5
A proposal and simulation of service policies for the Campos Basin

With the aim of improving the offshore logistics system of Petrobras, especially the transportation of deck cargo, according to the results of the empirical analysis (see Section 4.5), a service policy is proposed herein. The focus is on the service level and reliability rather than the financial cost. Only the transport of deck cargo and the processes between the berths and the offshore units will be considered, that is, all processes which occur prior to the arrival of cargo at the berths are not included in this study. The use of the berths for other activities, like mooring for crew changes or to make inspections and the effects of closing the port due to adverse weather conditions will not be considered.

The ideas related to the service policy are presented in Section 5.1 while the method to simulate the main points of the policy is presented in Section 5.2, such as the frequency of visits to the offshore units. The simulation was carried out using the same data considered in the empirical analysis (see Chapter 4). The real cargo demand was used, making it possible to ascertain how the logistic system would have behaved if a different policy had been used. The scenarios are presented in Section 5.3 and these results are discussed in Section 5.4.

5.1 A service policy

In this section, the main considerations that should be taken into account to improve the service policy of Petrobras will be presented. These considerations were collected from the academic literature, from the empirical experience of the personnel who conduct operations and from research carried out by Petrobras. Nevertheless, they are not intended to encompass all of the details that need to be considered in this context.

The first aim of the service policy is to reduce the trips and visits to the offshore units as well as the number of offshore units per trip. Reducing these should decrease the transport time between the port and the offshore units and the cycle time of the vessels. The offshore units will have fixed time windows to receive the vessels by means of fixed routes. During the whole period of the time window, the vessels are available for the offshore unit. When the window closes, the vessel goes to the next offshore unit even if the last offshore unit did not operate. To add some flexibility, one of the offshore units of the route can choose to receive an additional visit after the windows of all offshore units have closed. No offshore unit that does not belong to the cluster will be included in the route. The personnel of the offshore units included in a route can negotiate between themselves to shift the times of the windows. This process aims to add regularity to the service, allowing the planning of the offshore units and avoiding visits without operation.

The vessel will depart from the port with free space on the deck reserved for the first backload. The PSVs in the Campos Basin are refueled by tankers at sea and they will visit the tanker only after the last time window has closed.

The emergency and priority cargo will be transported on separated trips and never on a normal trip. The emergency trips will be undertaken by UTs and they will service up to five offshore units. The route will be decided according to the priorities.

If the weather conditions are bad, the vessel will wait and try to service the offshore units within the time windows. If the vessel can operate at some of the offshore units of the route, changes can be negotiated between the offshore units.

If the port closes, the departures during the closed period are canceled and a special plan will be designed and implemented as soon as the port reopens. This case will not be discussed in this study.

The routes will be built in the following way: the offshore units are divided into clusters and each cluster will have the required number of trips per week. The cargo demand for each cluster will be calculated and the largest vessel will have to fulfill the mean demand plus two standard deviations plus the first backload (see Section 5.2(a)), ensuring the reliability of the whole schedule. When the position of an offshore unit changes, one or more of the clusters will change and the time windows will have to be renegotiated. Rigs and production units will be routed in separated clusters, which makes it easier to manage changes due to rig movements. However, a scenario without this separation will be tested in this study.

5.2 The simulation method

This section presents a method to simulate the main points of the proposed policy. The same data considered in the empirical analysis was used (see Chapter 4), related to a period of 52 weeks (one year). The real cargo demand was used and different routes were created to meet this demand, making it possible to ascertain how the logistic system would have behaved if a different policy had been used. It is not the aim of this study to find the best schedule or best routes, but to investigate the service policies. Thus, a simple and easy clusterization method was chosen, that is, the Clarke and Wright method (Clarke and Wright, 1964).

The computational experiment consists of four phases.

Phase 1 The Clarke and Wright method was applied to build the clusters of offshore units.

Phase 2 According to the results of the Clarke and Wright method and the desired frequency for each cluster, a new timetable was created.

Phase 3 The historical demand of the offshore units was allocated to each trip on the timetable. This step determines only the demand for each trip, that is, the vessel capacity is not considered.

Phase 4 According to the demand for each trip, berth and vessel availability, a simulation to determine the mean transport time between the port and the offshore units, the fleet size and composition, the number of berths and other parameters was performed.

The clusters can be of different types. For the units in the Campos Basin the type of each cluster is dependent on the type of the offshore units visited as follows:

– (a) Rigs
– (b) Production units and maintenance units
– (c) Rigs, production units and maintenance units
– (d) Special vessels

In a single scenario, type (c) will not be mixed with (a) or (b). If the units are not in the Campos Basin the type of the cluster is related to the location of the units. These clusters are not needed every week as they are dependent on the special requirements of the other basins, for instance, a very large load of risers or strikes by employees at the public ports. The cargo demand of these can be high and affect the service for the Campos Basin. These are:

– (e) Espírito Santo Basin

- (f) Santos Basin
- (g) north and northeast of Brazil

The trips can be divided into different types. These can be *Normal* (undertaken by PSVs with no emergency cargo), *Emergency* (undertaken by UTs, emergency cargo) or *Special* (PSVs for delayed cargo, that is, the cargo that Normal trips did not have the deck capacity to load).

(a) Phase 1: Clarke and Wright method

The Clarke and Wright method was applied as presented by Novaes (Novaes, 2007). According to the method, the restrictions associated with the routes are the capacity of the vehicle and the duration of the trip. Nevertheless, in this study, the vessel capacity and the maximum number of offshore units per trip will be considered, which are related to the duration of the trip and the mean transport time between the port and the offshore units. To apply this method, it is necessary to know the locations of the offshore units. In real life, each time an offshore unit changes position, the routes have to be changed. However, as there are a large number of rigs in the Campos Basin, frequently moving from one field to another, for the sake of simplicity only changes from the beginning of one week to another, starting the weeks on Sundays, were considered. The Clarke and Wright method was applied to each type of cluster, scenario and week.

As it is not possible to know precisely the cargo demand of the offshore units in advance, the weekly mean demand and the standard deviation for each offshore unit were calculated. On applying the Clarke and Wright method, the capacity of the vessel was compared to the sum of the mean demands of the offshore units of the cluster, plus two standard deviations, plus the first backload, divided by the weekly frequency of the cluster, as shown in Equation (1). The useful capacity of the PSV 4500 (see Table 3.3) was considered. The aim of this computation is to ensure that for most trips there will be a vessel able to load all the cargo, ensuring the reliability of the schedule. As the demand of the rigs is strongly dependent on the activities carried out at the location and the field characteristics, a standard pattern for these was used.

$$Area = \frac{\alpha_1 + \alpha_2 + \cdots + \alpha_n + 2 \cdot \sqrt{\sigma_1^2 + \sigma_2^2 + \cdots + \sigma_n^2} + \beta}{f} \qquad (1)$$

where :

n : index of the offshore unit included in the cluster

α_n : mean weekly area of the offshore unit n, in $[m^2]$

σ_n : standard deviation of the offshore unit n, in $[m^2]$

β : backload of the first offshore unit, in $[m^2]$

f : weekly frequency of the cluster

(b) Phase 2: The mooring time

For each week, follow steps 1 to 5.

Step 1 For each type of cluster, depending on the weekly frequency of trips, compute the best interval between the departures of the trips of a cluster. For example, if two trips per week are required, the best interval is 3.5 days.

Step 2 For each type of cluster, compute the number of moorings (multiplying the number of clusters by the weekly frequency for each cluster). Distribute the moorings throughout the week with equally spaced intervals, but respecting the best interval for each cluster. For example, if there are two clusters, with two trips per week, there will be four moorings spaced $7/4 = 1.75$ days apart, and the interval between the trips of the same cluster will be 3.5 days.

Step 3 The clusters for the other basins are always included on Saturday afternoons and only once a week per basin, if needed. The cluster for special vessels is included every Saturday afternoon, once a week.

Step 4 Do the same for the emergency trips (the trips with UTs). For these trips, there are no pre-defined clusters, but instead only a required frequency, for example, twice a day, yielding fourteen trips per week.

Step 5 Combine the trips of all clusters into a table and place them in order according to the mooring hours. Compute again the mooring hours distributing them equally throughout the week, but respecting the order of the trips. The best interval between the trips of each cluster will be lost, but the result will be close to it.

Combine the results for all of the 52 weeks, resulting in a schedule for a whole year.

(c) Phase 3: Allocating the cargo demand

In this phase, the cargo demand for each planned trip is allocated. The objective here is not to consider vessel capacity or berth availability as this will be performed in the next phase. The aim is to ascertain the amount of cargo that would be required for each trip. All cargo that was dispatched from the port using the current schedule would be loaded using a different schedule. Using a real and fixed demand for all scenarios, the results produced can be analyzed and compared.

For a given trip, check its type (*Normal*, *Emergency* or *Special*).

If the trip is *Normal*: for each offshore unit to be serviced by this trip, sum all of the non-emergency cargo required by the offshore unit since the last *Normal* trip to this offshore unit, until the departure date of the current trip.

If the trip is *Emergency*: sum all the emergency cargo required by the offshore units since the last *Emergency* trip.

If the trip is *Special*: sum all cargo required by one or more offshore units that, for any reason, has not been included in the schedule.

Do this procedure for all trips, respecting their order throughout the year.

(d) Phase 4: Simulation

The simulation will be run n times (which includes steps 1 and 2 as detailed below), the first one being the warm up run.

Step 1 For all planned trips, calculate the duration of the trip. The trips can be divided into the following phases:

- navigation
- waiting or operating at offshore units
- refueling at the tanker
- off-hire
- additional visits

To compute the navigation time simply divide the total distance to be sailed (according to the planned route) by the average speed. The vessel might not sail in a straight line, thus a correction factor should be used (see Equation (2)). It is important to know the sail time between one offshore unit and another, in order to calculate the voyage time between the port and the offshore unit, so each stretch of the trip has to be calculated separately.

$$T_{navigation} = f_{correction} \cdot \frac{d}{v} \quad (2)$$

where :

$T_{navigation}$: navigation time

$f_{correction}$: correction factor

d : distance

v : velocity

When the vessel arrives at the offshore unit, it may wait for the offshore unit to become availability for operation or it may wait due to adverse weather conditions. Both of these scenarios have a probability of occurrence and when they occur their duration is also associated with a probability factor according to a statistical distribution. It is considered that the vessel will certainly operate, and the duration of the operation is also represented by a distribution. The values of all random variables were chosen according to their probability distributions. In this study, normal distributions with mean and standard deviation values computed from historical data were considered. Thus, for each visit, Equation (3) was applied.

$$T_{ofun} = B_{unit} \cdot T_{waitunit} + B_{WOW} \cdot T_{WOW} + T_{operating} \quad (3)$$

where :

T_{ofun} : waiting or operating time at offshore units

B_{unit} : binary variable indicating whether the vessel will wait for the availability of the offshore unit to operate

$T_{waitunit}$: waiting time at the offshore unit

B_{WOW} : binary variable indicating whether the vessel will wait due to bad weather

T_{WOW} : time spent waiting for better weather

$T_{operating}$: operating time

As the process establishes a six-hour time window for each offshore unit, if T_{ofun} is less than six hours, it is replaced with six hours.

The PSVs operating in the Campos Basin need to visit a tanker in order to refuel, but this operation is not carried out on every trip. Similarly, the vessel might remain off-hire on some trips. These conditions are considered according to Equation (4).

$$T_{toh} = B_{tanker} \cdot T_{tanker} + B_{offhire} \cdot T_{offhire} \tag{4}$$

where :

T_{toh} : tanker and off-hire time

B_{tanker} : binary variable indicating whether the vessel will refuel at the tanker

T_{tanker} : navigation time to the tanker, and waiting and operating times at the tanker

$B_{offhire}$: binary variable indicating whether the vessel is off-hire or not

$T_{offhire}$: off-hire time

Additional visits to the offshore units should be avoided but, as they might occur, these are also included in the computation of the trip time. Only 10% of additional visits were considered (1.1 visits/offshore units) and only one additional visit per trip. The probability of having an additional visit is calculated so that the global result of the trips will have 1.1 visits/offshore units. If it is decided by draw that the trip will have another visit, the computation given in Equation (3) is carried out.

This computation is performed for every trip. The total duration of the trip and the mean transport time between the port and the offshore units is then calculated considering the differences between the types of trips:

- If the trip is *Normal* or *Special*: historical values for PSVs are used.
- If the trip is *Emergency*: historical values for UTs are used; these vessels do not refuel at tankers and do not have additional visits; there is no six-hour window.

Step 2 This step is schematized in Figure 5.1. The time begins to run. For each lapse of time, verify the number of berths and vessels being used. When the mooring time of a trip is reached:

- If the trip is *Normal* or *Special*, verify whether there is a berth available. If the response is positive, consider the cargo demand (load, first backload and overall backload). Select the smallest PSV able to carry all of the cargo: the load plus first backload must be less than the useful area of the vessel, as in the case of the overall backload. If no vessel is able to carry all of the cargo, select the largest vessel available and save the remainder of the cargo in the *delayed cargo area*. Call the vessel to moor, considering that the vessel will moor only an hour later than the call time. Compute the turnaround time at the berth multiplying the number of lifts (load and backload) by the time per lift. Note that the number of backload lifts is determined by the previous voyage of the vessel, and not by the current trip. The time per lift is determined by the historical data according to the type of vessel. In this study this is defined as the total turnaround time divided by the number of lifts. The time per lift is dependent on the number of lifts: the greater the number of lifts, the shorter the time per lift. Compute the departure and arrival times of the vessel using the trip time as calculated in **Step 1** multiplied by the week factor (see explanation below).
- If the trip is *Emergency*, verify that both a berth and a UT vessel are available. In the case of a positive response, consider the cargo demand (load). If the vessel is not able to carry all of the cargo, save the remainder of the cargo in the *delayed emergency cargo area*.Otherwise, load the vessel with the cargo and use the free deck space to load some *delayed emergency cargo*. Call the vessel to moor, considering that the vessel will moor only one hour later than the call time. Compute the turnaround time at the berth multiplying the number of lifts by the time per lift. The time per lift is determined by the historical data according to the type of vessel. Compute the departure and arrival times of the vessel, using the trip time as calculated in **Step 1** multiplied by the week factor (see explanation below).

If there are more than 200 m^2 of cargo in the *delayed cargo area*, verify if both a berth and a PSV are available. If the response is positive, call the vessel to moor and compute the turnaround, the departure and the arrival times.

The results of **Step 1** are multiplied by a week factor f_{week} in order to represent the influence of the weather conditions throughout the year. The

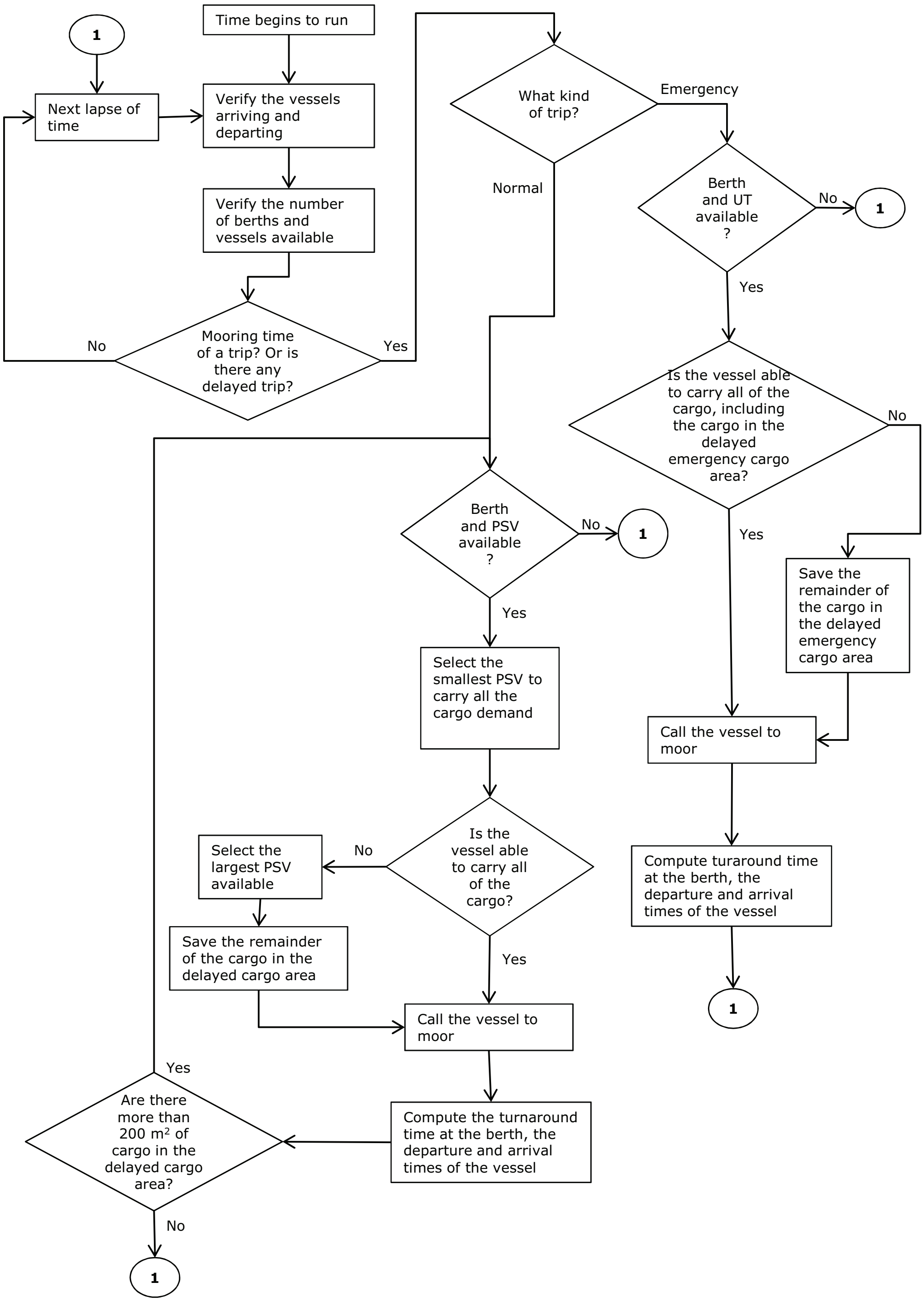

Figure 5.1: The second step of the simulation

f_{week} is calculated according to Equation (5). The mooring hour gives the reference for the week.

The results of **Step 1** are multiplied by a week factor f_{week} in order to represent the influence of the weather conditions throughout the year. The week factor is calculated according to Equation (5). The mooring time gives the reference for the week.

$$f_{week} = \frac{D_w}{D_y} \tag{5}$$

where :

D_w : mean duration of the trips in the week

D_y : mean duration of the trips in a one-year period

Repeat **Step 2** until the end of the time period.

5.3 Scenarios

Four scenarios were chosen to be analyzed in this study, and these are shown in Table 5.1. The basic scenario reproduces the current schedule and was built to validate the model. Rigs are serviced by seven trips a week and production units by two trips a week. Trips to production units do not include rigs, but trips to rigs may include production units. Hence, the routes to rigs have on average 10 units and those to production units have 8.4 units. In the basic scenario the Clarke and Wright method was not used but instead the real schedule for production units and the real service areas for rigs (see Section 4.1).The departure times were also reproduced. Unlike in the case of the other scenarios, the mean number of visits per offshore units is 1.5 (rather than 1.1).

In Scenario I, rigs are serviced three times a week and production units twice a week. Rigs and production units are never serviced on the same trip. A route is allowed to include up to five units, hence the mean number of units is slightly less than this figure.

In Scenario II both the frequency and maximum number of units are higher. Rigs are serviced four times a week and production units three times a week. Rigs and production units are never serviced on the same trip. A route is allowed to include up to six units.

In Scenario III rigs and production units are mixed on the routes. They are serviced three times a week and the maximum number of units is five.

In all scenarios, there are two emergency trips per day performed by UT vessels and one trip per week to service special vessels. All scenarios include trips to the other basins when necessary.

As the Port of Imbetiba has six berths, the number of berths was restricted to six. The basic scenario considered the fleet size and composition available in 2011.

Scenarios I, II and III were run three times:

Table 5.1: Scenarios that will be analyzed in this work

Scenario	Frequency		Maximum units		Mean number of units	
	Rigs	Production units	Rigs	Production units	Rigs	Production units
Basic	7	2	—	—	10	8.4
I	3	2	5	5	4.5	4.7
II	4	3	6	6	5.5	5.8
III	3		5		4.9	

1. **Free**: with no fleet restrictions

2. **Restricted**: with a selected fleet size and composition

3. **Current**: with fleet number and composition available in 2011

To select the number of vessels for the Restricted run, the time of utilization of the vessels in the Free run was analyzed. The number of vessels used in 95% of the time was selected, that is, it was ensured that in 95% of the time there would be vessels available for use. Figure 5.2 shows an example of the number of vessels on the x-axis (numbers are not shown) and the percentage of utilization on the y-axis. For the remaining 5% of the time, the required number of vessels is larger than the selected number. To select the composition of the fleet for the Restricted run, the number of PSVs 4500 that were required in 95% of the time in the Free run was first selected, followed by the number of PSVs 3000. Thus, the number of PSVs 1500 that was sufficient to achieve the total number of vessels was added.

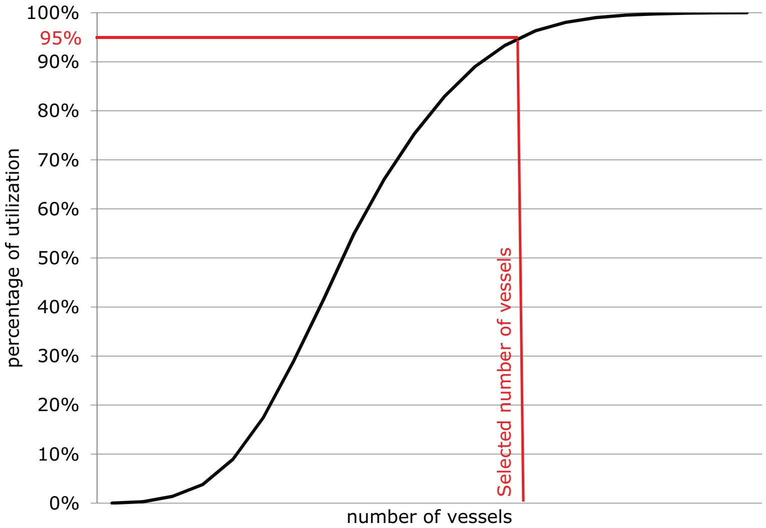

Figure 5.2: Example of the method to choose the number of vessels for the Restricted run

5.4 Results

Results will be analyzed in terms of berth utilization, fleet size and composition, the mean transport time between the port and the offshore units, the request time, the percentage of delayed moorings, the percentage of trips that did not meet demand, the percentage of additional moorings required to attend to the demand that was not met by regular trips, the percentage difference in the planned distance to be sailed by the vessels compared with the basic scenario, the cycle time, the time waiting anchored at the port and the deck occupation. As there is no difference between the scenarios in terms of the schedule for the emergency trips, no differences in the results were found. Thus, the trips undertaken by UTs will not be analyzed in this study.

Table 5.2 shows the difference between the historical data and the scenarios for the average occupation of berths. Differences range from -5% to -10%. Scenario I occupied less berths than Scenarios II and III, due to a lower number of moorings. There is a difference of -8% between the basic scenario and the historical data.

Table 5.2: Difference between the historical data and the scenarios for the average occupation of berths

Scenario	Free	Restricted	Current
Basic	—	—	-8%
I	-10%	-10%	-10%
II	-5%	-8%	-5%
III	-5%	-5%	-5%

Table 5.3 shows the difference between the 2011 fleet and the required number of vessels for the scenarios. These are divided into the average number of vessels being used and the number of vessels selected for the Restricted run. The fleet should not be sized according to the mean utilization, since this is a parameter used only to evaluate the results. Due to it having the lowest frequency of service, Scenario I (Restricted run) needs 33% less vessels than the 2011 fleet, Scenario II 16% and Scenario III 20%. The fleet size correlates with the number of required trips for each scenario. As the distances between the offshore units in the Campos Basin are relatively low, routing both the production units and rigs on the same trip does not reduce significantly the number of vessels, as can be observed when comparing Scenarios I and II with Scenario III. Therefore, further research is required, as the number of trips in each scenario should be equal in order to provide a better comparison. According to the mean values, the utilization of the fleet is lowest in Scenario I and highest in the basic scenario.

The fleet composition selected for the Restricted run and that of the basic scenario (which considers the 2011 fleet) are shown in Figure 5.3. Nowadays, Petrobras is working with a greater reliance on PSVs 3000. Scenario I requires more PSVs 4500 in the fleet composition when compared to the other scenarios.

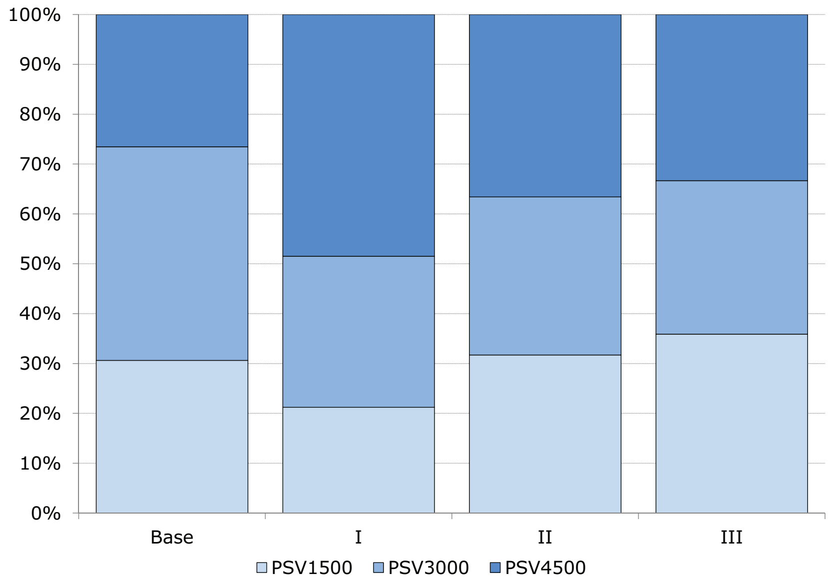

Figure 5.3: Fleet composition

Figure 5.4 shows the normalized[1] number of PSVs that transported more than 50 m^2 per week. A single run considering the basic scenario and the historical data are plotted. The two cases have a similar range of variation, although the curves do not have the same shape.

Table 5.3: Number of PSVs: difference between the 2011 fleet and the scenarios

	Mean			Selected
Scenario	Free	Restricted	Current	Restricted
Basic			-18%	
I	-49%	-48%	-48%	-33%
II	-37%	-36%	-36%	-16%
III	-39%	-38%	-38%	-20%

Table 5.4 shows the cycle time of the PSVs in the Restricted and Current runs. As the Free run does not have a limited number of vessels and some vessels undertake a single trip in the whole period, the cycle time would not be a reliable parameter in this case.

The historical cycle time of the PSVs is 6 days and in the basic scenario this is 8% higher. The results range from 5.3 to 6.8 days, thus there was no reduction in the cycle time. In scenarios I, II and III (Current run) the cycle

[1]Dividing the number of ships in each week by the mean of the number of ships in all weeks

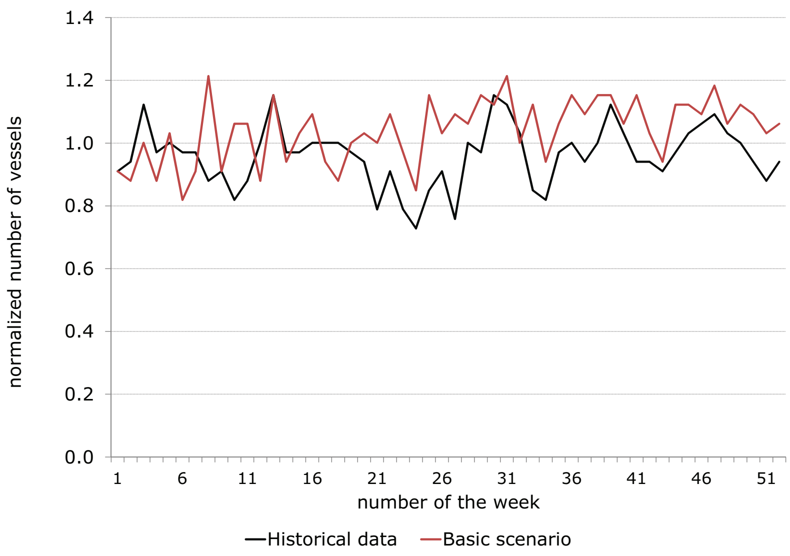

Figure 5.4: Normalized number of PSVs that transported more than 50 m^2 per week: basic scenario and historical data

time decreases as the number of trips increases. This is not true in the case of the basic scenario because of the different numbers of visits per offshore unit.

Table 5.4: The cycle time of the PSVs in the Restricted and Current runs (days)

Scenario	Restricted	Current
Basic	—	6.5
I	5.4	6.8
II	5.8	6.4
III	5.3	6.1

Table 5.5 shows the mean time in which the PSVs wait anchored at the port per cycle (values are included in the cycle). Values range from 1.0 to 2.6 days, while the historical value is 0.8 days. This waiting time is not due to queuing to moor. As some of the vessels will not be used during the whole period, these will wait anchored at the port. Table 5.6 shows the mean percentage of vessels waiting anchored at the port. Values range from 23 to 48%. Because of the hiring process, Petrobras can not use spot contracts for PSVs or UTs, hence the fleet needs to be oversized. An example of the utilization of the vessels is shown in figures 5.5 and 5.6. The percentage of the PSV fleet operating and waiting anchored during a one-year period considering scenario II and a Restricted run is shown in Figure 5.5. The fleet utilization is low in the period of good weather and high in the period of bad weather. This information, according to the type of vessel, is shown in Figure 5.6.

Table 5.5: The waiting anchored in the Restricted and Current runs (days)

Scenario	Restricted	Current
Basic	—	1.0
I	1.2	2.6
II	1.3	1.9
III	1.2	1.9

Table 5.6: Mean percentage of vessels waiting anchored at the port per cycle (values are included in the cycle)

Scenario	Restricted	Current
Basic	—	18%
I	23%	48%
II	23%	36%
III	22%	38%

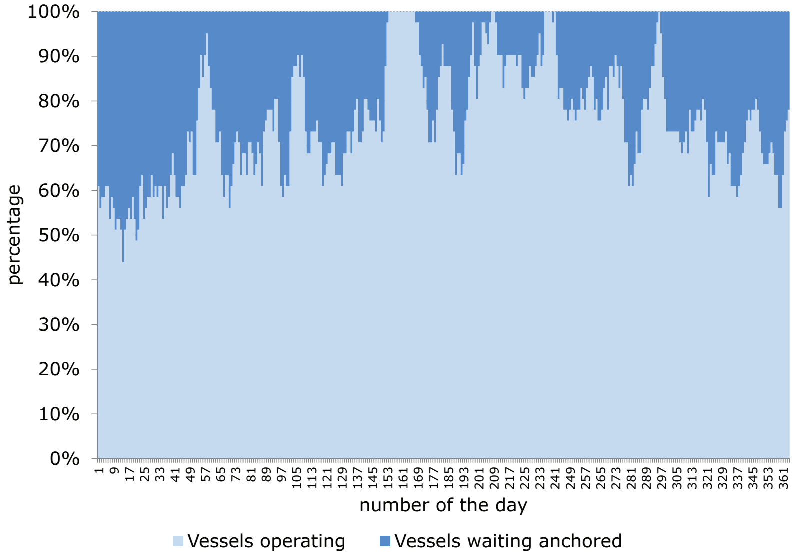

Figure 5.5: Percentage of the PSV fleet operating and waiting anchored during a one-year period of the scenario II, Restricted run

Table 5.7 shows the mean transport time between the port and the offshore units and the request time. The mean transport time between the port and the offshore units in Scenarios I, II and III is lower than in the historical data and in the basic scenario. This demonstrates the feasibility of decreasing the lead time. However, the request time for production units in Scenario I is high (4.6 days), as the frequency is low. Scenarios II and III achieve good results regarding both parameters.

Table 5.8 shows the percentage of delayed moorings in each scenario. The basic scenario has by far the worst result because of the mooring times which conflict with one another and the highest number of vessels required.

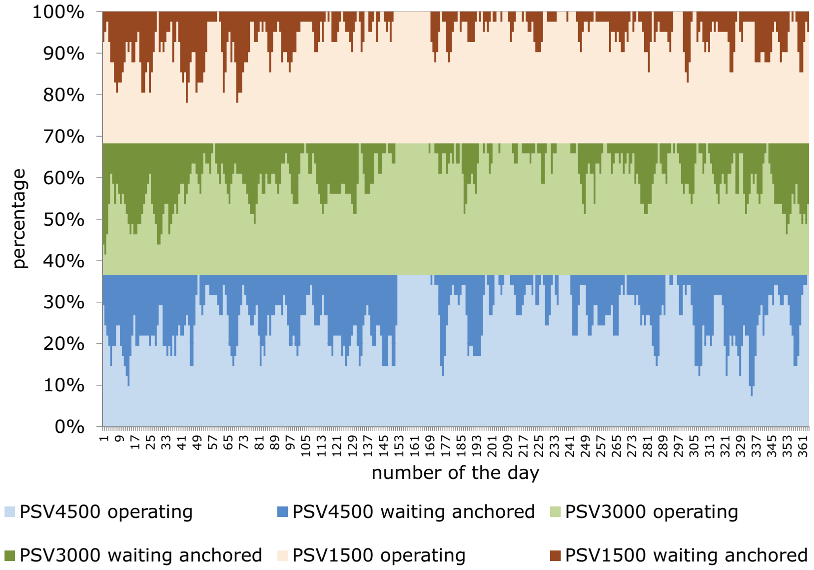

Figure 5.6: Percentage of the PSV fleet operating and waiting anchored during a one-year period of the scenario II, Restricted run, divided into the type of the vessels

Table 5.7: Mean transport time between the port and the offshore units and the request time

Scenario	Mean transport time between port and offshore units		Request time	
	Rigs	Production units	Rigs	Production units
Historical data	2.2	1.9	4.3	3.5
Basic	2.0	2.1	3.0	3.6
I	1.1	1.1	3.4	4.6
II	1.3	1.2	3.0	3.6
III	1.1		3.4	

The historical percentage of delayed **departures** is 47%, but the Port of Imbetiba has handled many other operations that are not considered in this simulation. The Restricted runs of Scenarios I, II and III achieve poor results which correlate with the number of moorings. These results range from 10.6 to 14.0%. However, during periods of bad weather this situation is much worst (see Figure 5.5) and hence the number of vessels should be increased to guarantee the robustness of the schedule.

Table 5.8: Percentage of delayed moorings

Scenario	Free	Restricted	Current
Basic	—	—	29.3%
I	2.2%	10.6%	3.5%
II	3.5%	14.0%	4.1%
III	3.9%	12.9%	4.1%

Table 5.9 shows the number of moorings, planned and realized, in each scenario, and Table 5.10 shows the ratio between the numbers of realized and planned moorings. The higher this ratio the higher is the number of trips that did not meet the demand. The basic scenario has the worst result.

Table 5.9: Number of moorings

Scenario	Free	Restricted	Current	Planned
Basic			3,376	3,147
I	2,906	2,926	2,928	2,813
II	3,212	3,238	3,229	3,146
III	3,330	3,364	3,339	3,267

Table 5.10: Ratio between the number of realized and planned moorings

Scenario	Free	Restricted	Current
Basic	—	—	7.3%
I	3.3%	4.0%	4.1%
II	2.1%	2.9%	2.6%
III	1.9%	3.0%	2.2%

Table 5.11 shows the percentage of the trips that the cargo required for a trip that was not met by the vessel capacity, generating additional trips. This number increases as the service frequency decreases or the number of offshore units of the clusters increases.

Poorer results were associated with the clusters of rigs compared to the clusters of production units. This is due to the higher uncertainties related to the rigs demands and to the method used to build the clusters of rigs. For the rigs, a standard pattern of the cargo demand was used, while for the production units the demand of each unit was considered separately, as explained in Section 5.2.

Due to the lowest service frequency, the results for Scenario I are worse than those for Scenarios II and III. The worst result by far was obtained for the clusters of the production units in the basic scenario.

Table 5.11: Percentage of the trips that the cargo demand was not met by the available vessel

	Free		Restricted		Current	
Scenario	Rigs	Production units	Rigs	Production units	Rigs	Production units
basic	—	—	—	—	6%	40%
I	11%	6%	13%	9%	12%	8%
II	9%	2%	11%	5%	10%	4%
III	4%		7%		5%	

Table 5.12 shows the percentage difference in the planned distance to be sailed by the vessels compared with the basic scenario. This correlates with the number of trips and with the length of the routes of each scenario. Regarding the distance sailed, Scenario I is the most economical.

Table 5.12: Difference from the basic scenario of the planned distance to be navigated

Scenario	Difference from Basic
Basic	0%
I	-22%
II	-10%
III	-11%

Table 5.13 shows the mean occupation of the deck, considering the load and the first backload according to the type of clusters, and Table 5.14 shows the mean occupation considering the backload. This correlates with the service frequency of each scenario and with the composition of the fleet.

Table 5.13: Mean occupation of the deck (load + first backload)

	Free		Restricted		Current	
Scenario	Rigs	Production units	Rigs	Production units	Rigs	Production units
Basic	—	—	—	—	35%	83%
I	65%	73%	62%	69%	65%	73%
II	62%	72%	60%	61%	62%	62%
III	63%		61%		62%	

Table 5.14: Mean occupation of the deck (backload)

	Free		Restricted		Current	
Scenario	Rigs	Production units	Rigs	Production units	Rigs	Production units
Basic	—	—	—	—	29%	75%
I	52%	66%	50%	63%	52%	66%
II	51%	57%	49%	56%	50%	57%
III	55%		53%		54%	