**UP902897**

**M352 – Advanced Decision Modelling**

**Coursework**

**Problem 1**

**a)**

**Decision variables:**

* – number of products i to produce in j percentage range of demand for product i.

, where 1, 2, 3 is product A, B, C, respectively.

, where 1 is 0% to 90% range of demand.

2 is 90% to 100% range of demand.

3 is excess of demand (>100%).

The Total Profit of the company needs to be maximised. It depends on quantity of product i produced (Raw Material and Labour Cost) and their selling price (Total Revenue) which depends on percentage range of demand for products i.

**Objective function:**

Maximise Total Profit (in £) = Total Revenue – Raw Material Cost – Labour Cost

Total Revenue = sum of the sell price in j percentage range of demand for product i \* number of products i in j to produce – penalty cost.

Raw Material Cost = sum of the raw material cost to produce one product i \* number of products i for all j.

Labour Cost = sum of the labour cost to produce one product i \* overall number of products i.

We could use only 6 variables, namely and for as we know that 90% of demand must be satisfied (1485 of A, 2762 of B and 630 of C), hence would be production of each product i between 90% and 100% of demand and would be production for each product i in excess of demand (>100%). However, this model is more general and if the guaranteed percentage of demand change, we just change the constraints and the domain for .

**Constraints:**

Resource constraints: sum of units of resource needed for product i\*number of product i.

Stainless steel (kg)

Rust protection (g)

Labour constraints: sum of activity hours needed for product i\*number of product i.

(hours)

Assemble

Edit the steel

Chemical process

Forge welding

**Decision variable domain:**

Guarantee at least 90% of the demand (j=1):

Between 90% and 100% of the demand (j=2): (not 0.1\*demand, due to rounding 0.9\*3068)

**Extra constraints:**

To set production in order is necessarily to make sure that implies , which is equivalent to

Either-or, so:

M must be big enough to not restrict production, we calculate . M=3453 (see calculations in excel file)

Excess of the demand (j=3):

We need to make sure that implies , which is equivalent to

Either-or, so:

**b)**

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Description automatically generated

The optimal solution is to produce 1650 units of product A, 4010 units of product B and 630 units of product C, which according to estimated sale price per product would give £9559496.50 profit. The company would cover demand for product A, make 942 units in excess of demand for product B, and make 630 units, minimum required of product C, paying penalty of £70000.

**c)**

**Answer report:**

Graphical user interface

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Clearly, the most limiting Resource/Activity to the company is amount of Rust Protection, which is indicated by value zero under Slack column and Rust Protection Usage row. The net profit for this solution is £9559496.50 .

**Sensitivity report:**

Graphical user interface, table

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The shadow price for Rust Protection is 318.5 which means that extra gram of Rust Protection increases profit by £318.5 and this is valid for any availability between 20645 and 27784 grams. If the Rust Protection amount stays within this limit the current basis remains optimal, which means company should not produce more than 90% of demand of Product C and in excess of demand of product A. However, within this range for Rust Protection we can meet the demand for A and B and minimum required for product C.

If the amount of Rust Protection changes within the above range the production plan is not going to change, company will use the resources to make Product B in excess of demand and cover the demand for A and minimum required for C (reduced cost for all = 0) but total profit is going to change by £796.25(Objective coefficient for excess of demand C) for each change by 2.5 gram in Rust Protection.

**d)**

i)

We need to add three extra variables, namely d, e, f and add three constraints:

ii)

Either-or, so we need to add two constraints:

iii)

If then , which is equivalent to:

Either-or , , so we need to add two constraints:

iv)

In this case we should change our Total Revenue formula to:

, where:

- number of products to buy in i percentage range of demand for product A

Also, we should change few decision variable domain constraints, namely:

, add:

There is no information about how many products A a third party can produce, neither how big is the budget of the company, M can be infinity.

Also, we should change few extra constraints, namely:

M can be infinity.

Cost of producing product A by the company is £1553.58 (see excel file)

If the company produce 903 of A, it will cost same as buying those from a third party. As we know minimum requirement for A is 1485 units, hence buying it makes sense, each product bought over 903 units saves roughly £553. Also, they will have more resources to use for products B and C. The company should definitely buy product A from a third party and do not manufacture them on them own as demand is big enough, it is cheaper to buy it and they need resources.

**Problem 2**

**a)**

**Conceptual Model:**

* The Problem Situation:

Restaurant`s order processing. Orders arrive and go through three service points, first is preparing, second cooking and the third arranging. If any of those is busy, orders wait in a queue. There are considered two queue priority rules:

First-In-First-Out (FIFO) and Shortest Expected Processing Time First (SPT).

* Modelling Objectives:

The objective is to determine the processing rule required that will minimise the average throughput time of an order.

* Model Inputs:

Orders

* Model Outputs/Responses:

Average throughput time of an order

* Experimental Factor:

Queuing priority will be set to FIFO or SPT

* Model Scope

|  |  |
| --- | --- |
| **Component** | **Justification** |
| Entity: Orders, Detail: | Flow through the service process |
| Activities: Preparation, Cooking, Arranging (Servers) | Required for average throughput time of an order |
| Queues:  Queue for Preparation  Queue for Cooking  Queue for Arranging | Required for average throughput time of an order and queuing priority experimental factor |
| Resources:  Kitchen personnel (excluded) | Simplification: represented by servers |

* Model Level of Detail

|  |  |  |
| --- | --- | --- |
| **Component** | **Detail** | **Justification** |
| Entity: Orders | Arrival Pattern: Different mean inter- arrival times which depend on time of the day. Different type of orders distribution.  Shift: No arrivals between 10pm and 9am | Required for flow of customers into the system |
| Activities: Preparation, Cooking, Arranging (Servers) | Service time:  Different service time which depends on type of the order | Required for average throughput time of an order |
| Queues:  Queue for Preparation  Queue for Cooking  Queue for Arranging | Queue discipline:  FIFO, SPT | Required for average throughput time of an order and queuing priority experimental factor |
| Resources:  Kitchen personnel (excluded) | N/A | Simplification: represented by servers |

* Modelling Assumptions:

No breakdowns of servers. (Missing ingredients, energy, electricity, cutlery etc)

* Model Simplifications:

Service personnel (resource) not specifically modelled, but represented by the

servers(activities).

No limit to the number of orders in the queue for service.

No balking or reneging from the queue.

* Process Flow Diagram

Diagram

Description automatically generated

**b)**

**i)**

As resources are not considered, I treated each operation (preparing, cooking, arranging) as one server and considered only the service time in the model. The clock runs for 24 hours, 7 days a week and order arrivals are constrained using shift pattern from 9 am to 10pm (after 10 pm restaurant does not accept orders). All the activities (processes) use the timing by label which is assigned to type of order at the start point (also probability profile assigned to the type of order).

Graphical user interface, application, Excel

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Steady state is being achieved every night after orders stop coming through. Without shift between 10pm and 9 am implemented on order arrival, queueing time in the system increases linearly to infinity.

**ii)**

Limit used: 1000.

Average throughput time at 1000 limit: 282.12 minutes

Precision needed:

Graphical user interface, application

Description automatically generated

Number of runs required: 59

95% CI for average throughput: (290.21, 311.24)

**iii)**

Average throughput time of an order of all three types: 300.73 minutes

Average throughput time of an order for cold plates: 290.48 minutes

Average throughput time of an order for hot meals: 298.28 minutes

Average throughput time of an order for fish dishes: 312.39 minutes

**c)**

Expected processing times:

* Cold Meal – 5+4+4=13 minutes
* Hot Meal – 10+12+6=28 minutes
* Fish Meal – 15+23+9=47 minutes

According to SPT rule, we need to prioritise every queue in the system in a way that Cold Meal leaves the queue first and Fish Meal leaves the queue last. By using Reverse Priority, we ensure that order is as required (1-CM, 2-HM, 3-FM, from 1 to 3).

Graphical user interface, application

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Running our simulation with following parameters:

Order limit: 1000

Number of runs in trial: 59

, gives the following results:

Graphical user interface, text, application, email

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Histogram of throughput time of an order for cold plates (59 runs):

Chart, histogram

Description automatically generated

Histogram of throughput time of an order for cold plates (59 runs):

Chart, histogram

Description automatically generated

So:

Average throughput time of an order of all three types: 224.99 minutes

Average throughput time of an order for cold plates: 45.47 minutes

Average throughput time of an order for hot meals: 131.8 minutes

Average throughput time of an order for fish dishes: 565.47 minutes

Comparing the result with the ones for FIFO rule from b)iii) we can see that average throughput time of an order for cold plate decreased from 290.48 minutes to 45.47 minutes (84.3%) and average throughput time of an order of all three types decreased from 300.73 minutes to 224.99 minutes (25.2%). While average throughput time of an order for hot meals decreased as well, we can observe that average throughput time of an order for fish dishes increased from 312.39 minutes to 546.47 minutes (74.9%).

Based on above calculations I would recommend using SPT queue priority rule.

In addition, the restaurant could use additional Cooking server, as the highest utilised process is Cooking (75.5%). It would significantly decrease order throughput time.

