Capacity modelling of the South Island chicken operation at Tegel Foods Ltd

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Abstract

Tegel seeks more accurate estimates of the capacity of its nationwide chicken operations. A prototype decision support tool for the South Island chicken operation was developed as a starting point in achieving this goal. The model calculates capacity and utilisations of the different areas of the operation as well as overall capacity. The capacity model aids strategic decision making and promotes understanding of different areas of the operation. Emphasis is placed on presenting relevant information in a user-friendly way, with the objective of adding maximum value in a limited timeframe. This paper describes the capacity model created and the logic behind the modelling process. The model is validated using 2006 forecasted demand. Extensions are recommended which will increase the accuracy and benefit of the model.

1 Introduction

Tegel Foods Ltd is a privately owned organisation specialising in the production and processing of poultry. It is the leading supplier to the New Zealand poultry market and employs over 500 people in the South Island alone. Tegel's high level of vertical integration means that it has control over most facets of a chicken's lifecycle.

Tegel frequently makes strategic decisions concerning production targets, new product introduction and facility expansion. These decisions are often made based on the experience of individual area managers with the support of little numerical evidence. This leads to what staff describes as time consuming and inefficient communication and does not promote the diffusion of knowledge amongst the company. Area managers at Tegel make operational decisions based upon demand forecasts produced by senior management. These forecasts describe demand in terms of whole birds per month and the prescribed average weight of birds.

Tegel seeks to improve its understanding of the capacity of its nationwide chicken operations. As the first step to achieving this, a decision support tool for the entire South Island chicken operation has been developed. It is a capacity model that, if it proves successful with managers, may be adapted for use nationwide.

Two main groups are expected to use the model. Senior management will explore the effect of strategic changes on capacity and the feasibility of production plans. Individual area managers will use the model to learn about the effect of changes on other areas of the operation and consider where bottlenecks lie. Interestingly, the managers who originally considered the model to be of least use to them are now most supportive and enthusiastic about its results. It demonstrates that the usefulness of model can be substantially improved if the misconceptions and threats of the model are broken down.

The model consists of a Microsoft Excel® spreadsheet with the use of Visual Basic for Applications. The use of Excel® ensures it is simple and user friendly to all users.

The capacity model is a prototype of a more extensive decision support tool that should be developed in the future. To make it a final product, product differentiation and improvement of estimates at the main plant should be undertaken. To allow future extensions and adaptation to other operations in the North Island, the model is designed to be adaptive and easy to control.

The model has been validated using production plans for the financial year of 2006. The capacity utilisations estimated by the model are close to those hypothesised by managers.

2 Problem description

The South Island Tegel chicken operation begins at the breeding of eggs and ends after goods are processed and distributed, as shown below in figure 1. At eleven breeder farms spread out across Canterbury, chickens are raised to produce eggs that are then transported to Tegel's hatchery in Hornby, where they are incubated and hatched. The day-old chicks are then sent to one of thirty broiler farms situated close by. These farms consist of large sheds where chickens are raised until they reach a desired weight and are gathered for processing. They are taken to the main processing plant in Hornby, where they are killed and transformed in to saleable product. Tegel also owns and operates the largest feed mill in the South Island, which produces the feed for both the breeder and broiler farms.

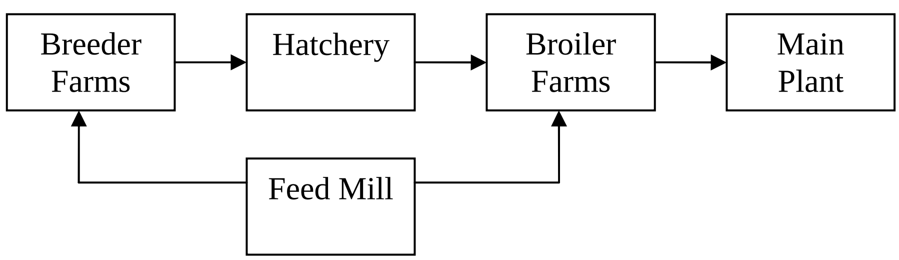

Figure 1. Tegel's South Island chicken operation

There are no models at Tegel that incorporate all areas of the operation and that are dedicated to estimating capacity. Most of the models in use at Tegel relate to the planning and scheduling of livestock.

Developing a capacity model presents many modelling challenges because of the nature of Tegel's chicken operation. Tegel has a long internal supply chain and consequently all parts of the operation must be considered to gauge the true capacity of any one area. Another challenge of developing a holistic capacity model is that the different areas of Tegel's chicken operation are highly dependent. Tegel is aware that being able to describe the interrelationships in a single model will be more beneficial than detailed independent models.

An illustrative example of the relationships between areas of the chicken operation is the decision to process larger but fewer birds at the main plant, in order to meet total kilograms demanded per month. Fewer eggs must be laid and hatched, requiring fewer breeder hens. Fewer birds must be grown at the broiler farms and processed at the main plant. However, birds must be grown for longer which requires more of the broiler farms in a given month. The processing speed of the plant may also slow down. Based on intuition alone, the net effect on overall capacity is unknown. Despite the same kilograms of product being supplied, the interaction between inputs is such that the effects on capacity can be very different.

3 Objectives

The objectives of the project were determined together with Tegel. These were to:

- Develop a capacity model that encompasses the livestock, feed mill and processing aspects of the South Island Tegel chicken operation. It should provide a high-level understanding of the capacity constraints of the operation and should illustrate the interdependencies between the different areas. It should be useful to all individual livestock, feed mill and processing managers by providing quantitative evidence of what they already intuitively understand about capacity and by providing understanding of relationships between different areas.
- Identify and develop key summary measures of capacity utilisation for the livestock, feed mill and processing areas.
- Develop a means to conduct 'what if' analysis, such as facility expansion or a change in operating procedure. This should be useful to senior management as an aid for strategic planning by allowing them to consider the quantitative implications on capacity from new scenarios.

4 Users of the model

The capacity model developed for Tegel Foods will be used by a variety of managers, each for a different purpose. The needs of the users are important because they determine the design of the content, the time frame and the form of the model.

4.1 Primary users

There are two primary users of the model.

The first primary user is the 'Business Integration Manager' at Tegel Foods, who plans production nationwide based on demand forecasts received from marketing. He will use the model to determine what capacity is for a given month or year, and consequently determine whether production plans appear feasible. It will save him considerable time and allow him to plan more efficiently because he no longer has to rely solely on guesstimates by managers and planners.

The second primary user is the 'South Island Manager'. The model is of benefit to him by allowing him to explore long term strategic changes to the South Island operation. In particular, he can assess the effect on capacity when hypothetical changes are made in the model. This might include the addition of new broiler sheds, the conversion of a breeder farm or the introduction of a better performing feed.

4.2 Secondary users

The secondary users of the model are the individual area managers. These include the breeder farms manager, the hatchery manager, the feed mill manager, the livestock planner and the main plant manager. Among the secondary users, two different responses to the project have been observed:

In the first group of responses, managers are eager that a highly detailed daily capacity tool be developed that allows them to plan capacity through scheduling and other optimisation techniques. It is of advantage to each manager that their particular area be modelled, yet not everybody can be satisfied in the time available. The conflicting interests in the project made it important to be clear about the strategic aims of the model and balance the detail of the individual area models with those aims.

The second group of responses to the project consists of managers who did not view an overall capacity model as being useful to them; that it does not contribute any further knowledge than they already have. It was crucial that the managers understand that the model aids their understanding, not replaces it.

5 The model

In all areas of the Tegel chicken operation collating relevant information is time consuming and challenging. In an operation of this size, there is extensive technical detail and data, only some of which is relevant to describing monthly capacity. It is a common requirement to collect data from staff who work in a detailed part of an area, such as a chicken farmer or mill worker, who are unaware of the project's objectives.

The design of the model was based upon six criteria taken from Little (1984). These criteria were that the model be simple, robust, easy to control, adaptive, complete and easy to communicate with.

4.1 Microsoft Excel capacity model

The capacity model is developed in Microsoft Excel®. This was chosen because it is widely used amongst managers at Tegel and allows them to alter and extend the model with ease, thus keeping it simple, adaptive and easy to communicate with. Features, such as the use of cell protection and undo options are included in the model to ensure that it is robust and valid. The planning spreadsheets currently in use at Tegel, described by staff as difficult to manipulate and understand, are large and contain unnecessarily complex macros. The capacity model is kept user-friendly by keeping the use Visual Basic for Applications macros to a minimum and by only using them for display features of the model. Likewise, formulae are kept as simple as possible.

The model consists of six worksheets, five for the areas of the operation and one to summarise the information of the model. The summary sheet includes overall capacity and utilisation and is designed for the use of senior management who do not understand the areas in depth.

4.2 Describing capacity

Hill (2003) defines capacity as “the maximum rate of output of a process, measured in units of output per unit of time”. Correspondingly, the model seeks to describe the maximum number of whole birds that can be processed in a month by Tegel’s South Island chicken operation.

Each area at Tegel Foods is made up of a number of parts, including machines, storage and transport. The capacity of an area is the minimum of the capacity on the individual parts. This is understood intuitively, a production line can operate no faster than the speed of its slowest process. Calculating capacity at the main plant is more complex because birds have different pathways through the factory depending upon what product it will become.

The capacity of the whole operation is calculated as the minimum of the capacities of the different areas. This is valid because the flow between areas is linear, as discussed below.

4.2.1 Measuring capacity

The model incorporates five different areas of operations (main plant, broiler farms, hatchery, breeder farms and feed mill), some of which operate in different units. For example, the main plant inputs live birds and outputs kilograms of product, whereas the hatchery processes eggs (unhatched to hatched) and the feed mill outputs tonnes of feed.

The model expresses the capacity of each area in its unique units because they are most meaningful to that area’s manager. Area capacities are calculated in comparable units so that overall capacity can be determined. Monthly production at Tegel is planned in terms of whole birds processed by the main plant (specific product demand is derived from this). Senior management is accustomed to communicating in these units. As a result, the summary sheet of the model displays the capacity of each area in terms of the number of whole birds entering the main plant in a month. Expressing area capacities in these terms is also new information to area managers and is very beneficial.

A benefit of measuring monthly capacity rather than daily or weekly is that it removes most uncertainties from capacity estimation. Over a day or a week, bird growth rates and machine processing speeds can vary significantly, but production data shows that over a month variation is minimal. Capacity is accurately described by using averages.

4.2.2 Theoretical vs. demonstrated capacity

The model distinguishes between machine (theoretical) capacity and achievable (demonstrated) capacity. Capacity estimates are used to determine the feasibility of product plans, and therefore it is important that what can actually be achieved is calculated. In the main plant machines cannot operate at one hundred percent efficiency. The maximum output that can be realistically produced will not be the same from day to day due to normal factors such as staffing, productivity and equipment breakdowns.

Capacity is first described in the model in terms of the maximum rate of output that can be produced if machines operate non-stop. Users of the model can view theoretical machine capacity and be certain of its accuracy. To describe reality, factors such as staffing and breakdowns are complex and require more analysis to accurately model.

Calculation of achievable capacity attempts to approximate these affects by estimating ‘maximum machine utilisation’. This is the maximum percentage of machine capacity that can be utilised when fully loaded. This was estimated through discussion with managers and shop floor workers, and by observing demonstrated capacity in times of peak demand. The use of achievable capacity ensures the model is easy to communicate with. It is in accordance with Tegel Food's operating policy that machine efficiency is the priority and that staff can always be employed to operate the machinery at its optimum. This operating strategy is the result of Tegel's high cost of capital investment and expansion; staffing costs are relatively cheap in comparison. Tegel also seeks to use maximum machine utilisation as a production target in the near future.

4.2.3 Qualitative aspects

Qualitative aspects of capacity play a significant role in determining the level of accuracy required when estimating capacity. These include the physical and financial feasibilities of increasing capacity. For example, if a machine is relatively cheap and can be installed in a short period of time, the benefit of modelling it in detail is small. Realistically, if the machine becomes a constraint on capacity it can be easily relaxed and an extra five percent of accuracy in estimating its utilisation will be of little benefit. The decision to model is a balance between the time involved and the benefit gained.

4.3 Factories

Among the areas of the chicken operation there are, by nature, two different types – the machine driven factories and the livestock farms. Each was modelled in different ways.

The machine driven factories include the hatchery (machines are used to hatch the eggs), the feed mill and the main plant. To use 'overall capacity is the minimum capacity of the parts', it was essential that the flow of product (eggs/feed/birds) was linear. This means that product flows sequentially along a line, it does not flow down an alternative path when one direction reaches capacity. This was definitely true of the feed mill and hatchery which are both relatively simple processes.

Capacity calculations also assume that the flow of product in these factories is constant. The reality is that, in the example of the main plant, a series of smaller birds may arrive at the factory and will consequently all be processed down the same line, whilst machinery dedicated to larger birds sits idle. To incorporate this into the model would require scheduling, which was deemed beyond the scope of the project; therefore capacity is calculated under the assumption that flows are constant. This is accounted for to some extent by maximum utilisation of machinery. The addition of scheduling is a possible extension to the model.

4.3.1 The hatchery

Modelling the hatchery is relatively simple due to linear flows and stable process times. Some difficulty arose regarding the fact that because of the hatchery's operating hours; eggs can only be put in and taken out of machines on certain days. This will always occur due to the availability of staff and is included because it affects achievable capacity (it causes downtime on the machines).

4.3.2 Modelling the feed mill

The useful information required by users of the model with respect to the feed mill is the amount of feed required and also when a type of feed is required by livestock. Capacity is shown, however utilisation is not important because the feed mill can reduce its production of non Tegel related feed if need be.

4.3.3 Modelling the main plant

The main plant is significantly more complex than the other areas of the operation. Production is made up of an automated processing line, approximately five different types of machinery in secondary processing and finally three refrigeration units. It is challenging to model the capacity of the plant in summary form.

Determining the flow of products along different paths was complex. Flow is driven by product demand and therefore the flow of fresh/frozen, whole birds/portions and a-grades/down-grades will vary from month to month. The same total demand, in terms of kilograms of product, may result in different capacities at the main plant dependent upon which specific products are produced. The model does not differentiate between products and, consequently, flows had to be approximated using the average proportions that are processed at respective machines. Historical data is used to make these approximations.

The flows at the main plant are non-linear. Circumstances arise when flow is directed elsewhere to alleviate a bottleneck on the line. However, these redirections are rarely planned or consistent and were too uncertain to model in the time available. The model therefore assumes linear product flows. Without a definite set of production rules, accounting for non-linear flows becomes very challenging and is a possible extension of the model.

Although capacity at the main plant lacks accuracy because of the approximations, the benefit is that it remains simple and easy to understand. With the exception of the main plant manager, the users of the model know little about how the main plant functions and need to be able to understand the consequences of altering key inputs and parameters. A more detailed daily capacity model of the main plant, which includes scheduling, would be extremely useful to the main plant manager but would not be appropriate for the other users. Ideally a summarised form of a more detailed main plant model could later be expressed in this capacity model.

4.4 Livestock farms

The livestock growing farms of the chicken operation at Tegel are the breeder and broiler farms. Capacity at these farms is calculated based on shed space and growth rates rather than machine processing speeds. The challenge when determining monthly capacity of these farms is that unlike the factories, not all resources are used to supply a single month’s demand. In other words, it takes longer than a month for a bird to grow to full size, or for a breeder to reach its oldest breeding age. Therefore, in the example of the grower farms, some sheds must be growing flocks to supply demand two months from now, whilst others grow for next months demand. To determine capacity of these farms the notion of a ‘growing cycle’ or ‘production cycle’ was used. This is the length of time from the beginning of growing/breeding till the next flock of broilers/breeders can begin. It will include both growing/breeding of a flock and time for cleaning and bio security checks. Once an accurate estimate of the average growing/production cycle is determined, and given the total time available in a month, the proportion of total capacity available for a single month is easily calculated.

4.4.1 Modelling the breeder farms

The breeder farms provide a challenge because they consist of separate facilities, one type for rearing and another for the production phase of the breeding hen's lifecycle. The two processes have distinctly different purposes and operating methods and are therefore modelled as independent parts. The relationship between the ages of the hen and number of eggs produced had to be modelled in the production farms.

4.4.2 Modelling the broiler farms

Tegel contracts 30 broiler farms in the Canterbury area to supply the main plant. Each grows birds from day old chick to a weight at which they are ready to be killed. The two key constraints on the capacity of the broiler farms are the total shed area and the stocking density limits, as defined by Tegel's nationwide policy (within welfare restrictions).

The most difficult aspect of the broiler farms is the significant variation between farms in the daily growth rates of birds. Standard deviations and other means of incorporating uncertainty in the model were considered, but are not necessary because all farms are treated equally by Tegel and therefore daily uncertainty balances out over the course of a month. It is a contractual agreement that all farms be placed with an equal spread of birds over the course of a year; it is not the case that some poorer performing farms only grow smaller birds whilst others grow the larger birds. Over half of the thirty farms grow for a specific month which showed to be sufficiently enough such that the predicted total growth in a month is close to what is observed in reality.

5 Validation of the model

It is essential that the model is a realistic representation of capacity so that users can consider the feasibility of a production plan or explore strategic changes with confidence. This includes ensuring that the model is robust and does not produce confusing solutions.

Triangulation was used as a method of validation in the factories. The model's estimates were compared to both historical data during peak demand and managers' expectations. The model determined that at the main plant, current production levels could only be achieved by running overtime, which is exactly what is occurring in reality. Although the results show that the models estimates are very close to observed capacity, it is unsurprising given that the same sources were used to determine the parameters of the model in the first place.

Validation of the livestock farms is more credible because modelling does not rely on manager's estimates. The growing and production cycles at the broiler and breeder farms determined by the model are very close to what is currently being observed.

Overall, the model shows what many staff at Tegel predicted. Given the production plan for 2006, almost all areas need to operate at high utilisation, although the main plant and the hatchery are of most concern because, unlike the livestock farms, they cannot easily be expanded.

6 Extensions

6.1 Developing a final product

The capacity model is a prototype of a complete decision support tool. A final product was not possible in the time available given the size and complexity of the operation. Project contacts at Tegel understood from the beginning that, whilst there remained many possibilities for modelling, not all were possible in this project.

The model, in its current form, is still useable and will be of high benefit to staff at Tegel Foods. It is designed to be as accommodating as possible to additions to the model. The extensions listed below are additions that would be expected of a complete product and should be undertaken in the short term future:

- The current model only deals in terms of whole birds. Converting this into specific products be useful to users and will improve estimation of the product flows between machines at the main plant. This may require the integration of the further processing plants (on site at Hornby) into the model.
- Some parameters currently used in the main plant model are estimates by staff that have not been validated thoroughly. Improvements include estimation of refrigeration capacity using cooling formulae and investigation into production rules.

6.2 Future modelling

There are a number of other possible extensions to the model, some of which will require significant undertaking. Users of the model will have to assess the costs and benefits of each of the extensions listed below:

- Many of the parameter and input changes that can be made in the model are not necessarily cost effective. Planners could better assess the benefits of strategic changes if both the capacity and costs were quantified in the model.
- The model estimates monthly capacity. This best suits the primary users of the model by aggregating the whole process to a level that can be easily understood. Tegel also needs more detailed capacity models in the main plant and feed mill so that the area managers can undertake capacity planning.
- Scheduling is a method of capacity planning that would be of high benefit to Tegel. The breeder and broiler farms are currently scheduled manually, sometimes in an ad-hoc manner. This method has been adopted to deal with the uncertainty in the growth rates of livestock and the production of the main plant. Despite this, there is definitely opportunity to improve their spreadsheet scheduling model by incorporating automated heuristics or optimisation techniques. There is also a potential to implement scheduling in the main plant.
- The scope of the model currently excludes the capacity of the supplier to Tegel’s breeder farms and of the distribution and storage of products. Estimating these capacity constraints will be useful to users.

- Adapt this model for use in the two North Island chicken operations.

7 Conclusion

A capacity model of the entire South Island chicken operation at Tegel Foods Ltd has been developed in Microsoft Excel®. It includes integrated worksheet models of the main plant, broiler farms, feed mill, hatchery and breeder farms at Tegel.

The model will aid senior management in strategic decision making, particularly through the use of 'what if' scenarios built into the model. The model will aid area managers by providing them with a capacity model of their area and by increasing their understanding of the interrelationships between areas of the chicken operation.

Forecasted demand for 2006 was used to validate the model. The model's results for this period were close to managers' estimates of capacity utilisations and showed that the hatchery and the main plant are the bottlenecks of concern, as predicted by many managers.

The model, although useable, is not a final product and should be extended by differentiating between products and improving the accuracy of estimated parameters at the main plant. Further modelling will be very beneficial to Tegel, in particular the automated scheduling of the livestock

8 Final comments

The development of the capacity model at Tegel Foods illustrates the value of a basic, user-friendly model that is unthreatening to managers. There remains large benefit to be gained from Operations Research methodology/modelling at Tegel at relatively low cost. Tegel is certainly not the only large scale manufacturer in New Zealand who could benefit from Operations Research. The challenge for consultants is to develop models that are not necessarily ground breaking in their technical processes, but that will continue to be used effectively by managers, such as the one developed in this project.

9 Acknowledgments

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