UNIVERSITY OF NEWCASTLE

BUSINESS SCHOOL

OPERATIONS, LOGISTICS AND SUPPLY CHAIN MANAGEMENT MSc

SUPPLY CHAIN AND LOGISTICS MODELLING AND CONTROL

ASSIGNMENT

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Word count: 1947

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Newcastle upon Tyne

January 2022

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TABLE OF ABBREVIATIONS

e.g.	exempli gratia
i.e.	id est
km	kilometers
min	minutes
pp.	pages
PPA	Patras Port Authority

PART A

CONTAINER LEASING DECISIONS IN MARITIME INDUSTRY

The industry of container shipping has flourished since the mid-1990s. Today, the rate of world container traffic has increased significantly over the world trade growth rate, and this is because the demand for larger containerships and containers has skyrocketed (Dong-Ping Song and Jing-Xin Dong, 2012).

The following table proposes the best leasing plan for the company. This plan is minimizing the total leasing cost to 406.000 £ compared to the initial plan, where the total cost was 880.000 £. To calculate the total leasing cost, both term and spot leasing costs are considered. Moreover, the suggested plan considers that spot leased containers can only be leased for a year and all the leasing fee is paid by the shipping company at the beginning of the lease term. Both spot and term leased containers are corresponding to the annual demand.

Table 1 **Suggested leasing plan**

Period	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Term-leased containers for **3 years**	**100**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Term-leased containers for **4 years**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Term-leased containers for **5 years**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Term-leased containers for **6 years**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Term-leased containers for **7 years**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Term-leased containers for **8 years**	**400**	**0**	**400**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Spot-leased containers	**500**	**600**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**800**
Term leasing cost	120000	0	96000	0	0	0	0	0	0	0
Spot leasing cost	50000	60000	0	0	0	0	0	0	0	80000
Demand	*1000*	*1100*	*900*	*800*	*600*	*700*	*800*	*600*	*400*	*1200*
Total leasing cost	**406000**									

According to the table, the *first year* 100 containers should be term leased for three years and 400 for eight years correspondingly. Meanwhile, 500 more containers should be spot leased in order to meet the demand of 1000 for year one. In *year two* 600 containers must be spot leased to meet the demand of 1100. In *year three*, 400 containers should be term leased for eight years. The demand for the *following years* is going to be satisfied by the already term leased containers until *year ten*, where 800 more containers should be spot leased. The above plan will cost the company a total of 406.000 £.

PART B

SUPPLY CHAIN NETWORK DESIGN

Network design decisions indicate the supply chain configuration and set constraints, which aim is either to decrease the total cost or increase the responsiveness to customers. They include the number of manufacturing plants, production lines and distribution centers, decisions about the location and capacity allocation to each facility and, which products should each facility produce, and which markets should each facility serve (Sunil Chopra, 2019, pp. 117).

The following tables suggest with which two suppliers from Tier 1 and Tier 2 contracts should be signed:

Table 2 **Tier 1 flow**

	D
S11	**2000**
S12	**1000**
S13	**0**

Table 3 **Tier 2 flow**

	S11	S12	S13
S21	**2000**	**0**	**0**
S22	**0**	**0**	**0**
S23	**0**	**1000**	**0**

Table 4 **Tier 3 flow**

	S21	S22	S23
S3	**2000**	**0**	**1000**

As shown in the tables the 3.000 units of products from Tier 3 supplier S3 should be transhipped to S21 and S23 suppliers from Tier 2 and S11 and S12 suppliers from Tier 1. All these suppliers have the necessary capacity for the 3.000 units, as the figures show. Therefore, S22 and S13 will be excluded from Tier 3 and Tier 2, respectively.

The suggested plan will have a total cost of 115.000 £, of which 79.000 £ will be the transportation fee and 36.000 £ the upfront fee that the company will have to pay the Tier 1 and Tier 2 suppliers.

PART C

DIFFERENTIAL PRICING IN FERRY BOATS

1. Introduction

Selling a service or a product is not an easy task. Every company tries to find out what price it should charge its customers so that it can increase its total profits. To do this many questions shall be answered. Critical parameters are the design, quantity, demand, season and much more. But the most important one is if the price it is going to charge is fair. And that is a complex task. The most powerful tool that every company uses to increase its supply chain profits is pricing. At the heart of this citation lies revenue management. *'Revenue management is the use of pricing to increase the supply chain surplus and profit generated from a limited availability of supply chain assets*.' When there are multiple customer segments, revenue management is concerned with selling the right asset to the right customer at the right price. The critical lever of this strategy is the use of differential pricing. Various prices can increase profits by matching better the supply and demand. Targeted differential management is at the heart of successful revenue management (Sunil Chopra, 2019, pp. 479).

Revenue management is the tool that helps to make demand management decisions. Decisions can be *structural* (which selling format to use, which terms of trade to offer), *price decisions* (how to price over time, how to discount over the lifetime of a product), and *quantity decisions* (how to allocate output or capacity to different segments, when to withhold a product and sell it later) (Talluri, Ryzin, Karaesmen and Vulcano, 2009).

Some of these questions were trying to answer local authorities in my hometown for use of ferry boats. Despite the huge technological improvement, the use of ferry boats is still popular. Some people travel for leisure and others do business. Ferry boats offer better prices to those who are willing to save money and are not in a hurry. They charge cheaper fares, and they are always an alternative way to travel. Thereupon, they still have a significant competitive advantage. But what fare should different vehicles be charged and what changes in price when there are capacity limitations? What is the impact on profit? The attempt of this study is to point out the importance of differential pricing for multiple customer segments when using ferries.

2. Problem Description

Patras is a small seaside town in Peloponnese, southwest of Greece. In this picturesque city, there is the 3 km *Charilaos Trikoupis Bridge* that crosses the Gulf of Corinth and connects Rio with Antirrio. The bridge opened in 2004 just before the Opening of the Summer Olympics in Athens (Gefyra.gr, *A great vision*). Previously, Antirrio could only be reached with ferry boats. For the time being, Rio-Antirrio ferry boats managed to survive the competition with the bridge, which carried millions of vehicles since it opened (Ilias Kanistras, 2005).

Nowadays, drivers use either the bridge or the ferries. On the one hand, drivers prefer to use the bridge because they can reach their destination faster and thus save more time. But unfortunately, the bridge charges high tolls and individuals are unwilling to pay that much. On the other hand, ferry boats offer better prices and a greater view of the landscape. But they need approximately 25 min to pass the Gulf; sometimes due to strong winds, more than 35 min may be required.

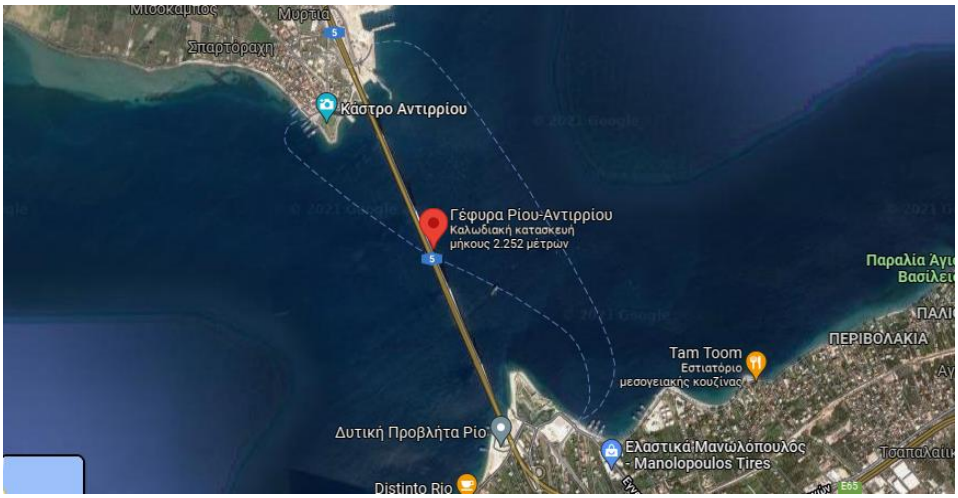

Figure 1 **Map of Rio-Antirrio bridge and ferry boat routes, Patras, Greece**

The economic crisis of the last decade has led many people to travel to Antirrio by using ferries because they were much cheaper. Patras Port Authority (PPA) had significantly decreased the fare to half the price of the bridge toll so as not to burden individuals further (Ilias Kanistras, 2005). Each vehicle was charged the same price regardless of being a private car or a 4-wheel truck. But this resulted in a great loss of income. Now that the situation is better a new model can be introduced.

Each ferry boat has a total capacity of 100 vehicles. The cost of using the ferry boat is 2 € per vehicle. The following table summarizes the demand of each customer segment:

Table 5 **Demand**

Vehicle category	Demand
Foot passengers	$d = 500 - 225p_1$
Private cars *(4-wheel cars of a height up to 2m) with or without a trailer or a caravan, up to 2m*	$d = 500 - 50p_2$
Private cars *with a trailer or a caravan, of a height more than 2m*	$d = 500 - 40p_3$
Camping cars	$d = 500 - 40p_4$
Motorcycles	$d = 500 - 150p_5$
Trucks *with 2 axles*	$d = 500 - 20p_6$
Trucks *with 3 axles*	$d = 500 - 15p_7$
Trucks *with 4 axles*	$d = 500 - 10p_8$
Trucks *with 5 or more axles*	$d = 500 - 7p_9$
Bus or coach *up to 20 seats*	$d = 500 - 22p_{10}$
Bus or coach *up to 40 seats*	$d = 500 - 16p_{11}$
Bus or coach *with more than 40 seats*	$d = 500 - 11p_{12}$

Firstly, the aim is to maximize the total profit by charging each vehicle a different price. *Secondly*, if PPA continues to charge each vehicle category a single price, what should be the price and the total profit. *Thirdly*, it is highlighted the significance of differential pricing. In other words, the study is going to indicate the increase in profits, when different customer segments are offered different prices. *And finally*, every New Year's Eve the number of ferry boats is limited to 15. In this case, the study attempts to find out what fare each vehicle should be charged.

3. Objective

The most important objective is profit. The aim of the PPA is to increase the total profit of the ferries in different situations. But profit depends on other objectives too. The company needs to determine the fare that each customer segment will have to pay to use the ferry. Different vehicles will pay different prices e.g., a motorcycle cannot be charged the same fare as a bus. In addition, some vehicles will be charged a different price, depending on the number of passengers they carry when it is a bus, or the number of axles the vehicle has when it is a truck. And finally, an important parameter is the demand. The demand equation depends on the maximum number of people that are willing to use the ferry and the actual number of customers that will respond to the price.

4. Data collection

The classification of vehicles into different categories is the actual classification that the PPA does. Nevertheless, due to the short period of time and limited availability of information, the data are hypothetical.

5. Assumptions

Three important assumptions need to be mentioned. Firstly, ticket prices are not only determined by the demand. In the real-world tax rates consider not only the demand but also the damage that vehicles produce, weather conditions, seasonality, capacity. Secondly, prices for each segment are determined; therefore, it is easy to predict future demand. And thirdly, although a ferry boat can carry almost 100 vehicles, some vehicles are bigger or smaller than others and thus the available capacity will not always be the same.

6. Proposed solution

Table 6 **Notation**

Task abbreviations	
Max	Maximum
d	Demand
p	Price

6.1 Task 1

PPA needs to maximize the total profit of ferry boats. Therefore, the following should apply:

Objective function

$$Max(p_1 - 2)(500 - 225p_1) + (p_2 - 2)(500 - 50p_2) + (p_3 - 2)(500 - 40p_3) + (p_4 - 2)(500 - 40p_4) + (p_5 - 2)(500 - 150p_5) + (p_6 - 2)(500 - 20p_6) + (p_7 - 2)(500 - 15p_7) + (p_8 - 2)(500 - 10p_8) + (p_9 - 2)(500 - 7p_9) + (p_{10} - 2)(500 - 22p_{10}) + (p_{11} - 2)(500 - 16p_{11}) + (p_{12} - 2)(500 - 11p_{12})$$

Constraints

a. The demand of every segment should be positive:

$$(500 - 225p_1) \geq 0,\ (500 - 50p_2) \geq 0,\ (500 - 40p_3) \geq 0,\ (500 - 40p_4) \geq 0,\ (500 - 150p_5) \geq 0,\ (500 - 20p_6) \geq 0,\ (500 - 15p_7) \geq 0,\ (500 - 10p_8) \geq 0,\ (500 - 7p_9) \geq 0,\ (500 - 22p_{10}) \geq 0,\ (500 - 16p_{11}) \geq 0,\ (500 - 11p_{12}) \geq 0$$

b. The price for every segment should be positive:

$p_1 \geq 0, p_2 \geq 0, p_3 \geq 0, p_4 \geq 0, p_5 \geq 0, p_6 \geq 0, p_7 \geq 0, p_8 \geq 0, p_9 \geq 0, p_{10} \geq 0, p_{11} \geq 0, p_{12} \geq 0$

Table 7 **Decision variables**

p_1	Charged price to segment 1
p_2	Charged price to vehicle 2
p_3	Charged price to vehicle 3
p_4	Charged price to vehicle 4
p_5	Charged price to vehicle 5
p_6	Charged price to vehicle 6
p_7	Charged price to vehicle 7
p_8	Charged price to vehicle 8
p_9	Charged price to vehicle 9
p_{10}	Charged price to vehicle 10
p_{11}	Charged price to vehicle 11
p_{12}	Charged price to vehicle 12

Implementation

Table 8 **Task 1**

Category	Vehicle category	Sub-category	Price	Demand	Profit
1	**Foot passengers**		2,12 €	23,57	2,77 €
2	**Private cars** (four-wheel cars of a height up to 2m) with or without a trailer or a caravan, up to 2m		6,00 €	200,02	800,00 €
3	**Private cars** with a trailer or a caravan, of a height in excess of 2m		7,24 €	210,27	1.102,50 €
4	**Camping cars**		7,24 €	210,27	1.102,50 €
5	**Motorcycles**		2,68 €	97,69	66,63 €
6	**Trucks** of a height in excess of 2m	2 axles	13,50 €	230,01	2.645,00 €
7	**Trucks**	3 axles	17,66 €	235,03	3.681,67 €
8	**Trucks**	4 axles	26,04 €	239,64	5.759,99 €
9	**Trucks**	5 or more axles	36,64 €	243,49	8.435,54 €
10	**Bus or coach**	Up to 20 seats	12,37 €	227,89	2.362,91 €
11	**Bus or coach**	20 to 40 seats	16,63 €	233,98	3.422,25 €
12	**Bus or coach**	40 or more seats	23,74 €	238,90	5.192,82 €
	Total		*171,86€*	*2390,75*	***34.574,56 €***

34.574,56 € will be the total profit of ferry boats if different customer segments are charged different fares.

6.2 Task 2

If PPA continued to charge a single price for each vehicle category i.e., a single price for private and camping cars, a single price for every truck and again, a single price for buses and coaches, the following should apply:

Objective function

$Max(p_1 - 2)(500 - 225p_1) + (p_2 - 2)(500 - 50p_2) + (p_2 - 2)(500 - 40p_2) + (p_2 - 2)(500 - 40p_2) + (p_5 - 2)(500 - 150p_5) + (p_6 - 2)(500 - 20p_6) + (p_6 - 2)(500 - 15p_6) + (p_6 - 2)(500 - 10p_6) + (p_6 - 2)(500 - 7p_6) + (p_{10} - 2)(500 - 22p_{10}) + (p_{10} - 2)(500 - 16p_{10}) + (p_{10} - 2)(500 - 11p_{10})$

Constraints

a. Demand of every segment should be positive:

$(500 - 225p_1) \geq 0, (500 - 50p_2) \geq 0, (500 - 40p_2) \geq 0, (500 - 40p_2) \geq 0, (500 - 150p_5) \geq 0, (500 - 20p_6) \geq 0, (500 - 15p_6) \geq 0, (500 - 10p_6) \geq 0, (500 - 7p_6) \geq 0, (500 - 22p_{10}) \geq 0, (500 - 16p_{10}) \geq 0, (500 - 11p_{10}) \geq 0$

b. The price for every segment should be positive:

$p_1 \geq 0, p_2 \geq 0, p_5 \geq 0, p_6 \geq 0, p_{10} \geq 0$

Table 9 **Decision variables**

p_1	Charged price to segment 1
p_2	Charged price to vehicle 2, 3 and 4
p_5	Charged price to vehicle 5
p_6	Charged price to vehicle 6, 7, 8 and 9
p_{10}	Charged price to vehicle 10, 11 and 12

Implementation

Table 10 **Task 2**

Category	Vehicle category	Sub-category	Price	Demand	Profit
1	**Foot passengers**		2,11 €	25,00	2,78 €
2	**Private cars** (four-wheel cars of a height up to 2m) with or without a trailer or a caravan, up to 2m		6,77 €	161,54	770,41 €
3	**Private cars** with a trailer or a caravan, of a height in excess of 2m		6,77 €	229,23	1.093,26 €
4	**Camping cars**		6,77 €	229,23	1.093,26 €
5	**Motorcycles**		2,67 €	99,98	66,67 €

6	**Trucks** of a height in excess of 2m	2 axles	20,23 €	95,38	1.738,93 €
7	**Trucks**	3 axles	20,23 €	196,54	3.583,05 €
8	**Trucks**	4 axles	20,23 €	297,69	5.427,16 €
9	**Trucks**	5 or more axles	20,23 €	358,38	6.533,63 €
10	**Bus or coach**	Up to 20 seats	16,31 €	141,27	2.020,97 €
11	**Bus or coach**	20 to 40 seats	16,31 €	239,10	3.420,62 €
12	**Bus or coach**	40 or more seats	16,31 €	320,63	4.587,00 €
	Total		*154,93€*	*2393,98*	***30.337,73 €***

In this case, the total profit will be 30.337,73 €. This decision would result in a loss of income. Although bigger vehicles would benefit from that, others, like private cars (6,00 € - 6,77 €) or 2-axles trucks (13,50 € - 20,23 €), would have to pay more than they normally did. Specifically, such a decision would result in an almost 12,8% and 49,8% increase in fare, respectively.

6.3 Task 3

The profit obtained in task 1 should be deducted from the profit obtained in task 2.

Implementation

Table 11 **Task 3**

Obtained profit in Task 1	34.574,56 €
Obtained profit in Task 2	30.337,73 €
Difference	***4.236,83 €***

In this case, differential pricing raises the total profit by 4.236,83 €. Therefore, charging multiple customer segments different fares is more efficient than offering a fixed price.

6.4 Task 4

In New Year's Eve, the available number of ferry boats are 15. Therefore, only 15 x 100 = 1500 vehicles can use the ferry boat to pass to the Antirrio.

Objective function

$$Max(p_1 - 2)(500 - 225p_1) + (p_2 - 2)(500 - 50p_2) + (p_3 - 2)(500 - 40p_3) + (p_4 - 2)(500 - 40p_4) + (p_5 - 2)(500 - 150p_5) + (p_6 - 2)(500 - 20p_6) + (p_7 - 2)(500 - 15p_7) + (p_8 - 2)(500 - 10p_8) + (p_9 - 2)(500 - 7p_9) + (p_{10} - 2)(500 - 22p_{10}) + (p_{11} - 2)(500 - 16p_{11}) + (p_{12} - 2)(500 - 11p_{12})$$

Constraints

a. The total demand should be less or equal to 1500:

$(500 - 225p_1) + (500 - 50p_2) + (500 - 40p_3) + (500 - 40p_4) + (500 - 150p_5) + (500 – 20p_6) + (500 – 15p_7) + (500 – 10p_8) + (500 – 7p_9) + (500 – 22p_{10}) + (500 – 16p_{11}) + (500 – 11p_{12}) \leq 1500$

b. The demand for every segment should be positive:

$(500 - 225p_1) \geq 0, (500 - 50p_2) \geq 0, (500 - 40p_3) \geq 0, (500 - 40p_4) \geq 0, (500 - 150p_5) \geq 0, (500 – 20p_6) \geq 0, (500 – 15p_7) \geq 0, (500 – 10p_8) \geq 0, (500 – 7p_9) \geq 0, (500 – 22p_{10}) \geq 0, (500 – 16p_{11}) \geq 0, (500 – 11p_{12}) \geq 0$

c. The price for every segment should be positive:

$p_1 \geq 0, p_2 \geq 0, p_3 \geq 0, p_4 \geq 0, p_5 \geq 0, p_6 \geq 0, p_7 \geq 0, p_8 \geq 0, p_9 \geq 0, p_{10} \geq 0, p_{11} \geq 0, p_{12} \geq 0$

Table 12 **Decision variables**

p_1	Charged price to segment 1
p_2	Charged price to vehicle 2
p_3	Charged price to vehicle 3
p_4	Charged price to vehicle 4
p_5	Charged price to vehicle 5
p_6	Charged price to vehicle 6
p_7	Charged price to vehicle 7
p_8	Charged price to vehicle 8
p_9	Charged price to vehicle 9
p_{10}	Charged price to vehicle 10
p_{11}	Charged price to vehicle 11
p_{12}	Charged price to vehicle 12

Implementation

Table 13 **Task 4**

Category	Vehicle category	Sub-category	Price	Demand	Profit
1	**Foot passengers**		2,22 €	0,00	0,00 €
2	**Private cars** (four-wheel cars of a height up to 2m) with or without a trailer or a caravan, up to 2m		9,33 €	33,46	245,32 €
3	**Private cars** with a trailer or a caravan, of a height in excess of 2m		10,58 €	76,85	659,28 €
4	**Camping cars**		10,58 €	76,85	659,28 €

5	**Motorcycles**		3,33 €	0,00	0,00 €
6	**Trucks** of a height in excess of 2m	2 axles	16,83 €	163,42	2.423,32 €
7	**Trucks**	3 axles	21,00 €	185,07	3.515,45 €
8	**Trucks**	4 axles	29,33 €	206,71	5.649,17 €
9	**Trucks**	5 or more axles	40,04 €	219,70	8.358,01 €
10	**Bus or coach**	Up to 20 seats	15,69 €	154,81	2.119,43 €
11	**Bus or coach**	20 to 40 seats	19,95 €	180,75	3.245,02 €
12	**Bus or coach**	40 or more seats	27,06 €	202,38	5.070,92 €
	Total		*205,94€*	*1500,00*	***31.945,21 €***

Such a decision would result in a significant increase in fare for every vehicle. At the same time, losses in profit would occur and demand would plummet.

7. Conclusion

In conclusion, revenue management is a powerful tool. When used properly it can increase the total profit of a company and in the meantime, it can leave the customers satisfied. As shown in the study above, when different customer segments are charged different prices a company can significantly increase its total profit. Prices are fair and coherent. The opposite happens when a single price is charged for different customer segments. Although this may be convenient for big vehicles, as they would have to pay less than they would normally do, other vehicles would burden further. Subsequently, this would have a great impact on the demand rates and the profit of the company.

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