Final

Prescriptive Analytics

2024

Instructions

Grading

You have until the end of the session to submit the exam. Per every minute that you submit late, you will lose 1 point.

Answers

There is one and only one correct answer.

- Each correct answer is worth 1pt.
- Each incorrect answer is worth -0.5 pts.
- Each blank answer is worth 0 pts.

Each question refers (only) to the figures that are labelled accordingly. Some questions may refer to more than one figure.

Question 1:

The plot below represents a sensitivity analysis of a dependent variable `Net Profit` versus two independent variables `Proportion of Supers(%)` and `Demand`.

The sensitivity of the `Net Profit` to `Demand` is…

(a) The Highest when the `Demand` is above `250000`

(b) Lower when the `Demand` is around `150000` than when `Demand` is around `250000`

(c) Equal to the sensitivity to `Proportion of Supers(%)`

(d) Higher when the `Demand` is around `150000` than when the `Demand` is around `50000`

Question 2

The plot below shows the cumulative distribution function of the output variable of the profit of the Wellyntoy company.

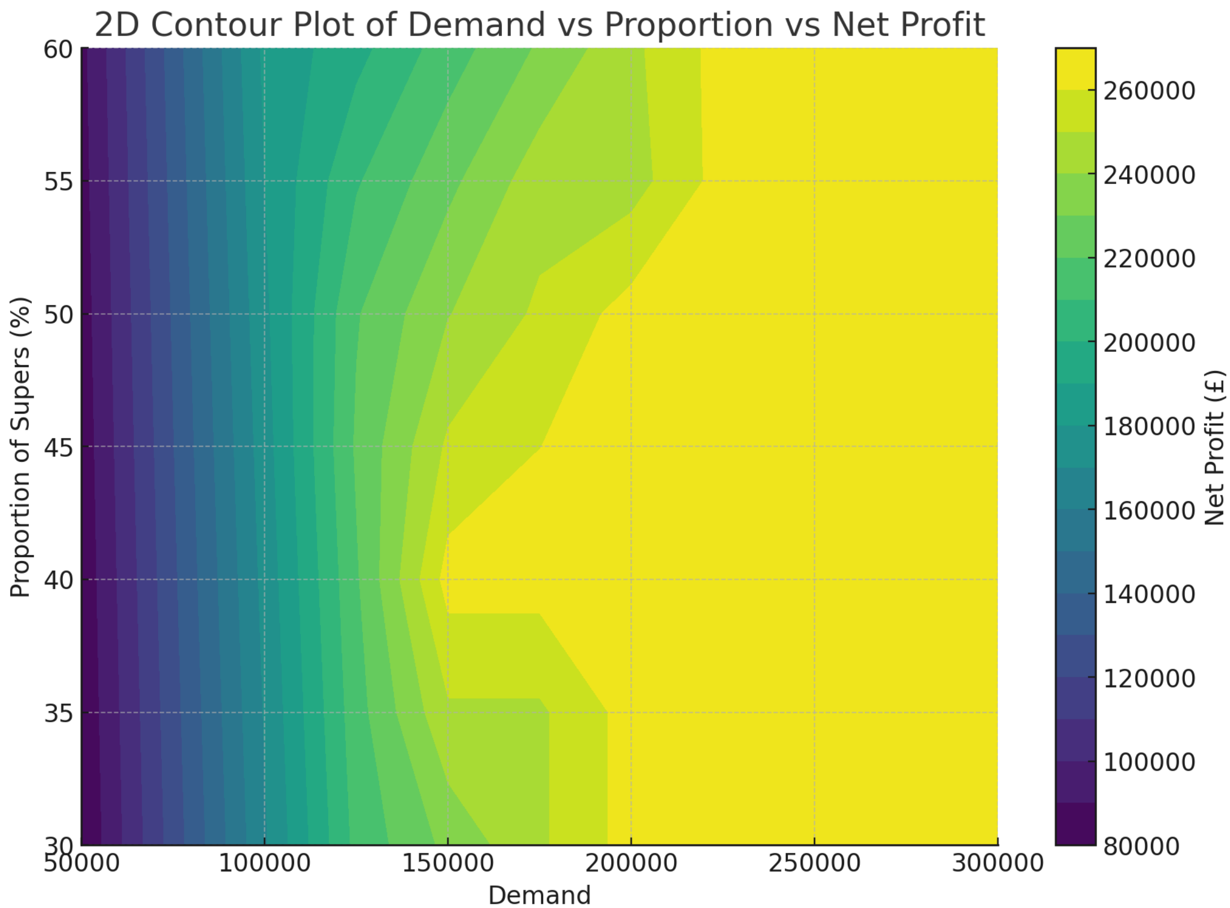

Figure 1: Question 1

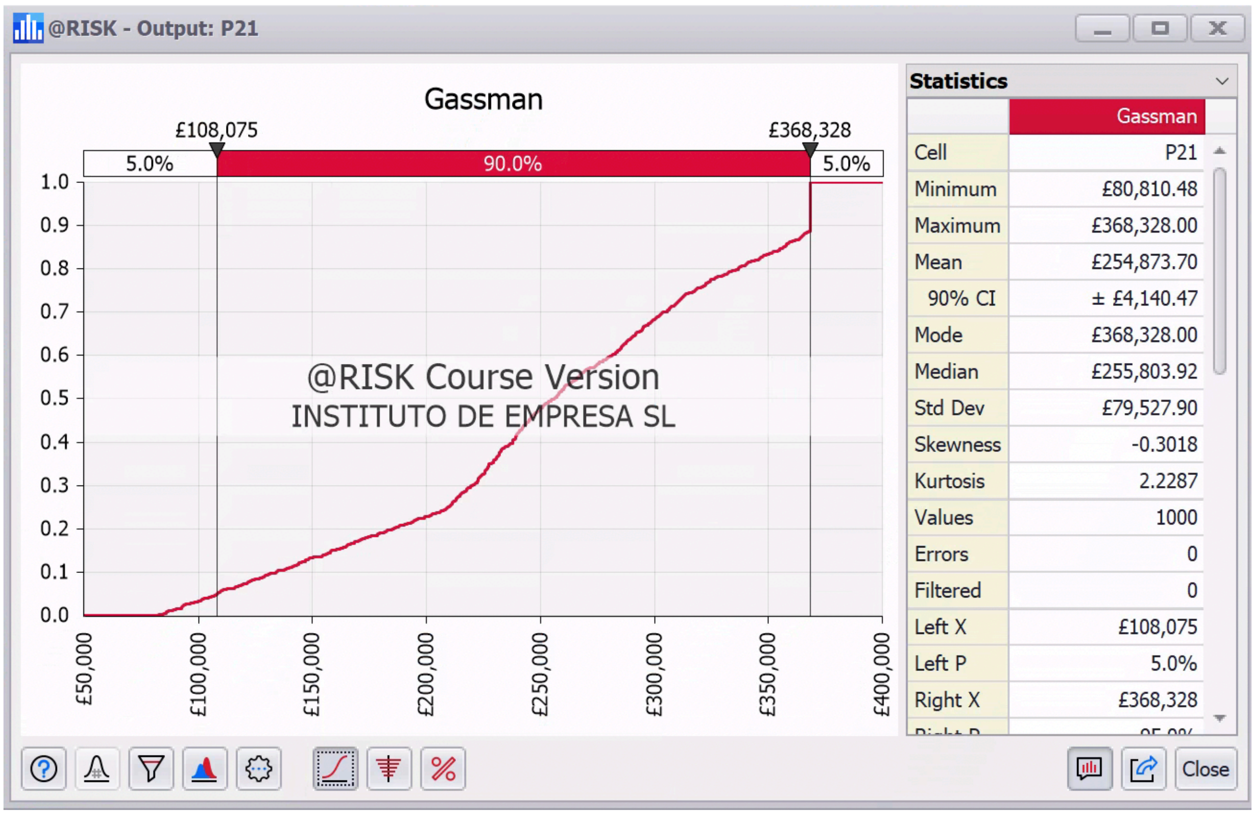

Figure 2: Question 2

Choose the correct statement:

(a) There is a 5% probability that the profit is £108,075

(b) There is a 70% probability that the profit is below 300,000 (approx.)

(c) There is a 90% probability that the profit is between 0 and £368,328

(d) There is a 30% probability that the profit is £225,000 (approx.)

Question 3

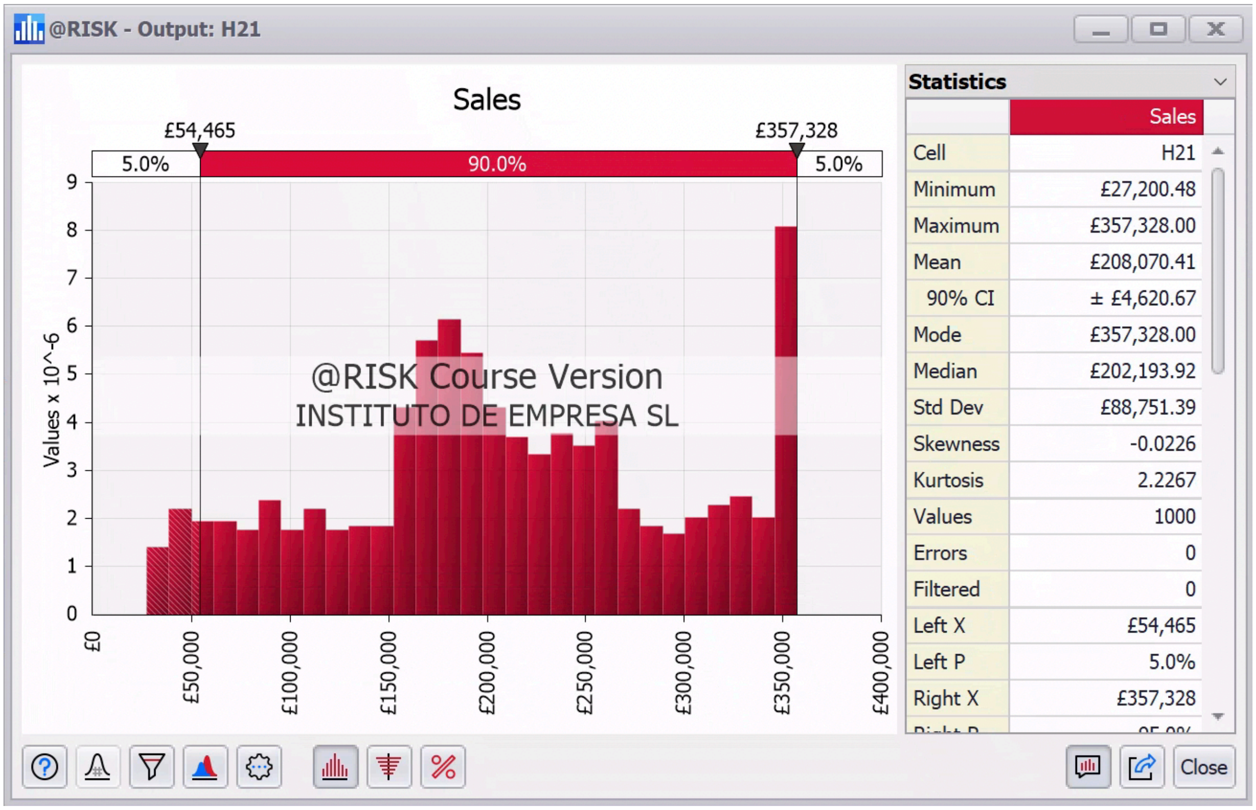

Figure 3: Question 3

Choose the correct statement:

(a) There is a 90% probability that the profit is £357,328

(b) There is a 5% probability that the profit is £54,465 or lower

(c) There is a 90% probability that the profit is either £54,465 or £357,328

(d) There is a 5% probability that the profit is £50,000 (approx.)

Question 4

What does this imply?:

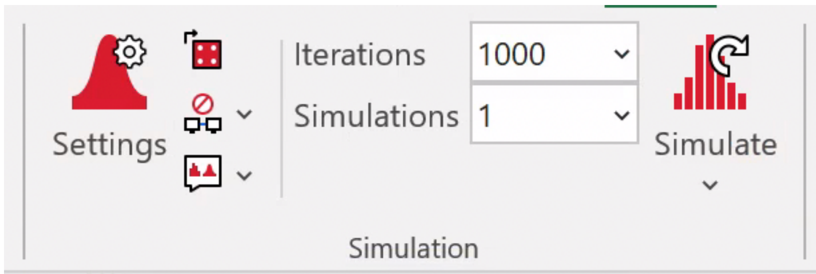

Figure 4: Question 4

(a) Samples will be drawn from each random variable 1,000 times
(b) 1,000 Open Solver simulations will take place
(c) An Open Solver simulation will be run, featuring 1,000 draws from each input random variable
(d) A Monte Carlo simulation with 1,000 iterations will be run, each with 1,000 random variables

Question 5

Which one is correct?

(a) The model has two decision variables
(b) The model an equality as a constraint
(c) The model tries to maximize the error between cell D21 and the target value
(d) The model will produce a Sensitivity Analysis

Question 6

Which one is false?

(a) The model has several sets of constraints
(b) The models assumes that this is a linear programming problem
(c) The model has several objective functions
(d) The model has nine decision variables

Question 7

Which one is correct?

(a) The multiple-cell boxes highlight the decision variables
(b) The single-cell box highlights the decision variables
(c) The shades highlight the constraints
(d) The horizontal boxes highlight constraints

Question 8

Which one is correct?

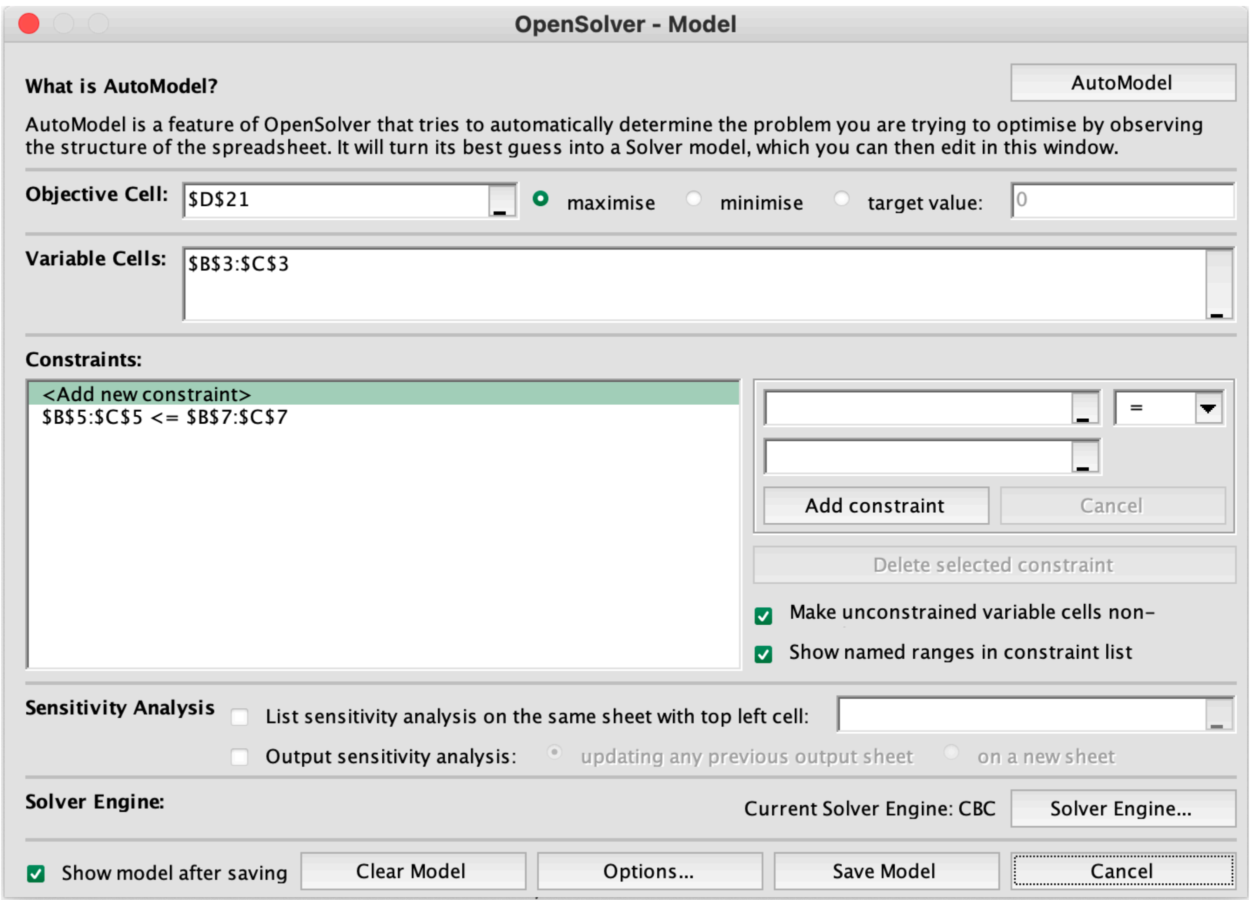

Figure 5: Question 5

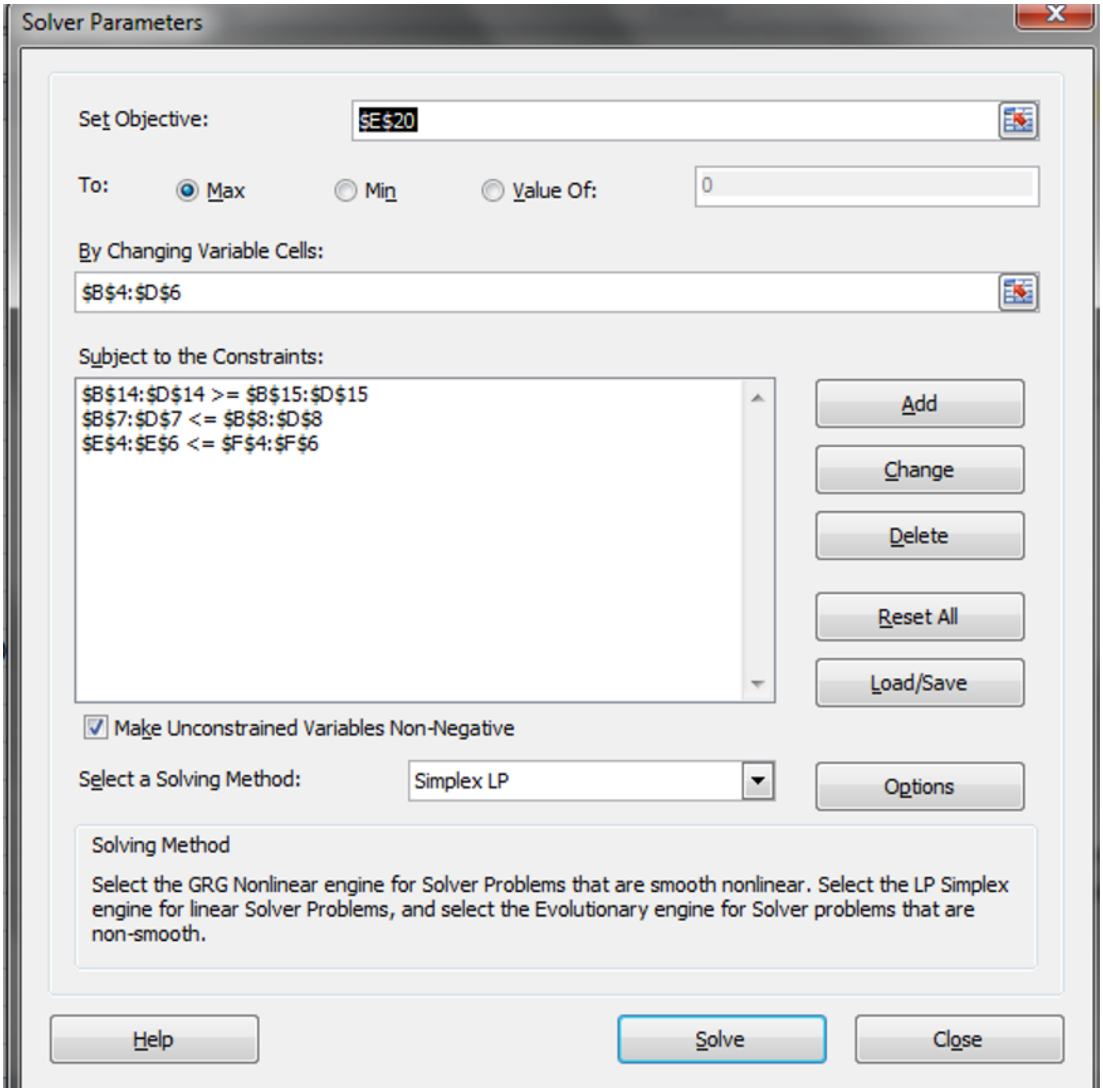

Figure 6: Question 6

RED BRAND CANNERS					
MIX DECISION	**Whole**	**Juice**	**Paste**	**Total Required**	**Available**
Grade A	239	125	0	364	≤ 364
Grade B	80	375	1,000	1,455	1,455
Total Production	318	500	1,000		1,818
Demand	≤ 600	500	1,000		
QUALITY	**Whole**	**Juice**	**Paste**	**Quality**	
Grade A	2,148	1,125	0	9	
Grade B	398	1,875	5,000	5	
Total Quality	2,545	3,000	5,000		
Required Total Quality	≥ 2,545	3,000	5,000		
Average Quality	8.0	6.0	5.0		
Required Average Quality	8.0	6.0	5.0		
PROFIT	**Whole**	**Juice**	**Paste**	**Total Contribution**	**Profit**
Contribution Margin	$247	$198	$222	$399,591	max $72,318

Figure 7: Question 7 and 8

(a) The demand of whole tomatoes seems to be not binding
(b) The demand of juice seems to be not binding
(c) The available A tomatoes seems to be not binding
(d) The quality of whole tomatoes seems to be not binding

Question 9

Choose the correct one (don't worry about the units or the converstion to 1,000s):

(a) Increasing the production of grade A tomatoes would bring a benefit of 600
(b) Increasing the production of grade A tomatoes would bring a benefit of 271.5 for at least 600 additional tomatoes
(c) Increasing the production of grade B tomatoes would bring a benefit of 2,400
(d) Increasing the production of grade B tomatoes would bring a benefit of 173.5 for at least 200 additional tomatoes

Question 10

Which one is true?

(a) the b coefficients are the decision variables
(b) Z is the objective function
(c) the C coefficients are the Lagrange multipliers
(d) the b coefficients are the shadow prices

Question 11

Is the solution in the screenshot correct?

OpenSolver Sensitivity Report - CBC
Worksheet: [RBC Lecture.xlsx] Model Sensitivity
Report Created: 23/9/24 22:35:41

Decision Variables

Cells	Name	Final Value	Reduced Costs	Objective Value	Allowable Increase	Allowable Decrease
B4	Grade A Whole	525	0	247	462.6666669	65.3333334
C4	Grade A Juice	75	0	198	65.33333342	462.6666669
D4	Grade A Paste	0	-98	222	98	1E+100
B5	Grade B Whole	175	0	247	1388.000001	65.33333342
C5	Grade B Juice	225	0	198	43.1111112	154.2222223
D5	Grade B Paste	2000	0	222	1E+100	48.5000001

Constraints

Cells	Name	Final Value	Shadow Price	RHS Value	Allowable Increase	Allowable Decrease
B12>=B13	Total Quality Whole	0	-24.5	0	466.6666667	600
C12>=C13	Total Quality Juice	0	-24.5	0	1400	200
D12>=D13	Total Quality Paste	0	0	0	0	1E+100
B6<=B7	Total Production Whole	700	0	14400	1E+100	13700
C6<=C7	Total Production Juice	300	0	1000	1E+100	700
D6<=D7	Total Production Paste	2000	48.5	2000	200	466.6666667
E4<=F4	Grade A Total Required	600	271.5	600	600	466.6666667
E5<=F5	Grade B Total Required	2400	173.5	2400	466.6666667	200

Figure 8: Question 9

Maximize:

$$Z = C_1 X_1 + C_2 X_2 + \cdots + C_n X_n$$

Subject to:

$$\begin{aligned} a_{11}X_1 + a_{12}X_2 + \cdots + a_{1n}X_n &= b_1 \\ a_{21}X_1 + a_{22}X_2 + \cdots + a_{2n}X_n &= b_2 \\ &\vdots \\ a_{m1}X_1 + a_{m2}X_2 + \cdots + a_{mn}X_n &= b_m \end{aligned}$$

With:

$$X_1, X_2, \ldots, X_n \geq 0$$
$$b_1, b_2, \ldots, b_m \geq 0$$

Figure 9: Question 10

DECISION VARIABLES

	X401	X402	X403
# Produced (in Chips)	47,133	31,765	26,818
# Outsourced	20,455	0	0
Total (chips)	67,588	40,000	26,818
# of Sales	64,209	34,000	23,600
# of shortages (in chips)	791	-7,000	0

OBJECTIVE

Sales Revenue	Production Cost	Shortage Cost	Outsourcing costs		Total Profit
$9,895,557	$815,337	-$45,920	$1,100,000	max	$8,026,140

raints

)2	X403
)0	23,600
:=	<=
)0	23,600

Production Line Constraints

		Workstation A	Workstation B	Y chips
Total Time Spent		639	900	200
		<=	<=	<=
Available Time	≤	720	720	200

Figure 10: Question 11

(a) Yes
(b) No
(c) I cannot tell from what is shown

Question 12

Choose the correct one:

(a) If Y chips could work 220 hours instead of 200, there would be a benefit of 815 per extra hour compared to the base case

(b) If Y chips could work 210 hours instead of 200, there would be a benefit of 815 per extra hour compared to the base case

(c) If Y chips could work 180 hours instead of 200, there would be a loss of 8.14 per missing hour compared to the base case

(d) All the hours worked by Y chips up to 200 have brought an additional benefit of 815

Question 13

Choose the correct one:

(a) If the demand for X401 were higher, profits would be higher than in the base case

OpenSolver Sensitivity Report - CBC
Worksheet: [2024-10-04_XMicron Template.xlsx] Basic Model Sensitivity
Report Created: 5/10/24 13:02:31

Decision Variables

Cells	Name	Final Value	Reduced Costs	Objective Value	Allowable Increase	Allowable Decrease
H3	# Produced (in Chips) X401	47133.416	0	55.88	29.20204151	55.88000012
I3	# Produced (in Chips) X402	31764.706	0	70.096	1E+100	24.05850011
J3	# Produced (in Chips) X403	26818.182	0	97.6356	1E+100	58.58310013
H4	# Outsourced X401	20454.545	0	7.972222222	1E+100	7.972222296
I4	# Outsourced X402	0	-27.630227	6.937111111	27.63022727	1E+100
J4	# Outsourced X403	0	-65.097045	8.343377778	65.09704545	1E+100

Constraints

Cells	Name	Final Value	Shadow Price	RHS Value	Allowable Increase	Allowable Decrease
B24<=B26	Total Production X401	105716.3	0	900000	1E+100	794283.6959
E24<=E26	Sales X401	64208.564	0	65000	1E+100	791.4362543
F24<=F26	Sales X402	27000	28.304118	27000	14252.08986	859.5198812
G24<=G26	Sales X403	23600	66.571705	23600	6261.922525	1049.017091
J24<=J26	Total Time Spent Workstation A	638.9587	0	720	1E+100	81.04129531
K24<=K26	Total Time Spent Workstation B	720	7143.75	720	6.516621322	368.688057
L24<=L26	Total Time Spent Y chips	200	815.34091	200	8.145776652	200

Figure 11: Questions 12 and 13

(b) If the demand for X402 were 50,000, profits would increase by 28.3 per extra unit of demand (versus the base case)

(c) If the demand for X403 were 22,600, profits would decrease by 66.57 per missing unit of demand (versus the base case)

(d) If the total production were higher, profits would be higher than in the base case

Question 14

DECISION VARIABLES

	X401	X402	X403
# Produced (in Chips)	47,133	31,765	26,818
# Outsourced	20,455	0	0
Total (chips)	67,588	31,765	26,818
# of Sales	64,209	27,000	23,600
# of shortages (in chips)	791	0	0

Figure 12: Questions 14 and 15

How is the shortage calculated?

(a) It is equal to the sales minus the demand

(b) It is equal to the demand minus the sales

(c) It is the remainder of the production after subtracting inventory

(d) It is equal to the production, including outsourced, minus the demand

Question 15

How are the sales calculated?

(a) They are equal to the production times the defective chips

(b) They are equal to the production times the yield (% of adequate chips)

(c) They are equal to the production minus the demand

(d) They are equal to the production minus the shortage

Question 16

	D	E	F	G
22		Demand Constraints		
23		X401	X402	X403
24	Sales	64,209	27,000	23,600
25		<=	<=	<=
26	Demand Forecast	≤ 65,000	27,000	23,600
27				

Figure 13: Question 16

Assume we want to turn the demand of `X401` into a random variable and run a Monte Carlo simulation. Which cells would you define as inputs in `@RISK`?

(a) `E26`

(b) `E24:G24`

(c) `E24`

(d) `E24:E26`

Question 17

Production Line Constraints			
	Workstation A	Workstation B	Y chips
Total Time Spent	639	720	200
	<=	<=	<=
Available Time	≤ 720	720	200

Figure 14: Question 17

Assume we want to turn the availability of Y chips into a random variable that is normally distributed and therefore defined by its mean and standard deviation. We know that it would be rare for Y chips to deliver less than 100 hours or more than 300 hours, but common for them to deliver 220 or 180 hours.

Which of the following would be a reasonable choice?

(a) $\mu = 720$, $\sigma = 50$

(b) $\mu = 200$, $\sigma = 5$

(c) $\mu = 200$, $\sigma = 500$

(d) $\mu = 200$, $\sigma = 50$

Question 18

	A	B	C	D	E	F
1	DYNATRON					
2		Standard	Super	Total		
3	Production	78,000	55,000	133,000		
4	Inventory leftover	12,000	5,000	17,000		
5	Available	90,000	60,000	150,000		
6					min	max
7	Demand	≤ 90,000	60,000	150,000	30,000	300,000
8	Proportion	60%	40%		30.0%	60.0%
9						
10	Sales	90,000	60,000			
11	Inventory	0	0			
12						
13	Price	£4.30	£5.50			
14	Direct Costs	£2.50	£3.20			
15	Gross Margin	£162,000	£138,000			
16	Add. costs	-£19,440	-£16,560			
17	Inventory costs	£0	£0			
18	Net Margin	£142,560	£121,440	£264,000		
19						
20	Capacity Costs			£0		
21	Net Result			max £264,000		
22						
23						
24		£264,000	30%	35%	40%	45%
25		50,000	80,170	81,305	82,440	83,575
26		75,000	124,425	126,128	127,830	129,533
27		100,000	168,680	170,950	173,220	175,490
28		125,000	212,935	215,773	218,610	221,448
29		150,000	232,680	248,340	264,000	251,745
30		175,000	248,340	264,000	264,000	264,000
31		200,000	264,000	264,000	264,000	264,000
32		225,000	264,000	264,000	264,000	264,000
33		250,000	264,000	264,000	264,000	264,000
34		275,000	264,000	264,000	264,000	264,000
35		300,000	264,000	264,000	264,000	264,000

Figure 15: Questions 18, 19, 20, 21, 22

How do you calculate the `Sales` for the `Standard`?

(a) `=MIN(B5, B7)`

(b) `=MAX(B5, B7)`

(c) `=B5 - B7`

(d) `=B7 - B5`

Question 19

Assume that you want to model the proportion of Super as a random variable. Which of the following distributions would make sense?

(a) A Pareto distribution

(b) A normal distribution with $\mu = 40\%$, $\sigma = 100\%$

(c) A normal distribution with $\mu = 40\%$, $\sigma = 1\%$

(d) A distribution bounded between 30% and 60%

Question 20

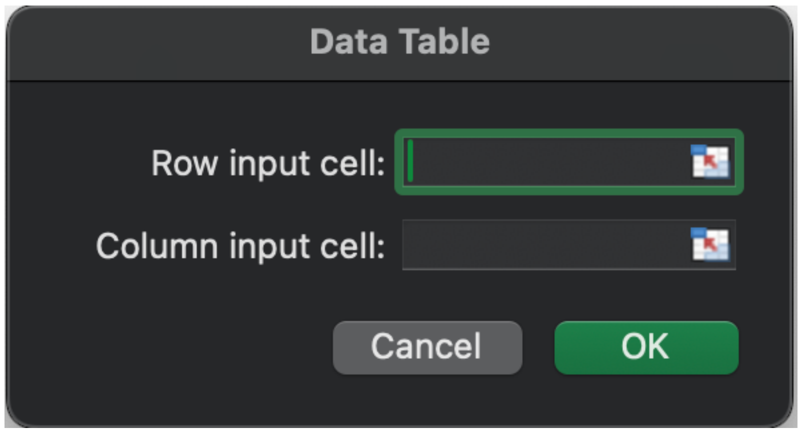

Figure 16: Questions 20 and 21

Which cell should we select as `Row input cell`?

(a) `D7`

(b) `C8`

(c) `C24:F24`

(d) `B25:B35`

Question 21

When defining the data table, which cell should we select as `Column input cell`?

(a) `D7`

(b) `C8`

(c) `C24:F24`

(d) `B25:B35`

Question 22

Which purpose does the data table serve?

(a) Illustrate the sensitivity of the optimal amount of `Super` toys for each level of the `Demand`

(b) Illustrate the sensitivity of the optimal amount of `Demand` for each level of `Super`

(c) Illustrate the sensitivity of the profit to both the `Super` toys and the `Demand`

(d) Illustrate the sensitivity of the optimal level of production for each profit level

Question 23

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		Optimizer				Field Sales				Production manager				Gassman			
2		Standard	Super	Total		Standard	Super	Total		Standard	Super	Total		Standard	Super	Total	
3	Production	78,000	55,000	133,000		130,000	95,000	225,000		80,000	70,000	150,000		115,000	85,000	200,000	
4	Inventory leftover	12,000	5,000	17,000		12,000	5,000	17,000		12,000	5,000	17,000		12,000	5,000	17,000	
5	Available	90,000	60,000	150,000		142,000	100,000	242,000		92,000	75,000	167,000		127,000	90,000	217,000	
6																	
7	Demand	≤ 90,000	60,000	150,000		90,000	60,000	150,000		90,000	60,000	150,000		90,000	60,000	150,000	
8	Proportion	60%	40%			60.0%	40%			60%	40%			60%	40%		
9																	
10	Sales	90,000	60,000			90,000	60,000			90,000	60,000			90,000	60,000		
11	Inventory	0	0			-52,000	-40,000			-2,000	-15,000			-37,000	-30,000		
12																	
13	Price	£4.30	£5.50			£4.30	£5.50			£4.30	£5.50			£4.30	£5.50		
14	Direct Costs	£2.50	£3.20			£2.50	£3.20			£2.50	£3.20			£2.50	£3.20		
15	Gross Margin	£162,000	£138,000			£162,000	£138,000			£162,000	£138,000			£162,000	£138,000		
16	Add. costs	-£19,440	-£16,560			-£19,440	-£16,560			-£19,440	-£16,560			-£19,440	-£16,560		
17	Inventory costs	£0	£0			£2,600	£2,560			£100	£960			£1,850	£1,920		
18	Net Margin	£142,560	£121,440	£264,000		£145,160	£124,000	£269,160		£142,660	£122,400	£265,060		£144,410	£123,360	£267,770	
19																	
20	Capacity Costs			£0				£70,000				£0				£15,000	
21	Net Result			max £264,000	max	max	max	max £199,160	max	max	max	max £265,060	max	max	max	max £252,770	max

Figure 17: Questions 23 and 24

Why do each of the four approaches yield different profits?

(a) Because each approach takes different random samples from the distributions

(b) Because the constraints are different in each approach

(c) Because OpenSolver is run separately for each approach

(d) Because each approach sets different production values

Question 24

Do you think the approach of the Field Sales representative has been optimized with OpenSolver?

(a) No, because it does not comply with the demand constraint

(b) No, because it does not yield the same result as Gassman, who has used OpenSolver

(c) Yes, because the profit is lower and we want to minimize it

(d) No, because it incurs in capacity costs

Question 25

Which of the following is correct?

(a) The Sales distribution has more upside potential and less downside risk than the Optimizer distribution

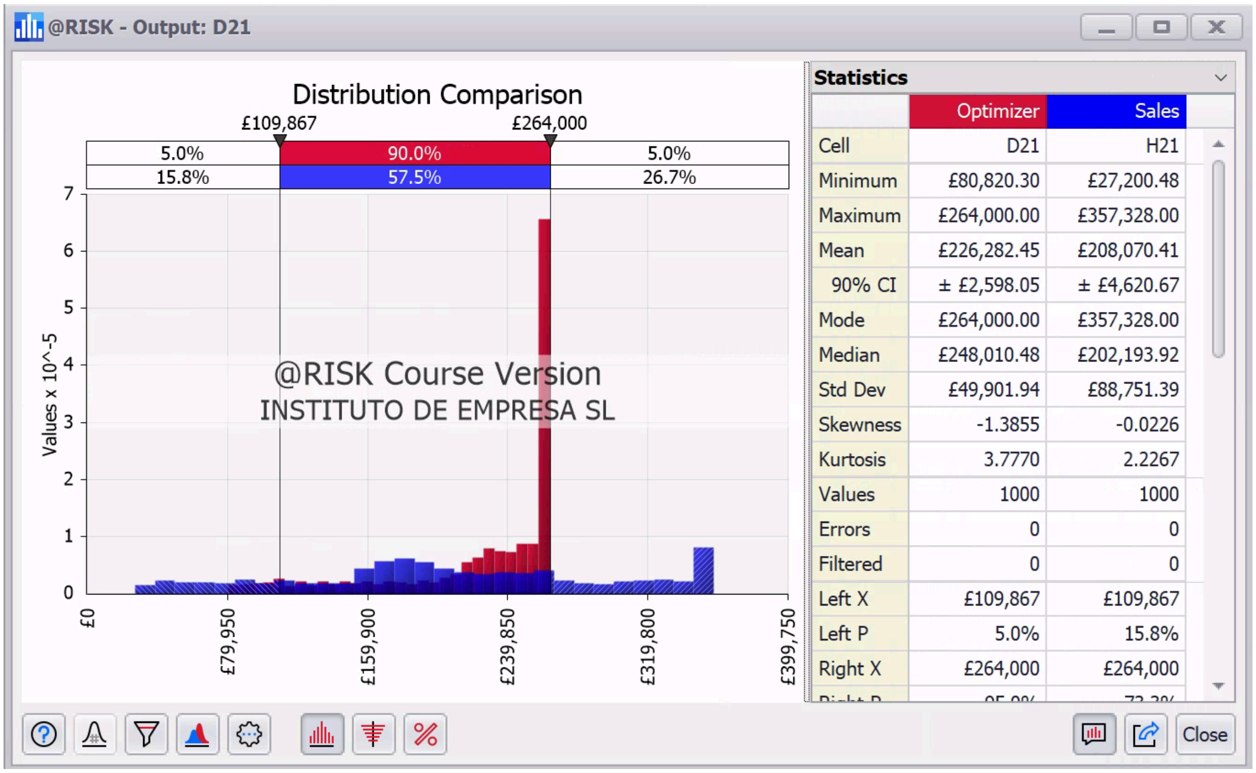

Figure 18: Questions 25 and 26

(b) The Sales distribution has more upside potential and more downside risk than the Optimizer distribution

(c) The Sales distribution has less upside potential and less downside risk than the Optimizer distribution

(d) The Sales distribution has less upside potential and more downside risk than the Optimizer distribution

Question 26

Which of the following is correct?

(a) There is a 5% chance that the Sales distribution yields more than £264,000

(b) The most likely value of the Optimizer distribution is £357,328

(c) There is a 26.7% chance that the Sales distribution yields more than £264,000

(d) There is a 57.7% chance that the Sales distribution yields more profit than the Optimizer distribution

Question 27

Which of the following is *not* correct?

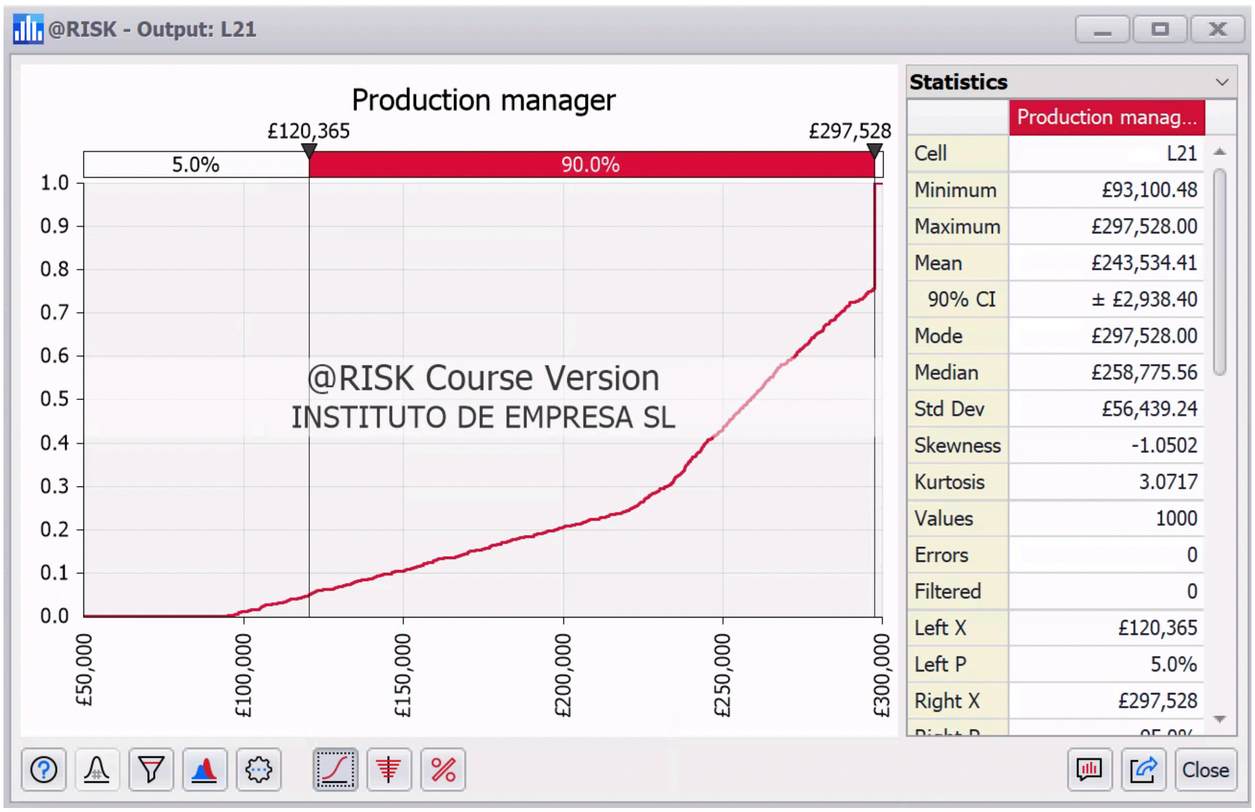

Figure 19: Questions 27 and 28

(a) There is a 90% probability (approx.) that the profit is below £297,528

(b) There is a 70% probability (approx.) that the profit is below £290,000

(c) There is a 10% probability (approx.) that the profit is below £150,000

(d) There is a 30% probability (approx.) that the profit is below £230,000

Question 28

Which of the following is *not* correct?

(a) The most frequent value of the distribution is £297,528

(b) The mean of the distribution is £243,534

(c) The standard deviation is greater than the mean

(d) £200,000 is below the first quartile

Question 29

What happens if OpenSolver cannot find a feasible solution within the given constraints?

(a) OpenSolver will add an extra decision variable

(b) OpenSolver will adjust the constraints to fit the objective

(c) OpenSolver provides a message that no feasible solution exists and displays the closest approximation

(d) OpenSolver automatically changes the objective function to find an alternative solution

Question 30

Which of the following is a key advantage of using Monte Carlo simulation over a deterministic model?

(a) It provides a single, optimal solution.

(b) It allows for consideration of the uncertainty in input variables.

(c) It eliminates the need for sensitivity analysis.

(d) It guarantees more accurate results than optimization methods.

Question 31

In OpenSolver, which of the following is true?

(a) The Simplex method is the best for non-linear problems

(b) Linear problems with continuous variables have a unique solution

(c) Linear problems with continuous variables have local optima

(d) The constraints of a linear problem must be modelled with `@RISK`

Question 32

Which of the following describes the use of scenario analysis (e.g. high/low demand for tomatoes)?

(a) A method to identify the single most likely outcome

(b) A technique to explore different potential futures by adjusting a few key assumptions

(c) An approach that eliminates the need for simulations entirely

(d) A method for ensuring that only optimal outcomes are simulated

Question 33

Why is sensitivity analysis important after solving an optimization problem in OpenSolver?

(a) It helps identify the optimal solution

(b) It ensures that the model constraints are correctly implemented

(c) It shows how sensitive the solution is to changes in the input data

(d) It guarantees that the solution will remain feasible if constraints change

Question 34

What is the main output of a Monte Carlo simulation?

(a) A single deterministic result.

(b) The optimal solution for a given set of constraints.

(c) A breakdown of the most frequent outcome.

(d) A range of potential outcomes with associated probabilities.