MATH10073: Linear Programming, Modelling and Solution (LPMS)

Case study: TomMac

The problem

As presented by the client: TomMac

Overview

TomMac is a small company which buys tomatoes to be processed into products. Specifically, we buy three types of tomatoes [Beef, Plum and Moneymaker] and process them according to certain production criteria to make four products [Juice, Sauce, Paste and Canned]. We need **your** advice on how to organise ingredient purchase, manufacture and inventory in order to make three important management decisions!

Introduction

We buy tomatoes which are grown by local farmers right through the year, but they are naturally more abundant and cheaper in the summer when they are grown in fields rather than greenhouses.

(a) Beef

(b) Plum

(c) Moneymaker

	Availability (kg)			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Beef	1500	4000	6000	1500
Plum	5000	10000	15000	5000
Moneymaker	4000	9000	13000	4000

	Cost (£/kg)			
	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Beef	0.90	0.60	0.40	0.90
Plum	1.00	0.70	0.50	1.00
Moneymaker	0.80	0.50	0.30	0.80

Tomatoes are used to make products by creating an initial mix for each product. Different types of tomato have different liquid and solid content

	Tomato properties		
	Beef	Plum	Moneymaker
Solid	0.59	0.68	0.64
Liquid	0.41	0.32	0.36

It is essential for product quality that this initial mix has the right liquid and solid content.

(a) Juice

(b) Sauce

(c) Paste

(d) Canned

	Mix properties			
	Juice	Sauce	Paste	Canned
Solid	0.60	0.62	0.65	0.67
Liquid	0.40	0.38	0.35	0.33

Each product is produced from its mix as follows

- The mix for **juice** is liquefied and then combined with another ingredient (water) in a ratio $1 : 0.25$
- The mix for **sauce** is liquefied, reduced by a factor of 0.8 and then combined with another ingredient (oil/flavourings) in a ratio $1 : 0.1$
- The mix for **paste** is liquefied and then reduced by a factor of 0.5
- The mix for **canned** tomatoes is chopped

In general, processing transforms M kilos of mix into P kilos of product via

- Reduction by a factor R
- Addition of another ingredient in a ratio $1 : I$

This can be expressed as the formula $P = (1 + I)RM$

	Mix properties			
	Juice	Sauce	Paste	Canned
R	1.00	0.80	0.50	1.00
I	0.25	0.10	0.00	0.00
	Costs			
Other ingredient (£/kg)	0.00	0.10	0.00	0.00
Production cost (£/kg)	1.00	1.50	2.50	1.00

Note that the amount of the other ingredient required is IRM.
In each time period `TomMac` has the following contract to sell each product at a given price

	Contract sales			
	Juice	Sauce	Paste	Canned
Contract (kg)	1000	2000	2500	3000
Price (£/kg)	1.84	2.42	4.25	2.07

The company also has the following demand for additional sales of each product at a given price

	Demand sales			
	Juice	Sauce	Paste	Canned
Demand (kg)	1000	1000	1000	2000
Price (£/kg)	2.05	2.77	4.59	2.29

Manufacture of each product in each time period is limited as follows

Production limit (kg)			
Juice	Sauce	Paste	Canned
4000	7000	7000	10000

However, to balance production through the year, `TomMac` has a warehouse which can hold a total stock of at most 5000kg of the products at a cost of £0.10 per kg in stock at the end of the quarter.

The consultancy process

As presented by a senior colleague of LPMS consulting.

Overview

1. Develop a "**base case**" model which replicates current decision-making
   Builds confidence with the client
   - Demonstrates understanding of status quo
   - Generates faith in future recommendations

2. Use the model to advise on three strategic decisions in a given set of scenarios
   Gives the client what was asked for

3. Identify a few further specific ideas for the client to consider
   Shows we do more than the minimum

4. Suggest what further consulting might consider
   Hope to get a further fee!

Stage 1

Identify characteristics of the base case model. It consists of the following

- Blending ingredients to make a mix for each product that has specific properties
- Limits on availability of ingredients—which must be purchased
- Limit on production due to manufacturing capacity—which has a cost—and storage available
- Demand for product—with a price

Identify the **Decision variables:**

- How many kilos of each variety of tomato should be used in the manufacture of each product in each time period?
- How many kilos of each product should be sold in each time period?
- How many kilos of each product should be held in stock at the end of each time period?

Identify the **Objective:**

- Income: From product sales
- Costs: For purchase of tomatoes and other ingredients, manufacturing and storage

Identify the **Constraints:**

- Ensure that all ingredients used are bought!
- Ensure that ingredients don't exceed the availability
- Ensure that the product mix has the required properties
- Ensure that the product mix is processed correctly
- Ensure that the production limit is not exceeded
- Ensure that the storage limit is not exceeded
- Ensure that the right price is paid for products sold to satisfy the contract or in response to demand

The necessary data are in `TomMac.dat` and `TomMacQuarters.dat`. Until you have implemented inventory, you can test your model with the single period data in `TomMacYear.dat`

Stage 2

`TomMac` must make three strategic decisions

- Rent new warehouse, or not?

  Another warehouse of capacity 5000kg is available at a cost of £3,000 per year

- Sign a new contract, or not?

  An new contract is available. Should it be signed, or not?

	New contract sales			
	Juice	Sauce	Paste	Canned
New contract (kg)	600	1000	1000	2000
New contract price (£/kg)	1.93	2.66	4.35	2.05

- Increase production capacity by 20%, or not?

  A machinery upgrade is available to increase production capacity for all products by 20% at a cost of £400 per year

For the base case, none of the strategic decisions is worth taking, but `TomMac` is looking to the future optimistically!

- They feel that product prices [for demand sales and both contracts] may increase by 0, 10% or 20%

- They feel that demand may increase by 0, 10% or 20%

Future uncertainty over wages and cost of energy mean that production costs may increase by 5%, decrease by 5% or stay the same. These represent $3^3 = 27$ different future **scenarios**. Each group will make the strategic decisions for a different scenario.
For the best set of decisions for a particular scenario, `TomMac` would be interested to know the extent to which profit can be increased by allowing the product mix properties to vary within 0.02 of the current fixed values.

Deliverables

Each group should give a 10-minute presentation, a report with a cover page and (then) no more than 4 sides of A4, one MOSEL file and one data file for its scenario. The breakdown of marks to be assigned is as follows

Marks	For
20	Results
20	Mosel skills
20	Report content
10	Slide content
10	Report-writing skills
10	Slide presentation skills
10	Bonus

The bonus is for observations/conclusions/recommendations and unprompted investigations

Presentation

The audience for the presentation is the manager and his assistant who understand business, but not linear programming. Everyone is to speak for 2-3 minutes and the presentation should introduce the group members, the context and base case results, present the results for the scenario investigated and suggest ideas and scope for further investigation. You should be graphically creative, but not too much!

Report

Report contents
The report should introduce the aspect of the company to be investigated, placing the investigation in context. It should not include large tables of data (refer to an appendix if necessary) or "equations". It must state the "base case" results clearly, using tables and charts (sparingly), showing the client that you are starting from a point well-understood. Consider the points to be investigated systematically, using tables and charts (sparingly), and don't just give results, but also interpretation and analysis. Think what else you could investigate with your model and offer general observations, conclusions and recommendations.
Report presentation
Aim to produce a neat and tidy document with right-left justified text, reported values quoted to a sensible number of significant figures and with tables and charts a sensible size. Don't spend **hours** beautifying your document since this can raise suspicions that the content might be weak. Something of **you** should come across!

Model

Write the model to be readable by a Mosel user, ensuring that the base case can be solved using `TomMac.dat` and `TomMacQuarters.dat`. Submit the file `TomMacPlan.dat` corresponding to your scenario and any other modified data files. Use good Mosel style.

Timeline

When?	**What?**
Tuesday 19 March (12:10-13:00)	Case study: Stage 1
Thursday 21 March (11:10-12:00)	Question-and-answer session in workshop
Tuesday 26 March (12:10-13:00)	Case study: Stage 2 Introduction to consultancy Question-and-answer session
Thursday 28 March (10:00-12:00)	Question-and-answer session in lab
Mon 1 April – Wed 3 April	Group presentation (10 minutes) Scheduled with Learn
Thursday 4 April (12:00)	Submission of written report