4
An empirical analysis

In this section, the service policy and the schedule of the vessels in the Campos Basin in 2011 will be described. In order to identify some aspects which can be improved, an empirical data analysis of the maritime operations will be carried out.

In Section 4.1, the current schedule will be shown and analyzed. In Section 4.2, a real example which shows a detailed service to an offshore unit will be given. In Section 4.3 the data analysis will be presented, and this will be followed by a comparison between the Campos Basin, the Santos Basin, a schedule presented by Halvorsen-Weare and Faberholt (Halvorsen-Weare and Fagerholt, 2011) and two of the cases presented by Kaiser and Snyder (Kaiser and Snyder, 2010) (Section 4.4). Finally, an overall discussion will be presented in Section 4.5.

4.1 Current schedule

A scheme of the schedule for the Campos Basin in 2011 is shown in Table 4.1. The trips can be divided into six types: (P) regular trips to production units, (R) regular trips to rigs and also to transport emergency cargo to production units, (RF) regular trips to rigs to transport food and drinking and industrial water only, (E) trips to transport emergency cargo, (S) regular trips to special vessels, and (D) trips ordered on demand, used mainly to transport risers. The number of clusters and the number of weekly trips per cluster are shown in Table 4.1. As the UTs have restrictions regarding the weight and size of the cargo, emergency cargo is often transported in (R) rather than in (E). However, since the positions of the rigs are constantly changing, the clusters of (R) are selected according to a delimited area. When the rig is moved to another area, this is transferred to another cluster. The production units inside each area are included in the corresponding cluster so that these can receive emergency cargo from (R). Most of the production units are planned to receive cargo twice a week, with the exception of emergencies. Only six small units receive cargo once a week. Rigs are planned to receive cargo every day, assumed there is the appropriate demand. The regular trips to production units are usually planned to service up to eight units, and the regular trips to rigs can service more than twenty units, as production units are also included in the clusters.

Table 4.1: Schedule for the Campos Basin in 2011

Code	Customer	Cargo	Vessel	Number of clusters	Trips per week per cluster	Number of units
P	Production units	Deck cargo and water	PSV 3000 or 4500	3	2	7 or 8
				3	1	5 to 8
R	Rigs	Deck cargo and water	PSV 1500 or 3000	4	7	3 to 8
	Production units	Emergency deck cargo				11 to 17
RF	Rigs	Food, drinking and industrial water	PSV 3000 or 4500	2	1	11 to 15
E	All offshore units	Emergency deck cargo	UT	-	7	—
S	Special vessels	Deck cargo and water	PSV 3000 or 4500	1	1	—
D	All offshore units	Mainly risers	PSV	on demand	on demand	—

Table 4.2 shows the weekly demand for deck area for five of the regular clusters of production units, which carry out two trips per week. The standard deviation is also shown along with a value which represents the 95% probability threshold (i.e. there is a 95% probability that the demand for the week is lower than this value according to the normal distribution profile). According to Table 3.3 (page 33), the mean useful deck area of a PSV 4500 is 660 m^2. Thus, it is clear that in approx. 40% of the weeks cluster 5 will need more than two PSV 4500, as $660 * 2 = 1320$ (here, the arrangement of cargo of different dimensions on the deck, which leads to a lower quantity of cargo on the deck, is not considered), and it should be mentioned that the other clusters might not provide sufficient deck area in some weeks. An imbalance in the demand for the different clusters is also noted, although this does not necessarily indicate bad practice. This imbalance was also found for the regular clusters of rigs, that is, while the highest cluster demand is 38%, the lowest is 9%, and the number of trips associated with the clusters is planned to be equal for the same kind of vessel.

4.2 An example of the daily operation

Does the planned schedule work well? To address this question, a data analysis has to be carried out. A closer look at one example can provide an insight into the day-to-day operation. Figure 4.1 shows a real example of the transport of deck cargo from Imbetiba Port to production unit PU-01 within a two-week period from 7 to 20 June 2011. The time line shows the day and

Table 4.2: Weekly deck area demand of 5 clusters of production units

Identification	Mean deck area (m^2)	Standard deviation	95% probability threshold in a week
1	853	209	1,197
2	1,001	161	1,266
3	907	191	1,221
4	989	142	1,223
5	1,241	295	1,726

the hour and vertical lines separate one day from another. The bottom line represents the port, while the top line represents PU-01. The arrows represent the trips beginning at the port and ending at the offshore unit. Red arrows are the emergency trips which are labeled from E1 to E6. Blue arrows are the regular trips for the PU-01 as planned in the schedule and are labeled from P1 to P4. Green arrows are regular trips to rigs which are used for emergency cargo for production units, labeled from R1 to R6.

All emergency trips were really fast and seem to fulfill their function, assuming they were in fact necessary. On June 7th, after the emergency trip E1, the regular trip P1 departed from the port. This trip made two visits to PU-01, the first one to deliver food and drinking water and the second one to deliver general cargo and to collect backload. On June 8th and 11th there were two more emergency trips. On June 11th, trip R1 departed and only one hour later trip P2 departed. Trip R1 arrived at PU-01 after the first visit of trip P2 and after the emergency trip E4. Trip P2 made three more visits to PU-01. On June 15th and 16th there were no vessels operating at PU-01 due to bad weather conditions, and four vessels departed from the port in less than twenty-four hours including PU-01 on their route. The order of the arrival of these vessels at PU-01 does not correspond to the order of their departure from the port. On the following days, trips E6, P4 and R6 were also carried out.

In fourteen days, sixteen trips to PU-01 were programmed to deliver and collect deck cargo, six of which were emergency trips, four were regular trips to PU-01 and six were regular trips to rigs. The offshore unit was visited nineteen times. The cargo included on trip R1 could have been sent on trip P2, and trips R2, R3, R4 and R5 could have been merging into a single trip. The multiple visits on trips P1 and P2 could have been eliminated. Thus, simply through better management of the current schedule, the trips programmed to PU-01 could have been reduced by 25% (four trips in sixteen) and the visits by 37% (seven visits in nineteen), probably without any drop in the service level.

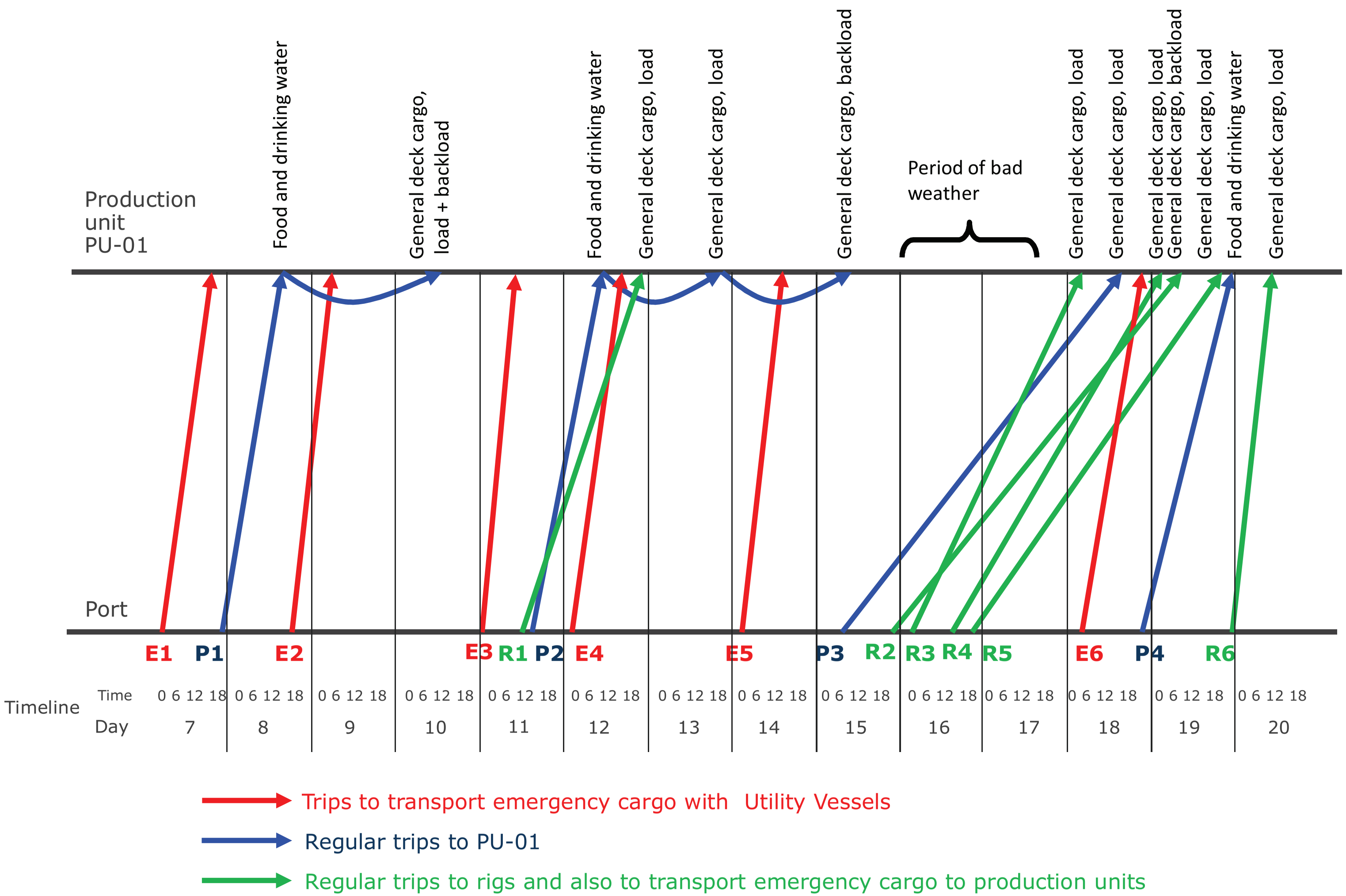

Figure 4.1: Example of a two-week period for the production unit PU-01

4.3 Data analysis

In order to understand how the offshore logistics system in the Campos Basin currently works, a large quantity of data was collected and analyzed. The data covered a one-year period, from April 2011 to March 2012. For the PSVs, only trips that departed and returned to the Port of Imbetiba, with load and backload deck cargo (with transshipments or not), delivering water or not, servicing two or more offshore units, with no responses to S.O.S. requests (thus eliminating trips that, for example, were used to look for a helicopter that had crashed, as happened in 2011) were considered. For the UTs, the difference is that no backload is required and the minimal number of offshore units per trip is one.

The cycle time of the vessels can be defined as the time between one and another arrival of the vessel at the port. The cycle time is subject to monthly and weekly variations, and is usually longer between August and October, as shown in Figure 4.2.

The cycle time is correlated with the number of visits, mainly because of the dependence of the trip duration on the number of visits, the trip comprising the time between the departure from and return to the port (see Figure 4.3).

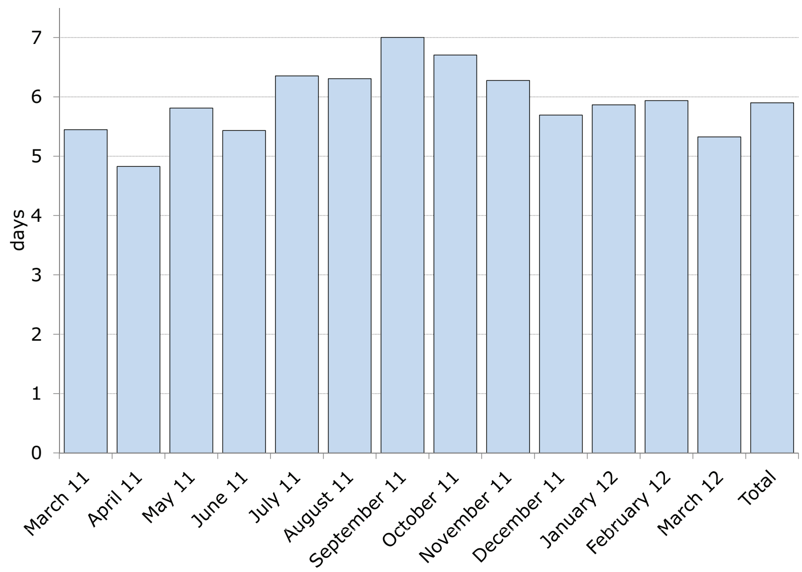

Figure 4.2: Cycle time of the PSVs at the Port of Imbetiba

The number of vessels used per week is also subject to large variations. The vessels that transported more than 50 m^2 were counted and the normalized[1] result is shown in Figure 4.4. On the y-axis, the number one is the mean of all weeks.

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

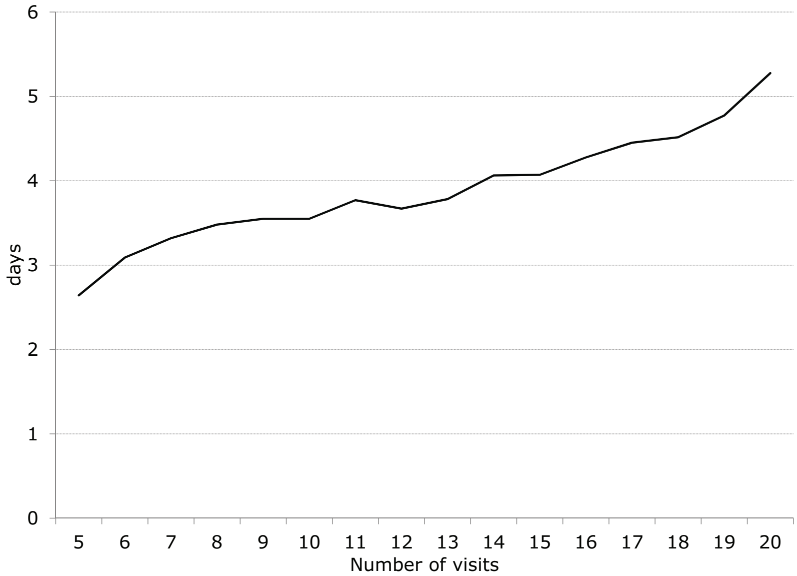

Figure 4.3: Trip duration per number of visits

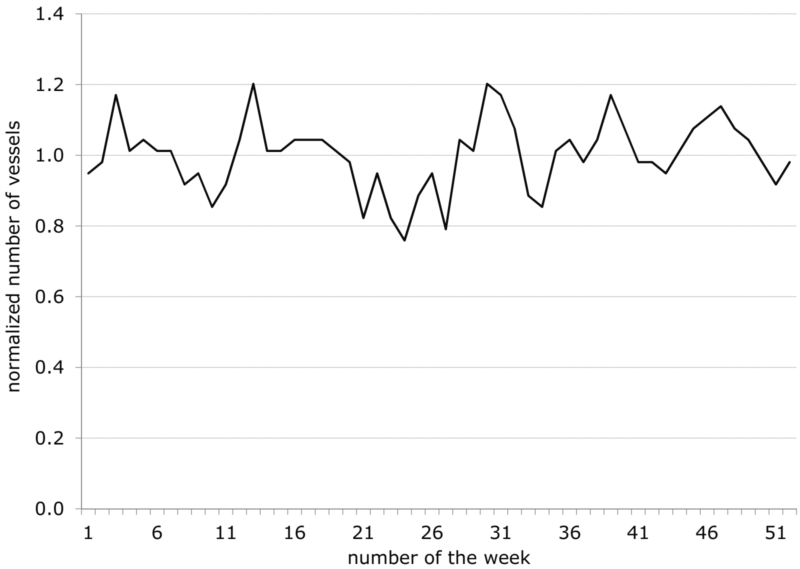

Figure 4.4: Normalized number of vessels that transported more than 50 m^2 per week

A histogram of the number of lifts per day at the Port of Imbetiba is shown in Figure 4.5 (intervals are not shown). The number of lifts per day has a standard deviation of 28% of the mean. Hence, the number of berths has to guarantee that on most days the port will have the capacity to load all of the cargo, including on days with a high number of lifts.

Another parameter to be investigated is the time between departures of vessels to the same offshore unit. Figure 4.6 shows the results segregated into rigs and production units. The emergency trips are not included in the histogram. In the case of the rigs, almost half of the departures occurred in

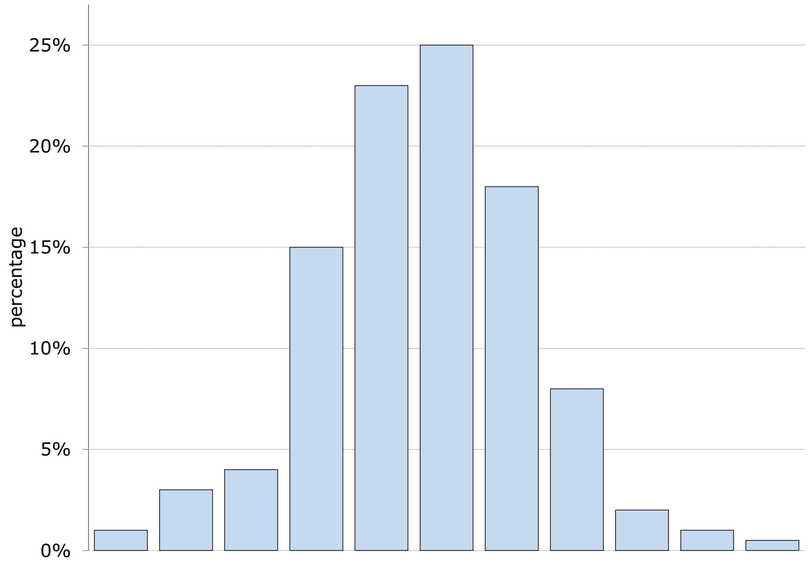

Figure 4.5: Histogram of the number of lifts per day at the Port of Imbetiba (intervals are not shown)

less than one day, and 81% occurred in less than two days. For the production units, 43% occurred in less than one day and 73% occurred in less than two days. This means that the planned two weekly trips to production units are not fulfilled, and trips planned to rigs are carrying normal production unit cargo and not only priority cargo.

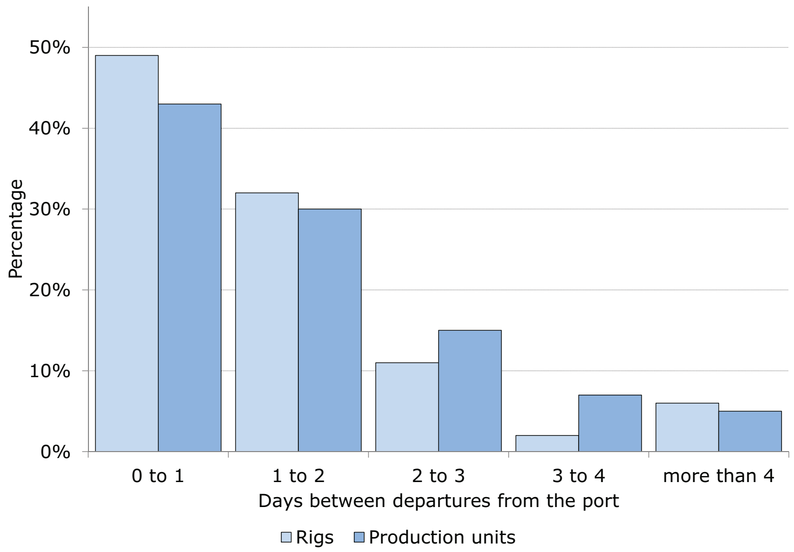

Figure 4.6: Days between departure of vessels to offshore units from the Port of Imbetiba

As shown in Table 4.3 (this table will be described in the next section), both production units and rigs receive on average 4.7 trips[2] per week (not including emergency trips). Figure 4.7 shows a histogram of this parameter. More than 40% of the offshore units receive between five and six trips per week, and some offshore units receive more than six trips. These numbers do not include multiple visits made within the same trip. In fact, 60% of the production units received more than 400 visits in one year, which means 7.6 visits per week only for deck cargo and water, and three units received more than 600 visits. It is common that an offshore unit is not able to deal with a vessel when it arrives there, because it is carrying out another operation and this situation represents 17% of the visits on a trip.

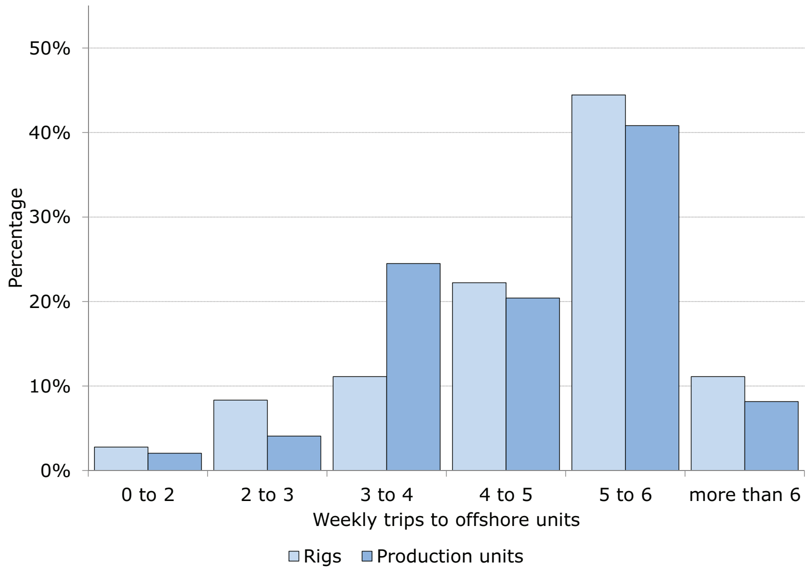

Figure 4.7: Number of weekly trips to the offshore units

4.4 Comparison between different bases

Table 4.3 shows a comparison between the parameters for different bases. These parameters are the cycle time, the number of offshore units per trip, the number of visits per trip, the weekly trips to production units and to rigs, the mean transport time between the port and the offshore units, and the request time (an explanation of this parameter will be given below). All parameters are mean values and, in some cases, the standard deviation is shown in brackets. The number of samples used to calculate the parameters and the number of units in the basin are also shown.

The cases considered in this comparison are the operation of the Port of Imbetiba (which services mainly the Campos Basin), Port of Rio de Janeiro

[2]Due to the multiple visits made within the same trip, to distinguish one another these will be called “trips” and “visits”.

(which services the Santos Basin), the schedule presented by Halvorsen-Weare and Faberholt (2011), and two of the cases presented by Kaiser and Snyder (2010).

There are many factors that influence results, thus this kind of comparison may lead to some misunderstandings if the differences between the cases are not well explained. The most similar operations in Table 4.3 are the ones from Port of Imbetiba and Rio de Janeiro. Both are from the same country and company and only for deck cargo and water (normal or emergency). The major differences between them are the distances between ports and offshore units (higher in Santos Basin), the density of offshore units in the basin (higher in Campos Basin), the weather conditions (worst in Santos Basin), and the time waiting and operating in the ports (due to legal regulations and utilization of maritime pilots, the time in Rio de Janeiro is higher). Those factors explain the higher cycle time in Santos Basin (7 days) than in Campos Basin (6 days), although the cycle time in Campos Basin could be much less if the number of visits were less. In fact, the greatest differences between those basins are the number of offshore units per trip, the number of visits per trip and the weekly trips for production units or rigs.

There are many factors that influence the results and thus this kind of comparison may lead to some erroneous conclusions if the differences between the cases are not well understood. The most similar operations in Table 4.3 are those of the Ports of Imbetiba and Rio de Janeiro which related to the same country and company and only to deck cargo and water (normal or emergency). The major differences between them are the distances between the ports and offshore units (greater in the Santos Basin), the density of offshore units in the basin (greater in the Campos Basin), the weather conditions (worse in the Santos Basin), and the waiting and operation times associated with the ports (due to legal regulations and the use of maritime pilots, these times being longer in Rio de Janeiro). These factors explain the longer cycle time in Santos Basin (7 days) than in the Campos Basin (6 days), although the cycle time in the Campos Basin could be much shorter if the number of visits were lower. In fact, the greatest differences between these two basins are the number of offshore units per trip, the number of visits per trip and the weekly trips to production units or rigs.

The Halvorsen-Weare and Faberholt's schedule (2011) may not be their best one. In fact, there is an offshore unit receiving two vessels at the same time on Sunday, although one vessel departed from the port thirty-two hours before the other. Furthermore, this is not historical data from a real operation.

Kaiser and Snyder (2010) carried out an empirical analysis of the use of vessels to service offshore units in the Gulf of Mexico. Many databases were studied and two were selected for this comparison, Apache and BP, because these were data from real operations and they provided a relatively high number of results to be compared.

The Apache data covered a four month period, 10 rigs were serviced and 461 visits were made by supply vessels (including data mainly from the Fourchon operations center and some trips originating from other ports may not be included in the data). The BP data covered all of the year 2008 and included 24 locations from the outer continental shelf, 20 of which were deepwater and 19 production sites. As there are several sites in different developmental stages, the stages overlap, as in the case of the Petrobras operations.

Kaiser and Snyder defined the *circuitry factor* as the number of locations visited on one trip. In this study, it is preferable to refer to the *circuitry factor* as the *number of offshore units per trip*, as this is more intuitive. Kaiser and Snyder stated that typical values for the *circuitry factor* are between 1.2 and 2, and that this seems to be an industry trend since for E&P companies the vessel availability is more important than a small saving which might decrease the service level. In the fields operated by Petrobras in the south and southeast of Brazil it is not common to have small circuitry factors, as operations are very concentrated with one operator in the same basin.

The authors of the articles from which the data were taken (Halvorsen-Weare and Fagerholt, 2011; Kaiser and Snyder, 2010) do not mention the type of cargo, so it was assumed that the vessels transported all types of cargo.

Although there is no organized data available for the Norwegian bases in the academic literature, Aas et al. (2007) and Aas et al. (2009) report that offshore units are visited by supply vessels one to three times a week, that the length of a trip is on average 2.25 days with large variations (although this seems to be the maritime voyage and not the cycle as defined in Section 4.3), and that the service vessels for the offshore units visit between three and six installations on one trip.

Table 4.3 shows the mean transport time between the port and the offshore units and the request time. The mean times between the port and the units for the Campos and Santos Basins are very close to one another, although the distances in the Santos Basin are larger. This is due to the high number of offshore units and visits per route of the trips departing from Port of Imbetiba. The request time is the period between two departures to the same offshore unit plus the trip duration of the second departure up to this offshore unit. This represents the maximum time that the offshore unit will have to wait to receive a requested cargo. The request time is approximately the mean time between the departure from the port and arrival at the unit plus the mean time between two departures (seven divided by the weekly frequency). In the Campos Basin, this is 3.5 days in the case of the production units and 4.3 days for the rigs. Considering the weekly trips to these units, it appears that these numbers could be improved.

The number of offshore units per trip is much greater for the Port of Imbetiba compared with the other ports. In the Gulf of Mexico it seems to be common for a vessel to service only one or two offshore units. The weekly trips planned by Halvorsen-Weare and Fagerholt are similar to those of the Port of Imbetiba, although the mean transport time between the port and the offshore units and the request time are much shorter, probably because of the number of offshore units per trip and the number of visits. The weekly trips carried out in the cases of the Apache and BP data range from 1.7 to 3.5.

The mean cycle time planned by Halvorsen-Weare and Fagerholt is half of the cycle time observed for the vessels departing from the Port of Imbetiba, and it is quite similar to the cycle time in the case of the BP vessels.

The Port of Imbetiba services around 75 offshore units. This is the largest operation of the cases being compared.

Table 4.3: Comparison between parameters for different cases. All parameters are mean values and, in some cases, the standard deviation is shown in brackets

	Port of Imbetiba		Port of Rio de Janeiro		Halvorsen-Weare and Fagerholt (2011)[3]	Kaiser and Snyder (2010) Apache	Kaiser and Snyder (2010) BP
Vessel	PSV	UT	PSV	UT	PSV	PSV	PSV
Type of cargo	Deck cargo and water	Emergency deck cargo	Deck cargo and water	Emergency deck cargo	All	All	All
Cycle time (days)	6.0 (4.5)	2.5 (1.4)	7.0 (5.4)	5.0 (4.2)	3 (1.8)	—	6.4
Number of samples	2014	523	577	261	7	461 visits	1219
Number of offshore units per trip	9.8	9.6	4.3	2.2	4.3 (1.4)	1.0	1.5
Number of visits per trip	14.2	10.9	5.6	2.3	4.3 (1.4)	—	—
Weekly trips to production units	4.7 (1.1)	1.4 (0.65)	2.1 (0.3)	0.45 (0.19)	4.3 (1.6)	—	3.0
Weekly trips to rigs	4.7 (1.5)	2.7 (0.8)	1.1 (0.5)	0.8 (0.3)		3.5 (1.4)	1.7
Mean transport time between the port and the production units (days)	1.9	—	1.9	—	0.65 (0.34)	—	—
Mean transport time between the port and the rigs (days)	2.2	—	2.0	—		—	—
Request time for production units (days)	3.5	—	5.0	—	2.6 (0.98)	—	—
Request time for rigs (days)	4.3	—	4.5	—		—	—
Number of units in the basin	around 75		around 25		7	10 rigs	24 locations

4.5 Discussion

Based on the issues discussed in this chapter, it is clear that the operations could be improved in terms of both the service level and the cost. As described in Section 4.2, in the example given, the programmed trips to PU-01 could have been reduced by 25% and the visits by 37%, probably without any drop in the service level. This example suggests a lack of control over the operations and that the management performance could be improved.

In the current schedule, there are clusters planned to service more than twenty units every day, although in most cases cargo does not need to be transported to all units. Table 4.2 shows the weekly area demand for five of the regular clusters of production units, and it is clear that some clusters need more than two PSV 4500 per week.

The large number of offshore units visited within the same trip and the multiple visits to the same offshore unit in one trip (see Table 4.3) increase the mean transport time between the port and the offshore units, and thus the cycle time of the vessels. Also, and perhaps more importantly, this makes the planning and control of the operation a very difficult task. The personnel from the offshore units do not know when a vessel will arrive or how many visits they will receive. Consequently, the customers can not organize themselves, leading to an inability to receive the cargo in some cases. The lack of regularity adversely affects the control of the fleet, and the personnel at the department that provides the routes for the vessels do not know when an offshore unit will be able to receive the vessel. The result is that visits which cannot be attended represent 17% of the total visits in one trip. After leaving the port, the cargo takes an unacceptably long time to arrive at the offshore unit. The frequent departures from the port to an offshore unit (see Figure 4.6) reduce neither the lead time nor the request time. The cycle times of the vessels, which could be shorter, correlate with the number of visits (see Figure 4.3), which need to be better controlled. Furthermore, there is room for improvement in relation to the use of the vessels.