Alliances and Risk Transfers in Intermodal Transportation

Carmen Juan*, Fernando Olmos and Pedro Alfaro
Instituto de Economía Internacional
Universidad de Valencia
Avda. de los Naranjos, s/n. 46022 Valencia.
Phone: +34963828369. Fax: +34963828370.
m.carmen.juan@uv.es, fernando.olmos@uv.es, pedro.al.fe@gmail.com

Rahim Ashkeboussi
Department of Marketing and Finance
Frostburg State University
101 Braddock Road
Frostburg, MD 21532-2303 (USA)
Phone: 204-527-2744. Fax: 240-527-2715
e-mail: ashkeboussi@frostburg.edu

Abstract

This paper addresses the problem of the strategic planning of an intermodal transportation chain, and analyses potential risk transfers between agents in the chain derived from the real options embedded in the underlying agreements for the operations of the chain. A planning methodology is presented that enables the calculation of the Expanded Net Present Value (ENPV) when the material resources necessary to carry out the project (fleets and terminals) are not known a priori, and the choice of resources may change throughout the planning period. Based on the results of such planning, we propose methods to assess the transfers of risk among agents in the chain. Specifically, we focus on risks transfers arising from clauses regulating the operation of a compensation fund that can refund those agents who are more exposed to risk derived from uncertainty concerning demand for the service. The article also discusses the terms of the mechanisms that regulate a possible departure of one of the agents. Such clauses are stated in terms of partial or total *put* and *call* options.

1 Introduction

Over the last decade problems inherent in the road transportation system (congestion, environmental impact, etc.) have prompted government authorities to consider the need to design mixed transport chains as an alternative to the difficulties currently posed by the sustainability of growth in road transportation over the short and medium-term ([3], [6], [7], [26]).

It is within this context that discussion has arisen about Motorways of the Sea (MoS). These are rapid connections between two ports, and are alternatives to highly congested road networks

*Corresponding author: m.carmen.juan@uv.es

that cross areas already suffering severe environmental externalities. An MoS is the result of combined and interconnected operations managed by the following agents:

1. Two government authorities (of the same or different countries) responsible for efficient border management and access;
2. Two Port Authorities (PAs) responsible for port management;
3. Two Terminal Operators (TOs) responsible for ground operations (loading and unloading);
4. One or more carriers responsible for maritime transportation (shipping companies);
5. One or more charter companies, which may participate in the formation of the fleet.

As an alternative mode of transport in competition with roads, an MoS must be competitive in two key areas: time and cost for the user. This coupled with the fact that large investments in infrastructure (port terminals) and superstructure (terminal equipment and fleet) are required means that such a transport chain would be highly risky from a commercial point of view.

Moreover, taking into account the different risk borne by each agent, an MoS cannot be the result of independent and uncoordinated activities by agents following their own business plans – because the failure of any of the agents inevitably leads to the failure of the chain.

Therefore, the operation of an MoS requires strategic planning, as well as the design of a strategic alliance (SA). Strategic planning is required in order to determine the necessary resources (fleet and terminals) for the operation, and its growth over time including economic profitability criteria. From the viewpoint of real options, planning will present the problem of determining the Expanded Net Present Value(ENPV) when resources are not known a priori, and may change at given moments during the planning period.

The purpose of the SA is to set a general framework that regulates sector agreements in the *land business* and *maritime business*.[1] The challenge is how to evaluate the strategic and operational options included in these agreements, so that the transfer of risk among agents in the chain can be quantified.

Specifically, this article focuses on risks transfers arising from clauses regulating the operation of a compensation fund that can refund those agents who are more exposed to risk derived from uncertainty concerning demand for the service. These funds can absorb some of the possible shortfalls with respect to initial expectations, but agents benefiting from them must repay any withdrawals after the business has been consolidated.

The article also discusses the terms of the mechanisms that regulate a possible departure of one of the agents. Such clauses are stated in terms of partial or total *put* and *call* options. The article explains the structure of these terms and a methodology for the quantitative analysis of risk transfers by analyzing the embedded strategic real options.

The paper is structured as follows: section 2 discusses the methodology proposed for solving the problem of strategic planning. Section 3 discusses the design of the terms, and proposes algorithms that enable an evaluation of the real embedded options; and the risk transfers arising from these options.

2 Strategic planning of the intermodal (land-maritime) transportation chain

The determining factor in the strategic planning of a land-maritime transportation chain is the determination of the fleet and its changes throughout the planning period. From this

[1] We understand the land operations business to include the ground operations, i.e. loading and unloading ships in terminals and port related activities (access, customs, pilotage, etc). This activity involves Terminal Operators (TOs) and Port Authorities (PAs) in the relevant sector agreement. The maritime business refers to the shipping operations (fleet management) and includes several shippers if they jointly operate a single line, as well as chartering companies, and/or government authorities.

analysis, it is possible to also deduce the sequence of investment in port infrastructure and superstructure.

Let us consider a long-term planning period and assume that, due to variations in uncertain demand, this period can be divided into sub-periods. Let's also assume that the ships operating in each of the sub-periods are chartered, which provides flexibility when matching the composition of a fleet to an uncertain demand. The planning problem addressed in this section can be stated as follows: for each of the sub-periods a fleet mix (number and type of vessels) will be selected that meets demand and constraints frequency, and maximizes the NPV for the period. Since the planning period is long-term, we assume that certain relevant inputs of the problem (import and export demand and fuel prices) are stochastic and can be modelled using scenarios.

From the standpoint of operational research, the problem of planning is a scenarios optimization problem with multiple interconnected decision dates. Due to flexibility concerning the mix fleet, from the viewpoint of real options, the problem to be solved is the equivalent to calculating an ENPV when the material resources necessary to carry out the project (fleets and terminals) are unknown a priori. This requires the resolution of a series of optimization problems in various scenarios.

Moreover, as the fleet operates under charter, the different costs of contracts in the short, medium, and long-term requires that the decision regarding the composition of the fleet takes into account future decisions. Therefore, planning should be made through a backward process.

The methodology proposed addresses the following points:

1. The generation of a multi-dimensional underlying scenarios tree for the problem. At each decision date, the tree provides the full probability distribution of the scenarios for that date. The tree also contains the corresponding transition probabilities between scenarios at consecutive dates.

2. For each of these scenarios in the tree, an optimization problem will be solved that provides the optimal fleet mix, as well as the optimal value of the profits. Optimization problems solved in final nodes (at expiry date) are distinguished from those related to intermediate nodes. For the latter, the objective function of the model incorporates the optimal solution of the nodes related at a future consecutive date, as well as the corresponding transition probabilities.

3. The resolution of these optimization problems is made backwards, modifying the objective function as indicated previously. By combining the optimal profits associated with each scenario at each of the decision dates with its probability of occurrence, the expected profits of the business (ENPV) as well as the probability distribution of the ENPV are obtained. Risk measures can be deduced from this result. The fleet mix for each scenario of the tree is also obtained.[2]

The research in this section is structured as follows: Section 2.1 describes the general algorithm for the generation of multinomial trees, both from the intuitive point of view found in Section 2.1.1, and the formal approach found in Section 2.1.2. The implementation of this algorithm with a numeric example is shown in 2.1.3. Section 2.2 discusses the complete strategic planning process. Construction of the base optimization problem begins in 2.2.1 and continues in 2.2.2 with the structure of the backward planning process. In 2.2.3 the strategic planning of the fleet mix of an MoS.

[2]Obtaining a 'robust' solution for the scenario optimization problem does not make sense in a planning process of this type. This is because of the NPV associated with the 'robust' fleet for each period hides the risk of the project provided by the tree of optimal solutions, which is key to the evaluation of risk transfer. At the same time, a 'robust' fleet has no meaning for the decision-maker, and hides valuable probabilistic information regarding the fleet mix.

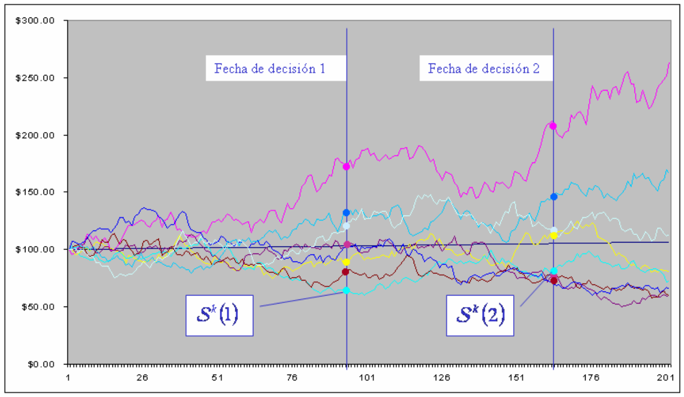

Figure 1: Generation of an one dimensional tree using simulation

2.1 Algorithm for generation of multi-dimensional scenario trees

The construction of one dimensional and multi-dimensional scenario trees has been widely studied from different points of view and has been applied to various fields such as risk evaluation and decision making. A partial list of works includes: [1], [2], [11], [27], [9], [12], [18], and [23]. The most important contribution to the field of proposed methodology is that it enables multi-dimensional trees to be built for any type of dynamic followed by the underlying processes because it does not use any of the specific characteristics of the stochastic processes involved.

2.1.1 An intuitive approach to the proposed design

The proposed algorithm can be defined as an algorithm for generating non recombining trees with multiple underlying processes using Monte Carlo simulation. The one-dimensional case is described below to illustrate intuitively it design and the key ideas on which it is based.

Suppose we have a unique underlying S, modelled by a stochastic process for a given time horizon. A Monte Carlo simulation of the process enables us to obtain a significant number M of paths with its behaviour over time (M is large enough so that the statistical criteria considered are consistent). Suppose we have two possible decision dates: $t = 1$ y $t = 2$; as shown in Figure 1.

For each decision date, the simulation process gives us M outcomes of the underlying processes (which we have denoted $S^k(1)$ y $S^k(2)$ respectively for $k = 1, \ldots, M$ y $t = 1, 2$). Using a standard statistical treatment, we obtain the histogram associated with each of these datasets. The representatives of each of the classes of histogram, together with their corresponding probabilities of occurrence, will constitute the tree scenarios for each of the decision dates. Figure 2 shows this process, where the space scenarios at each decision date have been denoted as $(e^r(1),\ p_1^r)$ y $(e^r(2),\ p_2^r)$.

The transition probability between two scenarios $e^i(1)$ and $e^j(2)$ at consecutive dates is obtained by computing the relative frequency of paths that pass across the scenario at the first date $e^i(1)$ and the scenario of the second date $e^j(2)$ with respect to all the paths that pass through $e^i(1)$. This will complete the construction of a one-dimensional scenario tree using Monte Carlo simulation.

When applying the methodology described above to a multi-dimensional case, we must solve the problem of the additional computational cost resulting from the use of multiple underlying processes, the so-called *curse of multi-dimensionality*. Next, we describe intuitively how the algorithm proceeds and a mathematical formalization of the ideas described below can be found

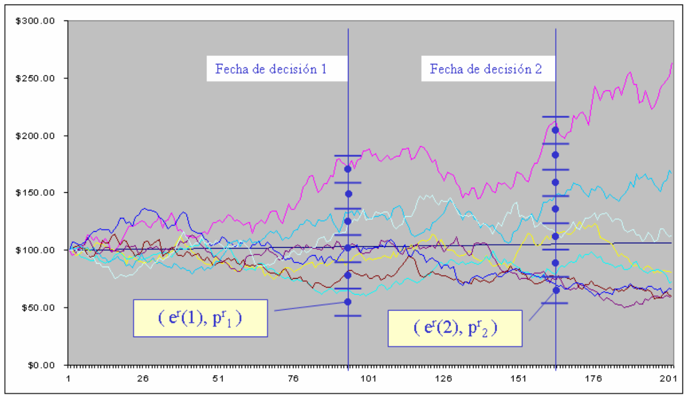

Figure 2: Scenario spaces in a one dimensional tree

in Section 2.1.2.

Suppose we have m underlying S_i, and in the same way as the one dimensional case, we set two possible decision dates. A Monte Carlo simulation of the m stochastic processes S_i enables us to obtain M outcomes for each of the decision dates. However, these outcomes will be m-tuples (denoted $(S_1^k(1), \ldots, S_m^k(1))$ and $(S_1^k(2), \ldots, S_m^k(2))$ respectively) instead of real numbers as in the one-dimensional case.

The statistical treatment of the m-tuples obtained requires the construction of an m-dimensional histogram. To do this, we partition the (m-dimensional) space of outcomes in class, each one of them will be an m-dimensional *cube* (*hypercube*) and having an associated m-tuple as a representative (the geometric centre of the *hypercube*, in the same way as the one-dimensional representative, is usually the geometric centre of the interval constituting the class). To make the above information computable, a bijection is defined so that each m-dimensional *cube* is uniquely determined by a scalar, termed its *label*. The multi-dimensional problem thus becomes a one-dimensional problem and can be implemented using the methodology described above.

2.1.2 Analytical formulation of the algorithm for constructing multi-dimensional trees

Let's consider m discrete stochastic processes (correlated) denoted by $S_i, \;\; i = 1, ..., m$. Suppose a planning interval strategic $[0, \; \tau]$ and denote by τ_0 the initial decision date. We set N sub-periods with a duration of $T = {}^{\tau}/_{N}$. Then the set $\{\tau_1, ..., \tau_N\}$ of all the possible decision dates is given by $\tau_j = j \cdot T, \;\; j = 1, ..., N-1$, y $\tau_N = N \cdot T = \tau$.

The algorithm proceeds as follows:

- **STEP 1:** Monte Carlo simulation of the processes S_i $(i = 1, ..., m)$ in the planning interval $[0, \tau]$.

We can see that the k-th outcome of the simulation provides an m-dimensional path given by $\left\{ \left(S_1^k(j), ..., S_m^k(j) \right) \right\}_{j=1}^{N}$, where $S_i^k(j)$ denotes the k-th outcome of the process S_i at the date τ_j.

For each date τ_j, we consider that the set $O(j) \subseteq \mathbb{R}^m$ contains all the m-dimensional vectors of the outcomes. If M denotes the total number of outcomes[3], then $O(j)$ is the set of M elements

[3]The minimum adequate value for M can be determined by establishing a confidence interval for those statistics considered in the probability distribution of each process S_i, $i = 1, \ldots, m$ at each date τ_j, $j = 1, \ldots, N$.

given by

$$O(j) = \left\{ \left(S_1^k(j), ..., S_m^k(j) \right) \right\}_{k=1}^{M}.$$

Thus, each set $O(j)$ needs for memory storage a matrix sized $M \times m$. In what follows, $O(j)$ refers indiscriminately to all outcomes and their matrix representation. The three-dimensional matrix sized $M \times m \times N$, and given by $O = (O(j))_{j=1}^{N}$, contains the complete information for the simulation performed.

- **STEP 2**: Construction at each date τ_j $(j = 1, \ldots, N)$, of an m-dimensional interval $C(j)$ containing the set of $O(j)$ outcomes.

Let's consider the interval given by $C(j) = [a_1(j), b_1(j)] \times \cdots \times [a_m(j), b_m(j)]$, where

$$a_i(j) = Min \left\{ S_i^k(j) \mid k = 1, \ldots, M \right\} \quad \forall i = 1, ..., m$$

$$b_i(j) = Max \left\{ S_i^k(j) \mid k = 1, \ldots, M \right\} \quad \forall i = 1, ..., m$$

Therefore, $C(j)$ satisfies $O(j) \subseteq C(j)$.

- **STEP 3:** Generation at each date τ_j $(j = 1, \ldots, N)$ of a disjointed partition $P(j)$ of the m-dimensional interval $C(j)$.

For each i $(i = 1, ..., m)$, consider a disjointed partition of the interval $[a_i(j),\ b_i(j)]$ in $\delta_i(j)$ sub-intervals. An adequate value for $\delta_i(j)$ is determined establishing a 5% of acceptable discrepancy for certain statistics, which are obtained simultaneously as a result of the simulation, and in turn from the histogram of frequencies associated with the partition $P_i(j)$ over $[a_i(j),\ b_i(j)]$ which we will build below.

Denote by

$$\left\{ a_i^0(j) = a_i(j),\ a_i^1(j),\ \ldots,\ a_i^{\delta_i(j)}(j) = b_i(j) \right\}\ i = 1, ..., m$$

all the points of the partition, and by $P_i(j)$ $(i = 1, ..., m)$ the corresponding set of partition sub-intervals. For the sake of simplicity, we identify the partition of an interval with the set of generated sub-intervals. Thus, a multi-dimensional disjointed partition $P(j)$ of an m-dimensional cube $C(j)$ is defined as the Cartesian product of the sets of $\delta_i(j)$ elements $P_i(j)$. An element of $P(j)$ is an m-dimensional interval $h^r(j)$ given by

$$h^r(j) = \left[\ a_1^{n_1^r(j)-1}(j),\ \ a_1^{n_1^r(j)}(j)\ \right] \times \cdots \times \left[\ a_m^{n_m^r(j)-1}(j),\ \ a_m^{n_m^r(j)}(j)\ \right],$$

where *r=1,...,R(j)*, and $R(j) = \prod_{i=1}^{m} \delta_i(j)$ being the cardinal of $P(j)$.

- **STEP 4:** For each date $\tau_j(j = 1, \ldots, N)$, the ***scenarios*** of the tree are defined as the corresponding ***space of scenarios*** .

For each $h^r(j) \in P(j)$, the m-dimensional vector $e^r(j) \in h^r(j)$ whose components are the half-way points of each of the intervals of $h^r(j)$ is termed a ***scenario***(or ***node***)of the tree at τ_j. The set $\mathrm{E}(j) = \{\ e^r(j)\ \}_{r=1}^{R(j)}$ of all the scenarios or nodes in τ_j are termed the ***space of scenarios*** at τ_j.

- **STEP 5:** Construction of a simple representation of each multi-dimensional partition $P(j)$ $(j = 1, \ldots, N)$.

Note that each m-dimensional interval $h^r(j)$ is uniquely determined by the m-tupla $(n_1^r(j), \ldots, n_m^r(j)) \in \mathrm{Z}^m$ and so:

$$h^r(j) = \left[a_1^{n_1^r(j)-1}(j), a_1^{n_1^r(j)}(j)\right] \times \cdots \times \left[a_m^{n_m^r(j)-1}(j), a_m^{n_m^r(j)}(j)\right].$$

Therefore, we can establish a bijection[4] so that each m-tupla $(n_1^r(j), \ldots, n_m^r(j))$ corresponds to an integer $l^r(j)$ given by the expression

$$l^r(j) = \sum_{i=1}^{m-1} n_i^r(j) \cdot \delta_{i+1}(j) \cdot \ldots \cdot \delta_m(j) + n_m^r(j).$$

Consequently, $h^r(j)$ is uniquely determined by $l^r(j)$. We will call $l^r(j)$ the ***label*** of $h^r(j)$. The set $\{\ l^r(j)\ \}_{l=1}^{R(j)}$ of all the labels constitues a simple representation of $P(j)$, and this set can be stored in a matrix sized $1 \times R(j)$.

- **STEP 6:** Construction of a simpe representation of the matrix $M \times m$ $O(j)$, as well as the corresponding simple representation of the matrix $M \times m \times N$ $O = (O(j))_{j=1}^N$ $(j = 1, \ldots, N)$.

For each $\left(S_1^k(j), ..., S_m^k(j)\right) \in O(j)$, there is a unique r_k, $1 \leq r_k \leq R(j)$, so that $\left(S_1^k(j), ..., S_m^k(j)\right) \in h^{r_k}(j)$. In this way, it is possible to establish an injection so that each m-dimensional vector $\left(S_1^k(j), ..., S_m^k(j)\right) \in O(j)$ corresponds to a label $l^{r_k}(j)$ associated with the corresponding $h^{r_k}(j)$. Through this injection, the matrix $M \times m$ $O(j)$ is replaced by the vector of integer numbers $M \times 1$ $L(j)$ and the matrix $M \times m \times N$ $O = (O(j))_{j=1}^N$ is also replaced by the matrix of integer numbers $M \times N$ $L = (L(j))_{j=1}^N$.

- **STEP 7:** Construction of a complete probability distribution for the scenario space $\mathrm{E}(j)$ $(j = 1, \ldots, N)$.

For each date τ_j, let's consider the discrete probability distribution where each $e^r(j) \in \mathrm{E}(j)$ has a probability p_j^r given by the ratio between number of times the label $l^r(j)$ of $e^r(j)$ appears as a component of vector $L(j)$, and the total of outcomes in the simulation M. If we denote with $\lambda_s(j)$ $(s = 1, \ldots, M)$ the components of vector $L(j)$, then p_j^r is given by the expression:

$$p_j^r = \begin{cases} 0 & \text{si } \ l^r(j) \notin L_j \\ \frac{|\ \{\ s\ |\ \lambda_s(j) = l^r(j),\ s=1,\ldots M\ \}\ |}{M} & \text{si } \ l^r(j) \in L_j \end{cases}$$

- **STEP 8:** Calculation of the transition probabilities between consecutive scenarios on the tree.

Suppose two consecutive decision dates τ_j y τ_{j+1}. Let's consider the corresponding vectors $L(j)$ and $L(j+1)$. Let's build the matrix $M \times 2$ with columns $L(j)$ and $L(j+1)$: $L(j, j+1) = (L(j)\,|L(j+1)\,)$. For each $e^r(j) \in \mathrm{E}(j)$ and each $e^t(j+1) \in \mathrm{E}(j+1)$, the transition probability $p_{j,j+1}^{r,t}$ between $e^r(j)$ y $e^t(j+1)$ is defined as the ratio between the number of rows of the matrix $L(j, j+1)$ equal to $\left(l^r(j),\ l^t(j+1)\right)$, and the number of rows of the matrix $L(j, j+1)$ whose first element equals $l^r(j)$. In this way, if $\lambda_{su}(j, j+1)$ $(s = 1, \ldots, M;\ u = 1, 2)$ denotes a generic element of the element $L(j, j+1)$, then $p_{j,j+1}^{r,t}$ is given by the expression:

$$p_{j,j+1}^{r,t} = \begin{cases} 0 & \text{si } \ l^r(j) \notin L(j) \\ \frac{\left|\ \left\{\ s\ |\ \lambda_{s1}(j,j+1) = l^r(j),\ \lambda_{s2}(j,j+1) = l^t(j),\ s=1,\ldots M\ \right\}\ \right|}{|\ \{\ s\ |\ \lambda_{s1}(j,j+1) = l^r(j),\ s=1,\ldots M\ \}\ |} & \text{si } \ l^r(j) \in L(j) \end{cases}$$

[4]The bijection is established between the set $\{(n_1^r(j), \ldots, n_m^r(j))\ \big|\ 1 \leq n_i^r(j) \leq \delta_i(j),\ i = 1, \ldots, m\ \}$ and the set $\{l \in\ \mathbf{Z}\ \mid \underline{L}(j) \leq l \leq \overline{L}(j)\ \}$, where $\underline{L}(j) = \sum_{i=2}^m \delta_i \cdot \delta_{i+1} \cdot \ldots \cdot \delta_m + 1$ y $\overline{L}(j) = \sum_{i=1}^m \delta_i \cdot \delta_{i+1} \cdot \ldots \cdot \delta_m + \delta_m$.

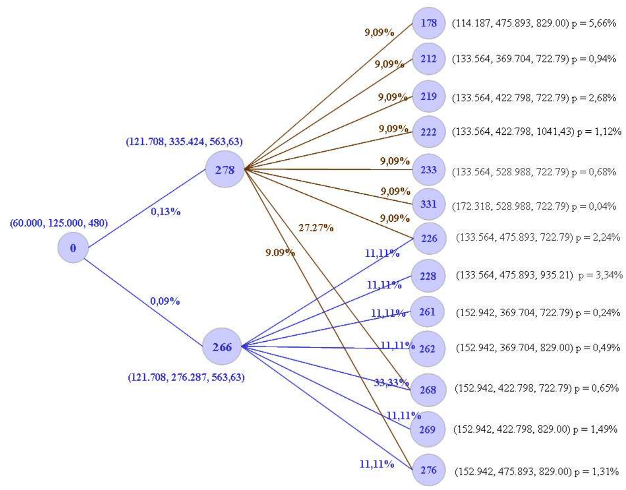

Figure 3: A section of the three-dimensional planning tree

2.1.3 Numerical example

The algorithm described in 2.1.1, and formalised in 2.1.2, has been implemented in Visual Studio.NET and C#. The program allows the number of decision dates and the intermediate periods between these dates to be selected, as well as the number and structure of the underlying processes.

Note that flexibility in deciding the decision dates and the dates between sub-periods is essential when applying this methodology to a real problem of strategic planning. Depending on the behaviour of the underlying processes, it may be more advisable to shorten the time between decision dates, and even make the time period vary within the planning horizon.

For the sake of simplicity in presentation, in our case, a time horizon of 15 years is established with two possible decision dates: at year 5 and year 10 respectively. The stochastic processes that model the evolution of export demand, import demand, and the price of fuel for ships (*bunker fuel*)have been considered as underlying processes. These have been adjusted in the same way as in models commonly used in studies of this type of demand ([5], [28], [29], [32]) and models used for studying commodity prices such as fuel ([17], [22], [24], [33]).

The final tree resulting from the implementation of the algorithm consists of 64 scenarios on the first decision date at year 5, and 100 scenarios on the second decision date at year 10. A matrix of 64×100 includes the transition probabilities between the two decision dates, where each scenario has been replaced by its corresponding label.

Figure 3 illustrates a section of the tree which shows for each scenario (denoted by the label), the three-dimensional vector with the complete information of the underlying processes, its probability of occurrence, the transition probability of related scenarios, as well as the absolute probabilities of occurrence of these latter.

2.2 The problem of strategically planning the fleet

This section discusses the modelling of the optimization problem for determining the optimal fleet mix that should operate on the MoS for a certain planning period. Fleet mix and *fleet scheduling* problems in the maritime sector have been studied for the deterministic case ([25],[10], [20], [21]). However, as noted in Section **??**intro), the characteristics of the problem studied in this article convert the problem into a stochastic problem with multiple and interrelated decision dates. Therefore, a specific methodology for its resolution is developed below.

2.2.1 Description of the optimization problem

This section describes the basic problem to be solved, how to model each of its elements, and the peculiarities that require a specific approach. This problem will be properly modified in Section 2.2.2 when it is used to implement comprehensive strategic planning on the scenario tree.

The basic problem is to determine the mixed fleet of vessels for a container roro shipping line that maximizes profits. This shipping line covers a distance of δ miles between a single port and a single destination. The fleet should operate without changing its composition during the period of T years between two consecutive decision dates. Therefore, capacity should be sufficient to meet export and import demand generated during that period (indicated by Ex_l and Im_l respectively, for each year l of the period). For the shipping line to be competitive with land transportation, it must offer a frequency of α sailings a day in both directions.

The fleet manager responsible for planning must first decide how many ships of each type will be required, chosen from appropriate ships available on the market. Assuming that the choice is between m different types of ships that meet these characteristics, then we can set the following family of variables:

$$x_k = \text{number of type } k \text{ ships} \quad k = 1, \ldots, m.$$

Additionally, for each year of operation, the plan should establish how many sailings each type of ship will make and what type of cargo will be carried in each sailing. In this way, the following sets of variables will be incorporated into the problem:

$$y_{kl} = \text{number of sailings of a type } k \text{ ship in year } l, \quad k = 1, \ldots, m, \quad l = 1, \ldots, T.$$

$$z_{kl} = \text{cargo carried on each sailing by a type } k \text{ ship in year } l, \quad k = 1, \ldots, m, \quad l = 1, \ldots, T.$$

Note that it is not possible to work with aggregate capacity of the fleet, nevertheless it is necessary to handle this level of detail when modelling the variables of the problem for the following reasons:

- As they must comply with frequency constraints, the shipping line must offer a minimum number of sailings per year, regardless of demand.
- Fuel consumption is a significant share of the operating costs of a shipping line. Consumption is shown in tons of fuel per hour of navigation, and therefore depends directly on the number of sailings.
- The maximum number of annual sailings of a ship is a function of cargo. In fact, one of the factors that most affects efficiency for shipping lines is the time taken in loading and unloading. This, in turn, is determined by the technology of the ship and the terminal; and the volume of cargo transported. This technical relationship between the variables y_{kl} and z_{kl} will be incorporated in a block of constraints indicated below.

In order to correctly select the fleet mix a manager needs to know a set of specifications for each ship. These specifications will determine the parameters of the constraints, the objective function of the problem, and therefore, the optimal fleet mix. Tables 1 and 2 contain these specifications, grouped into technical and financial aspects, respectively.

Taking into account the variables introduced earlier, as well as the inter-relationships between the specifications in Tables 1 and 2, the constraints of the problem can be expressed as follows:

Technical specifications for a type-k ship	
Capacity (standard cargo units)	C_k
Speed (knots)	v_k
Number of maintenance days	md_k
Fuel consumption (tons per navigation day)	f_k
Journey time (días)	$T_k = \frac{\delta}{24 \cdot v_k}$
Loading/unloading ratio (movements per hour)	hr_k
Time to load/unload a full ship	$Tcd_k = 2 \cdot \left(\frac{\rho \cdot C_k}{24 \cdot hr_k} \right)$
Annual minimum sailings (number of sailings full load)	$L_k = \left\lfloor \frac{365 - md_k}{T_k + \gamma + Tcd_k} \right\rfloor$
Maximum number of sailings (number of sailings empty load)	$U_k = \left\lfloor \frac{365 - md_k}{T_k + \gamma} \right\rfloor$

Table 1: Specifications for a type-k ship

Financial parameters for a type-k ship	
Construction costs	P_k
Annual crew costs l	ϑ_{kl}
Annual insurance costs l	ι_{kl}
Annual maintenance costs l	χ_{kl}
Depreciated value of ship at end of planning period	Ω_k
Annual charter costs	Λ_k
Long-term charter rate	r_k
Short-term charter premium	π_k
Annual bonus for long-term charter	b_k

Table 2: Financial parameters for a type-k ship

Frequency constraints

$$\sum_{k=1}^{m} x_k \cdot y_{kl} \geq 2 \cdot \alpha \cdot 365 \qquad \forall l = 1, \dots, T.$$

Demand constraints

$$\sum_{k=1}^{m} x_k \cdot y_{kl} \cdot z_{kl} \geq 2 \cdot \mathrm{Max}\left\{Ex_l,\ Im_l\right\} \qquad \forall l = 1, \dots, T.$$

Technical relationship between number of sailings and cargo carried

$$y_{kl} \leq \frac{365 - md_k}{\frac{2 \cdot z_{kl} \cdot \rho}{24 \cdot hr_k} + T_k + \gamma} \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$

Presence, or otherwise, of type k ships in the fleet If there are no type k ships in the fleet, then in each year l of the planning period, the number of sailings y_{kl} and the cargo z_{kl} should logically be 0. These constraints are included in the following way in the model (where M denotes a large arbitrarily natural number):

$$y_{kl} \leq M \cdot x_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$
$$z_{kl} \leq M \cdot x_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$
$$z_{kl} \leq M \cdot y_{kl} \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$

Upper bounds for the variables x_k An upper limit for the number of type k ships that can be part of the fleet is obtained assuming that only type k ships satisfy the shipping line frequency and demand constraints. The relevant constraints would be expressed as follows:

$$x_k \leq \mathrm{Max}_l \left\{b_{kl}\right\}$$

where b_{kl} is given by:

$$b_{kl} = \mathrm{Max}\left\{\left[\frac{2 \cdot \mathrm{Max}\left\{Ex_l,\ Im_l\right\}}{L_k \cdot C_k}\right] + 1;\ \left[\frac{2 \cdot \alpha \cdot 365}{L_k}\right] + 1\right\}.$$

Upper bounds for the variables y_{kl}

$$y_{kl} \leq U_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$

Upper bounds for the variables z_{kl}

$$z_{kl} \leq C_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T.$$

Once the constraints of the problem are established, the next step in modelling is to determine the expression of the objective function. This function quantifies the profits arising from the shipping line operations for the T years of planning. Suppose a adjusted risk discount rate of η. The various blocks involved in the final expression of the profits are shown below:

Income Income for the shipping operators comes from payments made by the users and these are determined by tariffs set for each unit of cargo (known as *freight rate*). If we denote Fr_l as the freight rate in the year l, then the total income during the planning year (Rev) will be given by:

$$Rev = \sum_{l=1}^{T} \left((Ex_l + Im_l) \cdot Fr_l\right) \cdot (1 + \eta)^{-l+1}.$$

Operating costs Denote Fl_l as the price of fuel for the year l. From the financial parameters given in Table 2, the expression of the operating costs (C_{op}) will be given by:

$$C_{op} = \sum_{l=1}^{T} \left(\sum_{k=1}^{m} (x_k \cdot \vartheta_{kl} + x_k \cdot y_{kl} \cdot T_k \cdot f_k \cdot Fl_l + x_k \cdot \iota_{kl} + x_k \cdot \chi_{kl}) \right) \cdot (1+\eta)^{-l+1}.$$

Charter costs For a short-term charter contract lasting the planning period of T years a rate r'_k is used. This is the the base rate for a long-term contract r_k, plus a premium π_k for a short-term charter. Therefore, the annual charter sum for a k type ship, Λ_k, should satisy the following equation:

$$P_k - \Omega_k = \sum_{l=1}^{T} \frac{\Lambda_k}{(1+r'_k)^{l-1}} = \Lambda_k \left(\frac{1}{r'_k} - \frac{1}{(1+r'_k)^T \cdot r'_k} \right).$$

The total charter payments for the planning period (C_Λ) can be shown as:

$$C_\Lambda = \sum_{k=1}^{m} x_k \Lambda_k \left(\frac{1}{\eta} - \frac{1}{(1+\eta)^T \eta} \right).$$

To conclude the section, the complete synthesised mathematical formulation for the problem is:

$$\begin{array}{ll}
\text{Max} & F = Rev - C_{op} - C_\Lambda \\
\text{s.a} & \sum_{k=1}^{m} x_k \cdot y_{kl} \geq 2 \cdot \alpha \cdot 365 \qquad \forall l = 1, \dots, T. \\
& \sum\limits_{k=1}^{m} x_k \cdot y_{kl} \cdot z_{kl} \geq 2 \cdot \text{Max}\,\{Ex_l,\ Im_l\} \qquad \forall l = 1, \dots, T. \\
& y_{kl} \leq M \cdot x_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T. \\
& z_{kl} \leq M \cdot x_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T. \\
& z_{kl} \leq M \cdot y_{kl} \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T. \\
& x_k \leq \text{Max}_l\,\{b_{kl}\} \\
& y_{kl} \leq U_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T. \\
& z_{kl} \leq C_k \quad \forall k = 1, \dots, m \ \forall l = 1, \dots, T. \\
& x_k,\ y_{kl}\ z_{kl} \geq 0,\ \text{integer}\ \forall k = 1, \dots, m \ \forall l = 1, \dots, T.
\end{array}$$

2.2.2 Backward planning on the scenario tree of a chartered fleet

For the three underlying processes considered in the problem (export demand, import demand and the price of fuel), we have constructed a tree of scenarios according to the methodology described in 2.1. We consider N decision dates in the tree separated T years. To incorporate into the planning decisions the cost difference between a medium and long-term charter, we have developed a backward methodology with sequential resolution of a series of optimization problems resulting from adequate modifications to the basic problem shown in 2.2.1. The stages in the process are shown below:

1. **Optimization problem for final scenarios.** Suppose we are in a final scenario of the tree. The scenario gives values for export and import demand, and the price of fuel for the year considered. Since we must resolve a plan for T years, we need the values for T for the next $T-1$ years until the end of the period. Using Monte Carlo simulation, and the values given by the scenario as initial values, we can calculate the parameters Ex_l, Im_l y Fl_l, $l = 1, \dots, T$, as the mean of the outcomes from the simulation.
2. **Optimization problem for intermediate scenarios.** Consider a scenario r of an intermediate decision date j. To modify the basic optimization problem, we must adequately combine the following information in the new objective function for the problem:

- From the backward process we have obtained the optimal planning for each scenario s of the next decision date $j+1$, i.e, we know how many ships of each type the line will operate. Therefore, to determine the optimum fleet for the scenario r of j we know how many of the selected ships will continue to the next period, and therefore would be entitled to a bonus for a long-term charter. The following expression formally models the bonus amount:

$$\text{Bonus(r,s)} = \sum_{k=1}^{m} \text{Min}\left\{x_k^*(s), x_k(r)\right\} \cdot b_k \cdot \left(\frac{1}{\eta} - \frac{1}{(1+\eta)^T \eta}\right),$$

  where $(x_1^*(s), \ldots, x_m^*(s))$ denotes the optimal planning of ships obtained for s, b_k the annual bonus for each type k ship in the fleet that continues in the fleet, and $(x_1(r), \ldots, x_m(r))$ is the possible plan for r.

- From the tree information, we know the transition probabilities from each scenario r of j to each scenario s of $j+1$ (denoted as $p_{j,j+1}^{r,s}$). Thus the following expression, which calculates the expected value of the bonus, must be incorporated in the objective function:

$$\text{Bonus(r)} = \sum_{s=1}^{R(j+1)} p_{j,j+1}^{r,s} \cdot \text{Bonus(r,s)}.$$

Moreover, as was the case with the final nodes, it is necessary to determine the values of the parameters Ex_l, Im_l and Fl_l, $l = 1, \ldots, T$. This is achieved in the same way described for the final nodes.

3. **Obtaining the final value of the profits associated with the MoS** Suppose the earlier process of backward planning is finished. Then, for each scenario r of the decision date j, we have the optimum profits associated with the shipping line operations during the subsequent planning T years(denoted as $F^*(r)$). Moreover, from the information provided by the tree, we know the probability of each of the $R(j)$ scenarios of j. Denote by p_r the probability of occurrence of the scenario r of j. Therefore, we can calculate the expected value of the profits of the shipping line during the T years of operations between the decision dates j and $j+1$ using the following expression:

$$\text{Rent}(j) = \sum_{r=1}^{R(j)} p_j^r \cdot F^{*r}(j).$$

   By discounting and accumulating the expected values for each of the possible N decision dates, we obtain the expected profits for the planning period of $(N+1) \cdot T$ years:

$$\text{Rent} = \sum_{j=0}^{N} \text{Rent}(j)(1+\eta)^{-jT}.$$

2.2.3 Numerical example of strategic planning for an MoS

To illustrate the methodology proposed in sections 2.2.1 and 2.2.2, we will consider the tree obtained in 2.1.3, and an MoS with the characteristics described below. To develop this example, industry benchmarks have been used, as well as data from various studies on short sea shipping in various countries ([4], [19], [26]).

Let's look at an MoS designed to cover a distance between the port of origin and destination of 350 miles at a rate of 3 daily sailings in each direction. We will make a strategic plan for operations over 15 years, while setting two decision dates for the renewal of the fleet mix – at year 5 and year 10 . A risk discount adjusted rate of 17% is set for the project. The charter market

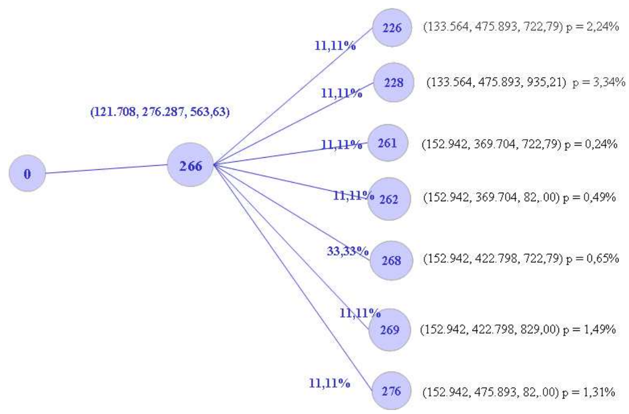

Figure 4: Caption for arbolpeque

is setting a rate of 19% for short-term contracts (5 years) and a bonus of 20% for long-term contracts (10 years).

Five different types of ships are available that match the transport mode and expected demand. The key differentiating characteristics are: ([19]):

1. **Ship type 1: BGV C180.** This is a fast, modern vessel with a capacity of 162 containers, a speed of 35 knots, and a fuel consumption of 192 tons per day. Its cost is $86,400,000 and the 5-year charter cost is $10,013,440. It can handle 50 movements an hour loading and unloading, and between 513 and 785 sailings a year, depending on the cargo.
2. **Ship type 2: BGV C230.** From the same family as the BGV C180. It has a capacity of 460 containers, a speed of 35 knots and a fuel consumption of 192 tons per day. It costs $174,171,563 and the cost of a 5-year charter amounts to $12,622,172. It can handle 50 movements an hour loading and unloading, and between 313 and 785 sailings a year, depending on the cargo.
3. **Ship type 3: Fast RORO.** Conventional RORO ship - faster than anything in its class. It has a capacity of 370 containers, a speed of 22 knots, and a fuel consumption of 110.4 tonnes per day. It costs $46,000,000, and the cost of an 5-year charter is $7,573,794. It can handle 30 movements an hour in loading and unloading, and between 220 and 510 trips per year, depending on the cargo.
4. **Ship type 4: Very fast monohull RORO.** A new trend in transport shipping. It has a capacity of 200 containers, a speed of 25 knots, and a fuel consumption of 144 tons per day. It costs $64,500,000 and the cost of a 5 year charter is $8,690,959. It can handle 30 movements an hour loading and unloading, and between 321 and 580 trips per year, depending on the cargo.
5. **Ship type 5: Tote 648.** Very large and fast ship for high volumes of demand. It has a capacity of 1296 containers, a speed of 25 knots, and a fuel consumption of 144 tons per day. It costs $150,000,000 and 5-year charter amounts to $13,854,072. It can handle 80 movements an hour loading and unloading, and between 195 and 576 trips per year, depending on the cargo.

As an illustration, let's consider the section of the tree of scenarios built in 2.1.3 and shown in Figure **??**. Following the methodology presented in 2.2.2, we will proceed to resolve the optimization problem for each of the final scenarios. The following table shows the composition of the fleet, as well as the maximum profits associated with each of these scenarios:

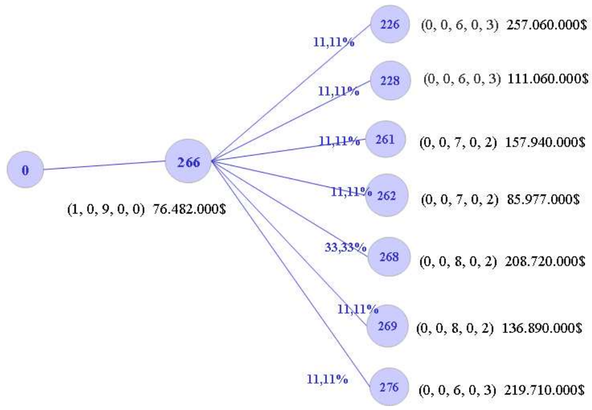

Figure 5: Caption for Solfin

Label node	Maximum profits ($))	Optimum fleet
226	257,060,000	(0. 0. 6. 0. 3)
228	111,060,000	(0. 0. 6. 0. 3)
261	157,940,000	(0. 0. 7. 0. 2)
262	85,977,000	(0. 0. 7. 0. 2)
268	208,720,000	(0. 0. 8. 0. 2)
269	136,890,000	(0. 0. 8. 0. 2)
276	219,710,000	(0. 0. 6. 0. 3)

Using the previous solutions, let's look at the problem of optimization for the intermediate node 266, where the objective function incorporates the expexted charter bonus shown in 2.2.2. The resolution of this problem provides us with an optimal fleet consisting of 1 type-1 ship, and 9 type-3 ships with maximum profits of $\$76,482,000$. Figure **??** shows all the optimal solutions obtained for this section of the tree.

The complete resolution on the tree of the corresponding optimization problems provides us with a new scenario tree where, associated with each node, we have information on the optimal composition of the fleet and its derived maximum profits. This *tree of fleets and profits* will be key in the methodologies for evaluating the transfers of risk associated with the clauses studied in Section 3.

Note that obtaining the final level of profits associated with the project, as well as the corresponding optimal fleets for each scenario of the tree, has a high computational cost. Loops must be implemented to sequentially resolve the various optimization problems and automatically update the parameters. Therefore, the information provided by the algorithm for generating a tree of scenarios described in 2.1, should be linked to the routine resolution of the corresponding optimization problems.

The optimization problems in the example 2.2.3 have been resolved using the SBB solver supplied as part of the GAMS program; and which develops a type of nonlinear Branch and Bound. A non-linear problem is resolved at each node of the Branch and Bound tree. Specifically, the SBB solver can use either the CONOPT or MINOS solvers and a combination of both has been used to obtain the results of the numerical example.

2.2.4 Forward planning on the scenario tree of an owned fleet

For an owned fleet, planning must be done *forward* on the scenario tree, and the objective function in the optimization problems associated with each node must be modified to incorporate possible gains/losses derived from selling a ship belonging to the fleet mix that will no longer be used. The formal modifications of the objective functions are the following:

Repayment cost In this case, C_Λ will denote the total repayment cost of the fleet during the planning period and Λ_k the annual repayment cost of a type k ship. Then C_Λ is given by the expresion:

$$C_\Lambda = \sum_{k=1}^{m} x_k \Lambda_k \left(\frac{1}{\eta} - \frac{1}{(1+\eta)^T \eta} \right),$$

where the repayment period is considered to be longer than the planning period considered. Additionally, Λ_k can be obtained as follows:

$$P_k = \sum_{l=1}^{T} \frac{\Lambda_k}{(1+r'_k)^{l-1}} = \Lambda_k \left(\frac{1}{r'_k} - \frac{1}{(1+r'_k)^T \cdot r'_k} \right),$$

being P_k the acquisition price of the ship at the beginning of the planning period and r'_k the repayment rate interest. We call Λ_k the *base repayment*.

On the other hand, if $(x_1^*(s), \ldots, x_m^*(s))$ denotes the optimal fleet associated with scenario s in decision date $i-1$, then the following expression quantifies, for a scenario r in decision date i, the variation in the *base repayment* derived from the ulterior acquisition of ships at a price that may be different from the price initially considered:

$$\Delta Amort(r,s) = \sum_{k=1}^{m} \text{Max}\left\{ x_k(r) - x_k^*(s), 0 \right\} \cdot a_k \cdot \left(\frac{1}{\eta} - \frac{1}{(1+\eta)^T \eta} \right)$$

where a_k denotes the percentage of annual variation of the *base repayment* Λ_k.

Divestment cost Selling a ship at decision date i, implies potential gains or losses depending on the behaviour and liquidity of the second hand ship market. Next expression quantifies this fact:

$$\Delta Desinv(r,s) = \sum_{k=1}^{m} \text{Max}\left\{ x_k^*(s) - x_k(r), 0 \right\} \cdot d_k \cdot \left(\frac{1}{\eta} - \frac{1}{(1+\eta)^T \eta} \right)$$

where d_k denotes the factor that models our expectations on the behaviour of the market at date i.

3 Evaluation of risk transfers

This section deals with the evaluation of risk transfers between agents in the chain. We use the results of strategic planning and discuss the options embedded in strategic and operational clauses governing sector agreements. Note that these clauses must be framed within a design that respects the traditional type of agreements used in the sectors involved. In particular, in the land business the most common method for managing port terminals is the granting of a build-operate-transfer (BOT) concession. This is a type of Private-Public Partnership (PPP) between port authorities and terminal operators, where the terminal operator is responsible for part of the construction and operation of the terminal for a certain period of time, after which ownership of the infrastructure reverts to the port authority. In contrast, in the maritime business, agreements often take the form of an Equity Joint Venture (EJV) among shipping companies and/or ship charterers, and these can operate their own or chartered ships. Given the high risk involved in such a chain, another type of possible partnership for the business is a Public Private Partnership (PPP). Under this system, a public authority purchases the ships and offers a form of *soft charter* to the shipping companies operating the line.

3.1 Compensation clauses

The design of the compensation clauses under this section is based on the structure of dynamic clauses for sharing profits and losses as used by joint ventures and strategic alliances for regulating transitional periods – in which one partner has losses in excess of their percentage of ownership in the joint venture, or over an amount stipulated in the agreement ([14], [15]). In the particular case of land-maritime transportation chains, we distinguish between the design of a compensation clause for the *land business*, and the corresponding clause for the *maritime business*.

3.1.1 Compensation clauses for the land business

Structure of the clause The purpose of this clause is to prevent the failure of the transportation chain. To this end, the consortium ensures a TO a minimum income while the business is in a consolidation phase through a compensation fund. It also provides a mechanism for the recovery of compensation funds paid when revenues of the TO are above the reference minimum (for a review of this clause in the context of economic-financial equilibrium of concession contracts for port terminals see [16]).

The system for determining the payment into a compensation fund or refunds will depend on the following conditions:

- Condition 1: If the accumulated revenues plus the funds received, less refunds contributions made, is below the guaranteed minimum.
- Condition 2: If the compensation fund is exhausted.
- Condition 3: If the business is in a consolidation phase, or is already established.
- Condition 4: If the TO has outstanding debts with the consortium for funds previously received.

Figure **??** shows the flow diagram with the basic structure of the compensation clause in a given year j. We denote APVR(j) the current value of the accumulated present value of revenues of the TO until the year j. A floor is then set for APVR(j), whose value of $\mathscr{B}_j$ in each year j is established by the consortium (a certain percentage of the expected APVR(j) may be suitable as the floor in the clause). Additionally, the consortium sets a maximum ϖ for the compensation fund and a number $\eta \in \mathbb{N}$ to better define what is regarded *consolidated business*: the TO business in the year j is assumed to be consolidated, if for η consecutive years prior to j, the accumulated present value of revenues is above the established minimum. That is to say, there is a year $r < j$ that satisfies the following condition:

$$\text{APVR(r + s)} \geq \mathscr{B}_{r+s} \quad \forall s = 1, \dots, \eta.$$

Also, if we denote Φ_j as the amount of fund received in the year j and Ψ_j as the amount of the corresponding payment for the possible refund, then the present value of accumulated funds received by the TO in previous years will be denoted by APVΦ(j $-$ 1) and, respectively, the refunds will be denoted by APVΨ(j $-$ 1).

If the accumulated present value of revenues of the TO, together with the accumulated present value of funds received, minus the accumulated present value of refunds made during previous years (APVR(j)+APVΦ(j-1)-APVΨ(j-1)) is below the floor $\mathscr{B}_j$, then an evaluation should be made as to whether the total compensation made exceeds the maximum amount ϖ set for the fund. If so, the TO cannot receive a fund, and therefore $\Phi_j = 0$. Otherwise, it must be determined if the business is already established. If yes, then again $\Phi_j = 0$. However, if the business is not established, the operator will receive a fund for the total deviation with respect to the floor $\mathscr{B}_j$: providing the fund does not exceed the amount of the balance of the compensation fund at the date j given by ϖ-APVΦ(j-1).

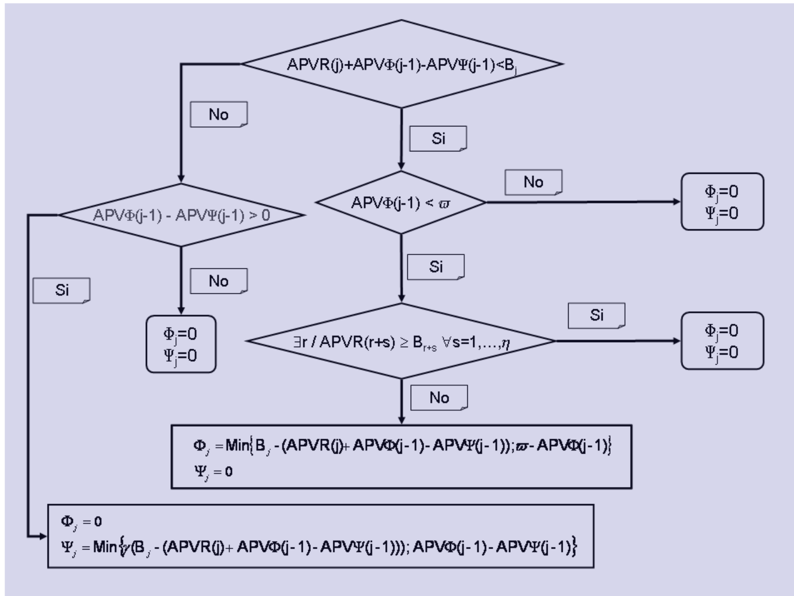

Figure 6: Caption for diagram

If, by contrast, the accumulated present value of revenues of the TO, plus the present value of the funds received, minus the present value of refunds made in previous years is above the floor $\mathscr{B}_j$, then the amount of outstanding debt must be computed as given by APVΦ(j-1)-APVΨ(j-1). If there is outstanding debt, the value of the refund Ψ_j is calculated as a γ percentage of the excess of APVR(j)+APVΦ(j-1)-APVΨ(j-1) on the minimum $\mathscr{B}_j$. Notice that the refunds are made regardless of whether the business is consolidated, and are only linked to the behaviour of the accumulated revenues with respect to the set minimum.

Embedded options This clause provides rights to the consortium and the TO. From the standpoint of the methodology of real options, this can be considered as a sequence of European-type, path-dependant options and whose number is uncertain because they are subject to compliance with the above conditions. These are European-type options because they can only be exercised on the dates considered in the plan. They are interrelated because either the TO has the option to receive funds, or the consortium has a corresponding option to receive a payment refund. These options are path-dependent because the amount of refund, and the determining conditions, are depend on the record of receipts and payments previously made.

Risk transfer This clause establishes a transitional period of allocation of losses, so that the consortium assumes 100% of the risk of deviations in the amount of the accumulated revenues of the TO with respect to the minimum. Thus, the direct risk that the TO is exposed to because of fluctuations in demand is transferred to the consortium. It also provides a transitional period of allocation of profits, so the consortium can receive a percentage of the profits from the TO as a refund for the compensations previously received. However, a full recovery by the consortium of funds made is not riskless, and there are scenarios where the total fund is lost. Thus, it is necessary to evaluate the transfer of risk associated with the special design of this clause.

For this, we simulate the probability distribution of the random variable $APV\Phi(\tau)-APV\Psi(\tau)$, where $APV\Phi(\tau)$ denotes the accumulated present value of funds received up to the termination of the agreement at τ, and $APV\Psi(\tau)$ denotes the corresponding value of the repayments made.

Once the probability distribution is known, the most appropriate risk measure can be calculated (*VAR, CVAR, ES*).

Algorithm for risk evaluation

1. Monte Carlo simulation of the revenues of the TO to determine the values of $\mathscr{B}_j$ at each decision date j. The expected value of accumulated revenues untill the year j, or a percentile of its probability distribution, can be considered appropriate for the role of floor for the activation of compensation rights.
2. Simulation of an m-dimensional path $\bar{S}(j) = (S_1^k(j), \ldots, S_m^k(j))$ of the underlying processes in the tree, and obtaining the corresponding path for accumulated revenues APVR(j), $j = 1, \ldots, \tau$.
3. Proceed forward on the path APVR(j) following the flow chart above to obtain the values of the variables Φ_j and Ψ_j in each of the decision dates $j = 1, \ldots, \tau$.
4. Calculate APV$\Phi(\tau)$ y APV$\Psi(\tau)$ and obtain the difference APV$\Phi(\tau)$ − APV$\Psi(\tau)$.
5. Repeat the process for each of the paths $\bar{S}(j)$ in the simulation, generating a complete probability distribution of APV$\Phi(\tau)$ − APV$\Psi(\tau)$.
6. Calculate the most adequate risk measure (VAR, CVAR, ES).

Numerical example (In process)

3.1.2 Martime business compansation clauses

Note that the clause in 3.1.1 has been focussed on the revenues of the TO, and quantifies deviations of demand with respect to the expectations initially established in the overall plan for the MoS. The requirements of land operations do not make recommendable the wording of the clause in terms of (net) flows – this is due to the risk of moral hazard and opportunistic behaviour on the part of the TO ([31], [8], [30]). However, the maritime business is different and the effect of the factor of efficiency of operations on business results is lesser. Moreover, the uncertainty of price behaviour regarding the price of fuel must be taken into account when determining entitlement to any compensation in combination with demand. The first significant difference between the model of compensation clause in the land business when compared with this type of clause for the maritime business is seen by the use of accumulated present value of (net) flows $APVF(j)$; instead of the corresponding accumulated present value of revenues $APVR(j)$.

Although the focus of the clause is the same as 3.1.1, the algorithm for the implementation and subsequent risk evaluation is different because it is phrased in terms of flows, and it must necessary look for information stored in the tree of scenarios so as to associate each simulated path with a fleet for each decision date; and consequently, with optimal flows derived from the operation of the fleet. The resulting algorithm is shown below:

Algorithm for risk evaluation

1. We use the scenario tree to calculate for each decision date j, the probability distribution of the variable $APVF(j)$. We establish the value of $\mathscr{B}_j$ which will act as a floor for the compensation mechanism.
2. Simulate an m-dimensional path $\bar{S}(j) = (S_1^k(j), \ldots, S_m^k(j))$ of the underlying processes in the tree. Then, for each date j we identify a scenario $e^r(j)$ nearest to $\bar{S}(j)$ (Euclidean distance) and transform the original path $\bar{S}(j)$ into a path of nodes $\bar{e}(j)$ so that we then have the corresponding path of the business flows.

3. Proceed forward on the path $\bar{e}(j)$ following the sequence of steps described in the flow diagram in **??** to obtain the values of the variables Φ_j and Ψ_j for each of decision dates $j = 1, \ldots, \tau$ and, finally, the value of the variable $\mathrm{APV}\Phi(\tau) - \mathrm{APV}\Psi(\tau)$.
4. By repeating the process for each of the paths $\bar{S}(j)$ of the simulation, we generate the full probability distribution $\mathrm{APV}\Phi(\tau) - \mathrm{APV}\Psi(\tau)$.
5. Calculate the most adequate risk measure (VAR, CVAR, ES).

Numerical example (In process)

3.2 Restatement of ownership clauses and evaluation of associated risk transfers

To ensure the continuity of an MoS it is necessary to regulate the eventual departure from the agreement of one of the agents through restatement of ownership clauses. Note that for land businesses these agreements mainly take the form of a concession contract, and especially a BOT contract, as discussed in Section 1. The final distribution of property is clearly established in such agreements and mechanisms for the eventual departure of a private agent are regulated in terms of the concession, so that, if it occurs, it will necessarily lead to a new tender for the concession. Therefore, it makes no sense to discuss the design of restatement of ownership mechanisms for these agreements.

In the case of maritime business we will study how to handle this kind of provision using *put* and *call* options, and how to evaluate the associated risk in the following cases:

1. The maritime business adopts a form of an EJV in which one of the partners has a *market price call* option on another partner's share in the EJV.
2. The maritime business adopts a form of an EJV in which one of the partners has a *market price put* option on another partner's share in the EJV.
3. The maritime business adopts a form of PPP in which the public agent owns the ships and also owns a *market price put* option on all, or part, of the fleet.

In the case of EJVs, when we discuss *market price put* and *market price call* options we are referring to options whose exercise price is fixed as follows:

- The market price M of the shares is taken at the specified time after receiving a notification from a partner who intends to exercise his rights.
- Three additional prices are obtained P_1, P_2 and P_3 as determined by three independent valuation companies (taken from a previously agreed list), as the result of an appraisal process.
- The highest and lowest prices are eliminated. Let's call the remaining price A. During the subsequent development, we consider that A is a proxy of the real value of the business - considering the resources available at the time of appraisal.
- For a call option, the price is set at $\max(M; A)$. This ensures at least the market price of the shares, and removes the possibility of opportunistic advantage being taken of market in a downward trend. Otherwise, when the value of M is higher than A, we shall see how – from the standpoint of risk assessment – the partner who has transferred his rights is favoured.
- For a put option the price is set at $\min(M; A)$. This will mean that the option will be exercised when the two prices are similar. For example, if price M is less than value A, then the holder of the put will receive for his part of the business a value less than the proxy of the real value A; and so he will wait until both values are closer together. In the opposite case, in which M is more than A, there is obviously no motivation for exercising the put option at the value of A when a higher price could be obtained in the share market.

3.2.1 Restatement of ownership clause with a *market price call option*

Structure of the clause Suppose one partner has a call option on the part α of another partner in the EJV with an exercise price of $\max(M; A)$ – as obtained using the above procedure. The option holder may exercise his right during a certain period stipulated in the agreement $[\tau_1, \tau_2]$, and in each of the exercise dates covered by this planning period.

Embedded options Bermuda-type call option.

Risk transfers In a prototypical case of a restatement of ownership clause through a call option, the risk that a partner assumes by giving away option rights is the loss of profits arising from the possible exercise of an underlying expansion option in the EJV.

To illustrate this idea, let's take the real case of a joint venture signed in 2002 between BMW and Brilliance for the construction of a plant in China for manufacturing and selling limousines in the Chinese market. The agreement also stipulated that BMW was the holder of a call option on the Brilliance part of the venture. In 2007, in view of the results, the venture was expanded with the construction of a new manufacturing plant to produce limousines and cars for the Chinese market. Thus, the risk assumed by Brilliance in agreeing such a call option was the eventual loss of the flows arising from the planned expansion due to an exercise of the option prior to the expansion.

Note that although the exercise is conducted at the *proxy* A of the true value of the company, such valuation A would have been made on the resources available to the company at the moment of exercise - meaning the current plant and the estimated current market, and not taking into account new plant or new markets.

In the case we are examining, let's consider as an estimation of A, the flows derived from the fleet that the JV currently operates as if it continues operating unchanged, and as an option for expansion, the possibility of replacing the fleet so as to take optimal advantage of an expansion in demand. To quantify the risk assumed by a partner who gives away a call option, we will compare this value A with the flows associated with the optimal fleet that could be operating from the exercise date on.

To assess risk, we consider A as a reference value for the EJV because if M were greater than A, meaning that the market over-value the EJV, then the potential losses from exercising the call option would be less than if the price was A.

In a prototypical case, the risk borne by ceding the call lies in the difference that may exist between the price received and the value of the venture when including the growth options (less the investment required to implement these options). The decision on whether to make the additional investments generally depends on internal business decisions. The price at which it is exercised may be less than the value of the venture once additional investment decisions are taken. In this case, the exercise of the call deprives the seller of the additional profits derived from the growth options.

Algorithm for risk evaluation Let's look at the planning tree for an owned fleet constructed in 2.2.4. For each possible exercise date j in $[\tau_1, \tau_2]$ and for each scenario on the tree $e^r(j)$:

1. We take as a proxy of A, the profits made for the EJV with the assets which the venture has at the time of the exercise of the option, i.e. the fleet currently operating from the date j on. Denote this value $\bar{A}^r(j)$.
2. Consider the profit $F^{*r}(j)$ as earned by the EJV from the optimal fleet associated with scenario $e^r(j)$ as stated in the tree 2.2.4.

To obtain the probability distribution in τ_1 which will enable us to quantify the risk from the exercise, proceed as follows:

1. In the final scenarios of τ_2, we calculate $\max \alpha(F^{*r}(j) - \bar{A}^r(j)), 0$.
2. In the intermediate nodes, we calculate $\max \alpha(F^{*r}(j) - \bar{A}^r(j))$, continuation value

Calculation of $\bar{A}^r(j)$ Note that there is no a single fleet currently associated with the scenario $e^r(j)$. The tree provides us with a fleet operating in the period between $j-1$ and j for each scenario of $j-1$ associated with $e^r(j)$. Therefore, we must quantify the profits of using each of these fleets in $e^r(j)$, and then weigh the results using transition probabilities to derive the value of $\bar{A}^r(j)$.

Numerical example (In process)

3.2.2 Restatemnt of ownership clause with a *market price put option*

Structure of the clause Suppose one partner owns a put option on his part of an EJV with exercise price $\min(M; A)$ obtained by the above procedure. During a period stipulated in the agreement $[\tau_1, \tau_2]$ and in each of the dates stipulated in this period, the option holder may exercise the right.

Embedded options Bermuda-type put option.

Risk transfers In a prototypical situation, the risk borne by the partner who cedes a *market price put option* results from the unfavourable position in which he may find himself after the option is exercised (strategic risk). To illustrate this idea, let's take the real case of the joint venture signed in 2000 by General Motors Corporation (GM) and Fiat S.p.A. (Fiat). In this alliance the two companies will partner in the European and South American automobile markets. As part of the agreement, GM cedes Fiat a put option so that, between the third and a half and the ninth year, on two occasions, Fiat may require a determination of the fair market value of Fiat shares. Then Fiat may decide to exercise its option an sell its shares to GM.

Five years after the sighed of the agreement, Fiat announced GM its intention of exercising its put option. The analysis of the different scenarios faced by GM led it to the conclusion that its position after the exercise would be strongly financially adverse. Then GM regarded two financial transactions carried out by Fiat to be a material breach of section 6 of their agreement regulating transfers of shares with third parties. According to the termination provisions, General Motors would have the legal right to terminate the agreement, prevailing the rules of liquidation over the put option Fiat intended to exercise. This fact forced Fiat into negotiation to avoid a costly and difficult legal process that would determine whether a material breach occurred. The result of the negotiation was the payment by GM of 1.55 billion euros to Fiat in order to *repurchase* the put option that was not finally exercised by Fiat.

As this example points out, a methodology for estimating the risk associated with this ty of clauses should take into account the potential losses from adverse market reactions following the exercise of the put (a reaction to the divestment), and the possible losses caused by the continuing activity without the partner (with or without additional investments) ([14]).

In our case of an MoS, we must highlight the fact that the SA provides a compensation mechanism that transfers the risk of the put option to the compensation clause described in **??**. This is an example of how SAs and JVs often include a hierarchical structure of clauses, which interact among them. Therefore an evaluation of risk transfers associated with a given clause can not be made by considering the clause as isolated but analyzing the complete agreement.

3.3 Resatement of ownership clauses in a PPP for a maritime business

Structure of the clause Suppose that the public agent has a *market price put option* on all or part of the fleet. The exercise of the option is subject to a stability of demand, and therefore to the consolidation of the business, and this stability will trigger the option. The exercise price is set at the market value of the second-hand ships.

Embedded options European-type option with an uncertain exercise date depending on a trigger, which is path-dependant.

Risk transfers Note that the risk borne by the private operator when ceding the put option to the public partner results from having to sell with possible losses (due to limited market liquidity) several ships of the current fleet mix, as this current fleet mix differs from the optimal fleet able to handle future demand expectations.

If when the put option is exercised, a given ship is part of the optimal fleet, then there will be no losses because the ship will continue operating. Otherwise, the ship must be sold and the calculation of potential losses is a function of the sales strategy set by the private operator. For example, the operator may choose to continue using the ship until finding a buyer prepared to pay a price equal to, or higher than, the price paid as exercising price of the put option. The operator may set a limit beyond which it should sell, even at a loss.

Algorithm for risk evaluation Let's look at the planning tree for the case of a chartered fleet built in 2.2.2.

1. Simulation of an m-dimensional path $\bar{S}(j) = (S_1^k(j), \ldots, S_m^k(j))$ of the underlying processes in the tree. Then, for each date j we identify the scenario $e^r(j)$ closest to $\bar{S}(j)$ (Euclidean distance) and transform the original path $\bar{S}(j)$ into a path of nodes $\bar{e}(j)$, so that we have associated with each node the corresponding maximum profits for the business.
2. We identify the first date j_0 and the corresponding node of the tree on which the business is consolidated.
3. Determine how many ships are not part of the optimal fleet for the following period.
4. Simulate the second-hand ship market.
5. Quantify the losses in terms of sales strategy. Consider the present value.
6. Repeating the process for each of the paths $\bar{S}(j)$ of the simulation, we generate the full probability distribution of losses, on which we calculate the most appropriate measure of risk (VAR, CVAR, ES).

Numerical example (In process)

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