difference between the buying and selling costs.

B. Assumptions

- There is a fixed known supply of chicks on each day.
- The growing cycle length for each pen is fixed.

- If chicks are placed in a pen on a particular day, chicks cannot be placed in that pen again until the next growing cycle.
- Chicks must be transported in crates, so optimization will be done per crate rather than per chick.
- Chick purchase cost and feed purchase costs depend only on the number of chick and are independent of placement. Therefore, they are not considered in this model.

C. Nomenclature

Our objective is to determine the number of crates (of chicks) to be placed in each pen for each day. Let i denote the index for pens and j the index fo the day in the period under consideration. We denote the number of crates allocated to pen i on day j by x_{ij}. We also introduce a binary decision variable $z_{ij} \in \{0, 1\}$ which denotes whether any chicks are added to pen i on day j. A minimum of P_i^{min} and crates can be added to pen i and the total number of crates allocated to pen i cannot exceed P_i^{max}. The total cost to grow a crate of chicks to maturity using pen i is denoted by C_i and this includes cost for feed, cost for feed delivery, sanitation costs, medication and vaccination costs, payment to contract and "buy back" farmers, litter cost, transport to the pen i and then delivery to the processing plant. Once a pen i is populated the cost for electricity (independent of the number of chicks it contains) is E_i. We will optimize placement of crates over a period of days T and N_j crates are available on day j. At the end of the period the optimization is repeated for the next T days, etc. The set of pens available during this period is denoted by $\mathbf{S}_0$. Pens that become available during this period will be handled after the period.

D. Optimization Model

The optimization problem can be stated as follows:

$$F = \min_{x_{ij} \in \mathbb{Z}, z_{ij} \in \{0,1\}} \sum_{j=1}^{T} \sum_{i \in \mathbf{S_j}} (x_{ij} C_i + z_{ij} E_i) \quad (1)$$

$$\textbf{s.t} \quad \sum_{i \in \mathbf{S}_j} x_{ij} = N_j \qquad \forall j \quad (2)$$

$$x_{ij} \le z_{ij} P_i^{max} \qquad \forall i, j \quad (3)$$

$$x_{ij} \ge z_{ij} P_i^{min} \qquad \forall i, j \quad (4)$$

$$\mathbf{S}_j = \mathbf{S}_{j-1} \setminus \{i : z_{ij-1} = 1\} \qquad \forall i, j \quad (5)$$

The objective function (1) states that the sum of the total cost of growing chicks in pen i on day j for all days across all pens must be minimized. Thus, it is not necessary to find the cost per day, since all days are considered in the cost. Constraint (2) reflects that the sum of all placements on day j should be equal to the number of chicks to be placed on day j. Constraints (4) and (3) ensure that placements in a pen are within limits if a pen is allocated crates. Constraint (5) ensures that once a pen is used it is removed from the set of available pens for future placements in the period.

E. Case Study

To test this model, a case study was conducted. Data were obtained from a chicken broiler company in Trinidad and Tobago. Details of company operations were provided through in-depth interviews, documentation, and email correspondence. This company raises chicks using both open-sided and tunnel farms. This company has 269 pens and the algorithm was used to determine the minimum cost for a six-month time frame.

Company-owned farms, contract farms, and 'buy back' farms are all types of farms present in this company's growing arrangements. Costs differ by farm type. For company-owned and contract farms, the company is responsible for feed transport costs, sanitation costs, and medication costs. For company farms, electricity costs are also considered. This can be a significant cost for tunnel farms. Contract farmers are also paid by the company for growing the chicks. For 'buy back' farms, the company only pays the difference between the selling and buying costs.

The company uses a minimum number of seven rest days between growing periods for each pen. However, thirteen days is regarded as the optimum number of rest days. Therefore, the minimum number of rest days was used as ten days in the model. With regards to planning, a period of about a week is considered by the company. Based on available farms, a selection of pens with suitable capacities is chosen for placement. The hatchery from which chicks are obtained packages chicks in crates of 100 for delivery to farms. Thus, optimization is done per 100 chicks, since an entire crate must be delivered to a pen.

In this company, transport costs from the hatchery to the pens are included in the cost of the chicks, which is fixed per head. The transport costs from the pens to the processing plant are also covered by the processing plant. Additionally, litter is purchased in bulk and is dispensed as needed by different pens. Feed is purchased based on the number of chicks, and thus is independent of placement. The length of the planning period, T, can affect the total minimum cost obtained for the entire time frame. This is because longer or shorter periods may result in different placement schedules for each period. Therefore, the optimum period length will also be investigated for this case study.

F. Description of Parameter Values

Costs vary greatly with the size of the pen. The general expense parameter values C_i included sanitation costs, feed transport costs, medication costs, and payment to farmers. Company farms generally had a smaller cost per crate, with values less than TT \$150 for the period. Private farms had larger costs, with values up to TT \$400 for the period.

The electricity value E_i was 0 for contract farms as farmers were responsible for covering this cost. For company-owned tunnel pens, this value ranged from TT \$2300 to TT \$4500 per pen for the entire period. For company-owned open-sided pens, it ranged from TT \$100 to TT \$1500.

The capacity of each pen and the number of growing days (age at slaughter) of each pen are important parameters in this model. Fig. 1 shows the average optimum placement capacity distribution of the pens. Optimum pen capacities ranged from 26 to 429 crates per pen. Typically, tunnel pens were able to house more chicks, as they were larger and allowed for a higher density of chick placement. Open-sided pens had capacities of less than 200 crates each. Most pens have smaller capacities of around 5 to 15 thousand chicks, while some company-owned tunnel pens have larger capacities of 30 to 40 thousand. Placement capacity depends on the size of the pens. Pens have rectangular-shaped bases and may be oriented in an east-west or a north-south direction. The shorter side of the pens ranged from 30 to 50 feet, while the longer side ranged from 100 to 550 feet. Tunnel pens can generally be larger than open-sided pens because the effects of heat stress would be reduced in temperature-controlled environments. The optimum placement for tunnel pens was around 1.5-1.6 birds per square foot, while for open-sided pens, it was around 0.8 birds per square foot. In total, there is farm space for almost 4 million broilers to be placed at a time.

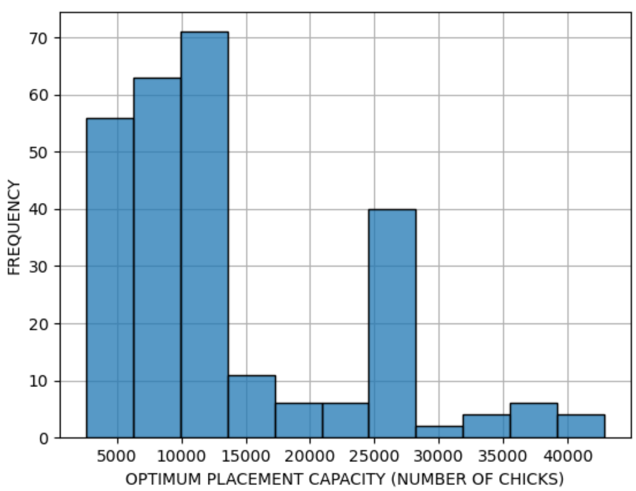

Fig. 1. Optimum Capacity Distribution for the Pens Considered

Fig. 2 shows the distribution of the average age at the time of slaughter for the pens, which is equivalent to the number of growing days. The most common age was 40 days, but some farms averaged up to 49 days. Globally, the typical age of slaughter varies by regional norms, requirements, and broiler type.

The cost-to-capacity ratio reflects the cost efficiency of the pens. Fig. 3 shows the distribution of cost per 100 chicks at each pen. Some pens have larger ratios, but lower ratios reflect greater cost efficiency. To minimize costs, chicks should be placed preferentially in pens with lower cost efficiency. The large disparity between the maximum and minimum cost is related to the type of farm. Contract farmers must be paid

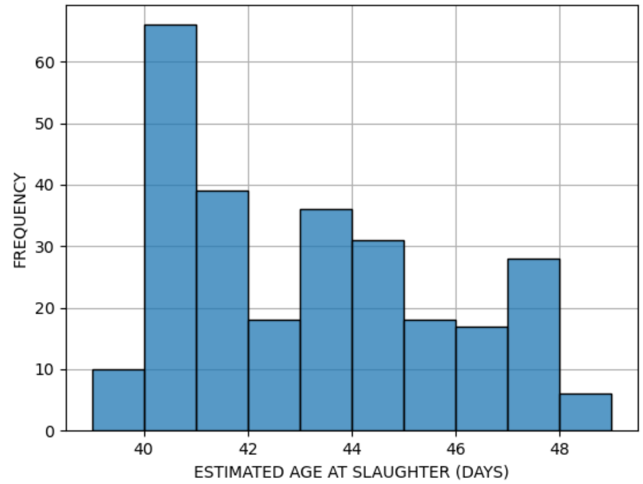

Fig. 2. Distribution of the Age at Slaughter for the Pens

additional costs for growing, while the company must pay electricity costs at pens it owns, leading to variation in costs.

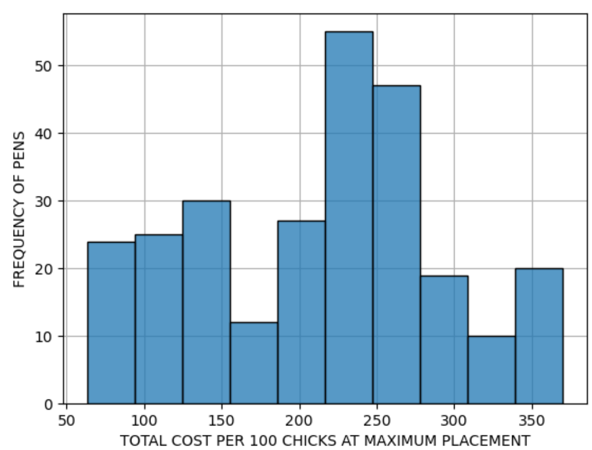

Fig. 3. Distribution of the cost-to-capacity Ratio for the Pens

IV. Results

Results were obtained using a laptop with 12 GB RAM and a 1.3 GHz processor. The Python programming language was utilized and the 'cvxpy' modeling language was used to implement the optimization problem. The CBC (COIN-OR Branch-and-Cut) solver was used for optimization. The model was used to determine optimum placements by estimating associated costs for six months. As mentioned previously, the model was run for a case consisting of 269 pens for 180 days. Periods ranging from one day to twenty days were investigated to determine which produced the minimum cost. A rest period of at least ten days between growing periods was used, reflecting typical operations at the company. Table

I shows the results of cost optimization over the six-month time frame. The length of each period T was varied and the minimum cost and run time for the entire time frame were recorded.

TABLE I
MINIMUM COSTS OBTAINED FOR DIFFERENT PERIOD LENGTHS

T Days	% Decrease from Actual Cost	Total Run Time (s)
1	9.46	234.339
2	10.80	465.039
3	10.63	1175.480
4	10.79	944.965
5	11.40	1289.243
6	11.62	1533.187
7	10.88	1615.301
8	10.64	2155.799
9	11.64	1475.884
10	14.26	1915.256
11	11.20	4018.259
12	12.49	2626.538
13	12.25	5651.597
14	15.50	3496.156
15	14.17	4078.635
16	13.03	5757.732
17	12.02	6383.447
18	16.72	6682.124
19	14.23	8589.725
20	16.09	12474.064

Fig. 4 shows the minimum costs obtained for the six-month time frame when planning periods of different lengths were used.

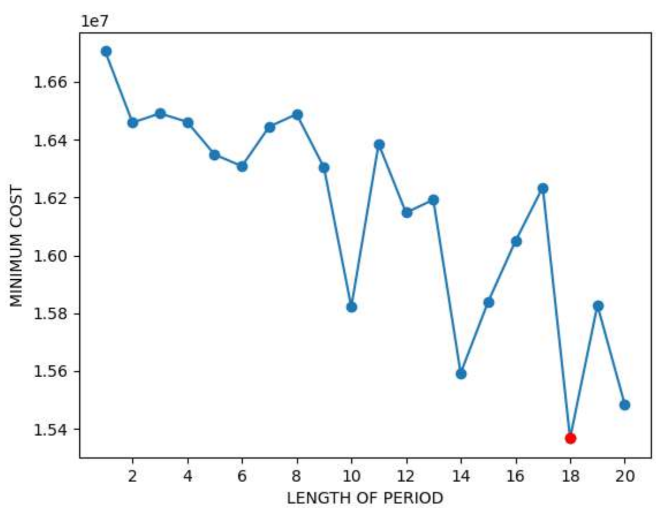

Fig. 4. Minimum costs for the six-month period for different values of T

From Table I and Fig. 4, the period length that resulted in the lowest cost for the company was $T = 18$. This resulted in a cost reduction of 16.72% relative to the cost estimate based on the actual placements done by the company, representing significant savings.

Fig. 5 shows the variation in run time with T, for the entire six-month time frame. There is a general increase in run time with some steep fluctuations.

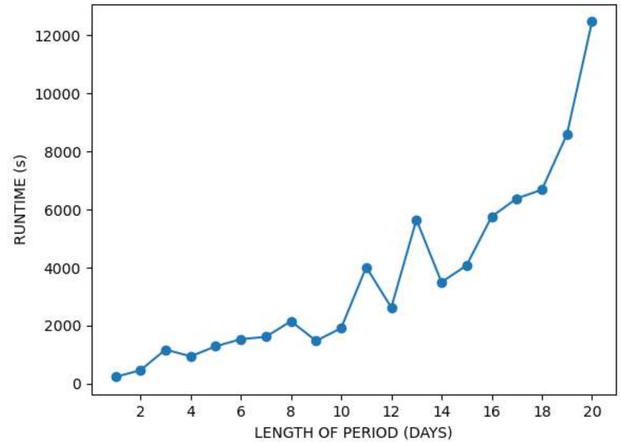

Fig. 5. Run Times for the entire six-month time frame for different values of T

Fig. 6 shows the comparison of cumulative costs for the time frame. For smaller time frames, there is not a great decrease in cost. However, by the end of the six-month time frame considered, there was a noticeable decrease in costs of 16.72%.

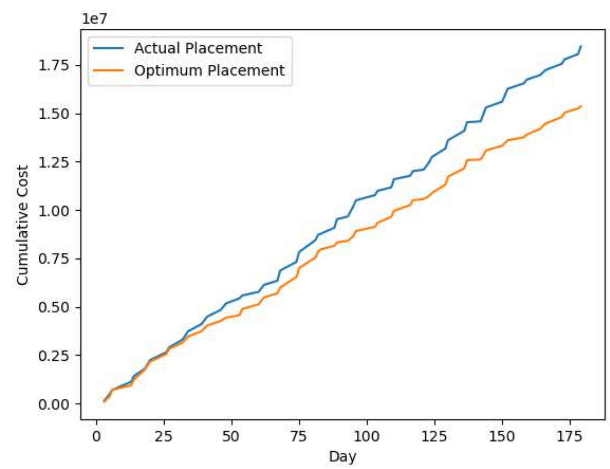

Fig. 6. Cumulative Costs for Raising the Supply of Chicks for the Six-Month Time Frame for a Period Length of 18 Days

The comparative histogram in Fig. 7 shows the number of times that pens with a certain cost-to-capacity ratio were placed over the time frame for both the optimum and actual placements. As expected, optimal placement included higher frequencies of pens with lower cost-to-capacity ratios, while the actual placement included higher frequencies of pens with higher cost-to-capacity ratios.

A. Additional Sensitivity Analysis

In addition to the variation of optimization period length shown above, variation in the rest period length and maximum

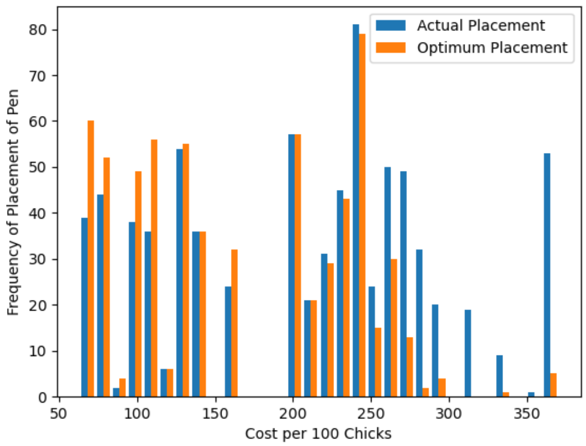

Fig. 7. Frequency of Placement of Pens vs Cost Per 100 Chicks for a Period Length of 18 Days

allowed deviation from optimum placement percentage were also investigated.

The minimum allowed rest period length used in the above analysis was 10 days, since this is a typical length used by the company. However, the optimum value determined by the company was 13 days for sanitation purposes. Also, the company sometimes allowed only 7 rest days between growing days, though this was uncommon. As such, the variation in minimum cost was investigated when a minimum of 7 and 13 rest days were used. A period length of $T = 7$ days was used in this analysis. The results are shown in Table II.

TABLE II
MINIMUM COSTS OBTAINED FOR DIFFERENT REST PERIOD LENGTHS

Minimum Rest Period Length	% Decrease from Actual Cost	Total Run Time (s)
7	17.89	1153.539
10	10.88	1615.301
13	9.81	1094.007

As expected, the minimum cost decreased when shorter rest periods were used. This is because more cost-efficient pens became available for new placements earlier. In contrast, for longer rest periods, the minimum cost was higher, as cost-efficient pens were unavailable for longer periods.

The maximum and minimum placement capacity of each pen is calculated based on its area and optimum placement percentage, which depends on the farm type, location, and other factors. Optimum placement percentages for each pen were obtained from the company. The minimum and maximum capacities were found by subtracting and adding 5% to this optimum percentage, on advice from the company. However, it is beneficial to investigate smaller or larger allowed intervals to determine if there is an effect on the overall costs. The deviation from the optimum should not be too great, so variations of 3% and 7% were investigated. In this analysis, the optimization period length was also used as $T = 7$ days, and 10 rest days were used between periods. Results are shown in Table III.

As expected, a decrease in minimum cost was observed as the range of allowed placement values increased in size. Although the increase was small, this reflects large cost savings for the company. As the range of allowed placements gets larger, more combinations of chick placements become possible. More chicks can be placed at more cost effective farms while less can be placed at less cost effective farms, leading to a decrease in cost.

TABLE III
MINIMUM COSTS OBTAINED FOR DIFFERENT ALLOWED DEVIATIONS FROM THE OPTIMUM PLACEMENT

% Deviation	% Decrease from Actual Cost	Total Run Time (s)
3	10.05	1165.986
5	10.88	1615.301
7	11.87	854.269

V. DISCUSSION

This project aimed to determine the optimum chick placement schedule at a poultry company by minimizing total costs subject to capacity and availability constraints. An integer programming model was formulated to determine the minimum cost of raising chicks by determining the optimum allocation to different farms across a period of time.

The case study was conducted using data from a broiler production company in Trinidad and Tobago. The formulated model was able to decrease the costs for the company when each different value of T was used. Even when a period of one day was used, the cost decreased by 9.46% of the estimated actual cost. The cost then decreased when a period of $T = 2$ was used, as illustrated in Fig. 4. Further increases and decreases were observed for different period lengths. For the case study, the actual supply of chicks to the broiler company for the first six months of the year 2023 was used. Optimum period lengths may depend heavily on this supply. Chicks were supplied two to three times per week, usually with gaps ranging from one day to six days between supply dates. Therefore, even though periods may have the same length, they may have different numbers of days with chicks supplied. Additionally, different days have vastly different placement amounts, with the minimum being 14,500 chicks and the maximum being 253,000 for the period considered. These factors may explain the fluctuations in cost reduction.

Despite large fluctuations in minimum cost with period length, a general decrease in costs is observed with increasing period length. Local maxima and local minima both generally decrease in value as the period length increases. This indicates that longer periods are generally more cost effective than shorter periods. This trend is expected to continue as period lengths further increase. If optimization were done over the entire six-month time frame, a smaller minimum cost may be observed. However, companies may not have certain information about the supply so far into the future.

As expected, run times generally increased as the period length increased. This is because the number of possible combinations of pen allocations increases greatly with period length. Additionally, this problem was formulated as an integer programming model, so decision variables are not continuous. This adds to the complexity. As shown, even for small period lengths, great decreases in profits are observed. The run times for a period increased to more than twenty minutes for the longest period length, $T = 20$ days. For larger companies with more pens, this time would be even greater. Therefore, if run times become too long, shorter periods can be used for similar results. However, companies must run the algorithm less often when longer periods are used. Generally, companies should optimize for the entire period for which information is available to obtain maximum cost savings.

As expected, the optimum placement schedule has more placement for pens with low cost-to-capacity ratios, as shown in Fig. 7. This is because the model is more likely to choose cost-effective pens over those with high costs for placements. This graph also shows that there are some pens that were not placed at all in the optimum placement schedule. The company may therefore be able to function with fewer pens, which can reduce costs.

In the broiler production company studied, allocation of chicks to farms is done by first making a list of available pens and then selecting a suitable set of pens based on their capacities. There is no method of choosing the best allocation. Planning periods of around one week were typical at the company. This indicates that the company has enough certainty in the supply one week in advance. The proposed model, if implemented, can provide cost-efficient schedules to improve placement planning. The proposed method provides a way for companies to find the optimal allocation to minimize costs. The model was shown to decrease costs by up to 16.72%. These cost savings can be used to expand business operations, upgrade infrastructure, or can be invested in improvements to the quality of products.

A. Comparison with Previous Models

Previous models considered cost parameter values to be the same for different farms. While this may accurately represent some costs, several costs are dependent on placement due to different conditions at each farm. This model allows costs to vary across farms. In previous studies such as [9] and [10], farms were considered to be of the same type and the main focus was on distance between farms. These were sometimes formulated as transportation problems. This model focuses not only on transportation costs, but allows other relevant costs to be included.

The developed model also requires that if chicks are to be placed in a pen, it must be placed to a certain minimum capacity. Chicks cannot be placed in a pen while another set of chicks is growing in that pen. This is useful when the age of chicks in a pen must be known with certainty. Some previous models allowed pens to be filled across more than one day [13].

This model is suitable for cases where chicks must be distributed among different farms with different costs associated with them. These farms may be of different sizes and have different locations. In contrast to some previous models such as [9] and [10], period length may be different for each farm. In addition, a fixed horizon was used instead of a rolling horizon, which was used in previous research [14]. Fixed horizons were used in this case because the model only ensured minimum costs when the schedule was followed for the entire planning period.

B. Implementation

To implement this model, certain data would need to be collected at companies. Firstly, relevant cost parameters would need to be determined. Depending on company operations and norms, some cost parameters may not be necessary, while others may need to be added. For example, a company may not have sanitation costs but may regularly do maintenance work on pens. The sanitation cost can be removed, and a maintenance cost can be added. If need be, other costs can easily be added to the model when calculating the value of C_i, or they can be added to E_i if they are independent of the number of chicks. In addition to the cost parameters, the values of the placement capacity and availability parameters must also be determined. Data should be collected on a regular basis to update costs which may change over time. Trends can also be observed for different times of the year to predict changes in costs such as sanitation and electricity, due to disease outbreaks or temperature fluctuations. The period length that results in the lowest cost for a company should be determined by running the algorithm for different values of T for typical supply values.

C. Limitations

For unusually large placements, finding the optimum allocation on a daily basis may not provide a solution, since there may not be enough farms available on that day. This is a limitation of this model when short period lengths are used. However, if planning is done over a longer period, placements may be done in such a way as to facilitate a large placement amount on that day. For example, placements to smaller farms can be done on days with less chicks to be placed, so that larger farms can be placed to their maximum capacities on days with larger numbers of chicks to be placed. However, the memory and run time required for longer periods is much greater than for shorter periods.

D. Suggestions for Future Work

In the future, measures of productivity other than the total cost can be considered. Suggested models include the minimization of the feed conversion ratio subject to capacity and availability constraints, and the maximization of chick weight subject to cost constraints. Minimization of environmental impact can also be considered.

In addition, parameters were treated as fixed in this model. In reality, there is some randomness present. The costs for each pen may vary based on economic conditions and seasonal variations. Future models can include cost forecasting based on past trends. The total growing period for each pen was also considered fixed. This may vary based on the desired final weight of the broilers. In the future, a stochastic model can be used to determine the average weight at different times on each farm, which can be used to determine the growing period length that will result in the desired weight. Pen capacities may also vary based on factors such as temperature and humidity, since heat stress is an important concern in raising broilers. Internet of Things devices can be used to monitor such environmental conditions and models can predict the optimum capacity range for each growing period.

VI. Conclusion

In this paper, an integer programming model for the minimization of costs for the growing stage of production at a broiler production company was proposed. This model included costs such as transportation, medication, sanitation, and utilities while excluding costs that were independent of placement. The aim was to determine the optimum placement schedule for a known supply of chicks across a period of time. Capacity, supply, and availability constraints were considered.

This model was evaluated using a case study. Data were obtained from a broiler production company in Trinidad and Tobago and was used to determine the optimum allocation for a six-month time frame. Optimization reduced costs in the company by 16.72% when optimization was done over 18-day periods. It is recommended that poultry production companies adopt optimized allocation schedules for chick placement as it provides significant cost savings.

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