Introduction:

Business optimisation is the process of reducing the redundancies, inefficiencies and the bottlenecks in a business's operation and thereby making it as efficient as possible. It's main goal is to improve revenue and productivity while reducing costs resulting in the maximization of profits.

Problem Identification:

In the above problem, a company randomly assigns a vehicle of any make to one of its different social media channels to be sold. We need to find the 3 most efficient selling platforms for each make. This means that they need to have a higher return on investment and a lower 'turnaround days'.

The Dataset:

	A	B	F	G	I	K	L	M	N	S	T	U
1	Status	Make	Purchase Price	Purchase Date	Sold Date	Total Price	Net Profit	ROI	Customer Source	Turnaroun d Days	Customer Source v2	
2	Sold	MINI	£ 1,487.87	01-06-2022	13-06-2022	£ 3,549.00	£1,482.23	99.62%	Online Plat	12	Online Platform 1	
3	Sold	SUZUKI	£ 2,823.45	01-06-2022	14-06-2022	£ 4,595.00	£1,447.91	51.28%	Online Plat	13	Online Platform 1	
4	Sold	BMW	£ 3,398.80	01-06-2022	14-06-2022	£ 4,850.00	£633.89	18.65%	Online Plat	13	Online Platform 1	
5	Sold	FORD	£ 2,118.43	01-06-2022	23-07-2022	£ 5,000.00	£2,372.93	112.01%	Online Plat	52	Online Platform 1	
6	Sold	FORD	£ 3,582.25	01-06-2022	19-07-2022	£ 5,495.00	£1,565.58	43.70%	Online Plat	48	Online Platform 1	
7	Sold	AUDI	£ 4,021.46	01-06-2022	06-06-2022	£ 5,500.00	£1,232.12	30.64%	Online Plat	5	Online Platform 1	
8	Sold	VAUXHALL	£ 3,200.19	01-06-2022	23-06-2022	£ 5,795.00	£2,088.96	65.28%	Online Plat	22	Online Platform 1	
9	Sold	VOLKSWA(	£ 1,000.00	01-06-2022	19-08-2022	£ 5,844.00	£3,491.83	349.18%	Local	79	Local	
10	Sold	MERCEDE!	£ 4,297.65	01-06-2022	14-06-2022	£ 6,099.00	£1,447.74	33.69%	Online Plat	13	Online Platform 1	
11	Sold	NISSAN	£ 4,350.00	01-06-2022	30-06-2022	£ 6,100.00	£1,429.95	32.87%	Local	29	Local	
12	Sold	NISSAN	£ 4,174.57	01-06-2022	30-06-2022	£ 6,250.00	£1,230.26	29.47%	Online Plat	29	Online Platform 1	
13	Sold	VOLKSWA(	£ 4,100.00	01-06-2022	16-08-2022	£ 7,150.00	£2,031.29	49.54%	Online Plat	76	Online Platform 2	
14	Sold	VOLKSWA(	£ 4,600.00	01-06-2022	14-09-2022	£ 7,295.00	£2,052.98	44.63%	Local	105	Local	
15	Sold	TOYOTA	£ 4,162.98	01-06-2022	24-06-2022	£ 7,295.00	£2,230.57	53.58%	Online Plat	23	Online Platform 1	
16	Sold	HYUNDAI	£ 5,720.00	01-06-2022	12-07-2022	£ 7,300.00	£1,288.29	22.52%	Online Plat	41	Online Platform 1	
17	Sold	TOYOTA	£ 5,960.00	01-06-2022	22-07-2022	£ 7,450.00	£1,162.54	19.51%	Online Plat	51	Online Platform 3	
18	Sold	HONDA	£ 4,760.00	01-06-2022	08-07-2022	£ 7,493.00	£1,916.45	40.26%	Online Plat	37	Online Platform 5	
19	Sold	NISSAN	£ 5,360.00	01-06-2022	16-06-2022	£ 7,500.00	£1,738.78	32.44%	Online Plat	15	Online Platform 1	

Fig (a)

Our dataset for this coursework is a synthetic car sales dataset. The company purchases second hand cars from people, refurbishes them and lists them on various online platforms with an intention to sell them. The time period between purchasing of a vehicle and its successful selling is denoted by the column 'Turn around days'. It is the difference between the columns 'Sold date' and 'Purchase date'. The return on investment or 'ROI' is the percentage of 'Net Profit' obtained from the original investment or 'Purchase price'. The 'Net Profit' is the result of the difference between the 'Total Price' and the 'Purchase price' (and refurbishment costs that haven't been specified in the dataset). The 'Status' shows the current 'Status' of the vehicle. Considering the fact that we need historic data to create the model, we will be using data of only those vehicles that have the 'Status' as 'Sold'. The 'Make' shows the company of the car. We use this column to further elaborate which car make is sold for what price within what turnaround days on which platform. The column 'Customer Source' lists the various online platforms used by the company to sell its cars. Since excel solver has a limitation of 200 decision variables, we have bucketed some platforms together so as to reduce the resultant decision variables. These new platforms are listed under the column 'Customer Source v2'. All other columns such as 'Model', 'Variant', 'Colour', 'Mileage', 'Gross Profit', 'F&I Profit', 'Deposit Date' and 'Chassis Profit' are redundant data for the scale of this model and have thus been greyed out. The columns containing this redundant data are hidden in the above screenshot.

Probable Solutions to Similar Problems:

After having a look at the problem statement of the company and its corresponding dataset, we can attest that the following methods of optimisation can be implemented.

1)A linear programming model maximising the return on investment.

2)An integer programming model used to choose which social media platforms provide the best return on investment.

3)A linear programming model minimising the turnaround days.

4)An integer programming model used to choose which social media platforms provide the lowest turnaround days.

5)Selecting a maximum number of online platforms for each car model to maximise the return on investment while minimising the turnaround days using integer programming.

There can be various other methods of optimising the platform selection, all of which depend on the goals that the marketing campaign is trying to achieve.

Literature review:

The research titled 'A Linear Programming Model for Budgeting and Financial Planning' tries to highlight budget allocation based on priorities of the organisation using linear programming (Ijiri et al., 1963).

The authors in this paper believe that traditional budgeting methods based on historical data do not consider the changes in the business environment. They may also ignore the organisation's priorities, resources and constraints. This results in suboptimal allocation of resources. Alternatively, the linear programming model takes into consideration the organisation's constraints and marketing goals and thus enables managers to make informed decisions regarding the allocation of resources.

This is explained by the authors in the paper by first presenting a mathematical formulation of the linear programming model and an explanation of how to implement it. It is then followed up by a case study of a manufacturing company, wherein the model's characteristics of optimising resource allocation is showcased resulting in the company's strategic objective being achieved.

In the end, the paper demonstrates the importance of using linear programming for resource allocation and budgeting.

Thus, as a whole, the paper showcases the method by which this process can be used on our dataset.

Another research titled 'Optimizing multi-channel marketing allocation using integer programming' similarly explores the use of integer programming for budget allocation for social media campaigns

(Kim & Sen, 2014). It holds the view that previous models have limitations like oversimplification of the problem in addition to being unable to handle huge data.

The authors hold the belief that the business model can be optimised using integer programming especially while allocating marketing resources. It takes into considerations multiple variables such as channel costs, conversion rates as well as budget limitations and channel capacity.

They did their research by applying the integer programming model to a real-world dataset from a retail company. The simulation resulted in a model that gave a 5.5% increase in revenue compared to traditional methods. We have used a similar model while optimising our dataset.

Problem Modelling:

Objective function:

Maximize: Σ Xij*Aij

Where i = 1 to 25 (number of car makes)

j = 1 to 6 (platforms to choose from)

X = Business KPI

Aij = Binary decision variable whether a car make i is advertised on platform j

Decision Variable:

There are a total of 25*6=150 decision variables in this model which show if each car type is advertised on each platform. We use binary decision variables Aij to decide whether car type i is advertised on platform j. If Aij=1, then car type i is advertised on platform j. Similarly, if Aij=0, car type i is not advertised on platform j.

Constraints:

ΣAi <=Li ; where i = 1 to 25;

L = is the limit variable for the maximum number of platforms accepted for each car make.

This constraint ensures that each vehicle type is advertised on a maximum of L platforms.

Aij = Binary

Thus, the model can be **written as**:

Maximise: Σ Xij*Aij

Where i = 1 to 25 (car makes)

j = 1 to 6 (platforms to choose from)

Subject to:

Ai <= L; where i = 1 to 25;

Aij = Binary

Processing the data for the model:

Status	Sold							
	Column Labels							
	Local		Online Platform 1		Online Platform 2		Online Platform 3	
Row Labels	Max of Turnaround Days	Min of ROI	Max of Turnaround Days	Min of ROI	Max of Turnaround Days	Min of ROI	Max of Turnaround Days	Min of ROI
ALFA ROMEO			27	56.20358306				
AUDI	47	33.03633548	80	13.23883309	51	27.01842165	29	28.35108411
BMW			103	6.892532928	56	26.20348837		
CITROEN							47	68.01661356
FORD	48	22.07845304	52	21.65885044	44	18.15184087	40	24.5048483
HONDA			66	32.00708447				
HYUNDAI			41	22.52255245				
KIA			100	21.53997397				
LEXUS			37	19.35520889	68	34.43712329		
MAZDA			76	28.59018346	38	50.09116107		
MERCEDES			35	25.89374873				
MERCEDES-BENZ	34	31.44200627	54	12.5550789	11	37.64865886		
MINI			80	23.02829783	37	194.145		
MITSUBISHI			8	15.99029126				
NISSAN	111	14.986644	100	14.83684783	12	166.665		
PEUGEOT			65	20.28973076				
RENAULT	32	29.26697322	39	32.5467783				
SKODA			51	15.61939024				
SMART					84	17.04461131		
SUZUKI			96	21.6565823				
TOYOTA	51	23.07458333	87	17.92790539	30	14.65657177	51	19.5057047
VAUXHALL			91	22.85298891	36	107.6449438	11	52.53342939
VOLKSWAGEN	105	42.62398082	88	12.31597754	76	49.54365854	33	24.9264974
VOLVO			14	49.5870216	18	43.87563884		
Grand Total	**111**	**14.986644**	**103**	**6.892532928**	**84**	**14.65657177**	**51**	**19.5057047**

Fig (b)

The above image is a screenshot of the original dataset that has been pivoted. It has been cropped so as for it to be sufficiently visible while also fitting the page. It shows the data being filtered to only display the vehicles with the status ‘Sold’. This pivot table displays the ‘maximum turnaround days’ and the ‘minimum return on investment’ for each type of ‘car make’.

The Business KPI:

Business KPI Ratio = Min ROI / Max Turnaround days						
Row Labels	Local	Online Platform 1	Online Platform 2	Online Platform 3	Online Platform 4	Online Platform 5
ALFA ROMEO	0.00	2.08	0.00	0.00	0.00	0.00
AUDI	0.70	0.17	0.53	0.98	0.74	0.37
BMW	0.00	0.07	0.47	0.00	0.00	0.70
CITROEN	0.00	0.00	0.00	1.45	0.00	0.00
FORD	0.46	0.42	0.41	0.61	0.00	0.49
HONDA	0.00	0.48	0.00	0.00	1.11	1.09
HYUNDAI	0.00	0.55	0.00	0.00	2.86	0.00
KIA	0.00	0.22	0.00	0.00	2.20	0.00
LEXUS	0.00	0.52	0.51	0.00	0.00	0.00
MAZDA	0.00	0.38	1.32	0.00	0.00	0.65
MERCEDES	0.00	0.74	0.00	0.00	0.00	0.00
MERCEDES-BENZ	0.92	0.23	3.42	0.00	0.00	0.00
MINI	0.00	0.29	5.25	0.00	0.00	0.00
MITSUBISHI	0.00	2.00	0.00	0.00	0.00	0.00
NISSAN	0.14	0.15	13.89	0.00	0.36	0.00
PEUGEOT	0.00	0.31	0.00	0.00	0.00	0.97
RENAULT	0.91	0.83	0.00	0.00	0.00	0.00
SEAT	0.00	0.00	0.00	0.00	0.00	0.00
SKODA	0.00	0.31	0.00	0.00	0.00	0.00
SMART	0.00	0.00	0.20	0.00	0.00	0.00
SUZUKI	0.00	0.23	0.00	0.00	0.00	0.00
TOYOTA	0.45	0.21	0.49	0.38	0.00	0.00
VAUXHALL	0.00	0.25	2.99	4.78	0.36	0.00
VOLKSWAGEN	0.41	0.14	0.65	0.76	1.92	0.58
VOLVO	0.00	3.54	2.44	0.00	3.71	0.00

Fig (c)

The above image displays the business KPI created by us. It is the ratio of the 'minimum return on investment' to the 'maximum turnaround days'. Our model aims to maximise this particular KPI for it's objective function. This will help the business show a client the minimum ROI that can be expected for any particular car make on any given platform while at the same time showing the maximum turnaround days that that particular platform would require to sell that particular car make.

The Model:

	A	B	C	D	E	F	G	H	I	J
1										
2	**Row Labels**	**Local**	**Online Platform 1**	**Online Platform 2**	**Online Platform 3**	**Online Platform 4**	**Online Platform 5**	**Total Customer Sources**		**Count Limit(L)**
3	ALFA ROMEO	0	0	0	0	0	0	0	<=	3
4	AUDI	0	0	0	0	0	0	0	<=	3
5	BMW	0	0	0	0	0	0	0	<=	3
6	CITROEN	0	0	0	0	0	0	0	<=	3
7	FORD	0	0	0	0	0	0	0	<=	3
8	HONDA	0	0	0	0	0	0	0	<=	3
9	HYUNDAI	0	0	0	0	0	0	0	<=	3
10	KIA	0	0	0	0	0	0	0	<=	3
11	LEXUS	0	0	0	0	0	0	0	<=	3
12	MAZDA	0	0	0	0	0	0	0	<=	3
13	MERCEDES	0	0	0	0	0	0	0	<=	3
14	MERCEDES-BENZ	0	0	0	0	0	0	0	<=	3
15	MINI	0	0	0	0	0	0	0	<=	3
16	MITSUBISHI	0	0	0	0	0	0	0	<=	3
17	NISSAN	0	0	0	0	0	0	0	<=	3
18	PEUGEOT	0	0	0	0	0	0	0	<=	3
19	RENAULT	0	0	0	0	0	0	0	<=	3
20	SEAT	0	0	0	0	0	0	0	<=	3
21	SKODA	0	0	0	0	0	0	0	<=	3
22	SMART	0	0	0	0	0	0	0	<=	3
23	SUZUKI	0	0	0	0	0	0	0	<=	3
24	TOYOTA	0	0	0	0	0	0	0	<=	3
25	VAUXHALL	0	0	0	0	0	0	0	<=	3
26	VOLKSWAGEN	0	0	0	0	0	0	0	<=	3
27	VOLVO	0	0	0	0	0	0	0	<=	3

Fig (d)

The columns B to G contain the decision variables. These variables start from cell B3 to cell G27.

The columns H to J are the constraints. We can see that we have decided to allow a maximum of 3 platforms to be selected for each car make. This can however be changed whenever the need arises.

L	M
Objective Function:	
Maximising the business KPI:	0
Business KPI= minimum ROI/maximum turn around days	

Fig (e)

This image shows the objective function (or the business KPI) that we are trying to maximise.

Figure (f) below shows the constraints used in excel solver to create the model. These constraints have been explained in previous parts.

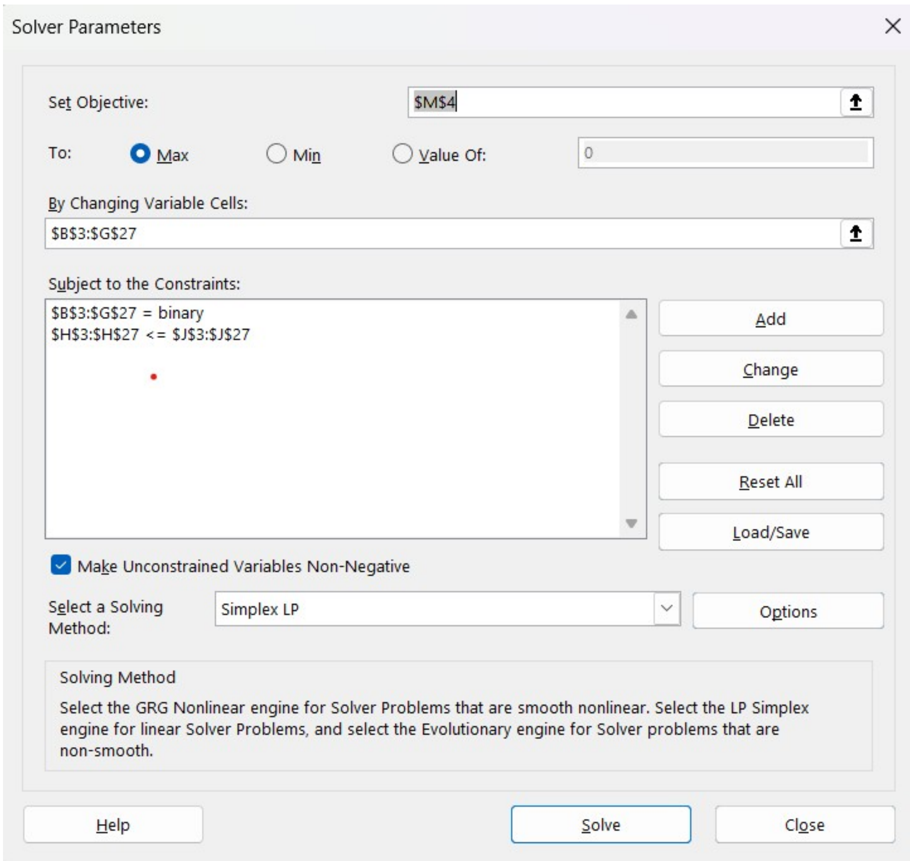

Fig (f)

The result:

	A	B	C	D	E	F	G	H	I	J
1										
2	Row Labels	Local	Online Platform 1	Online Platform 2	Online Platform 3	Online Platform 4	Online Platform 5	Total Customer Sources		Count Limit(L)
3	ALFA ROMEO	0	1	0	0	0	0	1	<=	3
4	AUDI	1	0	0	1	1	0	3	<=	3
5	BMW	0	1	1	0	0	1	3	<=	3
6	CITROEN	0	0	0	1	0	0	1	<=	3
7	FORD	1	0	0	1	0	1	3	<=	3
8	HONDA	0	1	0	0	1	1	3	<=	3
9	HYUNDAI	0	1	0	0	1	0	2	<=	3
10	KIA	0	1	0	0	1	0	2	<=	3
11	LEXUS	0	1	1	0	0	0	2	<=	3
12	MAZDA	0	1	1	0	0	1	3	<=	3
13	MERCEDES	0	1	0	0	0	0	1	<=	3
14	MERCEDES-BENZ	1	1	1	0	0	0	3	<=	3
15	MINI	0	1	1	0	0	0	2	<=	3
16	MITSUBISHI	0	1	0	0	0	0	1	<=	3
17	NISSAN	0	1	1	0	1	0	3	<=	3
18	PEUGEOT	0	1	0	0	0	1	2	<=	3
19	RENAULT	1	1	0	0	0	0	2	<=	3
20	SEAT	0	0	0	0	0	0	0	<=	3
21	SKODA	0	1	0	0	0	0	1	<=	3
22	SMART	0	0	1	0	0	0	1	<=	3
23	SUZUKI	0	1	0	0	0	0	1	<=	3
24	TOYOTA	1	0	1	1	0	0	3	<=	3
25	VAUXHALL	0	0	1	1	1	0	3	<=	3
26	VOLKSWAGEN	0	0	1	1	1	0	3	<=	3
27	VOLVO	0	1	1	0	1	0	3	<=	3

Fig (g)

The result is shown in Fig (g). It shows that 'Online Platform 1' is the only suitable platform to sell a car of the make 'Alfa Romeo'. Similarly, for a 'Volkswagen, the only suitable options can be 'Online platform 2', 'Online platform 3' and 'Online platform 4'. The importance of each of these options among themselves can be found on the business KPI sheet where the highest value of the KPI ratio is the best choice among the three finalised options. The corresponding values for the minimum expected return on investment and the maximum turnaround days needed to sell a vehicle of that make on that platform can be found on the sheet showing the pivot table.

For examples, if we refer Fig (c), we can deduce that a 'Volkswagen' can be sold for the best result on 'Online platform 4', followed by 'Online platform 3' and then by 'Online platform 2'.

Similarly, while referring to Fig (b) showing the pivot table, we can further elaborate this as a Volkswagen car can be sold for a minimum return on investment of 44.0574% within a maximum turnaround days of 23.

The dynamic result page:

	A	B	C
1	Car Make	BMW	
2			
3	Platform	Online Platform 1	
4	Average ROI%	36.97996141	
5	Average selling price	10165.294	
6	Maximum turnaround days	103	
7	Number of cars sold	20	

Fig (h)

The dynamic result page, as the name suggests provides a quick overview of options that the model has suggested for any particular car type. The 'Car Make' option is a drop down that can be used to select cars makes that have the status 'Sold'. Similarly, the 'Platform' dropdown provides a list of channels that the model has recommended any of which can be selected.

Reflection and future scope:

This model has been limited due to the shortcomings of the dataset. Ideally, the model could have been designed to find the best platforms to sell a particular type of car (sedan, SUV, hatchback, etc). This would enable the company to recommend platforms for 'car makes' that haven't been dealt by the company based on the car type.

Similarly, the presence of the cost to market a vehicle on a particular platform, the conversion rates, marketing budget for the company and click through rates would have helped us develop a model that would distribute the budget to different platforms keeping the objectives of the marketing campaigns in mind.

Additionally, this dataset is only for four months. There is a chance that a single vehicle of a certain make that has been sold on a particular platform for a high ROI and a low turnaround days count will lead to that particular platform being recommended over a platform that has sold multiple vehicles and has realistic data recorded.

Comparison of alternative model created by team member:

Row Labels	Local	Online Platform 1	Online Platform 2	Online Platform 3	Online Platform 4	Online Platform 5	Total sources choosen		Limited to 3
Hatchback	1	1	0	1	0	0	3	<=	3
Sedan	1	1	1	0	0	0	3	<=	3
SUV	1	1	0	0	1	0	3	<=	3
Coupe	1	1	0	0	0	1	3	<=	3
MPV	1	1	1	0	0	0	3	<=	3
Convertible	0	1	0	0	1	1	3	<=	3
Objective Function	394.7172359								
	Maximizing the Business KPI								

Fig (i)

The above picture is a screenshot of the model created by a group member (Ishita). It is an integer model based on the

KPI = (Minimum net profit /Minimum turn around days) * (Cars sold per category)

This has led to the model displaying results which take the number of vehicles sold on that platform into consideration. It helps in eliminating biases that arise due to a single outlier vehicle being sold at a very high ROI within very few turn around days on a particular platform leading to the model suggesting that particular platform as the optimum one. The increase in data will keep on improving the model further as data of more vehicles being sold are taken into consideration. However, the downside of this model is that it is based on minimum net profit. The problem with net profit is that it doesn't take into account the invested value and hence ignores the ROI.

Example: A car sold for 120,000, when bought for 100,000, thus showing a net profit of 20,000 would be ranked higher than a car sold for 20,000 when purchased for 10,000. The ROI for the former vehicle is 20% and is 100% for the later. This biases the data towards platforms that have sold high end vehicles.

Conclusion:

By having a look at the result of the model based on the dataset, we can conclude that the integer programming model can yield results which can help a company optimise its budget allocation method.

Furthermore, the model created by us, based on the available dataset is descriptive in nature as it is based on historic data. With relevant strategic information regarding costs, performance matrix, efficiency, etc of the marketing platforms and the number of car resales projected in the future, it can be helpful to build a predictive model.

References:

1. Ijiri, Y., Levy, F.K. and Lyon, R.C. (1963) “A linear programming model for budgeting and Financial Planning,” *Journal of Accounting Research*, 1(2), p. 198. Available at: https://doi.org/10.2307/2489855.

2. Kim, S.J. and Sen, S. (2014) “Optimizing Multi-Channel Marketing Using Integer Programming,” *Journal of marketing research* [Preprint].