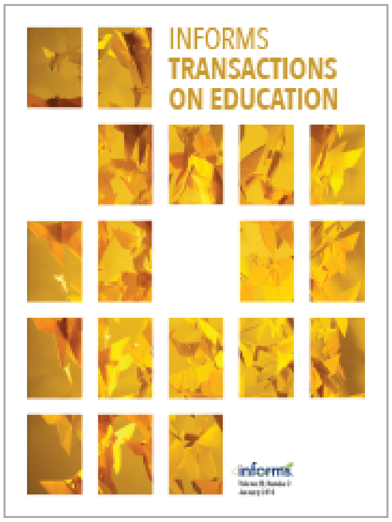

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Case—Production and Distribution Optimization of Beach Equipment for the Marinero Company

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1. A Message from Marinero's Chief Executive Officer

Dear applicant,

Marinero is an Italian firm leading in the field of high-quality beach equipment. Our main business is production and sale of deckchairs, beach umbrellas, sun beds, director's chairs, and frisbees for two main independent markets: private customers (e.g., beach and camping lovers) and business clients (e.g., resorts, hotels, and camps). We produce our products in several manufacturing plants and supply them to sales outlets strategically located all over Italy.

Our products are appreciated, and our brand is indisputably considered high quality. Nevertheless producing and distributing our products has become more and more complex, and the use of a ground-rule approach only based on the expertise of our managers seems to no longer be sufficient to tackle the complexity of the overall system.

We opened a call for selecting a decision support model to identify a competitive strategy for the management of operations.

The proposals should present a feasible solution for our production and distribution planning over the next six months. Proposals must be submitted within the deadline using the format specified in the technical details sheet of the call. The evaluation of the proposals is done by our experts with the solution assessment tool (SAT), which allows them to check the actual effectiveness of the proposed choices.

I am sure that you can help Marinero to improve its production and distribution system.

2. The Business and the Logistics System

We first describe the context in which Marinero operates and the main characteristics of the firm. Marinero produces five beach products (deckchair, beach umbrella, sun bed, director's chair, and frisbee) in three production plants and distributes them to eight possible sales centers, strategically located all over Italy as reported in Figure 1. Products are sold to two different markets, the consumer's market and the firm's market. Storage is possible only in the sales centers. Your task is to define a strategy for the production and the distribution of the five products along a semester, with the aim of maximizing the overall profit as the difference between the revenue obtained by selling minus the overall costs.

We denote as

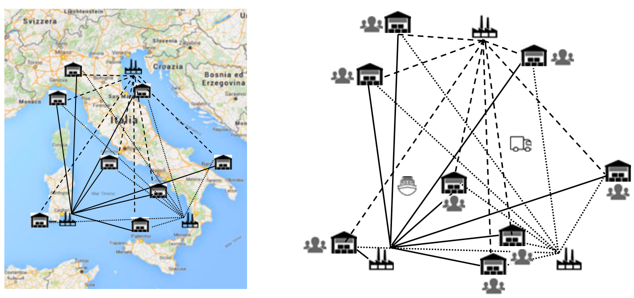
- $\sharp_{months}$ the number of months along which production must be determined ($\sharp_{months} = 6$);
- $\sharp_{products}$ the number of products ($\sharp_{products} = 5$);
- $\sharp_{plants}$ the number of production plants ($\sharp_{plants} = 3$);
- $\sharp_{sales}$ the number of sales centers ($\sharp_{sales} = 8$);
- $\sharp_{materials}$ the number of raw materials used in the manufacturing of the products ($\sharp_{materials} = 4$).

In the next sections we describe details of the production and distribution system.

2.1. The Products

Marinero produces $\sharp_{products} = 5$ beach products: deckchair, beach umbrella, sun bed, director's chair, and frisbee. Frisbees are produced only for advertising purposes, and they are supplied for free (see

Figure 1. Geographical Representation of the Distribution System



Section 2.4). Each profitable product $n = 1, \ldots, 4$ has a selling price in the consumer's market and the firm's market, which are respectively p_n^C and p_n^F. Note that fixing a high price may induce a positive effect on the profit value but a negative one on the product demand that will decrease according to a nonlinear law defined in Section 2.5. On the other hand, a low price has the opposite effect.

You must provide the products' prices p_n^C and p_n^F.

2.2. The Plants

Marinero has $\sharp_{plants}$ production plants located in Jesolo (northern Italy), Cosenza (southern Italy), and Cagliari (Sardinian island). Production plants have no warehouse, thus all the produced items must be sent to the sales centers.

Each production plant is characterized by different features, so that manufacturing one product unit in a plant may require different resources than producing the same product unit in another plant. We report below the main characteristics of a production plant to be considered in the model.

2.2.1. Fixed Production Costs. Activating production in a plant requires fixed costs, which do not depend on the amount of items produced. Marinero can decide to either activate production or not in a plant, namely not all the plants must be used. If a production plant i produces even one single unit of a product in one single month, it must sustain a fixed cost F_i^P for the semester.

The fixed costs differ from one plant to another, and their values can be found on the technical sheet.

2.2.2. Labor. Production obviously requires manpower. The hours needed for the production of each unit of product n in production plant i are reported on the technical sheet.

Manpower costs are due to the workers' monthly salaries. Each plant can decide the number of workers to be hired each month. Workers have a daily working time that depends on the plant. Note that the number of hired workers may vary from month to month in the same plant. Whenever a production plant works in a month, the number of hired workers must be in a given interval between a lower and an upper limit. Of course if a plant is closed, hired workers must be set to zero.

Worker's daily working time and monthly salary are reported on the technical sheet.

You must provide the number of hired workers w_i^k at each production plant i in each month k.

2.2.3. Raw Material Consumption. Each product is made up of $\sharp_{materials}$ different raw materials: plastic, aluminum, textile, and rubber. Production of a product unit of type $n = 1, \ldots, \sharp_{products}$ requires an amount r_m^n of raw material $m = 1, \ldots, \sharp_{materials}$. The quantities r_m^n, expressed in kg/unit of product, are reported on the technical sheet.

Raw materials are bought at the beginning of the semester in each production plant independently. There is no limit on the purchase, but it impacts the cost. Indeed, raw materials have decreasing marginal costs, as depicted in Figure 2. Indeed, raw materials can be bought at two different rates $T^{high} > T^{low}$ (euro/kg). Raw material is bought at the higher price T^{high} up to the amount $Q^{\max}$; once this limit has been reached the price decreases to T^{low}. Prices T_m^{high}, T_m^{low} (in euro/kg) depend only on the raw material m, whereas the amounts $Q_{mj}^{\max}$ (in kg) depend both on the raw material m and on the production center j. They are reported on the technical sheet.

For example, assume that Jesolo's plant needs to buy 40,000 kg of plastic for production during the whole semester. From the technical sheet we know that $T_{plastic}^{high} = 0.5$, $T_{plastic}^{low} = 0.3$, and $Q_{plastic,Jesolo}^{\max} = 29{,}597.3$. Therefore the total cost for the plastic faced by Jesolo's plant is $T_{plastic}^{high}\, Q_{plastic,Jesolo}^{\max} + T_{plastic}^{low}(40{,}000 - Q_{plastic,jesolo}^{\max}) = 0.5 \cdot 29{,}597.3 + 0.3 \cdot (40{,}000 - 29{,}597.3) = 17{,}919.46$ euros. On the other hand, if the plant needs only 20,000 kg of plastic the cost is $T_{plastic}^{high} 20{,}000 = 0.5 \cdot 20{,}000 = 10{,}000$ euros.

2.2.4. Power Consumption. Production of each unit of product n in plant i requires an amount of power K_i^n expressed in kWh. Each plant i purchases power monthly at two different marginal prices: T^{low} (in

Figure 2. Raw Material Decreasing Marginal Cost

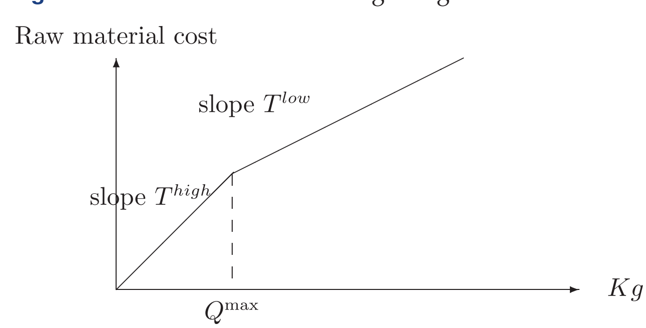
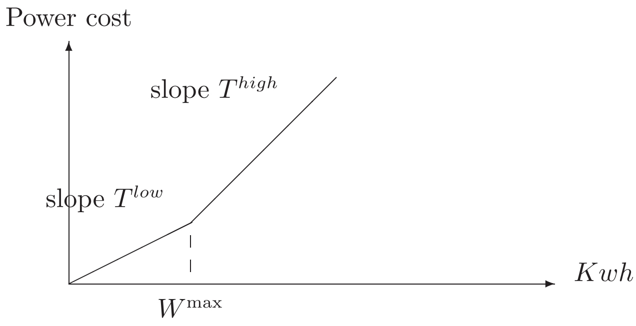


Figure 3. Increasing Marginal Power Cost



euro/kWh) up to a given limit $W_i^{\max}$ (in kWh); the unit price increases to T^{high} (in euro/kWh) after the limit is reached. The behavior is reported in Figure 3.

Price is a piecewise linear function like the one for raw materials, but there are two major differences:

- The graphic for the power cost is a convex function, whereas for the raw materials it is concave.
- Power is bought monthly, and the value $W^{\max}$ represents the limit in each month. This means that, even if in one month the limit is exceeded so that the higher rate is paid, in the following months Marinero may still pay the lower rate if the limit is no longer exceeded.

The values $W_i^{\max}$, T^{low}, and T^{high} are reported on the technical sheet.

2.3. The Sales Centers

There are $\sharp_{sales} = 8$ possible sales centers located in different italian cities: Fiumicino, Genova, Rimini, Bari, Cagliari, Palermo, Milano, and Salerno. Each of these sales centers experiences a specific demand function (see Section 2.5), which represents a maximum amount of saleable product's units (i.e., sales volume cannot exceed the demand). Each sales center has a warehouse that can be used to store unsold products to sell them during the following months.

Demand at each sale center does not need to be fully satisfied. Whenever the available amount of products' units is not enough to fully satisfy the demand on both consumers' and firms' markets, the selling strategy requires first satisfying the demand with a higher price and then using remaining units to satisfy demand with a lower price.

As an example, assume that in a given month a sales center's demands for sun beds are 300 and 200 units for consumers' and firms' markets, respectively, and that the prices on the two markets are 20 and 15 euros, respectively. If only 450 sun beds are available, 300 are sold on the consumers' market (since its price is higher) and the remaining 150 on the firms' market.

Sales centers experience different costs.

2.3.1. Transportation Costs. The transportation costs from the production plants to the sales centers are paid by the sales centers. The transportation cost of each month from production plant i to sales center j depends on the amounts of products skipped (expressed in volume) and on the distance from i to j. On the technical sheet you can find the unit transportation cost (in euro/m^3) from each production plant to each sales center and the volume of each product (in m^3).

2.3.2. Inventory Costs. If the production in a month exceeds the demand, the unsold products are stored at the warehouse of the sales center where they have been delivered. There is no stock at the beginning of the semester. Stored products are available for selling in the following months. Storing has a monthly cost s_j^n that depends on the product n and the sales center j. These costs are reported on the technical sheet.

2.3.3. Fixed Costs. Activating a sales center requires a fixed cost, which does not depend on the amount of items sold. If a sales center j receives even one single unit of a product in one single month, it must pay a fixed cost F_j^S. For commercial reasons only seven of the eight possible sales centers can be opened. The fixed costs differ from one sales center to another, and their values can be found on the technical sheet.

The choice of the center that must be closed is one of your tasks.

2.4. Advertising

Marinero may invest in advertising to increase the demand. Advertising expenditure can be indirect (frisbees supplied for free) or direct (money investment) and define the advertising coefficient A_{kj}^{mkt}, which varies with the market "mkt" that can take the values C or F to denote the customer and the firm markets, respectively (see Section 2.5), the month k, and the sales center j. Products' demands depend on these advertising coefficients A_{kj}^{mkt}. The advertising coefficient is calculated as

$$A_{kj}^{\text{mkt}} = \frac{S_k^{\text{mkt}} + 10F_{kj}}{10^5}, \tag{1}$$

where

- S_k^{mkt} is the advertising expenditures on market "mkt" ("C" or "F") in month k;
- F_{kj} is the number of frisbees delivered to sales center j in month k.

You must provide both the advertising expenditures S_k^{mkt} and the number of frisbees F_{kj}.

2.5. The Demand

Prices and direct/indirect advertising affect the products' demands. The choices of the products' prices p_n^{mkt} and the value of the advertising coefficients A_{kj}^{mkt}

given by (1) can drastically affect the solution because the profitable products' (i.e., all products except frisbees) demands at each sales center j in month k in each market depend on them.

We denote the demand in month k at sales center j for product n in market "mkt" as D^{mkt}_{kjn}. The function of the demand D^{mkt}_{kjn} for profitable products is:

$$D^{\text{mkt}}_{kjn} = \mathcal{M}_{jn}\left(\max\left\{2 - \frac{p^{\text{mkt}}_n}{\mathcal{P}^{\text{mkt}}_n}, 0\right\}\right)^a \frac{\mathcal{Q}^{\text{mkt}}_k}{10}(1 + b\,A^{\text{mkt}}_{kj}), \quad \text{if } p^{\text{mkt}}_n > 0,$$

where $\mathcal{M}_{jn}, \mathcal{P}^{\text{mkt}}_n, \mathcal{Q}^{\text{mkt}}_k$, and a, b are parameters defined as follows:

- $\mathcal{M}_{jn}$ is a parameter that changes with the sales center and the product;
- $\mathcal{P}^{\text{mkt}}_n$ is a price reference parameter of the product n on the given market;
- $\mathcal{Q}^{\text{mkt}}_k$ is an amount reference parameter of the month k on the given market;
- $a \in \mathbb{R}_+$ and $b \in \mathbb{R}_+$ take the values in Table 1.

If the price p^{mkt}_n is set equal to zero (i.e., for frisbees that are supplied for free), the value D^{mkt}_{kjn} is the maximum amount that can be put on the market, and it takes the form

$$D^{\text{mkt}}_{kjn} = \mathcal{M}_{jn}(2.1)^a \frac{\mathcal{Q}^{\text{mkt}}_k}{10}(1 + b\,A^{\text{mkt}}_{kj}).$$

All parameters $\mathcal{M}_{jn}, \mathcal{P}^{\text{mkt}}_n, \mathcal{Q}^{\text{mkt}}_k$ involved in the demand function are reported on the technical sheet.

3. Submission of the Proposal and Conduct of Play

Each team should submit its final proposal within the deadline of the call. The proposals are evaluated using the SAT (see Section 4).

In your final proposal you must provide:

1. quantities of the five products manufactured by Marinero in each month and in each of the three plants and their distribution strategy month by month to each of the eight sales centers. Please note that you may ignore integrality on the products, but continuous solutions are rounded off;
2. selling prices p^{mkt}_n of the four profitable products on the two markets (the price of frisbees must be set equal to zero in both markets);
3. advertising investment S^{mkt}_k in the two markets for each month;
4. number of workers in each production plant in each of the six months.

To submit a solution you should provide a folder named "input" containing the following 35 files in .txt format:

- *workers.txt*: each row contains the number of workers hired at a production plant in the six months. It is a $(\sharp_{plants} = 3) \times (\sharp_{months} = 6)$ matrix;
- *firm-price.txt* and *cust-price.txt*: each file contains the prices, in columns, for the $\sharp_{products} = 5$ products in the firm's and the customer's markets, respectively;
- *firm-adv.txt* and *cust-adv.txt*: each file contains the investments in advertising in the six months, in rows, in the firm's and the customer's markets, respectively;
- *qty-month-product.txt*, where *month* takes the six values Apr/May/Jun/Jul/Aug/Sep, and *product* takes the five values deckchair/beachumbrella/sunbed/director/frisbee. These are 30 files qty-Apr-deckchair.txt, qty-May-deckchair.txt,..., qty-Sep-deckchair.txt, qty-Apr-beachumbrella.txt, qty-May-beachumbrella.txt,..., qty-Sep-beachumbrella.txt, etc.

Each file contains the quantities of the corresponding *product* that are transported from each production plant to each sales center during the given *month*. Thus each file contains a $(\sharp_{plants} = 3) \times (\sharp_{sales} = 8)$ matrix: each element ij of the matrix gives the amount of the product transported from plant i to sales center j.

Your team must indicate its own strategy for tackling the choice of prices, the satisfaction of the demand, and the mathematical model you want to fit. Intermediate solutions can be submitted to the SAT to check whether your work-in-progress results match with the actual values. Strategy can be changed to better fit the actual values.

Table 1. Values of Parameters a, b Appearing in the Demand Function D^{mkt}_{kjn}

Market	a	b
Firm	1.6	0.05
Customer	1.5	0.1

4. The Solution Assessment Tool

Your proposal will be evaluated using the SAT. It checks whether the submitted choices are feasible and returns the corresponding profit and costs in reports. The SAT runs under Windows and Linux operating systems. After launching the SAT, a command window opens up, asking for the team name and which actions the user wants to do among the following choices:

- *p - to print parameters*: press "p" to print the file *parameter.txt*, the parameter values used by the SAT as parameters; they should coincide with the ones on the technical sheets;
- *v - to upload variables*: press "v" to upload the values contained in the files in the input folder; these values are printed out in the file *variable.txt*;

Table 2. List of Supplemental Files Available for Students

File name	Description
Marinero_technical_sheet.xlsx	Technical sheet containing all parameters (Excel format)
Input	Folder containing files of a tentative solution that can be submitted to the SAT
marinero_full_Windows.exe	SAT for the problem (working under Windows operating system)
marinero_full_Linux	SAT for the problem (working under Linux operating system)

- *q - to exit Solution Assessment*: press "q" to quit the SAT.

After variables have been successfully uploaded, you can start solution assessment

- *s - to start solution assessment*: press "s" to start solution assessment. You get a short video message and the *Final-report.txt* is generated, where you can find the summary of
  - overall revenue
  - overall profit divided for the two markets
  - overall costs, divided into transportation costs, inventory costs, raw material costs, power consumption costs, manpower costs, and fixed costs; and
  - overall investments
- *q - to exit Solution Assessment*: press "q" to exit.

Other reports can be generated on request. You have the following choices:

- *d - print the demand report*: it returns the file *demand. txt* containing the value of the demand estimated with the given values of prices, investments, and frisbee quantities;
- *r - print the profit report*: it returns the file *profit. txt* containing the amount of products sold and the corresponding profit obtained by selling the products at the fixed price;
- *t - print the transportation report*: it returns the file *transport.txt* containing the details of the transportation costs;
- *m - print the inventory report*: it returns the file *inventory.txt* containing the details of inventory costs;
- *k - print the raw material report*: it returns the file *rawmaterial.txt* containing the details of raw material costs;
- *e - print the power costs report*: it returns the file *power.txt* containing the details of power consumption costs.

5. Supplementary Material

A list of supplemental materials available for students is in Table 2.

Acknowledgments

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