Technical Report

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Report Title: The tactical model in optimisation of boning room management

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ALMTech Carcase Optimisation Users Group

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Executive Summary

Development of carcase optimisation tools that can be used by industry to identify opportunities to add further value to carcase inventories is a point of focus for ALMTech. The current effort has resulted in the development of a Lamb Carcase Optimisation Tool that has the capability to quantify opportunities to better allocate 'the right carcase to the right cut'. However, the complexity of the current tool is providing challenging to incorporate into the day-to-day management of a functioning lamb supply chain. Consequently, an alternate approach has been identified in collaboration with Gundagai Meat Processors that is targeted towards allocating carcases in the inventory to pre-set boning (cut) plans.

This "Tactical" optimisation model has been modelled mathematically, and its initial evaluation is presented in this report. Additional evaluation of the model is planned in 2021, and if successful it will likely result in an actionable tool for the rapid adoption by lamb supply chains.

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1 Problem Statement

One of the major tasks of a boning room manager is to decide the daily cutting plan based on the carcass availability, the customer's demands, and the operational constraints. Then a running sheet will be created to show how to set and manage the cutting process.

An example of the running sheet is shown in Fig. 1. In the example, there will be 2000 carcases to be processed in the boning room. In the *FQ* region, the boning room manager choose to produce "Sq Cut Shldr 10mm Fat Cap, St. Cut (4Rib)" using the first 1000 carcases. Then production line is changed to produce "Best End Shldr Chops 6mm Fat Cap", "Neck off Cut, St. Cut", and "Round Bone Piece BO, 6mm Fat Cap" using 1000 carcases. At last, the production line is changed again to produce "Boneless Shldr 6mm fat cap, chuck roll out" and "Chuck roll" using the last 1000 carcases. Similarly, in the *HQ* and *Loin* region, the production line is changed after processing 2000 carcases. We define the *cutting pattern* as the set of the cut types that a carcase is thoroughly processed. In the example, there are 3 different cutting patterns, and 1000, 1000, and 1000 carcases are processed according to these patterns respectively.

<table>
<tr><th>Index</th><th>HQ</th><th>LOIN</th><th>FQ</th><th>Note</th></tr>
<tr><td>1-1000</td><td rowspan="2">Chump BO (6mm)
Leg chump off, shk on, tip on, 6mm fat cap</td><td rowspan="2">Abdominal Flap
Rib Flap B/I
Rack, 8x100mm rib, CFO, scap in, 6mm fat, cap on
Shortloin cap 50mm tail, 10mm fat cap</td><td>Breast
ForeShank Tipped
Neck Straight Cut
Sq Cut Shldr 10mm Fat Cap, St. Cut (4Rib)</td><td>PATTERN 1</td></tr>
<tr><td>1001-2000</td><td>Breast
ForeShank Tipped
Neck Straight Cut
Best End Shldr Chops 6mm Fat Cap
Neck off Cut, St. Cut
Round Bone Piece BO, 6mm Fat Cap</td><td>PATTERN 2</td></tr>
<tr><td>2001-3000</td><td>Butt tenderloin
Heel Muscle_2
Hind Shank Tipped_2
Round
Rump
Silverside fat cap on
Topside Fat Cap On</td><td>Flap
French rack, 8x100mm rib, 50mm Fr., Capoff, False capoff
Shortloin eye
TDR Butt off/Side Off</td><td>Breast
ForeShank Tipped
Neck Straight Cut
Boneless Shldr 6mm fat cap, chuck roll out
Chuck roll</td><td>PATTERN 3</td></tr>
</table>

Figure 1: An example of running sheet.

Different from the "Strategic" optimisation problem [1], in the "Tactical" optimisation model, we assume the boning room manager has already created the daily running sheet.

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However, we have multiple types of carcases which have different weights and fat scores, and the profit gain from processing a carcase varies from one cutting pattern to another. Therefore the objective of the Tactical model is to maximize the overall profit by optimizing the order of the carcases to be processed.

2 Mathematical Model

2.1 Assumptions

1. Each carcase has an associated weight and lean meat yield (LMY) or fat score measurement. Given a lamb carcases population, the carcases are grouped into discrete classes based on the weight and lean meat yield score. We assume that all carcases within a carcase class are treated equally.
2. Here we ignore the cut tree constraints, as we assume that the cutting patterns created by the boning room manager has already considered that.
3. We assume that the constraints on product quantities is already considered in the generated running sheet, which shows in the different cutting patterns.
4. We assume all the available lamb will be processed thoroughly.
5. We assume that the labour allocation would be fixed when the running sheet is generated.

2.2 Indexing

The following notation is used to refer to carcase types, cut types (products) and markets:

I	the number of carcase types (under the given binning by weight and LMY/fat score)
J	the number of cut types
K	the number of cut patterns
$i \in [1, \cdots, I]$	the i^{th} carcase type, where each index i maps to a (weight, LMY/fat score) pair
$j \in [1, \cdots, J]$	the j^{th} cut types
$k \in [1, \cdots, K]$	the k^{th} cut pattern

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2.3 Input parameters

N	the total number of available carcases
N_i	the number of available carcases of type i
M_k	the number of carcases processed in cutting pattern k
nc_j	the number of pieces of cut type j in one carcase
$w\_cut_{i,j}$	the weight of a piece of cut j that is got from a carcase of type i
$w\_fat_{i,j}$	the fat weight when trimming to obtain one piece of cut j
$w\_trim_{i,j}$	the trim weight during the process to obtain a piece of cut j
$f\_cut_{i,j}$	the whole sale price per kilo of the cuts j from carcase type i
f_fat	the market price (per kilo) of the fat
f_trim	the market price (per kilo) of the trim
$e_{i,k}$	the incomes earn from the cuts produced by a carcase from carcase type i in cutting pattern k

2.4 Allocation variables and constraints

We employ the following notation for the decision variables and constraints:

$x_{i,k}$	the (integer) number of carcases of type i allocated to produce cut pattern k
$\mathcal{P}$	the set of the cut types index that a carcase is thoroughly processed in a given cutting pattern

2.5 Income

The income from the cuts produced by process a carcase from carcase type *i* in cutting pattern *k* is:

$$e_{i,k} = \sum_{j \in \mathcal{P}_k} (f\_cut_{i,j} \cdot w\_cut_{i,j} + f\_fat \cdot w\_fat_{i,j} + f\_trim \cdot w\_trim_{i,j}) \cdot nc_j \quad (1)$$

2.6 Cost

In this model, we investigate the boning room management from an operational point of view. We assume that all the available lamb will be processed without any carcase left. It means the purchase cost and slaughter costs are fixed in this model. Furthermore, when the running sheet is created by the boning manager, the labour allocation and machine setting up is also fixed. Then labour/machinery (or boning/packaging) costs are also fixed in this model. Therefore, in the Tactical model all costs are fixed, which could be ignored from the optimisation process.

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2.7 Constraints

In the Tactical model we consider two type of constraints;

1. The number of available carcases of a given carcase type constraint:

$$\sum_k x_{i,k} = N_i \tag{2}$$

2. The number of carcases processed in given cutting pattern constraint:

$$\sum_i x_{i,k} = M_k \tag{3}$$

The cut tree constraints and cut type constraints should be considered by the boning room manager before the running sheet decided.

2.8 Statement of optimisation problem

Our optimisation problem can be stated as;

$$\begin{aligned} \max_{x_{i,k}} \quad & \sum_i \sum_k e_{i,k} \cdot x_{i,k} \\ \text{subject to} \quad & \sum_k x_{i,k} = N_i \quad i = 1, 2, \cdots I \\ & \sum_i x_{i,k} = M_k \quad k = 1, 2, \cdots K \end{aligned} \tag{4}$$

Note that both the objective function and the constraints are linear, therefore the Tactical model can be classed as an integer linear program.

3 Case study

We study the case with the running sheet in Fig. 2. The weights data are from the DEXA LVC, which is the same as the data used in “carcase gmp dexa” APP. The carcase population in the simulation has 3000 carcases, with weights from 13kg to 39kg, and lean meant yield from 49% to 65%. It is also the same as the default population in “carcase gmp dexa” APP.

When we ran the optimisation tool, the optimized profit was $770618.57, or $256.87 per carcase. For comparison, we also run the random allocation 200 times. The distribution of the profit from random allocation is shown below:

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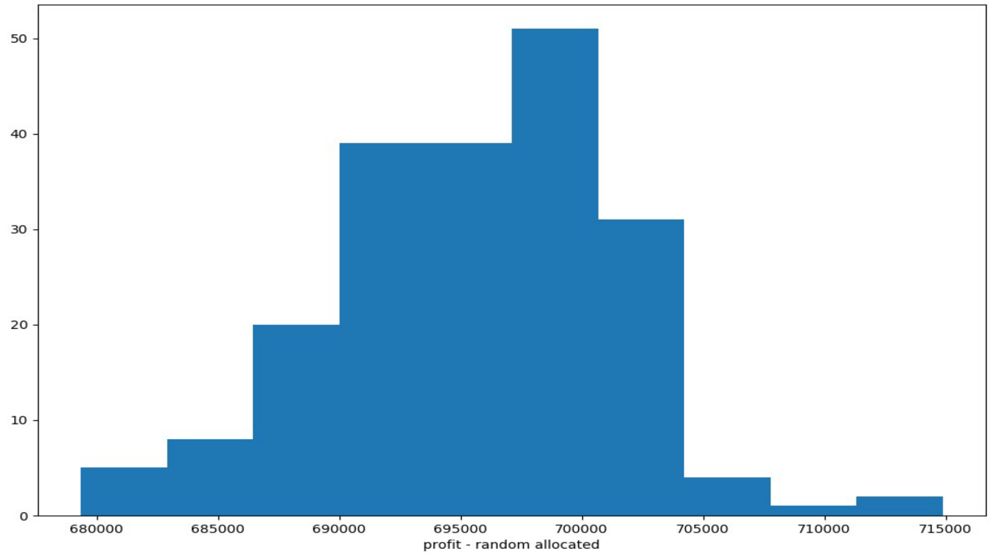

Figure 2: The distribution of the profit from random allocation.

The full result is listed in the following table. we can see that the optimized profit was improved 10.80% compare to the mean profit of the random allocation.

Table 3: Simulation result

Optimized profit	$ 770,618.57
Mean profit of the random allocation	$ 695,475.70
Max profit of the random allocation	$ 714,876.96
Min profit of the random allocation	$ 679,358.28
Improvement to Mean	10.80%

4 Conclusion

The Tactical model reviews the optimisation problem in the boning room management from an optional point of view. It does not break the existing boning room management procedure, or change the running sheet created by the boning room manager. It increased the boning room profit by adjusting the processing sequence of the carcases, which is very easy to implement. It could be a good starting point for the real world operational improvement for our industrial partners.

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References

[1] Andre Costa, Michelle Henry, Sean Miller, Wayne Pitchford, Chris Smith, and Vince Wang. *Optimal Allocation of Carcases to Product Types in Lamb Processing Operations*. Technical Report, Teletraffic Research Centre, The University of Adelaide.

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