# Algorithmic Method for Efficient Cruise Program

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*Abstract*—One of the mayor problems of programming a cruise circuit is to decide which destinations to include and which don't. Thus a decision problem emerges, that might be solved using a linear and goal programming approach. The problem becomes more complex if several boats in the fleet must be programmed in a limited schedule, trying their capacity matches best a seasonal demand and also attempting to minimize the operation costs. Moreover, the programmer of the company should consider the time of the passenger as a limited asset, and would like to maximize its usage. The aim of this work is to design a method in which, using linear and goal programming techniques, a model to design circuits for the cruise company decision maker can achieve an optimal solution within the fleet schedule.

*Keywords*—Itinerary design, cruise programming, goal programming, linear programming

## I. INTRODUCTION

THE cruise companies business has grown very much in the last decade. It has been favored by several factors which has let it became an important source of tourism demand. Thus, today the shipping companies fight each other to lead among a growing market. Itineraries are spread worldwide, being the most demanded, for instance, Caribbean, Mediterranean, Alaska, North Europe, etc.

Leading companies often have been American, but lately – from ten years on- several European shipping firms, and very competitive, have turned up. Among American we can find Disney, Royal Caribbean, Celebrity Cruises or Seaburn, while within European side Cunard, Costa, Festival or MSC stands out.

These lines own huge fixed assets which have to be made the most optimally, due that the costs linked to maintenance and operational ability for a cruise ship are enormous. This is the reason why they need to keep the fleet moving as much time as possible, aiming to work at full capacity.

Shipbuilding engineering has developed quite effective engines, with navigation systems very safe and not as pollutant as they used to be years ago. When designing a cruise ship, lines aim to maximize usable spaces for the passengers and the crew, without sacrificing naval performance or critical places for the ship's course. So, shipyards have easily produced boats which displace 120,000 tons, also carrying four or five thousand people, both passengers and crew. The advantage of these firms over other tourism companies such like, for instance, hotel chains, is that they can put their accommodation units on motion. When season starts lowering, ships can move to other itineraries where to make a better profit, adapting to seasonality of the demand. This, that is a strategic advantage itself, is also an aspect which hides underlying risks, which will arise in the moment that the shipping company selects a wrong itinerary for its units.

To meet several destinations with a given capacity in the short term is something that requires certain efforts to understand the best way of doing it, and several analytic techniques also.

A shipping company, who supports huge fixed costs, cannot afford to meet minor markets who are not important enough to pay off for the company's assets. On the contrary, the line should always observe the fluctuations of the demand, so they might to take advantage of the best opportunities not only for its ships, but also looking for the best experience for the passenger.Therefore, shipping lines need to provide themselves with the necessary intelligence to program the itineraries and courses in an optimal way, and not only profitable. The boat's crew deals with the state of the many variables who affect the course from A to B, so the captain takes a decision about the best way to follow. However, is the company who defines these consecutive points, the estimated times to cover them, and –of course- the acceptable costs the crew could incur to achieve the program without jeopardizing the safety of boat and passengers.

## II. JUSTIFICATION

The need for optimize the itineraries of the cruise lines is justified by several reasons, among which we can find the following:

First, the cruise market is becoming more competitive and exigent. So it will reward worthy to those lines who manage themselves in a competitive way, offering the best options to the demand and matching price exigencies. As seen in [9] and [31], trends show that in the last twenty years number of lines is growing, also getting bigger in terms of number of units and capacity of them, as shown in [5]. As a result, a large number of ports are continuously investing [2] to become attractive enough from the service requirements point of view.

Moreover, an increasing number of companies, offering more customized and cheaper products lead the user to a decision between multiple options difficult to compare simultaneously.This is especially important when the economies of scale burst onto this stage with virulence not

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seen before. The existence of larger boats helps to strengthen the offer, but in exchange makes the lines have more difficult to adapt themselves to the changes of the demand. It seems the situations runs for meeting a small number of ports (like hubs) with broader boats, instead of visiting a wider number of ports using medium capacity ships. The aim of it is to make profit from the economies of scale provided by very large boats, definitely cheaper compared with smaller ones in terms of variable cost. This is why the cruises enterprises need business models to match huge offer blocks up with a scattered demand along several potential ports, and detect the best potential itinerary.

Disintermediation is another problem that tourism markets are facing. Selling through long channels is being substituted by direct selling, mainly online. For the first time, the commercial tools formerly controlled by distribution channels are now at the lines' hands. As a result, now they have primary information not only about what are the customers' demands onboard, but also how do they approach the purchasing procedure, how much time they desire to make the decision, what's the information they need, and hoy they finally make the payment. And this amount of information remains at the system to be used for detecting clusters or groups with special demands. It also would be useful to add value to itineraries implementing changes to exploit latent demands in certain ports.

On another hand, customer is actually quite exigent, and looks for a unique experience during the cruise, always within the service standard he is used to. So, many of the current passengers will be disappointed if the cruise accommodation is not as comfortable as a hotel on a similar category.

An increasing number of tourism destinations with singular resources accessible from the coast (e.g. Croatia or Tunisia) has led to a wider competence between them, addressing partially the cruising flows to these locations and seizing it from the traditional cruising destinations (e.g. Egypt, Italy). Consequently, the demand is breaking up, whereas the profitability of the traditional lines is decreasing.

Furthermore, the demand has split into a crowd of clusters which companies pretend to satisfy by creating new services adapted to each particular niche. Many of products thought and designed for these groups are coming each day to the markets: congresses cruises, thematic cruises (couples, singles, or seniors) or "*a forfait*" itineraries. This has brought two consequences: a) taking advantage from groups whom it is possible to apply a positive differential within the price, and b) the dispersion of company resources, which has to use part of the capacity of their fleet to the use of these customers, taking it from the standard service.

On the costs side of business, we can identify three main items when operating an itinerary: labor costs, assets payoff, and fuel. Generally, labor comes from countries with shipping tradition, but always contracted under the best conditions for the shipping line. It is not strange to find crew members coming from Greece, Philippines, or Thailand. Officers are

other structure, coming from most diverse countries, sometimes with military careers and having shifted to cruises afterwards. Salary evolution is sometimes one of the knots of the problem, and company has to keep it inside the limits of a thin band, trying to balance the cost and the productivity of each labor hour.

On the other hand, each shipping company has enormous assets that should be profitable in times generally shorter than other tourism companies. While there are hotels whose buildings dates back centuries and are still operating, the construction of a cruise ship constitutes the immobilization of large sums of money to be recouped in about ten or twenty years. Early repayment plays a key role in the balance sheets of companies and, despite the naval technology plays in favor of shipping companies and ships was not ever produced cheaper and safer, the reality is that it remains an important part in the balance of each company.

Fuel costs have been, for its part, the main parameter to be concerned not only to shipping companies, but to any company related to tourism, played or not a major role in the sector of tourist transport. The recent increases in oil prices did not help carriers become more competitive, but quite the opposite, making consumption per mile of each unit of the fleet was reviewed and adjusted to a minimum. The problem is that many cruise lines, not necessarily the largest, still have among its fleet units with machinery dating from before the price hikes of oil in the seventies, expensive to replace and which difficult to maneuver the boats. Fortunately, technology is also allowing naval engines drive and maneuver much more effectively in terms of consumption and performance.

In addition, the traditional tourist circuit usually used by the cruise lines is shifting from ten years on to another form. The traditional operating way consisted the shipping companies decided a single port (e.g. Barcelona) for embarking and disembarking the passengers of the whole itinerary. It was the port of call, and other stops were secondary, landing and returning passengers to board only for shore excursions. The port of call, therefore, enjoyed a large volume of tourists during the time needed for pre-boarding cruise first, then during the time the traveler, once down on the shore, was transported to origin. The pressure over the company from many cities to become port of call is currently ongoing for that and other reasons.

However, currently the itinerary design model is changing, and many shipping companies embark and disembark their passengers at multiple ports in the same travel, selling the travel sections and keeping the boat moving around the same circular route. And although there is usually a major port even in this way of working, used for refueling and provisioning, it is normal to work with a passenger control which can check embarks and disembarks in each scale, so as to allow for a forecast exact housing needs and adjust the use of common areas of the ship. Of course, this trend leads an even greater need to seek efficient routes for the company.

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## III. Objective And Methods

### A. Objectives of this work

Therefore, the aim of this paper is to set the first steps to establish a tool that tries to capture the intelligence that carriers need, and try to solve advanced transportation problems, using the analytical techniques necessary for this. However, this primary goal serves, for its part and subsequently, to achieve the two secondary objectives, which represent the ultimate goal for this project:

• First order objective: to build a model to determine the shipping design a roadmap that enables the optimization of resources.

• Second order objectives: to maximize revenues and minimize costs associated with each of the routes determined by the model, so the operating profit margin of the trip could be extended.

### B. Method

To determine the model that allows the optimization of cruise itineraries, multiple programming apply to our specific problem, allowing by that way to carry out a decision process from different suboptimal indicated by the model.

In general theoretical terms, the problem at the end of the process, after successive refinements of the work, should be considered like (1):

$$\text{Optimize } Y = f\left[f_1(x), f_2(x), f_3(x), f_4(x) \ldots f_m(x)\right]$$

$$\text{Subject to} : x < X$$

(1)

Where:

- $x = (x_1, x_2 \ldots x_n)$ are the decision variables
- $X$ is the set of opportunities and decision space
- $f_i$ is becoming one of the objective functions
- $f = (f_1, f_2 \ldots f_n)$ is the objective vector function
- $Y = f(X)$ is the object space

As a starting point, there is the need to define a goal vector function on the problem that expands operating profit margins of shipping, which are gross revenues associated with the trip minus the trip operating costs. This definition implies the optimization of two objective functions:

•To maximize revenues associated with travel.
•To minimize operating costs of the journey.

Moreover, decision variables would be elements like:

• Ports where visitors embark and disembark.
• Distance between ports.
• Seasonal calendar.
• Known demand of each port and season.
• Time for cruisers to go touring on each port.
• Days which commercially cruise lasts.
• Number of ships and fleet units.
• Maximum speed of each unit of the fleet.
• Capacity of each unit of the fleet.
• Rates of docking and undocking at each port.
• Mooring fees per day of stay in each port.
• Cost of fuel in navigation.

• Operating costs per passenger.

Finally, the space object or set of solutions driven by the model must come expressed as follows:

• Boat 1: ports $a_1$, $b_1$, $c_1$, d ... in season i, j, k,...
• Boat 2: ports $a_2$, $b_2$, $c_2$, d ... in season i, j, k,...
• ...
• Boat n: ports $a_n$, $b_n$, $c_n$, $d_n$... in season i, j, k,...

Each route should be associated with a particular level of customers that embark, disembark, or make excursions at every stop, so that it could be calculated either occupations of the boats by section of the route and their operating profits.

It is expected to get a utility model for shipping companies, such that by entering known information, could be obtained the set of optimal routes for its fleet at every season.

## IV. Literature Review

Studies related to the management of the cruise lines are neither as developed as in other sectors of tourism, nor business in general. Today, after several models overcome, the studies focus on the competitiveness of companies, consumer behavior-cruisers, the brand loyalty to every shipping line or, closer to the object of this research, efficiency of operations-cruise hotel.

Authors related to the above are, for example, [15] and [6], who have produced excellent work on the expansion and consolidation of Carnival Corporation. Also in that year [4] published which differences must be taken into account when analyzing the hospitality of a cruise ship, stating that it must not be considered merely as a floating hotel, because it retains virtues necessary form the study. From his part [10], [22], [23] and [25] provided useful input regarding the human resources at cruise industry, including crew members, while issues relating to lobbying and influence by the destination management organizations (e.g. DMO) have been studied more recently by [3].

The ports, referred as tourist destinations, have also been addressed in the literature and have been a source of analysis, particularly in regard to the study of economic leverage that provides a cruises line to a destination (see [14]). This line has been complemented by the strategies provided by [2], which not only set the port external economy but also the services that the facility on land must include to be competitive, so it consolidates the cruises affluence to destination.

Cruise lines have also been extensively investigated in the literature, but often with very little relevance to the objectives of this study. The first studies began to try to understand the variables that determine the importance of the respective carriers in the various market ranking, as shown in [13] and [24]. Also the Nash equilibrium was used trying to model, using game theory, the behavior of carriers in the itinerary board, as is in [5] and [16]. Also the sub-operations have been analyzed, as evidenced by the work of [8]. But beyond those early models, are emphasized, above all, two studies of 2009,

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which examined the supply chain of shipping (see [27]), and proposed a microeconomic model to correlate the results of the shipping its marketing strategy, like [29]. A good work who preceded them was [32].

The sociological aspect of the cruise has not been neglected, but is irrelevant to this work. It is worth noting in this regard the work of [30] and [20], which seemed to open a new line of analysis looking at the cruise as a tourist destination in itself, but has not had continuation, except the work of [11], which deploys a very fast glance to investigate the social ties that arise among the passengers.

Moreover, the study of the profile of cruise passengers has hardly been addressed in the literature, keeping in the framework of shipping lines' technical studies, very difficult to obtain. The few documents that have been detected in this area are local-approached and unconnected. In 2003 was opened the main line of research as we know it today, with works like [7], which defined the expected behavior of cruise passengers from their gender, age and experience on cruise ships. Later on, [21] advanced an estimation of the demand-price elasticity of customers, although his work was soon outdated due to their limited applicability. Then [17] tried to contribute with a range of predictors of customer satisfaction and purchase, surpassing the work of [7]. After that, the literature became scattered in various fields fragmented, addressing the customer profile through the study of partial aspects of it. Moreover, are interesting the works of [1], establishing a correlation between motivation, satisfaction and the chance to buy again, or [12], who have recently proposed a scale to assess barriers to the purchase of a cruise. Unfortunately, they do not show results of particular relevance to this work, since they work with aggregate demand. It is important to note also the works of authors who, albeit timidly, have brought unprecedented concepts and techniques into the tourism business sector by making them converge on the cruise area. Such is the case of revenue management, which has been investigated by the authors [26] and [18]. Both have come to interesting conclusions, such that carriers hold substantial advantages to apply yield management within its boats, compared with other tourist accommodations. However, the most interesting for this work has been to find the writings of [9] and [19], which perfectly reflect the concerns that have the managers of the current shipping lines. Among them are recruiting and training of manpower, availability of crew, concern about whether technical or operational management are advisable or efficient, or the potential that ICT offer to improve the dynamics of each cruise company. These issues have ample room in the problems presented in this work, which aims to provide a proposed solution to the major concerns arising from them. It is detected, however, an academic vacuum, at least as regards to the authors on business economics, about issues related to the choice of routes and design of efficient networks and routes. We do not have detected any manuals, papers, or reviews to be considered useful enough to this question, so that we nearly start from scratch.

## V. RESULTS

The cruise line design is an exercise in complex analysis that combine a multitude of variables, which in turn integrate functions that should be maximized or minimized, and always within limits set by limiting resources, schedules, calendars, or capacity of ships.

The model presented here is based on the technical evaluation of operational programs, and works under the Kuhn-Tucker conditions to be evaluated and treated as a linear programming problem by objectives, with modifications presented in this section.

It assumes that a cruise company aims to meet three objectives:

1. To maximize their fleet usage.
2. To occupy to the limit the bearing capacity of the units yet placed on the market.
3. To make profit of the peaks of demand.

The problem is that sometimes it is difficult to accomplish three goals, so that the company has no choice but to prioritize some over others, in a clear exercise of multi-objective linear programming.

In addition, demand is changing and the company is not always clear from which changes in demand is worth altering the programming of the cruises offered, (i.e. the circuit placed on the market).

Sometimes companies need to respond to questions that contain a certain complexity, such as:

• Is it worth, known the demand for each scale, to program the itinerary with two ships operating in parallel and adding their capacities?

• Would it be advisable that the various ships in the fleet were deployed in a large market, covering longer routes, or it would be better to concentrate on short trips?

• To what extent should play an important role to meet the demand in a particular port?

To answer questions like these in this paper will be proposed different models in increasing complexity. It is therefore left for future work to adapt the models to the exact circumstances of the market and run it with real data, proposing here only the theoretical model and adding its mathematical matrix.

### A. Simple uni-objective linear programming model

The data in this model of decision making are simple and do not present a very high level of discussion, but are included in this work as the base of problems with evolved form that arise later.

Take, for example, the case of a shipping company that wants to maximize their business results. It is known that its product portfolio is composed with n kinds of cruise ($n \in R$), which operates with a single ship, whose capacity is up to k persons ($k \in R$). Each ticket sold by the shipping line for each n cruise will report, in respect of unit contribution margin, an amount of "$C_i$" euro. In principle, one could deduce that it would suffice to sell the vessel's full capacity to maximize operational benefits.

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However, the resources used to produce the shipping service are more than the actual capacity of the boat. Above all, it needs human resources to provide the service. That is, needs people who, for example, as a department floor fix the cabins of users daily. In addition, the waiters need to invest some time waiting tables, preparing food, etc. Finally, officers and crew needed to attend to the tasks inherent in the course of the ship. In reality, the users experience more needs when cruising, but for the sake of illustrative simplicity of the model are considered only the three already mentioned.

Given that operational processes (cleaning cabins, care of tables, seaman tasks) are time-consuming for employees who must perform them, and they have a limited workday, a restriction could be established within which the company can sell tickets. Outwards from that restriction there is only the production impossibility space, since that would never be reasonable to sell more cabins that the labor contracted can attend. Inputs are fixed in the short term, and the shipping company knows it. Therefore, the capacity of the ship is not the only factor of production: human resources are another.

Assuming that the number of services that human resources must give is "m" types, and each passenger to consume, on average, a certain known amount of the workday top "L", the question would remain:

How many tickets would be sold to maximize the overall contribution of that business unit?

This represents a simple linear programming problem, the easiest considered in this work, and would apply to an expression as below:

$$Max\left(Z = C_1 x_1 + C_2 x_2 + ... + C_n x_n\right)$$

$$S.a. \sum_{i=1}^{n} a_{1i} x_i \leq L_1$$

$$\sum_{i=1}^{n} a_{2i} x_i \leq L_2$$

$$...$$

$$\sum_{i=1}^{n} a_{mi} x_i \leq L_m$$

$$\forall x_i \geq 0$$

(2)

Where "Z" is the net income (benefit) of the line, "$x_i$" is the quantity of tickets sales to each of the "n" segments of the itinerary and the coefficient "$a_{mi}$" is the average consumption of the input "m" to produce one unit of the segment "i".

The resolution of such problems implies to use a simplex algorithm lacking any difficulty.

### B. Simple multi-objective linear programming model

The above model is extremely simple to the point that does not provide useful information for decision making in the company. Thus, it is convenient to establish more complex problems, so it can be reached an acceptable modeling level, approximating parsimoniously to the complexity of decisions

to be taken on a cruise company.

The choices to be considered from the perspective of a naval carrier not only are restricted to the profitability of ticketing issued. In addition, it is best to take advantage of the vast assets available. Working in a context that assumes a full sale, a shipping company that works with several units and several crews would be in doubt about how much to sell not only to maximize the added value of the sale, but also to make the maximum use of its bearing capacity.

Therefore, above all is needed to provide a maximum efficiency to balance two forces who do not always work in the same direction: the return of the tickets issued and the vessel capacity. The more is increased the occupation of a boat, the better are amortized the fixed costs associated with it. Therefore, it is necessary to use a system in which restrictions are proposed in the same way, although variables change. The itineraries for the fleet could be the variables, whereas the capacity restrictions would be orthogonal restrictions (i.e. input limitations). The input consumption for each passenger would play the role of non-orthogonal restrictions, since staff can be allocated efficiently to serve on each boat. For instance, regarding the specific case of a shipping company that is willing to cover three routes, with known capacity and resources given, the production reachable space would be defined by the polygon □(AF) in the figure 1:
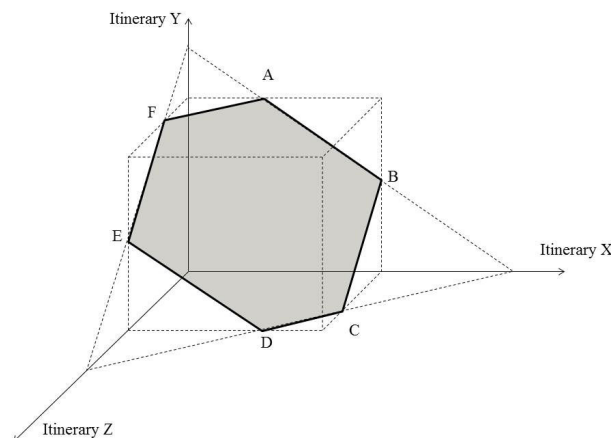


Fig. 1 Production possibilities space for three itineraries, considering one non-orthogonal and three orthogonal restrictions.

In the figure 1 can be seen that orthogonal forms respond to structural capacity limits, while the shape defined by the limits of resources is an active polygon that marks the boundaries of production possibilities. To take account of more possible routes author has to address to hyperplanes analysis, as the graphic representation is not useful anymore.

At this point, it should be advisable to introduce a variant that allows to properly analyzing the problem. Usually cruises are sold as a closed circuit, leaving a port of call and arriving at the same port after several days, usually one week. Therefore, it is the programmer's task to decide which cruise itineraries will be offered to the market, for which he should

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know at least the following information:

• Cost and price of each segment of the itinerary, so he has accurate information about the advisability of travel segments in an order or another.

• Capacities of the fleet which must operate in this sense, assuming that the routes might not be made in the same order.

• Consumption of fixed resources to each passenger carried per trip, which will determine the crew to embark at each leg of the course.

Knowing this, the problem could be defined following the nomenclature of the above, although this time the variables "$x_i$" will represent tickets sold for each of the segments of the itinerary. The scheme of restrictions requires that the segments are consecutive, so as to eliminate results that would represent a reversal of the ship, considering only those solutions who starts and finish in the same port of call.

Needless to say there will be many segments of travel as a result of possible changes in the fleet of shipping to cover the circuit. In the case of a number "p" ($p \in R$) of ports in the circuit, the number of possible ways to meet the same circuit will be a permutation of all ports to play, minus the port of call, which is:

$$Per\left[p-1\right] = (p-2)(p-3)(p-4)...3\cdot2\cdot1 \qquad (3)$$

Thus, for instance, in the case of an itinerary with six ports (including the initial port of call), there will be 5x4x3x2x1 = 180 ways to meet it, without repeating any scale and departing and arriving through the same port. So there would be at least 180 functions to maximize every ship operating this circuit. As it can be seen, the number of features to maximize soars with each new port added to the itinerary.

Moreover, if this itinerary was operated with two vessels, then the combinations would be 180x2 = 360 possible ways to program operations. Each segment should be identified in the model and associated with both its carrying capacity (limited to "K" people for each boat) as the cost in fuel consumption (which integrates with price to obtain "$C_i$"), so the problem reduces to finding the path that optimizes the capabilities of the company into a useful space of restrictions defined by the use of available resources on board, but that can be exchanged from ship to ship as needed.

The problem would be, considering all the above, like (4), where functions aim to maximize the profitability of each of the modes of operation for each ship.

$$Max\left(Z_1 = \sum_{i=1}^{n} C_{i1}x_i\right)$$

$$Max\left(Z_2 = \sum_{i=1}^{n} C_{i2}x_i\right)$$

$$...$$

$$Max\left(Z_Q = \sum_{i=1}^{n} C_{iQ}x_i\right)$$

$$S.to \sum_{i=1}^{n} x_{1i} \leq K_1$$

$$...$$

$$\sum_{i=1}^{n} x_{mi} \leq K_m$$

$$\sum_{i=1}^{n} a_{m1}x_1 \leq L_1$$

$$...$$

$$\sum_{i=1}^{n} a_{mn}x_n \leq L_m$$

$$\forall x_i \geq 0 \qquad (4)$$

*C. Complex decision taking: the possibilities of metaheuristics tecniques*

Previous models, although possibly useful for simple problems, work under the assumption that the company is interested in selling only profitable trips or maximize occupancy of the ship. The problem here is that many companies do not have in mind that the profitability or efficiency are the only valid parameters to program the activity of the cruise units. Under the current business philosophy is almost as valuable to be present in the market by offering competitive destinations like being able to monetize them. Proximity to customers is critical, and to offer exactly the trips that are demanded has not been ever more necessary.

Cruise lines, therefore, are concerned to meet the aggregate demand in the ports, either embarking or disembarking. Knowledge of the demand is fundamental here, and inserting that information in the algorithm is the real challenge of this part of the work. Maybe it could work with Markov chains of order 1, which would set the total number of passengers on each leg of the course, knowing the passengers embarking and disembarking.

Having this information present, the ship can plan more appropriately to match its demands for each port. In general, it would be possible to deduce an algorithm to know the best combinations, using matrices of embarkation / disembarkation. Due that this calculation exceeds the scope of this work will be left for future research, as an extent towards combinatorial programming.

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Using game theory, namely a decision tree, the alternatives would be clear enough for this proposal. Even the decision tree could, in theory, be used as part of the resolution algorithm combinations that carriers must resolve, at least if they have cleared the options across the spectrum of combination between scales of the cruise.

However, as can be supposed, there could be combinations which implied having several boats never stopping at the same port simultaneously during the performance of these circuits. This possibility makes impossible to create synergies between units of the fleet and therefore contribute very little to use the capabilities of the ships combined, for instance to attend a huge peak of demand from one port to another. By contrast, the opposite possibility would be that both ships followed the same course together as a single vessel whose capacity was the sum of separate bearing capacities of the two units. This solution would be good to maximize the capacity demand in a case of not having problems selling. That is, assuming that demand in each scale is so large that firm simply chooses the most advantageous circuit to operate. The limitations of mobile resources would be here the variables that define the solution of the problem. However, to operate two ships the same circuit could be wasteful, because with a larger boat, assuming less average fixed costs, could sell the same service in a much more profitable way. In this sense, economies of scale in the short term play an important role.

Nevertheless, the shipping companies might find solutions that would allow the firm to schedule their ships taking into account the capacity of each ship, trying to achieve the best possible combination to coincide to those sections of the course. Perhaps could be useful for the company to have several cruise ships moving together across only one or two segments of the itinerary, and then get them apart to continue their trip by each one's way, matching an scattered demand with only one or two important segments to attend.

Thus, the company could evaluate the benefit obtained by the use of their ships in all those combinations that might be profitable and convenient, maximizing the demand attended on each port. Also might distribute better the fixed costs and, therefore, could offer lower prices with the same resources.

This would be solved through a complex multi-objective problem of linear programming combined with metaheuristics techniques.

For a fleet size of "n" boats, and a number of possible circuits "m", the total number of cruise schedules "$\phi$" that would be possible is defined by the combinatorial hyperplane shown in (5):

$$\phi = m^n \tag{5}$$

Knowing that, to its part, "m" depends on "p" number of ports, something already shown in (3), we have:

$$\phi = [(p-1)(p-2)(p-3)...3 \cdot 2 \cdot 1]^n \tag{6}$$

Therefore, it would be useful to have an array of paths that represent the bearing capacity of the ships that moved from one port to another, and compare it with the demands, so that a function of minimizing the difference between the two could be executed.

Moreover, perhaps there could be detected itineraries whose demand exceeded the capacity available, or underperforming segments not demanded enough, unacceptable to the company. In those cases, such an array could help to re-program the itinerary (e.g. removing some segment of the journey, or transferring the resources to serve the passengers from one vessel to another).

The matrix analysis of used capacity of the ship, from the formal point of view, looks like this:

$$UC_{xy} = C_{xy} - D_{xy} \tag{7}$$

Where "$UC_{xy}$" is the used capacity of the fleet in the segment from port "x" to port "y", "$C_{xy}$" is the capacity available of the ships in the segment, and "$D_{xy}$" is the demand for each specific pathway.

Each cell of the "$UC_{xy}$" matrix means the following: Customers who are not attended appear with negative sign, whereas positive numbers indicate an excess of capacity that involves underperforming of the boat each way. In the best case for the shipping firm, the sum of all was zero, which would mean that ships are matching exactly the demand. Apparently, anything different from zero in the overall result, in absolute terms, puts the company in a situation of high unemployment or lack of adjustment to demand. Therefore, we conclude that, in order to fulfill the idea of efficiency, the result that should give the absolute value of the sum of cells is 0. Or, what is the same, the condition of efficient occupation of the shipping line is:

$$\sum_y \sum_x |C_{xy} - D_{xy}| \approx 0 \tag{8}$$

This analysis should be repeated for all combinations of trips which could be planned; so that this procedure would not be complete until having verified what combination is the furthest from the idea of efficiency and which less. The combination closer to zero will be that best meets the demand with available capacity. That is, for the minimum of the matrix defined by the set of combinations of routes, which formally is:

$$Min\left\{\sum_y \sum_x |C_{xy} - D_{xy}|\right\} \forall UC \in \Re \tag{9}$$

However, this would not be enough, as it should be noted that the mere use of the capacities of the vessels is not enough to approve a schedule of courses. There must be, above all, a necessary condition: to maximize the benefits of cruise operations.

Therefore, taking into account each segment price, average variable costs and fixed costs, operating profit could be calculated by a function to be maximized within the feasible area allowed by the constraints that have been previously established, as in (10):

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$$Max\left\{Z = \sum_{y}\sum_{x}\left[P_i \cdot Q_{xy} - (AVC_i \cdot Q_{xy} + FC)\right]\right\}\forall V \in \Re$$

(10)

Where "P" is the price at which each segment is sold, "AVC" is the average variable cost of operating the ship between two consecutive ports "x" and "y", and "FC" is the fixed cost to be considered by the company. "Q" is the level of sales for each segment, which is the same, ticketing sold to cover the demand to go the way from the port "x" to "y".

The problem, in this case would be that sales are not directly extractable from the demand matrix if there is not a slight modification. In fact, the array where the occupations were calculated contains all the information. By simply specifying a logic constraint, which is set to be taken into account only the amount served. This is achieved by forcing the manager to perform the following operation:

1. Raise demand as conceived in their matrix.

2. Subtract the demand from places offered by the carrier, which will be those cells adversely affected in the amount that indicate.

3. Some cells will still remain in positive sign (i.e. the company's offer exceeded the demand for that way), others will remain in negative sign (i.e. the demand has not been covered in the service of shipping). By deducting again the initial demand, the cells who have not been affected will be zero, while all others will be left with a negative sign. These amounts are those that will later indicate the sales price.

Thus, it would allow obtaining an optimal solution to the capacity, matching optimally the demand and minimizing also the cost per trip and ship.

## VI. DISCUSSION

### A. Application of this work

The direct consequences of using such a model in the operation of a shipping company derived primarily from the alterations that result in the operating model, adjusting the process so that the costs were lower, the resource utilization higher and, ultimately, much higher overall efficiency.

The advantages of such a system for a shipping line are: lower costs, better allocation of units by capacity, the better chance to pay off the units of the fleet, better planning of capacities and added value of the itineraries, design routes of greater value to passengers and, therefore, to fit more favorable prices.

First of all, a model to improve the programming of cruise ships allowed optimizing the route, with the consequent improvement in fuel costs, which is one of the largest inputs that carriers support.

Fuel costs depend mainly on the length of the journey, but also the weather, load, energy use of the boat, and even the type of engine and the age of the boat. To model the consumption function of the vessels is outside of this work's scope, but it should be noted that the shorter the segments, the lower consumption.

A model to establish optimal routes between ports, and worked under various objective functions, one of which is consumption, should produce efficient or suboptimal paths that allow, among other things, determine the minimum fuel that the shipping company must face in order to cover a line with their units. In short, the model should be adjustable to give more importance to some objective functions than others, and the fuel consumption function is one of the first to be considered.

Moreover, there are other operating costs that make advisable to optimize the use of ships, particularly labor costs. We have already spoken of the need to enlist crews yet experienced in navigation, usually from countries with low wage levels. Generally this workforce receives a low fixed salary, having it complemented with the results obtained with additional tips and other income earned during service in the boat. However, wage costs to maintain a floating city with almost a thousand crewmen are enormous, especially when many of them attend passengers in very rare occasions if the journey is not operated at full capacity.

Therefore, a model to predict, accurately and in time, the demand that is going to have a route would allow to accommodate the needs of labor, especially for passenger service, as well as catering supplies, entertainment program, etc. Operating costs of tour operators who work on board would also be improved as it would be easier to predict the demand for tours, guides, etc.

On the other hand, efficient planning of routes not only implies the possibility of reducing operating costs of shipping. It also implies an improvement in the use of units with a constant capacity, whose allocation must conform to parameters defined by an ever-changing demand.

A shifting demand makes it very difficult to assign ships, so it may happen that the number of tickets that are sold in the market, which depends on the capacity of the vessel, exceeds or falls below the demand for that particular route. This then has implications on the profit and loss account. Operating an itinerary with low occupation involves a waste of resources, whereas allocating ships with less capacity of what the market would have demanded involves underperform the potential of the company, which renounces to take advantage of the complete demand within a specific route.

Hence one of the main concerns of cruise companies: to offer so that the occupation of the ship meets the demand. However, to give an adequate response to that decision, firms must first know the demand and seasonality on each port, so that they can then construct a model to enhance the ability of vessels in each scale. Ideally, to transfer the passage of a vessel to another would be the best solution to achieve optimal programming, according to the usage of the airlines or the urban transport companies. These companies use transport units of less capacity for journeys of less demand (fingers or legs), while using large capacity transport units to communicate network nodes with high demand (hubs). This implies a transfer of passengers, but it is not something that

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can be easily put into practice in the cruise market, since one of the great attributes of a cruise is the fact of remain always in the same means of transport and drift from one point to another. The experience would lose much value to the passenger if he is forced to shuttle to maximize the transport capacity of the fleet, although it is an idea that could be modeled for future research. Perhaps it could be possible to find a niche market made up of passengers who accept the transfer in exchange for a sufficient price reduction. The question is then whether such reduction would be reasonable for the company, or which would compensate for the reduction of costs due to better exploit its fleet.

Moreover, a major use of the bearing capacity of the fleet would also allow accelerated depreciation of the ships. Each cruise ship that joined the fleet involved the immobilization of millions of euros, to be amortized across its lifetime or, if possible, in advance. An increased use of boat involves greater cash flows for each year at service, allowing accelerated depreciation of assets. In addition, this would involve tax advantages as the balance of the company would have a more favorable asset composition. Enabling early amortization of the units of the fleet would also create larger sinking funds, helping the shipping companies to improve its financial position in the capital markets.

Another application of this work enhances the value of the consignee role. The consignee is the on-land representative of the shipping line. Consignee offices are generally bearing their behalf and provide all the services that the vessel required before, during and after the call at the port.

Today is a purely functional role, in which the processes are highly mechanized and standardized. The relationships of each port with the consignees of the shipping companies that operate at them are very close, although limited to the mere technical context. On the other hand, in the case of the consignees of cruise companies, these also play a role in representing the shipping, and tour operators that want to sell their services to customers in the boat address to them.

However, there is a role of the consignees, although it is still performed today, which has been relegated by their other functions: sales representative. By their nature, number and location, they are the first-order traders of the lines, who can gather information on the demand for cruises in each port. With minimal training in commercial prospecting they can obtain valuable information on customer profiles, most requested services, new potential demands underlying population clusters, competitors, etc.

Therefore, a model that seeks information from market must not ignore the commercial and information potential that consignees can exert. They could provide information with which to build an allocation model that yielded efficient and robust.

The appropriation of consumer surplus is one of the current trends in many of the current business models, and shipping companies are not an exception. It is needed more than ever to know how much is the price that each single consumer is willing to pay for the cruise experience, and identify those clusters of users that maximize the value for the sales.

The gap between perceived value and the price is highest in commercial transactions. That is, the customer buys only what he perceives more valuable in relation to the price he pays. Typically, strategies that companies can use to increase this differential are two: to reduce the price of the ticket (and automatically the expected income), or to increase the perceived value of service (not increasing the costs beyond the acceptable level).

The cost reductions that enable the company to set more attractive prices than its competitors are already adequately covered in this work, although it's been a revision in depth yet into the value the customer perceives for the cruise. Although it is defined by many variables, it should be noted that the literature indicates several as the most important (see [21], [28] and [30]):
- The itinerary.
- The amenities on board.
- The likelihood of customizing the service.

Last two are outside our scope, but, being left for future research. However, the first one does have to the objective of this document.

A model to maximize the value that the customer gives to the itinerary, programming it trying to meet the demand peaks at all times, would be a very helpful model for the cruise lines, especially when markets experience great fluctuations in the price and clear references are needed. This could allow carriers to offer services with high perceived value, offering less vulnerability to the price wars that often appears in the sector. As a corollary, the business managers and operations managers of shipping companies should have a scientific model that provides the necessary business intelligence, eliminating the possible subjectivity and stochastic phenomena. In exchange, the model should allow creating the program for the fleet based on destinations, stops, times, fleet capacity, and so on, according to a serious, robust, and reasonable algorithm. In addition, planning for carriers could be more ambitious, working with frequency distributions and trying to balance, according to the weights established by the business managers, the cost functions, perceived value, benefits, etc.

Therefore, based on these possible uses, which are introduced here for indicative and not exhaustive, it can be a simple conclusion: an increase in corporate intelligence of routing may trigger an increase in the efficiency of shipping and partners on the ground.

### B. Limitations

The main limitations of the model developed are the following:

Need for plenty of background information. And data at this market is scarce or expensive, or it is measured at incompatible scales as in the analysis. That is why the present work could not present already a contrast verified with real information.

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There are no time references that might be specified optimally. Estimating the timing in which demand is stable is hard. Therefore, we should make a separate study to substantiate the periods in which demand can be seen in the predicted level. Considering the case of stochastic measures of demand would fit their parametric properties, which could be easily calculated having enough primary information.

The model considers two types of port: ports of call (to embark and disembark) and visiting ports, but there is also the type hop-on/hop-off, which requires a much more complex, but similar, analysis. In theory, with a simple alteration of the calculation, the model would now consider variations, not permutations, of the ports. This is so due that each port remains equal than others. Therefore, the problem is reduced to more computing needs, but no consequence is found from the methodological point of view.

The model also uses discrete measures. So, an application to optimize the objective functions proposed in the model through the combination of discrete steps, calculated by metaheuristics methods, in theory, could be modified to use continuous variables, which seek optimal functions. This works under the assumption that the company was able to run enough parametric tests to model each scale of demand from season to season. In this sense, the length of the journey could even converge to real values by using the central limit theorem. In fact, the different parameters of the stochastic demand functions accumulate its effects by the linearity of the itinerary.

Furthermore, it requires many resources of the system to converge. We must find ways to minimize the resources needed to run the calculation in a more agile way. Moreover, it requires an *ad-hoc* application undeveloped. However, these approaches far exceed the scope of this work, and leave its future development to next projects.

### C. Conclusions

The cruise market is currently booming. The powerful U.S. companies compete in every European destination, and some of them are also historically very powerful.

These companies operate under a port of call model (base port or header port), after which different scales draw a cruise circuit, which is scheduled in tours and visits. Normally, the ship travels overnight between the ports.

The vessel capacity and market rigidities and saturation are making the offer becomes important to design a profitable and competitive itinerary, with enough perceived value to be purchased by customers.

The market would reward those carriers that best meet the demand because, as described in the literature, making the purchase decision by the customer focuses on the convenience of travel. This hinges on the adequacy in length of the scales, the trips on land, the starting and ending dates, on-board facilities, tourist destination features, and so on. That is, the customers are who decide what cruise purchase, based on all these parameters. This configures a model that has been studied and is configurable for each port and season.

The need for intelligent models to assign circuits and vessels engaged justifies the effort in getting an application that can yield robust results in this regard. The shipping line find, thus, a source of differentiation and competitive advantage as it could anticipate changes in demand and schedule the use of its resources by mobilizing ships, people and flows in the best way.

Faced with the exhaustion of linear programming techniques, metaheuristics methods are expressed highly competent to provide the appropriate framework of analysis that is required. It is therefore necessary to approach the study of this issue from a less deterministic perspective than that which presides discrete linear programming, and use techniques that are based on the calculation capacity of modern systems to assist the programming manager.

This paper has developed a description of metaheuristic techniques dealing with discrete variables, leaving for a second project its extension to continuous measures parameterized.

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