Lorena Para-González
Carlos Mascaraque-Ramírez
Ana E. Madrid

http://dx.doi.org/10.21278/brod69305
ISSN 0007-215X
eISSN 1845-5859

OBTAINING THE BUDGET CONTINGENCY RESERVE THROUGH THE MONTE CARLO METHOD: STUDY OF A FERRY CONSTRUCTION PROJECT

UDC 629.5.01
Original scientific paper

Summary

The naval sector of new construction is characterised by high cost programmes and a low degree of definition in the stages of tendering. With these requirements, an initial, highly-competitive budget should be developed with acceptable risk. For this reason, it is usual in this field for a budget Contingency Reserve to be defined, in order to cover probable range increments, as well as probable deviations that could trigger economic losses. The budget Contingency Reserve estimate is usually carried out based on shipyard experience. However, problems arise when the shipyard does not have enough experience in the concrete type of vessel to be built. In this research, the use of an extension of the triangular Monte Carlo distribution model is proposed, with the aim of calculating the likelihood of complying with the calculated budget. From this result, a Contingency Reserve that provides enough security to execute the project within the limits of the economic risk defined by the organization can be calculated. The proposal introduced in this study allows managers to obtain a more optimal estimate of the Contingency Reserve, therefore reducing economic risks.

Key words: *uncertainty; Budget Contingency Reserve; Monte Carlo simulation, Project Management; shipbuilding projects.*

1. Introduction

In shipyards dedicated to new construction, for example, the production of merchant or military vessels and offshore structures, it is common to find difficulties when elaborating budgets, which is mainly due to two factors. The first one is the need for adjustment to current market prices, a necessity that arises in a highly globalised sector and with great competition from Asian countries [1]. The second factor is that generated by the uncertainty that emerges in naval projects. This is due to the fact that shipyards build a limited number of units per series, making it difficult to apply mass production techniques. Therefore, it is difficult to optimize series production lines when only 2 or 3 units of a vessel are produced. In addition, it is common to apply modifications among the different ships in the series, on account of technological changes and the introduction of improvements from one vessel to the next in the series. This increases the problem of using production techniques from other sectors, such as those of automobile and aerospace. It is therefore advisable to work under the concept of independent unit construction or prototypes [2]. In this respect, the research of Kolić, Lee and Fafandjel [3] identified the necessity of mitigate risks in large engineering construction project (LECP), especially in the case of prototype vessels, using Monte Carlo simulation to execute a contract risk analysis so that shipyard management could choose the contracting model with the least amount of risk.

Shipyards have to take their historical data into account, which are very useful for the generation of production simulation models [4], in order to be more efficient and competitive. Similarly, an alignment between design and manufacturing must be sought [5]. The studies of Song, Woo and Shin [6] on the systematisation and progress of shipbuilding production management for a flexible and agile response, reducing time and cost, show the importance of always maintaining the idea of the shipyard as a company in terms of the fulfilment of the budget calculated for the project.

The agreed on budget in the bidding process will not only have an impact on the production of the vessels, but will also be relevant for the life cycle of the project and the need to extend the lifespan of the ships [7]. At the same time, these budgets will be crucial in order to define the company's competitiveness [8] and the risks they are able to take in reducing the sale price of their ships [9].

It is well known that the design of a ship evolves during its construction and undergoes multiple modifications, as a consequence of the spiral design itself and the improvements applied in the successive ships in the series [10]. But this circumstance is difficult to translate to the project budget, since the budget will evolve and will be revised throughout the life of the project [11]. However, the total amount agreed on in the contract between the manufacturing shipyard and the ship operator will always be maintained, with different management tools put into practice in order to control the cost and the execution time of the shipbuilding projects [12].

Following the model developed by the Project Management Institute (PMI) [13], the project budget is made up of two large components: the cost baseline or control accounts and the management reserve. In turn, the cost baseline is divided into the Contingency Reserve and the work package cost estimates.

Regarding the project budget stipulated in the contract, it becomes key, due the nature of the bidding process, to develop a calculation as reliable as possible of the total amount at an early stage [14]. These international biddings have turned into very disputed processes, where the different shipyards present their offers with adjusted term and cost offers [15].

Due to the uncertainty of most projects, it is necessary to endow the budget with the relevant entry of Contingency Reserve to bear the impact of cost deviations. These variations are usually produced by range variations, changes in timetable rates, modifications of the suppliers' prices [16], etc. Contingency Reserves are often viewed as the part of the budget intended to address the "known unknowns" that can affect a project [13].

It is common for companies to calculate management reserves by means of fixed percentages without entering into detailed studies, due to the lack of means to carry out better approximations. That is why different authors have focused their attention on the subject and have tried to develop models capable of covering this need [17].

In the specific case of shipbuilding, being able to estimate the best possible values of the Contingency Reserve is clearly necessary, due to the high cost of the projects to be developed. Therefore, great interest in the definition of calculation models which will be as reliable as possible for the definition of these values, has been expressed. In this sense, there are several deterministic, probabilistic and modern mathematical methods for obtaining the value of the Contingency Reserve, such as the Fuzzy Techniques and Artificial Neural Network [18]. This research is focused on probabilistic methods, and more specifically, on the methods based on Monte Carlo simulations.

In these types of probabilistic techniques, it is very important to study different probabilistic distributions, because depending on the chosen option, the results may vary. Therefore, it is necessary to know how to make the most suitable choice, depending on the characteristics of the project being analysed. In this regard, several authors have compared different probabilistic distributions with the intention of optimising the results obtained [19, 20]. This research will carry out a study in this line, with the aim of contrasting the results for the prediction of the management reserve, with two different probability distributions for the Monte Carlo method. Another area this type of methodology could be used in is risk analysis. In fact, although in this research the methods developed will only be presented for cost estimation, they could also be developed for the field of risk analysis, as noted in recent publications [21, 22]. Similarly, these methodologies are also employed in areas such as the cost estimate for decommissioning [23] or in the search for optimal maritime harbour design and improvement [24]. The use of the Monte Carlo model can also be implemented in design, prediction and probabilistic analysis tools, such as, for example, those used in collision and grounding analysis [25], in the study of reliability-based inspection planning [26], or in economic modelling, in order to reduce costs at different stages of the project, such as reducing the cost of ballast tank corrosion [27]. All these examples show that the tool and methodology presented in this research are of great applicability in the naval sector.

In order to lessen project control uncertainty, the Monte Carlo method has become a useful method [28]. For this reason, this study proposes a new methodology with the aim of estimating the Contingency Reserve of the budget using the Monte Carlo method. The final purpose is to provide managers with a better global budget, so as to improve the controlling process [29]. As a whole, what is sought is not only the success of the project, but also its efficiency [30], since without a good initial budget estimate for this type of project, costs can exceed the market price and make the project unfeasible [31]. In this respect, it is important to control both the budget and the costs of the project throughout its execution [32]. This is why the use of predictive cost models, such as those developed by Adoko, Mazzuchi and Sarkani are recommended [33].

The proposed methodology is appropriate for both the initial budget calculation and the revision of the budget throughout the project, as current research, such as that of Chou suggests [34]. These calculation tools are of special interest in large-scale projects, where the requirements to meet deadlines and costs are even more demanding. Therefore, recent works such as [35], focus on the importance of the schedule and budget of long-term projects, like those involving shipbuilding, where project definition at the earliest stages will help to achieve the above commented objectives.

2. Objectives

This research has as its main goal the estimation of the Contingency Reserve of new shipbuilding projects. In order to achieve this objective, the Monte Carlo method will be employed by using different probabilistic distributions and its verification will be realised through a specific case study: the construction program of a series of 3 ferries.

Results will be focused on improving decision making for shipyard managers. Moreover, the principal advantages and disadvantages of each calculation model employed will be specified. In addition, several guidelines will be developed in order to be able to implement each variant of the Monte Carlo model., Therefore, it will be applicable to other large scale projects, either in the naval or other sectors like automobile, aerospace, metallurgic, aeronautic, etc.

3. Monte Carlo method application procedure

With the aim of accomplishing the stipulated goals, it is necessary to become familiar with the calculation options of the Contingency Reserve through the Monte Carlo method, as well as the basic criteria for its proper execution.

As a consequence, in the following paragraphs, the methodology employed for the Monte Carlo simulations will be described, as well as the recommended calculation methodology for the different budgets with which it can be accurately used.

3.1 Description of the Monte Carlo method for the budget Contingency Reserve estimate.

The budget Contingency Reserve of a large scale project should be calculated with particular care. If its value is too high, the project will not be competitive in the bidding processes, [15] while if the value is too low, it could lead to losses, even causing the company to go bankrupt [36].

Inside this framework, a method as reliable as possible for the attainment of the Management Margin should be developed. In this sense, the Monte Carlo method has been established [13], and its refinement and precision has been sought, employing different probability distributions.

Before using the Monte Carlo technique, a preliminary budget is calculated, also estimating the probability of its compliance. The most current bibliography in Project Management [13, 36], recommends that the final budget for the project have a reliability rating of between 80% and 90%.

The difference between the base budget, calculated using the different budget estimation techniques [37, 38], and the budget calculated with a reliability of between 80% and90% will be the amount that comprises the Contingency Reserve concept.

This number is significantly high, with values that vary between 5% and 15% of the total quoted [13], which implies that it should be calculated as accurately as possible.

With this aim, the present research develops the Monte Carlo method by using two alternatives: triangular distribution and an extension of it.

3.2 Triangular distribution for the Monte Carlo method

Triangular distribution, whose density function is given as

$$f(x \mid a,m,b) = \frac{2}{b-a} \times \begin{cases} \frac{x-a}{m-a} & if \quad a \le x < m \\ \frac{b-x}{b-m} & if \quad m \le x \le b \end{cases} \tag{1}$$

requires three parameters or points (a, m and b) for its calculation. In the budgetary context [39] these points are defined as:

- Base budget or most likely budget: m.
- Most optimistic budget: a.
- Most pessimistic budget: b.

The first one, the base budget or most likely budget, is obtained by the different internal calculation processes and corresponds to the probabilistic distribution mode. This budget can be calculated using different procedures. This will depend on the shipyard and can range from the use of historical data to the use of a formula adapted for the type of vessel to be built. In the case of this research, the formulation developed by Alvariño-Castro, Azpíroz-Azpíroz and Meizoso-Fernández [37] has been used. This formulation is employed to estimate the budgets of merchant vessels in the initial stages of the projects, starting from the basic data of the vessels, such as the length, breadth, deadweight, installed power, etc.

The most optimistic budget is the lowest, corresponding to the lower end point of the probabilistic distribution.

At the other extreme, the most pessimistic budget is the highest, and corresponds to the upper end of the probabilistic distribution. In Figure 1, the three points that define the triangular distribution are shown as employed for the calculation of the budget.

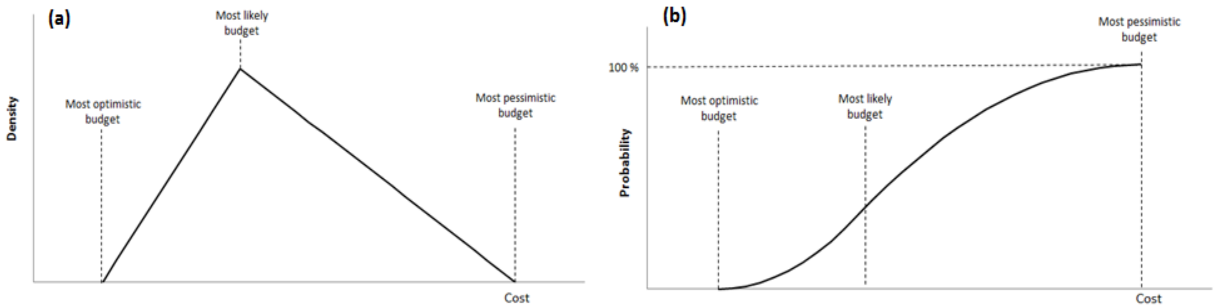

Fig. 1 Triangular distribution applied to budget generation: (a) Density probability function; (b) Cumulative distribution function

By definition, the integral of the density curve will have the value of 1, as can be observed in Figure 1b. In this regard, depending on the cost value calculated for the most optimistic, the most pessimistic and the most likely budgets, the density value assigned to the point of the most likely budget will vary, always maintaining the principle that the integral of the resulting curve will be 1.

In Project Management, it is common to use the Monte Carlo method with the triangular distribution for budget generation, since the literature has validated its use [40].

3.3 Extension of the generalized triangular distribution for the Monte Carlo method

The extension of the generalized triangular distribution [41], known as TSP using its English acronym (Two-Sided Power distribution), whose density function is given as

$$f(x \mid a,m,b,n) = \begin{cases} \dfrac{n}{b-a}\left(\dfrac{x-a}{m-a}\right)^{n-1} & if \quad a < x < m \\ \dfrac{n}{b-a}\left(\dfrac{b-x}{b-m}\right)^{n-1} & if \quad m \le x < b \end{cases} \quad \text{and } n>0 \tag{2}$$

extends the classic triangular distribution in Figure 1, through a fourth parameter or calculation point, n, for which it will be necessary to provide more information about the model [42]. This new alignment produces a distribution of density with very diverse shapes, as can be observed in Figure 2.

This fourth point modifies the shape of the distribution curve, due to the fact that it provides two types of data: its value on the x-axis, i. e. the cost value given by the specialist, and the probability of compliance with this budget, which is translated into the value of the integral of the probability curve up to this point, which will give a concave or convex shape to the curve.

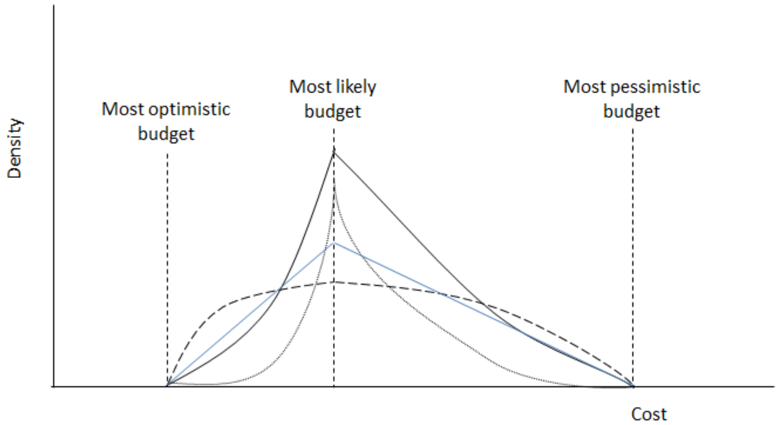

Fig. 2 Density probability functions of TSP distribution applied to budget generation

In order to operate with this distribution in the budget generation context, 4 points are necessary [43]:

- Base budget or most likely budget
- Most optimistic budget
- Most pessimistic budget
- The value of the n parameter, obtained from the data provided by the specialist

The three first points are similar to the ones described in the previous section. The fourth point is the one that is new and necessary for this extension. The calculation of this fourth point can be carried out using the following information:

- A budget value provided by a specialist in the area to be analysed
- The assignation of the compliance probability value given by the specialist

The criteria and proceedings for the attainment of each one of the four necessary points, and especially the value of n, will be developed in the following sections.

3.4 Calculation procedure for the base budget of a new shipbuilding project

The first aspect that is necessary to calculate is that corresponding to the base budget of the new shipbuilding project, for one ship or for a series of ships. This value is needed for the distributions employed with Monte Carlo, as a base for all the budget processes of the shipyard [16].

As has been indicated, revisions will be carried out throughout the life of the project, and will evolve according to design and construction changes. The increases or decreases will be managed using the Contingency Reserve. Therefore, the budget value cannot exceed, in any case, the sum of the Contingency Reserve and the initial base budget [36]. If this situation occurs, the budget will be greater than that stipulated in the initial contract, which would mean that the project would have to be written off.

For base budget calculations, there are different proceedings. The most exact one is to start from a calculation executed previously by the shipyard. However, if the shipyard has never executed constructions of this type of vessel before, it is recommendable to use other methods, such as that of Alvariño-Castro, Azpíroz-Azpíroz and Meizoso-Fernández [37] or to follow the cost groups that are developed in the technical manuals of the US Navy [38], represented in Figure 3:

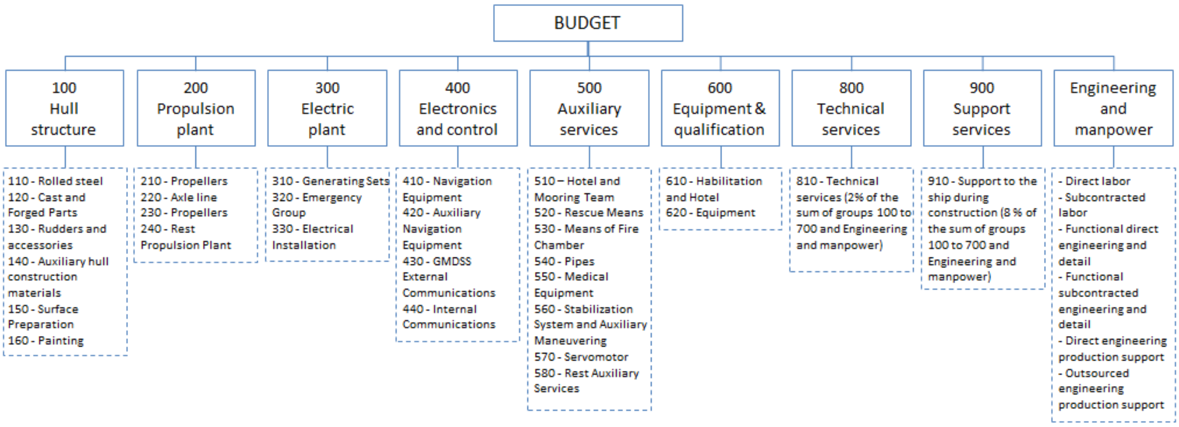

Fig. 3 Structure of the base budget

Regarding the 900 "Support Services" concept, its scope includes all the indirect concepts needed to carry out the project, such as scaffolding, cleaning, insurance for building and construction, management costs, etc.

3.5 More optimistic and more pessimistic budgets of the calculation procedure for ships

Starting from the base budget, disaggregated into every concept shown in Figure 3, the most optimistic and the most pessimistic budgets are developed.

For this aim, a certainty grade is assigned to each concept [13], and corresponding to each certainty grade, a perceptual grade of pessimistic and optimistic value, referenced to the base budget of each concept.

The certainty or definition grade is defined according to the maturity of the design and the knowledge of each concept at the time of budget calculation [16]. The most recent project management theories propose 3 degrees of certainty to be assigned to each concept [13], which are reflected in Table 1. In order to assign a certainty grade to the correct budget item, it is necessary to evaluate the knowledge that the yard has of the item to be assessed, as well as or whether the scope of these activities is known in great or too little detail. An example is the case of the cost of painting. If the surface area in square meters to be painted has been defined for each type of surface finish, a high degree of certainty can be assigned, but if the exact number of square meters and the requirements required for each type of painting are not available, a low degree of budgetary certainty will be provided for this item.

Table 1 Evaluation of the degree of definition of budget concepts

Definition grade	Optimistic budget	Pessimistic budget
Low	-25%	+75%
Medium	-10%	+25%
High	-5%	+10%

Once the definition grade of each evaluated allotment is assigned, the results will be added together, thus obtaining the most optimistic and pessimistic overall budgets.

By obtaining each of these two values, together with the value of the base budget, the three necessary points for the execution of the simulation of the Monte Carlo triangular distribution will be obtained.

3.6 Criteria for the allocation of the degree of compliance with the budget provided by specialists

Referring to the budget provided by the specialist, as has been mentioned in section 3.3 two types of data are required: the budget and the grade of likely compliance.

Regarding the amount of the budget, it is important to choose the specialist carefully, selecting the person who has the best knowledge possible to contribute to this value. This specialist could be part of the shipyard personnel or an external supplier. Research, such as [44], investigates variations in project management practice. For this reason, the evaluation should be different when the specialist is internal rather than external.

When the concepts correspond to work carried out by the shipyard's own personnel, this amount will be requested from the workshop or department that is to carry out the work. In the case of an external supplier, an estimate will be requested from the supplier.

To assign the likelihood of compliance with the budget, the specialist should be evaluated. In order to do this, the following criteria are proposed:

- In the case of an in-house specialist, two values will be taken into account: the first will correspond to the level of automation and optimisation of the workshop where the work will be carried out. The second will be set according to the stability of the business in which the work will be carried out. For example, in the case of a welding workshop, market fluctuations in the prices of the materials used for welding will be assessed.
- Similarly,when referring to an external supplier, two aspects will be valued: the first one corresponding to the supplier’s qualification, following the parameters Tier One, Tier Two or Tier Three [45, 46]; Tier parameters are assigned by the shipyard to its suppliers, evaluating the quality of the services provided, that is, if the expectations of the products have been met within the established deadlines and costs. This assessment is reviewed periodically to keep the information updated, and thus allowing decisions regarding the choice of suppliers to be made. The second valuation will be based on the stability of the business.

Each of these assessments is assigned a certain degree of compliance probability, as shown in Tables 2 and 3, and the final compliance probability with the specialist budget will be obtained as the average between the results of the two assessments.

Consequently, the budget provided by the specialist may be higher or lower than the shipyard's estimate. If it is lower, the probability of compliance should be less than 25%. Conversely, if it is higher than the shipyard’s budget, the probability of compliance should be higher than 50%. These two considerations are necessary for the distribution of the TSP to be well defined.

Applying the above consideration, which is necessary in order to use the TSP distribution, two application ranges are obtained, which are 0% to 25% if the specialist's budget is lower than estimated, and 50% to 100% if it is higher. In order to assign a specific value within each interval, these will be broken down into 3 levels of certainty, following the criteria that were employed in assigning the 3 levels of confidence to the base budget, as defined in Table 1, thus proposing the allocation shown in Tables 2 and 3.

Table 2 shows the values to be allocated in the event that the budget estimated by the specialist is lower than the basic budget calculated by the sales department.

Table 2 Valuation of the compliance grade of the budget provided by the specialist: Specialist budget lower than the base budget.

Automation level and optimization of own workshop or confidence level in the supplier	% Confidence	Stability level of the business	% Confidence
1	25%	1	25%
2	20%	2	20%
3	15%	3	15%

In the event that the budget transmitted by the specialist is higher than calculated, the confidence values shown in Table 3 will be assigned.

Table 3 Valuation of the compliance grade of the budget provided by the specialist: Specialist budget higher than the base budget

Automation level and optimization of own workshop or confidence level in the supplier	% Confidence	Stability level of the business	% Confidence
1	90%	1	90%
2	75%	2	75%
3	50%	3	50%

Once the base budget values, the optimistic budget, the pessimistic budget and the specialized budget are available, along with the degree of confidence for each concept, either the Monte Carlo simulation or the TSP distribution can be carried out.

4. Case study

In order to verify the use of the Monte Carlo method with the two probability distributions described in the previous section, the triangular distribution and the Two-Sided Power distribution, a specific case study will be presented, consisting of a project to construct a series of three ferry-type vessels.

To apply the methodology described above, the following series of steps will be followed:

- Description of ship.

- Calculation of the base budget for the series of vessels.
- Definition of the most optimistic and most pessimistic budgets. This step will be oriented to the application of the Monte Carlo method with triangular distribution.
- Specialist budget and assigned degree of achievement, completing the previous step with the definition of the values needed to apply the TSP distribution.
- Contingency Reserve estimation, comparing the results obtained from the application of the two proposed distributions.

4.1 Characteristics of the ship under study

As the first point of the investigation, a ferry which is representative of the sector must be selected. For this purpose, the Ferry “Volcán de Tindaya” has been chosen. It is a ferry belonging to the ARMAS shipping company.

The choice of this ship is due to the fact that it contains the most relevant properties of the ships of its type, such as dimension, velocity, passenger capacity and route of operation. The “Volcán de Tindaya” services the route Fuerteventura (Spain) – Lanzarote (Spain), which it carries out in approximately 40 minutes, at a service speed of 16 knots. The main characteristics of this ship are reflected in Table 4.

Table 4 Main characteristics of the base ship

Concept	Value
Overall length	78,10 m
Length between perpendiculars	65,50 m
Extreme breadth	15,50 m
Depth to lower deck	4,80 m
Depth to upper deck	9,80 m
Mean draft	3,30 m
Deadweight	450 t
Net tonnage	1114 t
Gross tonnage	3715 t
Designed sea speed	16 kn
Range	2300 miles
Superstructure	3 levels

It is capable of transporting up to 700 passengers, distributed among different lounges and other spaces, such as terraces, cafeterias, etc. The crew consists of 18 people who sleep on board. In addition, it has 110m of 3m wide paved surface for the transport of trucks, and 480m of 2m wide paved surface for the transport of cars. All vehicles are transported in a continuous round cargo space from bow to stern. For the loading and unloading of vehicles, the ferry has two stern ramps of 6.5m in length and 5.5m in beam for vehicles of up to 48 tons. It also has a bow rudder to give access to the bow ramp.

4.2 Base budget of the ship

Following the structure of the technical manuals of the US Navy [38], the base budget of each of the concepts that are shown in Figure 3 has been developed.

The calculations have been based on the reference formulation of Alvariño-Castro, Azpíroz-Azpíroz and Meizoso-Fernández [37], updating the rates to current market values.

Table 5 serves as a summary of the first-level concepts.

Table 5 Base Budget of the construction of a series of 3 Ferries

Concept	Value
100 - Hull structure	4.215.381 €
200 - Propulsion plant	1.871.150 €
300 - Electric plant	3.467.586 €
400 - Electronics and control	582.000 €
500 - Auxiliary services	3.288.006 €
600 - Equipment and qualification	2.789.402 €
800 - Technical services	1.130.470 €
900 - Support services to the manufacturing	4.521.882 €
Engineering and manpower	40.310.000 €
3 vessels total cost	***62.175.877 €***

4.3 The most optimistic and the most pessimistic budgets

Following the criteria established for the definition of the most pessimistic and optimistic budgets, work has been done in each of the concepts of level 2 in the budget, which contained a total of 35 concepts, in some cases falling to level 3 in order to estimate the value in greater detail.

To each one of these last level concepts, a value of definition coefficient (high, medium, low) has been assigned, and the coefficients defined in Table 1 have been applied to it.

Table 6 shows the summary of the values obtained from the optimistic and pessimistic budgets. These values refer to each of the first-level budget concepts. The definition coefficient shown in the table is the average of the coefficients applied to level 2 of the cost concepts, which is the level at which the calculations have been made, and therefore an indicative value that cannot be directly applied to the values in Table 6.

As indicated above, the calculations have been carried out at a more detailed level of cost concepts, level 2, which is too extensive for presentation. Each of the level 2 concepts has been assigned a definition coefficient (low, medium, high), as this is a case study focused on the verification of estimation methods, and not a budgeting case study. The coefficients have been arbitrarily assigned to cover the widest possible range of combinations in order to better evaluate the Monte Carlo method.

Table 6 Development of the optimistic and pessimistic budgets

Concept	Definition coefficient	Optimistic budget	Base budget	Pessimistic budget
100 - Hull structure	High	3.998.772 €	4.215.381 €	4.630.157 €
200 - Propulsion plant	Medium	1.684.036 €	1.871.150 €	2.338.939 €
300 - Electric plant	Medium	3.120.827 €	3.467.586 €	4.334.483 €
400 - Electronics and control	Low	436.500 €	582.000 €	1.018.500 €
500 - Auxiliary services	Low	2.479.464 €	3.288.006 €	5.785.416 €
600 - Equipment and qualification	High	2.649.933 €	2.789.402 €	3.068.343 €
800 - Technical services	Medium	1.017.636 €	1.130.470 €	1.413.383 €
900 - Support services to the manufacturing	Medium	4.070.543 €	4.521.882 €	5.653.533 €
Engineering and manpower	High	38.294.500 €	40.310.000 €	44.341.000 €
3 vessels total cost		***57.752.212 €***	***62.175.877 €***	***72.583.754 €***

4.4 Budget provided by the specialists and their degree of compliance

As for the specialist budget, each final level concept has been studied, defining, in the first place, whether the work will be done by its own staff or by a supplier.

The second step is to obtain the degree of compliance, which will be applied to the budget provided by each specialist. For this purpose, the criteria in Table 2 have been followed, assigning each concept a value between 1 and 3 for the level of optimisation of the workshops themselves or the level of the supplier, and another value of 1 to 3 for the stability of the business.

Taking the values of Tables 2 and 3 corresponding to these allocations and according to whether the specialist budget is higher or lower than the base budget, the degrees of compliance are obtained. Table 7 shows the example of the group "100 - Hull structure".

Table 7 Specialist budget and confidence level assigned for the concepts of the group "100 – Hull structure"

Concept	Base budget	Specialist budget	% Specialist compliance	Own staff/ Supplier	Workshop level or Tier	Business
110 - Rolled steel	2.762.439 €	2.800.000 €	75%	Own	2	2
120 – Cast and Forged Parts	44.985 €	43.000 €	20%	Own	2	2
130 - Rudders	205.350 €	200.000 €	20%	Own	2	2
140 - Auxiliary materials	227.076 €	243.440 €	75%	Own	2	2
150 - Surface Preparation	624.627 €	650.500 €	70%	Own	3	1
160 - Painting	344.757 €	368.600 €	83%	Supply	1	2

4.5 Contingency Reserve estimation

Once all the budget values for each defined concept have been calculated, the Monte Carlo simulation can be carried out.

When it comes to getting the 4 budget points (base, optimistic, pessimistic and specialist) as well as the triangular distribution, the TSP distribution can be used. Figure 4 shows the results obtained by carrying out the Monte Carlo method with the two distributions, making a total of 1 million simulations for each distribution.

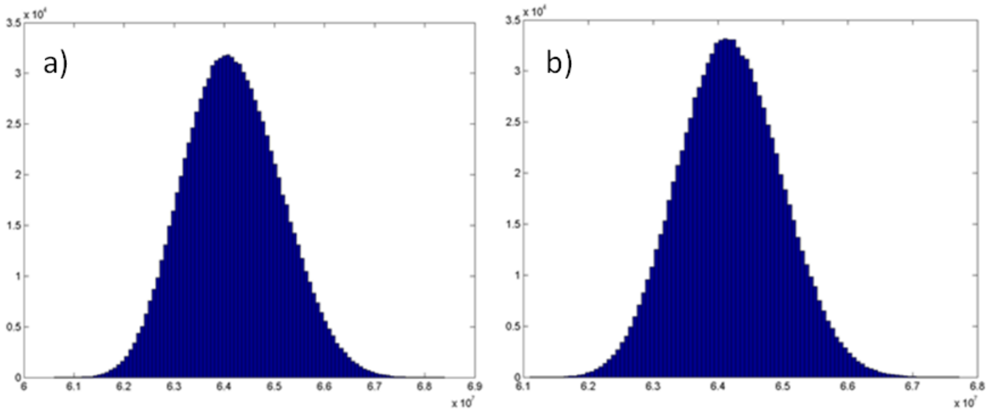

Fig. 4 Monte Carlo results, a) triangular distribution, b) TSP distribution

With these results, the Contingency Reserve can be calculated as the difference between the obtained budget of the simulation for the desired grade of confidence and the ship construction base budget. The level of risk assumed will vary according to the type of project to be carried out and the company's experience in this field [47].

Table 8 shows the results for both distributions, which are obtained by taking the compliance values of 80%, 85% and 90% of the million simulations that have been executed for the two probability distributions studied for the Monte Carlo method. The calculations have been made by programming the models using Matlab.

Table 8 Contingency reserve for different degrees of confidence

Confidence grade	Triangular distribution budget	TSP distribution budget	Triangular distribution Contingency Reserve	TSP distribution Contingency Reserve
80%	64.987.462 €	64.856.604 €	2.798.603 €	2.667.745 €
85%	65.186.089 €	65.014.343 €	2.997.230 €	2.825.484 €
90%	65.434.446 €	65.212.860 €	3.245.587 €	3.024.001 €

5. Results

The results obtained throughout the research have been classified into two main groups: those obtained from the triangular distribution model and those obtained with the TSP distribution.

5.1 Results obtained with the triangular distribution

In relation to the triangular distribution, it's use for project management is well known and has been validated by literature [40]. In the case of this research, a Contingency Reserve of between 2.8 and 3.2 million euros is achieved, which amounts to between 4.5% and 5.2% of the ship's base budget.

The choice of the margin of confidence is based on the level of risk that the organization can assume in the new contract [36], as well as the needs that the company has to enter in a new sector [2].

5.2 Results obtained with the extension of the generalized triangular distribution

The TSP distribution shows more favourable results than the ones obtained with the triangular distribution, resulting in a Contingency Reserve of between 2.6 and 3 million euros. This is between 4.3% and 4.9% of the base budget.

Note that this distribution is calculated at a higher information level, which suggests that this estimate is more correct than that made with the triangular distribution.

5.3 Comparison of the results obtained with the different distributions employed with the Monte Carlo method

By comparing the results of the simulations using the triangular distribution and the TSP distribution, Figure 5 is obtained.

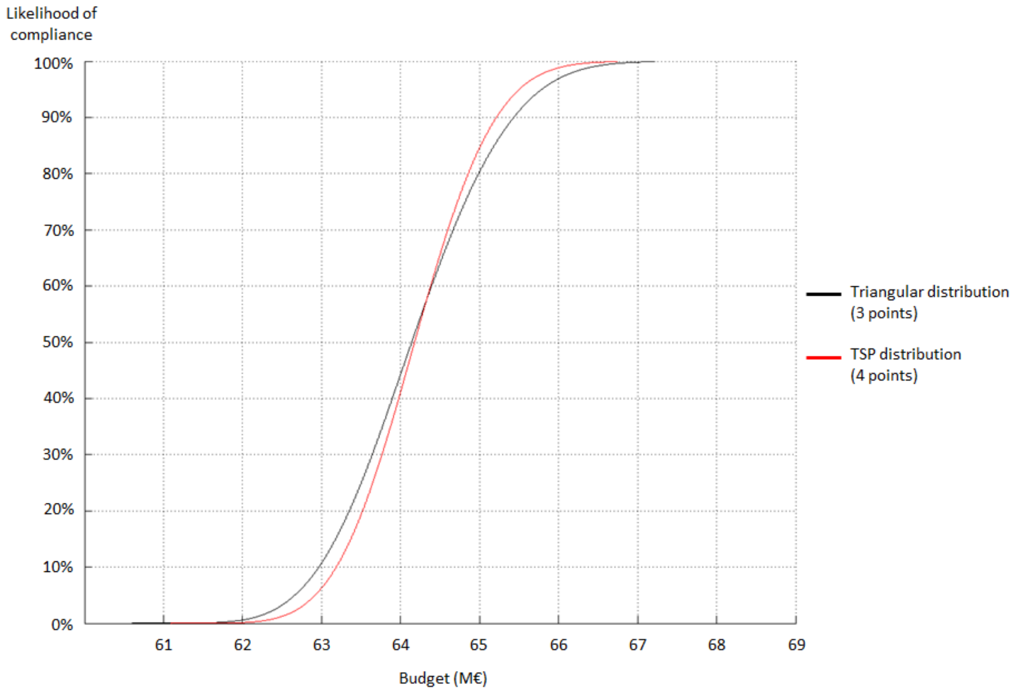

Fig. 5 Comparison of the resulting distributions after the Monte Carlo simulations

As can be seen, the distribution of the TSP covers a smaller range of values, which can be translated into a better definition of the model and therefore, the results with this distribution can be assumed to be more reliable.

6. Conclusions

The importance of estimating a correct budget in the bidding stages is essential in order to be able to compete under the best circumstances. If the company presents too high a budget, this could result in a loss of competitiveness for the tender. Conversely, if the company opts for contracts with too low a budget, the result could be a breach of contract, leading the yard to bankruptcy.

The present research contributes with an estimation method of the Project Contingency Reserve in the early budget calculation stages, examining two evaluation options regarding the quantity of information that could be obtained from the different components that make up the budget structure.

Both the triangular distribution (three-point) and its generalization (four-point) are valid for resolving the value of the Contingency Reserve, the latter being preferable if precise information is available for use by specialists. This extension of the Monte Carlo method can also be used in risk analysis, where it will improve uncertainty, both in the areas of the term and cost of the risks analysed with triangular distribution or beta distribution. This is a field of study in which various research projects are currently being carried out.

Finally, it can be concluded that the correct estimation of the Contingency Reserve will allow us to have the most accurate budgets possible, in order to bid in international tenders and therefore, be able to compete with the risk margins that the organisation considers appropriate to assume.

REFERENCES

[1] LR-Lloyds-Fairplay, 2015, IHS Fairplay Register of Ships 2015-2016, IHS Global Incorporated, Redhill, UK.

[2] Birkler, J., Schank, J. F., Arena, M. V., Keating, E. G., Predd, J. B., Black, J., Danescu, I., Jenkins, D., Kallimani, J. G., and Lee, G. T., 2015, Australia's Naval Shipbuilding Enterprise, Rand Corporation.

[3] Kolić, D., Lee Storch, R., and Fafandjel, N., 2014, "Transformation of advanced contract types for the shipbuilding industry with risk analysis", Brodogradnja/Shipbilding, 65(4), pp. 53-64.

[4] Back, M.-G., Lee, D.-K., Shin, J.-G., and Woo, J.-H., 2016, "A study for production simulation model generation system based on data model at a shipyard", International Journal of Naval Architecture and Ocean Engineering, 8(5), pp. 496-510. https://doi.org/10.1016/j.ijnaoe.2016.05.005

[5] Ruy, W.-S., Ko, D.-E., and Yang, Y.-S., 2012, "The implementation of the integrated design process in the hole-plan system", International Journal of Naval Architecture and Ocean Engineering, 4(4), pp. 353-361. https://doi.org/10.2478/IJNAOE-2013-0102

[6] Song, Y.-J., Woo, J.-H., and Shin, J.-G., 2011, "Research on systematization and advancement of shipbuilding production management for flexible and agile response for high value offshore platform", International Journal of Naval Architecture and Ocean Engineering, 3(3), pp. 181-192. https://doi.org/10.2478/IJNAOE-2013-0061

[7] Temple, D. W., and Collette, M. D., 2015, "Minimizing lifetime structural costs: Optimizing for production and maintenance under service life uncertainty", Marine Structures, 40(Supplement C), pp. 60-72. https://doi.org/10.1016/j.marstruc.2014.10.006

[8] Mascaraque-Ramírez, C., Para-González, L., and Madrid, A. E., 2016, "Project Management Improvement Tools: Study of the Construction of an Ocean Patrol Vessel," Actas DESEi+d 2016 IV Congreso Nacional de i+d en Defensa y Seguridad, C. U. D. San-Javier, ed.San Javier, pp. 217-225.

[9] Hopkin, P., 2017, Fundamentals of risk management: understanding, evaluating and implementing effective risk management, Kogan Page Publishers.

[10] Eyres, D. J., and Bruce, G. J., 2012, Ship Construction, Butterworth-Heinemann.

[11] Flyvbjerg, B., 2014, "What You Should Know About Megaprojects and Why: An Overview", Project Management Journal, 45(2), pp. 6-19. https://doi.org/10.1002/pmj.21409

[12] Mascaraque-Ramírez, C., Para-González, L., and Moreno-Sánchez, D., 2018, "Improvement of the construction project of tuna purse seine vessels through a cost and term analysis", Ships and Offshore Structures, 13(1), pp. 20-27. https://doi.org/10.1080/17445302.2017.1335576

[13] PMI, 2014, A Guide To The Project Management Body Of Knowledge (PMBOK Guides), Project Management Institute, Newtown Square, Pensilvania.

[14] Curtis, S., 2014, The law of shipbuilding contracts, CRC Press.

[15] Ballesteros-Pérez, P., Skitmore, M., Pellicer, E., and González-Cruz, M. C., 2015, "Scoring rules and abnormally low bids criteria in construction tenders: a taxonomic review", Construction management and economics, 33(4), pp. 259-278. https://doi.org/10.1080/01446193.2015.1059951

[16] Kapurch, S. J., 2010, NASA Systems Engineering Handbook, DIANE Publishing Company, Washington, D.C. USA.

[17] Idrus, A., Fadhil Nuruddin, M., and Rohman, M. A., 2011, "Development of project cost contingency estimation model using risk analysis and fuzzy expert system", Expert Systems with Applications, 38(3), pp. 1501-1508. https://doi.org/10.1016/j.eswa.2010.07.061

[18] Bakhshi, P., and Touran, A., 2014, "An Overview of Budget Contingency Calculation Methods in Construction Industry", Procedia Engineering, 85, pp. 52-60. https://doi.org/10.1016/j.proeng.2014.10.528

[19] Xenidis, Y., and Stavrakas, E., 2013, "Risk based Budgeting of Infrastructure Projects", Procedia - Social and Behavioral Sciences, 74, pp. 478-487. https://doi.org/10.1016/j.sbspro.2013.03.049

[20] Eldosouky, I. A., Ibrahim, A. H., and Mohammed, H. E.-D., 2014, "Management of construction cost contingency covering upside and downside risks", Alexandria Engineering Journal, 53(4), pp. 863-881. https://doi.org/10.1016/j.aej.2014.09.008

[21] Zhang, Y., and Fan, Z.-P., 2013, "An optimization method for selecting project risk response strategies", International Journal of Project Management, 32(3), pp. 412-422. https://doi.org/10.1016/j.ijproman.2013.06.006

[22] Hwang, B.-G., Zhao, X., and Toh, L. P., 2014, "Risk management in small construction projects in Singapore: Status, barriers and impact", International Journal of Project Management, 32(1), pp. 116-124. https://doi.org/10.1016/j.ijproman.2013.01.007

[23] Kaiser, M. J., and Liu, M., 2014, "Decommissioning cost estimation in the deepwater U.S. Gulf of Mexico – Fixed platforms and compliant towers", Marine Structures, 37(Supplement C), pp. 1-32. https://doi.org/10.1016/j.marstruc.2014.02.004

[24] Diab, H., Younes, R., and Lafon, P., 2017, "Survey of research on the optimal design of sea harbours", International Journal of Naval Architecture and Ocean Engineering, 9(4), pp. 460-472. https://doi.org/10.1016/j.ijnaoe.2016.12.004

[25] Pedersen, P. T., 2010, "Review and application of ship collision and grounding analysis procedures", Marine Structures, 23(3), pp. 241-262. https://doi.org/10.1016/j.marstruc.2010.05.001

[26] Guo, J., Wang, G., Perakis, A. N., and Ivanov, L., 2012, "A study on reliability-based inspection planning – Application to deck plate thickness measurement of aging tankers", Marine Structures, 25(1), pp. 85-106. https://doi.org/10.1016/j.marstruc.2011.12.002

[27] De Baere, K., Verstraelen, H., Rigo, P., Van Passel, S., Lenaerts, S., and Potters, G., 2013, "Reducing the cost of ballast tank corrosion: an economic modeling approach", Marine Structures, 32(Supplement C), pp. 136-152. https://doi.org/10.1016/j.marstruc.2012.10.009

[28] Acebes, F., Pereda, M., Poza, D., Pajares, J., and Galán, J. M., 2015, "Stochastic earned value analysis using Monte Carlo simulation and statistical learning techniques", International Journal of Project Management, 33(7), pp. 1597-1609. https://doi.org/10.1016/j.ijproman.2015.06.012

[29] Turner, P. J. R., 2000, "Controlling progress with planned cost or budgeted cost", International Journal of Project Management, 18(3), pp. 153-154. https://doi.org/10.1016/S0263-7863(99)00049-6

[30] Serrador, P., and Turner, R., 2015, "The Relationship Between Project Success and Project Efficiency", Project Management Journal, 46(1), pp. 30-39. https://doi.org/10.1002/pmj.21468

[31] Hwang, B.-G., Zhu, L., Wang, Y., and Cheong, X., 2017, "Green Building Construction Projects in Singapore: Cost Premiums and Cost Performance", Project Management Journal, 48(4), pp. 67-79.

[32] Olaniran, O. J., Love, P. E. D., Edwards, D., Olatunji, O. A., and Matthews, J., 2015, "Cost Overruns in Hydrocarbon Megaprojects: A Critical Review and Implications for Research", Project Management Journal, 46(6), pp. 126-138. https://doi.org/10.1002/pmj.21556

[33] Adoko, M. T., Mazzuchi, T. A., and Sarkani, S., 2015, "Developing a Cost Overrun Predictive Model for Complex Systems Development Projects", Project Management Journal, 46(6), pp. 111-125. https://doi.org/10.1002/pmj.21545

[34] Chou, J.-S., 2011, "Cost simulation in an item-based project involving construction engineering and management", International Journal of Project Management, 29(6), pp. 706-717. https://doi.org/10.1016/j.ijproman.2010.07.010

[35] Maier, E. R., and Branzei, O., 2014, "“On time and on budget”: Harnessing creativity in large scale projects", International Journal of Project Management, 32(7), pp. 1123-1133. https://doi.org/10.1016/j.ijproman.2014.02.009

[36] Hermarij, J., 2013, Better Practices of Project Management based on IPMA competences, Van Haren Publishing, Zaltbommel, The Netherlands.

[37] Alvariño-Castro, R., Azpíroz-Azpíroz, J. J., and Meizoso-Fernández, M., 2007, El proyecto básico del buque mercante [The basic project of the merchant ship], Fondo Editorial de Ingeniería Naval, Madrid, Spain.

[38] USN, 2005, "Naval Ships' Technical Manual," No. S9086-AA-STM-010/CH-001R45, Direction of Commander, Naval Sea Systems Command, Arlington (VA).

[39] da Silva Pereira, E. J., Pinho, J. T., Galhardo, M. A. B., and Macêdo, W. N., 2014, "Methodology of risk analysis by Monte Carlo Method applied to power generation with renewable energy", Renewable Energy, 69, pp. 347-355. https://doi.org/10.1016/j.renene.2014.03.054

[40] Wing Chau, K., 1995, "The validity of the triangular distribution assumption in Monte Carlo simulation of construction costs: empirical evidence from Hong Kong", Construction Management and Economics, 13(1), pp. 15-21. https://doi.org/10.1080/01446199500000003

[41] Ren é van Dorp, J., and Kotz, S., 2002, "A novel extension of the triangular distribution and its parameter estimation", Journal of the Royal Statistical Society: Series D (The Statistician), 51(1), pp. 63-79.

[42] García Pérez, J., Cruz Rambaud, S., and García García, L. B., 2005, "The two-sided power distribution for the treatment of the uncertainty in PERT", Statistical Methods & Applications, 14(2), pp. 209-222. https://doi.org/10.1007/s10260-005-0115-9

[43] Pleguezuelo, R. H., and Pleguezuelo, J. M. H., 2015, "Practical use of TSP distribution in the valuation method of the two betass two betas", Economía Agraria y Recursos Naturales (Agricultural and Resource Economics), 15(1), pp. 121-129.

[44] Hobbs, B., and Besner, C., 2016, "Projects with internal vs. external customers: An empirical investigation of variation in practice", International Journal of Project Management, 34(4), pp. 675-687. https://doi.org/10.1016/j.ijproman.2016.02.010

[45] Lane, P., Foster, R., Gardiner, L., Lanceley, L., and Purvis, A., 2013, "Work Programme Evaluation: Procurement, supply chains and implementation of the commissioning model," Department for Work and Pensions, London.

[46] Kug, J.-S., Kang, I.-S., and Choi, D.-H., 2008, "Seasonal climate predictability with tier-one and tier-two prediction systems", Climate dynamics, 31(4), pp. 403-416. https://doi.org/10.1007/s00382-007-0264-7

[47] Hobbs, J., 2010, "A methodology for setting contingency reserves using probabilistic cost risk analysis in small to medium construction projects", Word Count, 19521, pp. 1-71.

Submitted: 12.11.2017.
Accepted: 29.05.2018.

Lorena Para-González,
University Centre of Defence at the Spanish Air Force Academy, Economics and Juridical Sciences Department, Santiago de la Ribera (Spain), E-mail address: lorena.para@cud.upct.es

Carlos Mascaraque-Ramírez
Technical University of Cartagena, Naval Architecture Technology Department, Cartagena (Spain), E-mail address: carlos.mascaraque@upct.es

Ana E. Madrid
University Centre of Defence at the Spanish Air Force Academy, Science and Informatics Department, Santiago de la Ribera (Spain), E-mail address: anae.madrid@cud.upct.es