

## **Mestrado Integrado em Engenharia de Serviços e Gestão 2020/2021**

### **Investigação Operacional**

#### **Caso de Estudo**

Sweetland – What Merchant Navy?

Adaptado de um caso de estudo didático sem autor conhecido em uso no IST e na FEUP desde o início dos anos oitenta.

## Sweetland – What Merchant Navy?

Dr. Peter Hops, Prime Minister of SWEETLAND, intends to restructure the merchant navy fleet of his country. He contacted you in order to help him to decide the number of vessels of different types that should be purchased and how the trips should be assigned to these vessels in order to meet the import and export requirements of the country. With this purpose, he gave you a recording of the Council of Ministers where the issue was discussed, as well as copies of the documents referred to during the meeting. This recording is transcribed below.

**Dr. Peter Hops:** Gentlemen, for the good image and survival of our government we need to decide how to organize our merchant marine. It is a sector that so far has been living on the basis of international freight, which makes us dependent on foreign ship-owners.

As I promised to the electorate, the sector should be free to export our surplus of wheat and corn, and import iron and copper from FATLAND and SEALAND, countries with which we have preferential relations and that absorb the totality of our exports.

I would therefore like to hear your progress report in order to have a clearer idea of the situation.

**Eng. Anthony Gossip (Minister of Transport):** Our merchant navy has been, for some years, a troubled sector with huge problems. However, we have recently signed a new collective labor agreement, which allows the vessels to depart loaded from our ports, discharge at the destination port, load back in the harbor where they were unloaded or in another port within SEALAND or FATLAND, and return loaded to the port of origin.

In Annex 1, we have the characteristics of two types of vessels that we can acquire. They are all bulk vessels, which can make the transport of grain or minerals. However, they may never make the transport of two different products because they have no space to the separation of cargo. Note also that there are restrictions on the draft of vessels both in the ports of origin and destination (see Annex 2).

I would like also to say that the ships can operate continuously, 24 hours a day for 345 days a year. The remaining 20 days are used for the annual maintenance of the units.

**Dr. Berry Happy (Minister of Finance):** For the purchase of the units, we achieved a significant international aid, which allows us to pay in fixed installments without interest over 25 years. The annual maintenance cost is 10% of the initial cost of each ship, the fuel obviously depends on the distance traveled and the type of unit and, finally, the labor needed (crew members) only depends on the type of unit. The cost of fuel is \$0.8/liter. These elements are provided in Annex 2, prepared together with Eng. Gossip.

**Eng. Michael Fields (Minister of Agriculture):** According to the indications given by Mr. Alvin Barriers (Minister of Industry) which, due to a travel abroad, could not join us in this meeting, I prepared a table of imports and exports of SWEETLAND, SEALAND and FATLAND (Annex 3). There you can find the necessary quantities and the various products available in the ports in which we operate.

**Dr. Peter Hops:** But after all what is the monetary amount involved in the acquisition of new units? What should be the recommended fleet to ensure exports and imports?

Use your knowledge of modeling, solving and interpreting Linear Programming problems to help the government of SWEETLAND and his Prime Minister. Prepare a report to be read by the technical staff of his Prime Minister, where you should describe the problem and your model assumptions. Present the results obtained and discuss their implications, including the issues described below.

1. Define the different itineraries that the vessels can be assigned, describing the type of cargo transported in the outgoing and return journeys and the type of vessel that can be assigned to each itinerary (Small vessels – type 1 or Large vessels – type 2). These itineraries should take into account that the vessels must depart with exports either from DOCE or BOM and return loaded with imports from SKY, MOON or MARS (either from the port where they unloaded the cargo or from another port in FATLAND or SEALAND). Note that large vessels cannot go to MOON, as they do not satisfy the draft allowed.
2. Formulate a linear programming (LP) model for this problem, considering a planning horizon of one year. Explain verbally the meaning of all components of the model (i.e., decision variables, restrictions and type of costs considered in the objective function).
3. Obtain the optimal solution of the LP model. What is the total cost of the fleet that should be available to support the country's imports and exports during one year? How many vessels of each type should be bought and which trips should be assigned to each vessel? Describe in detail the export flows of wheat from BOM and corn from DOCE, indicating the ports of destiny, the itineraries used and the total amount of the commodity transported in each type of itinerary.
4. Generate the sensitivity report for the LP model and use it to find the allowable range for the labor cost of each vessel that would keep the optimal number of vessels of the SWEETLAND fleet unchanged. Justify your answer.
5. Use the sensitivity report to determine the impact on the annual cost of the fleet if the maintenance of vessels of type 1 changed from the current value of 20 days to 15 days per year. Justify your answer.
6. Now consider that the total exports of SWEETLAND remain unchanged, but the demand of corn and wheat of FATLAND and SEALAND doubles, such that some of the cereals demand from these countries cannot be satisfied by SWEETLAND. Formulate a new linear programming model to represent this new context.
7. Obtain the optimal solution of the LP model. What is the total cost of the fleet that should be available to support the country's imports and exports in this new scenario? Highlight the differences between the export flows of wheat from BOM and corn from DOCE between this scenario and the previous scenario described in question 3.
8. Generate the sensitivity report for the LP model used in question 7. If the amount of corn imported by MARS increased to 25000 tons, what would be the effect on the total cost of the fleet?

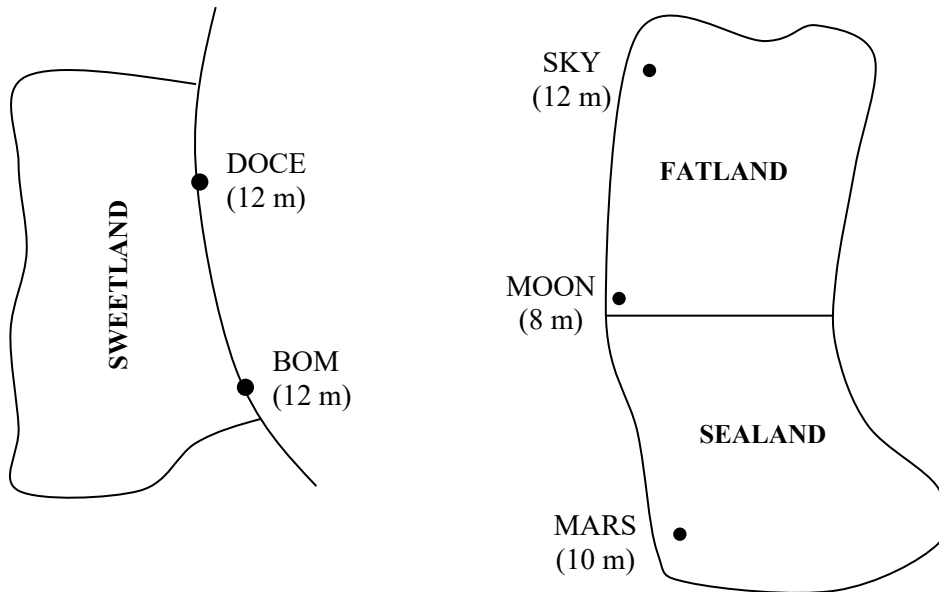
## ANNEX 1

### Characteristics of the vessels

TYPE OF VESSEL	TONNAGE (tons)	DRAFT (meters)		SPEED (km/h)		FUEL CONSUMPTION (liters / 1000km)		COST OF VESSEL PURCHASE (x10 <sup>3</sup> \$)	COST OF CREW (x10 <sup>3</sup> \$ / year)
		Loaded	Empty	Loaded	Empty	Loaded	Empty		
Vessel 1	35	8	6	25	30	50	42	1000	70
Vessel 2	70	10	6	20	24	40	30	1500	75

## ANNEX 2

**Map of ports and allowed draft (meters)**



**Distance matrix between ports (in km)**

	DOCE	BOM	SKY	MOON	MARS
DOCE	-	na	6000	5000	5500
BOM		-	6000	5800	4800
SKY			-	500	2000
MOON				-	1000
MARS					-

### ANNEX 3

#### Import / Export Map (tons)

##### SWEETLAND

	Export		Import	
	Wheat	Corn	Copper	Iron
<b>BOM</b>	50000	-	-	50000
<b>DOCE</b>	-	40000	20000	20000

##### SEALAND

	Export		Import	
	Copper	Iron	Wheat	Corn
<b>MARS</b>	-	30000	20000	10000

##### FATLAND

	Export		Import	
	Copper	Iron	Wheat	Corn
<b>SKY</b>	10000	40000	30000	-
<b>MOON</b>	10000	-	-	30000