3
Offshore logistics system to support exploration and production operations

Offshore Exploration and Production (E&P) operations are supported by a logistics and service system, which requires a large variety of specialized vessels, helicopters, ports, airports, warehouses, trucks and many other components. These offshore support activities can be divided into two categories: logistics and services. The main logistics activities are (Moreira, 2007; Kaiser, 2010):

1. cargo transport to and from offshore units
2. transport of residues from offshore units
3. transport of personnel
4. storage
5. inland transport and cargo handling

The main service activities are (Moreira, 2007; Kaiser, 2010):

1. towing and mooring rigs
2. mooring of floating production units and rigs
3. inspection of offshore units
4. support for FPSO offloading
5. oil recovery, stand by and rescue vessels
6. supporting offshore construction projects
7. clean out and stimulation of wells
8. diving services
9. pipeline installation

Logistics activities can also be referred to as upstream logistics or offshore logistics. Logistics and service activities may share many resources, for example, ports and warehouses. Thus, during the phase of infrastructure planning, all activities must be considered; however, in the day-to-day running these two activities are usually operated separately.

In this chapter, a general view of the offshore logistics will be given by describing the customers, the typical cargo, the logistics system, the vessels and ports, the deck cargo composition, the demand uncertainty and the productivity measurement techniques. Also, a brief overview of the offshore logistics in Brazil operated by Petrobras will be provided. Transport of personnel will not be addressed, as it is not the focus of this work.

3.1 Customer

The main customers of the offshore logistics system are offshore drilling and production units (in this text also called offshore units), and many special vessels, like those which install pipelines. The cost of the offshore operations and the value of the production are high; therefore these activities should not be interrupted due to cargo delays. Furthermore, the logistics system needs to be prepared for emergencies, as unexpected events on offshore units are frequent and they may change the cargo needs, especially in drilling units (Aas *et al.*, 2007; Aas *et al.*, 2009).

The production units used in Brazil are of the types fixed, FPSOs (Floating, Production, Storage and Offloading) and SS (Semi-Submersible) while the drilling units can be of the types anchored SS, dynamic position SS, jack-up or drillships, and each one may have specific logistics requirements. For example, a dynamic position SS needs more diesel than an anchored SS, but generally it is very difficult to correlate the type of unit to its logistics demands and to cluster units according to their demands. Each unit has its own characteristics in terms of the deck area, diesel and bulk storage capacity limit, water maker, operating water depth, well depth, unit size, people on board, age, maintenance program, fixed or mobile, etc. These characteristics lead to a unique demand pattern. Moreover, the different stages of the E&P life cycle require different logistics services (Kaiser, 2010). During *geophysical surveying*, the operations are performed by specialized vessels and require reduced logistics services, especially when the vessel returns to port. In the stage of *exploration drilling*, the operations are performed by rigs and require a logistics service of excellent quality. Large quantities of pipes and risers need to be transported, the demand uncertainty is higher and emergencies are frequent. Additionally, rigs have a high financial cost, which means that a shortage of equipment may be costly. In the *development* stage, many wells are also drilled, completed and hooked up to a production unit; therefore the logistics requirements are similar to exploration drilling. Pipeline installation may require the transport of pipes to lay barges. In the stage of *production*, under normal operations, the required cargo is transported to maintain production and periodic maintenance of the units. During the startup of units, drilling and workover activities the demand and required number of visits of vessels can increase. Maintenance which requires production stoppage may need special services.

Figure 3.1 shows two production units lifting containers in Campos Basin, during a trip undertaken by the vessel Maersk Vega

3.1(a): 3.1(b):

Figure 3.1: Production units lifting containers in Campos Basin (Sena, 2009)

3.2 Typical cargo

Cargo can be categorized as deck cargo, water, diesel, fluids (other than water and diesel) and dry bulk.

Deck cargo Loaded on the vessel deck, this can be unitized or not (see Figure 3.2). Containers do not have the standard size of 1 or 2 TEU (Twenty-foot equivalent unit), but instead they are usually smaller. Bags, tanks and skids are also used. Thousands of different items are transported, from pens to valves, screws to engines, and mattresses to instrumentation. Food and drinking water are transported in refrigerated containers. Chemicals and radioactive loads need different treatment, as does the backload comprised of waste and garbage. Non-unitized cargo can consist of risers, Christmas trees, BOPs (blowout preventer) and other heavy equipment (see Figure 3.3). Pipes are usually tied together. Special tools are transported for specific tasks in short periods. Many goods and tools need to be backloaded, as do empty containers.

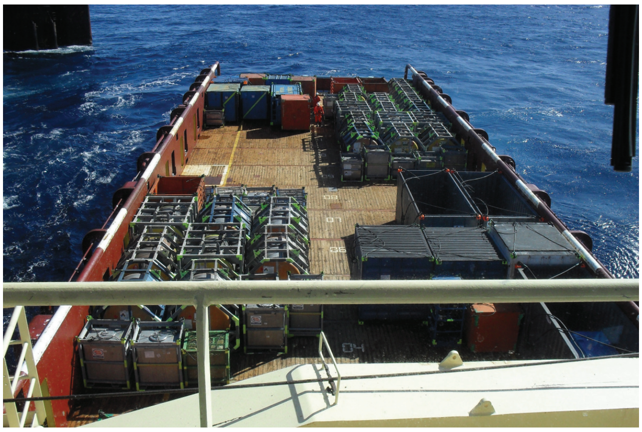
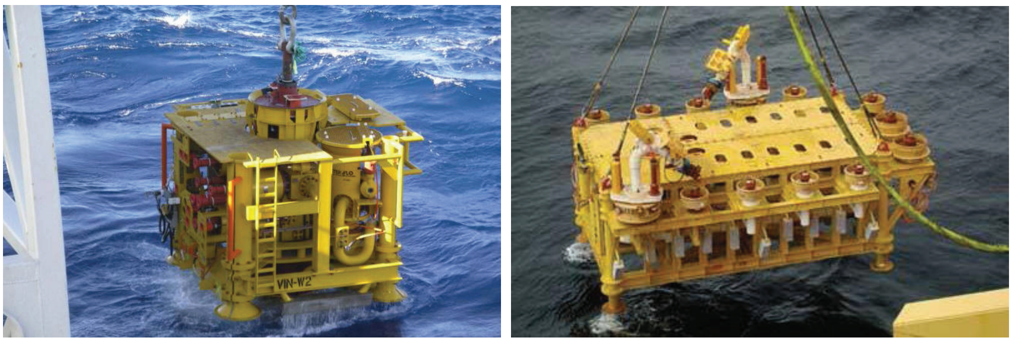


Figure 3.2: Cargos arranged in the deck of Maersk Vega (Sena, 2009)

The complexity of the operation is due to the large variety and number of items (with very different sizes and weights), the deadlines for the arrival of equipment and supplies on the units in order to ensure continuity, the efficiency and safety of the operations, the distance from the coast and the sea conditions for offshore loading and unloading. Also, some equipment is rented at a very high daily rate and therefore it should not wait around too long before transport (Aas *et al.*, 2009).

Figure 3.3 shows some non-unitized cargo used in well completion.



3.3(a): Subsea tree (Goldsmith, 2012) 3.3(b): Manifold (Howard and Hampshire)

Figure 3.3: Non-unitized cargo used in well completion

Deck cargo can be divided into general cargo, food and drinking water, pipes, risers, chemicals, waste and garbage. Table 3.1 shows the characteristics of each type of deck cargo. General cargo can be loads (from port to offshore units), backloads (from offshore units to port) or transhipments (from one offshore unit to another); unitized of not, but it is never refrigerated. Food and drinking water are always loads, unitized and refrigerated.

Table 3.1: Characteristics of each type of deck cargo

Type of cargo	Load	Backload	Transhipment	Unitized	Non-unitized	Refrigerated
General cargo	X	X	X	X	X	
Food and drinking water	X			X		X
Pipes	X	X	X	X	X	
Risers	X	X			X	
Chemicals	X	X	X	X		
Wastes and garbage		X		X		

Industrial water This is transported in appropriate tanks underneath the vessel deck and delivered to offshore units.

Diesel This is transported in appropriate tanks underneath the vessel deck and delivered to offshore units. Diesel is used in Brazil, while in the Gulf of Mexico some units use methanol (Kaiser, 2010).

Fluids Brine and drilling mud are the most common fluids and the vessels have appropriate tanks to carry them.

Dry bulk Cement, barite and bentonite are the most common dry bulks and the vessels have appropriate tanks to carry them.

3.3 Logistics system

The infrastructure of the E&P logistics system comprises ports, airports, warehouses and hubs. A simplification of the flow of cargo is shown in Figure 3.4. The inland flow can be handled by trucks or trains, although in Brazil most of the cargo is transported by trucks. The offshore flow is handled mainly by Platform Supply Vessels or PSVs (see Section 3.4). Nowadays, in the fields operated by Petrobras in the Espírito Santo, Campos and Santos Basins, the only cargo that uses a hub is diesel. In this case, a mobile hub is used: tankers are loaded at the ports and navigate to the basins where PSVs pick up the diesel and carry it to offshore units.

The supply chain of E&P activities as a whole is quite complex. Although the simplified model of the cargo flow shown in Figure 3.4 can be applied to most operations around the world, each company and base has its particularities. Looking closely at the fields operated by Petrobras and located in the Brazilian south and southeast, which includes the Espírito Santo, Campos and Santos Basins (Pelotas Basin has no activities), the supply chain can be outlined as shown in Figure 3.5. However, this scheme is still incomplete as its focus is on the logistics system, hence the "initial suppliers" are a simplification

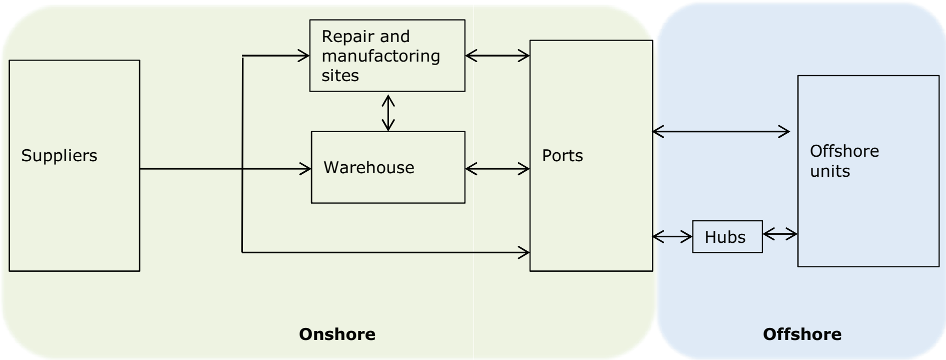


Figure 3.4: A simplification of the flow of cargo

of the innumerous companies that work in the supply chain of E&P operations, as detailed below.

Equipment, instrumentation and general goods These can be delivered to the warehouses, where they will be rerouted to the port or stored. They can also be delivered to the repair and manufacturing sites or directly to the port. Stored cargos can be requested and sent to the port. These are deck cargo and much of them, after use, are returned to land as backload, along with empty containers. There is also a flow between the warehouses and the repair and manufacturing sites.

Chemicals These are stored in the warehouses and sent to the port whenever a request is made. They are deck cargo.

Pipes and risers Like chemicals, these are stored in the warehouses and sent to the port when a request is made. They are deck cargo and can return to land or not.

Food and drinking water As these are perishable, they are delivered directly to the port by the suppliers in refrigerated containers.

Industrial water Petrobras is allowed to collect and treat the water that serves the Macaé Base, located in Campos Basin. Nevertheless, in other bases the local water company delivers it to the base. Usually, the tanks of the PSVs are filled even if there is no request for water, and it is delivered when offshore units are visited.

Salt and other supplies for fluids These are utilized in the manufacturing of drilling fluids, like brine and mud. Fluids are transported in dedicated PSVs.

Barite and bentonite These are received at the fluid plant and are transported to the offshore units in dedicated PSVs.

Cement Usually, trucks deliver the cement directly to the vessels at the port.

Diesel Tankers are loaded at the ports and navigate to the basins where PSVs pick up the diesel and carry it to offshore units. Periodically, a PSV loaded with diesel goes to the Port of Imbetiba to fill its tanks, so that vessels that operate at this port can be supplied with fuel.

Wastes and garbage These are transported to land and receive treatment by specialized companies.

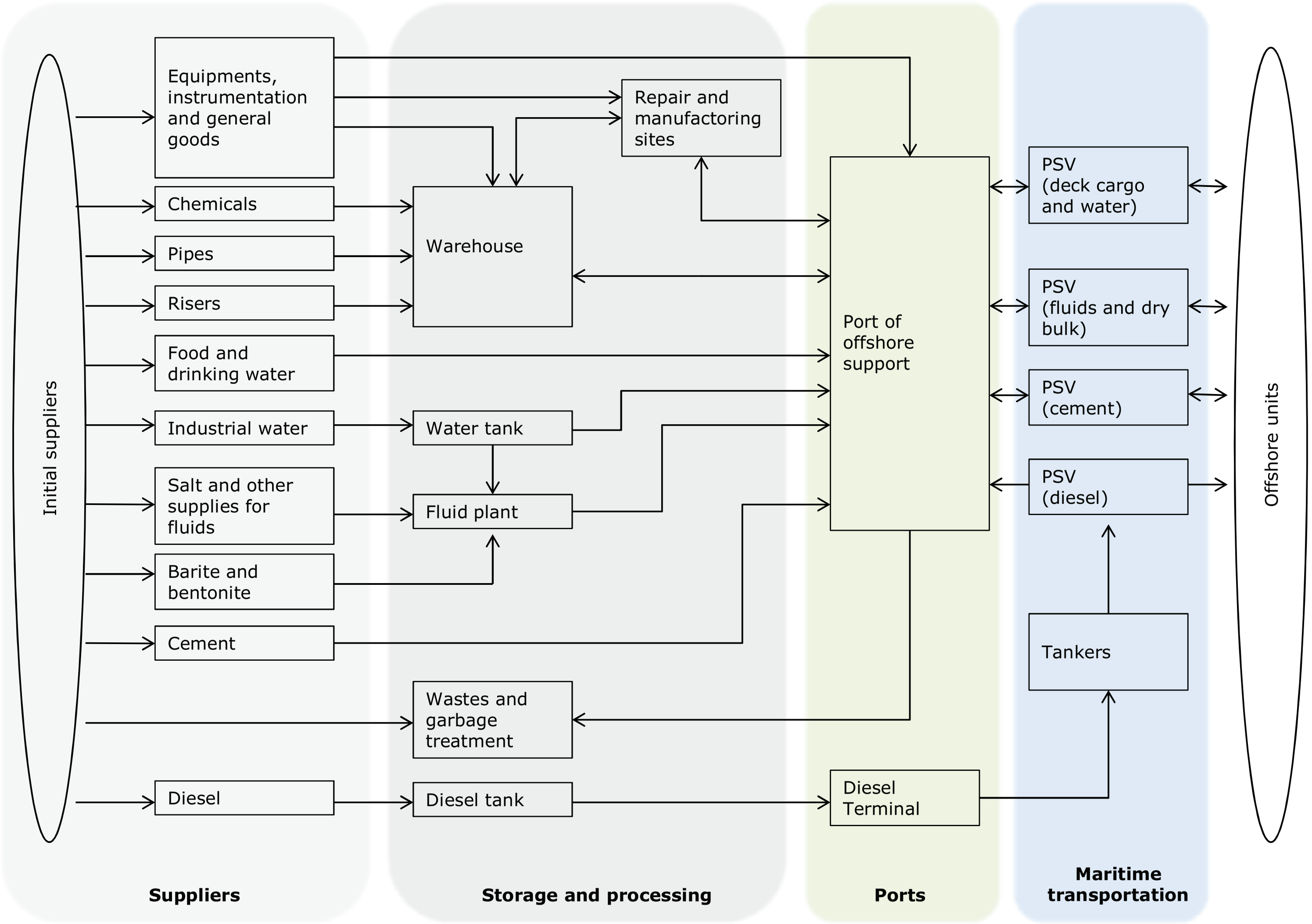


Figure 3.5: Supply chain of the fields operated by Petrobras and located in the south and southeast of Brazil

3.4 Vessels

The offshore support activities require a large variety of specialized vessels, which can be divided into service and transport vessels, as shown in Table 3.2 (Moreira, 2007). Some vessels, classified as service vessels, usually transport the cargo that will be used in service. For example, an AHTS transports the anchors that will be used in the anchoring activities of the offshore unit, and the DLV transports the pipes that will be installed on the seabed. LH, TS and AHTS can also be used for deck cargo, but this is not common.

Table 3.2: The main types of vessel used in offshore support activities (Moreira, 2007)

Abbreviation	Name	Transport or service	Usage
PSV	Platform Supply Vessel	Transport	Deck cargo, water, fluids, dry bulk and diesel
UT	Utility	Transport	Emergency deck cargo limited in weight and size
P	Passenger Boat	Transport	Transport of personnel
LH	Line Handling	Service	Line handling
TS	Tug Supply	Service	Tug and deck cargo
AHTS	Anchor Handling Tug Supply	Service	Anchoring, line handling, tug and supply, among others
OSRV	Oil Spill Response Vessel	Service	Stand by and rescue
DSV	Diving Suport Vessel	Service	Diving services
RSV	ROV Support Vessel	Service	Operations with remotely operated vehicles (ROVs)
WSSV	Well Stimulation Support Vessel	Service	Clean out and stimulation of wells
SESV	Subsea Equipment Support Vessel	Service	Operations with subsea equipment
DLV	Derrick Pipelay Vessel	Service	Pipeline installation

In this study, the focus will be on PSVs and UTs, as they are the vessels used for the logistics activities. Passenger boats are not used in the south and southeast of Brazil.

PSVs are specially designed for loading and unloading operations at sea (see Figure 3.6). They are able to transport all cargo mentioned in Section 3.2, that is, deck cargo, water, diesel, fluids (other than water and diesel) and dry bulk. In Brazil, Petrobras uses PSVs dedicated to specific types of cargo (Oil PSV, Fluid PSV, Dry Bulk PSV, Cement PSV and Deck Cargo/Water PSV), although they are designed for all types of cargo. PSVs can also be used as rescue and stand by vessels.

PSVs are classified according to their deadweight which is represented by a number after the abbreviation PSV, that is, the deadweight of a PSV 4500 is around 4500 ton. The most common PSVs in Brazil are PSV 1500, PSV 3000 and PSV 4500. In general, the load restriction of the PSVs is not the deadweight, but rather the deck area and the size of the tanks. The service

Figure 3.6: Campos Commander, a PSV 4500, arrives at Port of Imbetiba

speed is about 10 knots. The PSV 4500 type is the largest operating for Petrobras in Brazil, its length is approx. 87 m, width 18 m and maximum draft around 6.2 m. The deck area may exceed 1000 m^2, although the useful area is smaller. The power of PSVs can reach 7000 BHP and they have excellent manoeuvrability, achieved through mechanisms such as bow and stern thrusters, flap rudders and dynamic positioning systems (see Tables 3.3 and 3.4 for the average values for each PSV class and UT).

Table 3.3: Average dimension values for each PSV class and UT

Vessel type	Deck area (m^2)	Useful deck area (m^2)	Length (m)	Width (m)	Maximum draft (m)	Strength of deck (t/m^2)	Water capacity (m^3)	Water flow (m^3/h)	Service Speed (knot)
PSV 1500	394	295	62	15	4.7	4.0	565	96	10.0
PSV 3000	575	431	70	16	5.7	5.1	972	68	10.0
PSV 4500	880	660	87	18	6.2	5.0	1379	81	10.2
UT	183	137	50	9	2.9	2.3	85	42	20.2

Table 3.4: Average diesel consumption and capacity values for each PSV class and UT

Vessel type	Diesel capacity (m^3)	Diesel flow (m^3/h)	Consumption in service speed (ton/day)	Consumption in stand by (ton/day)	Consumption at the port (ton/day)
PSV 1500	485	93	11,4	4,3	1,1
PSV 3000	652	70	13,3	4,3	1,3
PSV 4500	1.832	91	16,7	5,7	1,3
UT	66	42	21,8	2,4	0,8

The Utility Vessels, or UTs, are used in the south and southeast of Brazil for emergency deck cargo, as they are faster than PSVs (service speed is 20 knots). The deadweight of the UT 4000 is approx. 390 ton and deck area is around 183 m^2 (see Table 3.3). UTs can also transport water and diesel, although they are currently used for smaller emergency deck cargo. They originated in the Brazilian Potiguar Basin as modified fishing boats, and were used for handling supplies and lines (Fayad *et al.*, 2008).

According to Aas *et al.* (2009), the following characteristics are important to PSVs: reliability and operational capability, carrying capacity, sailing capacity and loading / unloading capability. These characteristics are also important in the case of UTs.

The offshore support vessels operate at sea, far from the shore, and in many operations they need to be static close to the offshore units and under the influence of ocean currents, winds and waves. Therefore, the vessel design should consider not only the speed, but also the manoeuvring abilities at sea, including operation under bad weather conditions. The machinery, propulsion arrangement and hull design are the main characteristics that determine the vessel's sailing capacity under bad weather conditions (Aas *et al.*, 2009).

The hiring of the vessels is usually the most significant cost in offshore logistics, and companies usually rent vessels rather than own them. Fuel and harbour dues are also paid by the oil companies; the spot market is not well developed in Brazil but it is available in other countries (Aas *et al.*, 2009).

The loading and unloading capability of the PSVs is dependent on the lifting capability of the offshore units, the maneuvering characteristics of the vessel, and the weather and sea conditions (wind, visibility, currents, wave height). Operations can be stopped under bad conditions. All these factors also influence the capacity for carrying out simultaneous operations (bulk and deck cargo) (Aas *et al.*, 2009).

Table 3.3 shows the characteristics of PSVs and UTs which are important for this work (mean values), i.e., the deck area of each type of vessel, useful deck area, deck resistance, water capacity, water flow and service speed, as well as other characteristics including the length, width and maximum draft. The useful deck area is smaller than the deck area due to the paths required to allow the movement of workers on the deck, the various sizes of the cargo, making it impossible to perfectly fit all pieces of cargo, and the need to keep the pieces of cargo of each unit next to each other in order to make the operation at sea easier. In addition the useful deck area varies according to where the operation is performed, at port or at sea, and to the weather conditions, in operations at sea. In general, the usable deck area is considered to be 75% of the deck area and this is the value shown in the table.

Table 3.4 shows the characteristics related to the diesel capacity (for the vessel consumption) and consumption (mean values), i.e., diesel capacity, diesel flow, and consumption when sailing in service speed, during stand by and at the port.

3.5 Ports

Ports for offshore operations need to be prepared for the logistics and service activities of offshore support. They can be prepared for all activities or they can be specialized. Figure 3.7 shows the Port of Imbetiba, the main port for offshore operations in Brazil, located at Macaé, a city 180 km north of Rio de Janeiro.

3.7(a): Photo from (Petrobras, 2012b)

3.7(b):

Figure 3.7: Port of Imbetiba

A port prepared for offshore support satisfies the following criteria:

1. the number of berths supplies the demand of the offshore units
2. the berths have sufficient depth, length and floor strength
3. berths have facilities like cranes, overhead cranes, special equipment (if required), lines for fluids and dry bulk
4. the port has sufficient area for the deck cargo that will be loaded and for the deck cargo that has just been unloaded
5. the port has segregated area for chemical, waste and garbage, if required by legislation
6. the port has tanks for diesel, water, fluids and dry bulk
7. the port has access to water and diesel suppliers
8. the port has the licenses required by legislation
9. the maritime access needs to be compatible with the size of the vessels
10. the road or train access needs to be compatible with the cargo size and weight

It is preferable that the warehouse is close of the port or that the base hosts the port and warehouse within the same area.

3.6 The typical composition of deck cargo

There are three ways to measure the deck cargo: by tonnage, by area or by lifts, that is, the number of crane movements required to carrying the cargo to and from the vessels. Each of these is applied for different purposes. Tonnage is usually used for payment of the port operators and for enabling comparisons with other types of cargo, like fluids or dry bulk. Area is used when analysis must consider the deck occupation of the vessels, and lifts are used to calculate the operation time of the vessels at the port.

Table 3.5 shows the composition in percentage of deck cargo according to the type of offshore unit and divided into load and backload.

Data were collected from the units of Campos Basin between April 2001 and March 2012, and the results are shown in area, tonnage and lifts. Depending on which measure is used the composition of the demand is different. For example, for the production units, the general cargo was 49.1% of the area transported to the offshore unit, 39.6% of the tonnage and 50.6% of the lifts; and it was 76.0% of the area transported from the units to the port. For special vessels, general cargo and food are almost all of the load cargo, but general cargo, waste and garbage are the main backload cargo. For the production units, chemicals have a great importance in relation to the load cargo, but they are not so important to backload. Food and drinking water are important to load, but the empty refrigerated containers return as general cargo and some of the food returns as garbage. For the drilling units, risers and pipes have great importance. Note the different proportion of risers according to different measurements. As they are large and heavy, they are 13.7% of the tonnage of the load, 7.8% of the area but only 4.0% of the lifts.

The ratio between backload and load of the deck cargo is 0.7 when it is measured in tonnage[1], 1.0 when it is measured in area and 1.1 when it is measured in lifts. Table 3.6 shows the ratio according to the type of offshore unit. The ratio for the area and lifts for the production units was a surprising result, as usually the load is higher than the backload.

The typical cargo density is 0.66 ton/m^2 for load and 0.46 ton/m^2 for backload, and the typical size of the lift is 5.2 m^2 for load and 5.0 m^2 for backload (see Table 3.7).

3.7 Demand and its uncertainty

To build a schedule, it is necessary to calculate the weekly demand for deck area for each type of offshore unit and to understand its variations over a

[1] This is close to the 0.8 reported by Aas *et al.* (2007).

Table 3.5: Composition in percentage of deck cargo according to the type of offshore unit

		Backload			Load		
		Area	Tonnage	Lifts	Area	Tonnage	Lifts
Special vessels	General cargo	81.5	83.1	77.6	47.6	38.4	58.7
	Chemical	0.2	0.5	0.6	0.7	0.9	1.1
	Food and drinking water	0.0	0.0	0.0	51.7	60.7	40.2
	Waste and garbage	18.2	16.4	21.9	0.0	0.0	0.0
	Riser	0.0	0.0	0.0	0.0	0.0	0.0
	Pipes	0.0	0.0	0.0	0.0	0.0	0.0
Production units	General cargo	77.6	76.0	69.6	49.1	39.6	50.6
	Chemical	9.9	10.4	12.6	26.0	39.3	29.4
	Food and drinking water	0.0	0.0	0.0	22.8	19.7	15.5
	Waste and garbage	10.2	9.7	13.3	0.0	0.0	0.0
	Riser	0.0	0.0	0.0	0.0	0.0	0.0
	Pipes	2.1	3.6	4.5	2.1	1.4	4.5
Drilling units	General cargo	67.8	55.5	61.4	47.2	37.3	39.0
	Chemical	4.9	6.0	8.2	12.4	14.5	25.5
	Food and drinking water	0.0	0.0	0.0	9.3	10.0	7.8
	Waste and garbage	6.4	5.0	6.3	0.0	0.0	0.0
	Riser	8.9	16.7	4.9	7.8	13.7	4.0
	Pipes	11.7	16.7	19.2	23.3	24.5	23.6

Table 3.6: Typical ratio between backload and load according to the type of offshore unit

	Area (m^2)	Tonnage	Lifts
Special vessels	0.8	0.8	0.9
Production units	1.2	0.6	1.3
Drilling units	0.9	0.8	0.8
Total	1.0	0.7	1.1

longer period. Table 3.8 shows the mean demand for deck area and its standard deviation for the Campos Basin. The weekly demand for each offshore unit was calculated and then the general mean was obtained. The standard deviation is high in all cases, but lower for the load cargo for the production units. This finding confirms information provided by personnel at the operational areas and has also been reported by Aas et al. (Aas *et al.*, 2009).

It was surprising to observe that the backload area was larger than the load area. The demand is dependent on which activities the offshore units are carrying out. It is usually difficult to correlate the characteristics of the units and their activities with the demand. There are many variables in the processes and a database should be prepared for this kind of research. Factors like the stage of the life cycle of the unit (for example, if it is new or old), water and well depth, the need for chemicals, the type of unit, the site characteristics, the quality of the planning for the unit and many other factors may influence the demand.

Table 3.9 shows the mean demand for water and its standard deviation for

Table 3.7: Typical cargo density and size of the lift

		Backload		Load	
		Density	Size of the lift	Density	Size of the lift
		(ton/m^2)	(m^2)	(ton/m^2)	(m^2)
Special vessels	General cargo	0.53	5.4	0.40	4.1
	Chemical	1.15	1.6	0.59	3.9
	Food and drinking water	—	—	0.57	6.9
	Waste and garbage	0.40	4.3	—	—
	Riser	—	—	—	—
	Pipes	—	—	—	—
	Total	**0.50**	**5.1**	**0.47**	**5.2**
Production units	General cargo	0.37	4.7	0.56	4.3
	Chemical	0.39	3.8	0.93	4.1
	Food and drinking water	—	—	0.57	6.9
	Waste and garbage	0.35	4.2	—	—
	Riser	—	0.0	—	—
	Pipes	—	0.0	—	—
	Total	**0.37**	**4.5**	**0.67**	**4.6**
Drilling units	General cargo	0.60	6.2	0.56	6.3
	Chemical	1.09	4.9	0.88	4.4
	Food and drinking water	0.00	0.0	0.67	6.6
	Waste and garbage	0.46	6.4	0.00	0.0
	Riser	1.58	20.4	1.15	20.7
	Pipes	1.20	4.6	1.23	9.8
	Total	**0.66**	**6.3**	**0.66**	**6.4**
Total		**0.46**	**5.0**	**0.66**	**5.2**

Table 3.8: Weekly demand for deck area for each type of offshore unit and its standard deviation

	Backload		Load	
	Mean area (m^2)	Standard deviation	Mean area (m^2)	Standard deviation
Special vessels	35	25	22	20
Production units	156	112	133	54
Drilling units	192	159	195	171

the Campos Basin. Also, the proportion of weeks in which water was required was included, as it is not delivered every week. The weekly demand for each offshore unit was calculated and then the general mean was obtained.

Table 3.9: Weekly demand for water for each type of offshore unit, its standard deviation and the proportion of weeks in which water was required

	Mean (m^3)	Standard deviation	Weeks in which water was required
Production units	467	214	59
Drilling units	536	241	41

One of the main characteristics of offshore logistics is the uncertainty of the demand. Figure 3.8 shows the weekly demand for deck area for a production unit in the Campos Basin, between April 2011 and March 2012 (backload is not included), and Figure 3.9 shows the same data for a drilling unit. There were large variations in the cargo demand from one week to the next. The food and drinking water demand of the production unit was almost constant, and its peaks could be predicted. Although the necessity for food is constant, in some weeks, probably due to weather conditions, it was not possible to ship the food, so it was postponed to the next week. The drilling unit had shipments of risers and pipes in some weeks but not in others and the general cargo showed large variations during the year.

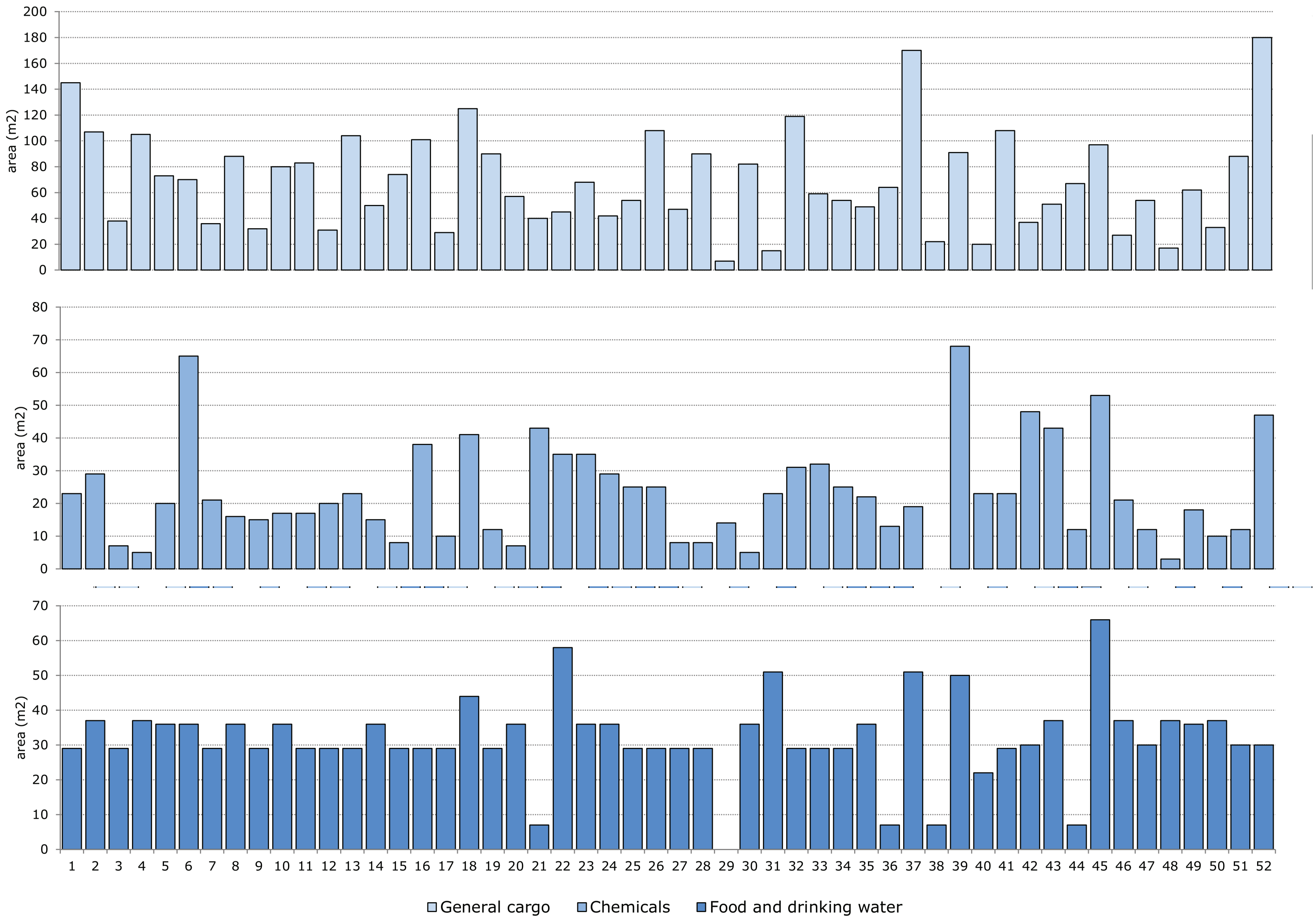


Figure 3.8: Weekly demand for deck area for a production unit in Campos Basin, between April 2011 and March 2012. Backload is not included

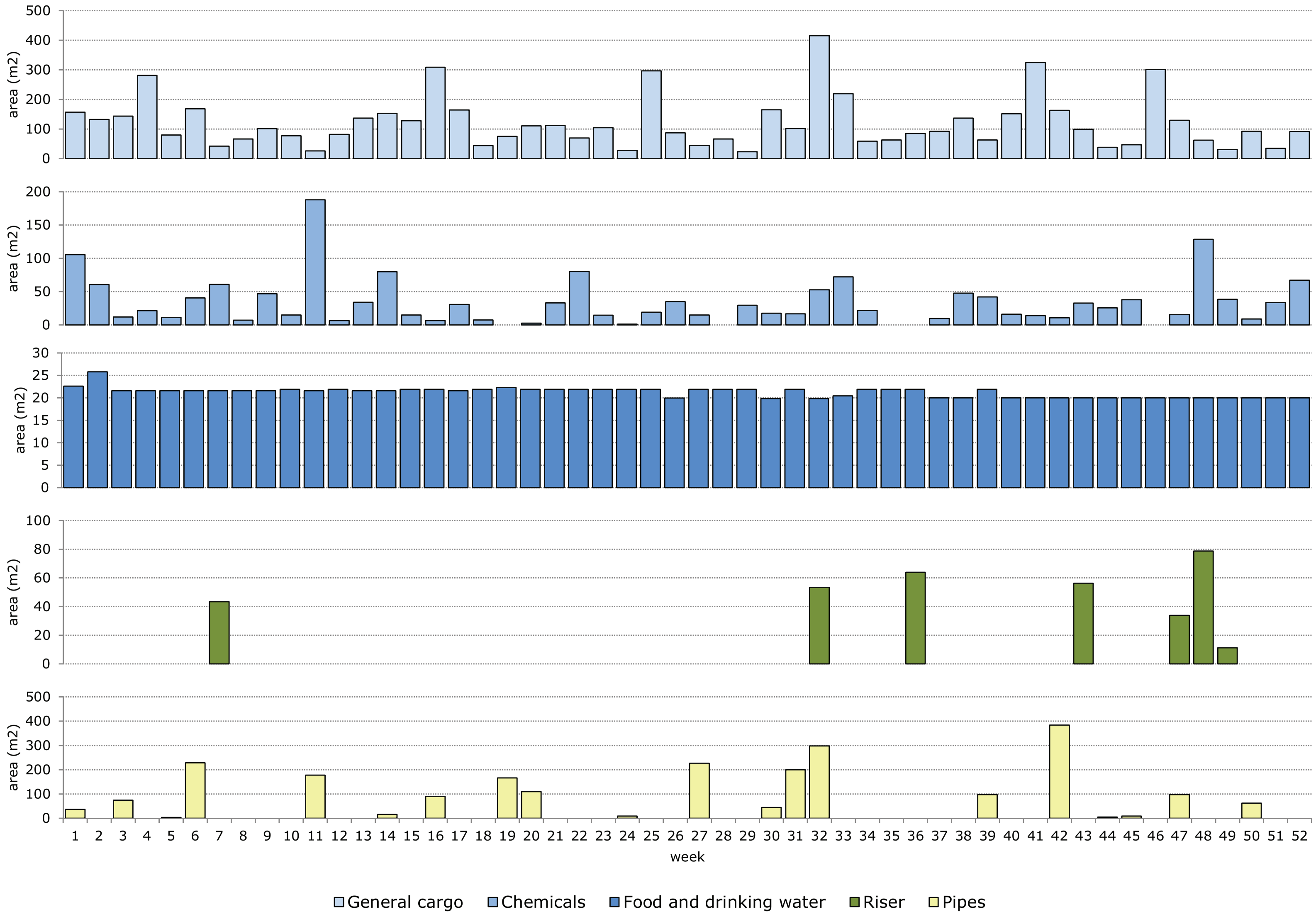


Figure 3.9: Weekly demand for deck area for a drilling unit in Campos Basin, between April 2011 and March 2012. Backload is not included

3.8 Productivity measures

Some parameters can be calculated to serve as measures of the productivity of the logistics system. For all parameters, the average values and the standard deviation can be calculated, but a histogram or box plot can also plotted when the data for certain parameters do not provide a normal curve profile. The maximum and minimum values can also be shown.

The main parameters for port operations are:

1. Number of lifts per vessel (load and backload)
2. Number of lifts per hour
3. Number of lifts per berth per day
4. Flow per hour of diesel / fluids / cement / water at the berths
5. Occupation rate of the berths
6. Number of shipcalls per berth per week
7. Turnaround time at the berth
8. Turnaround time of the load and unload operations
9. Number of offshore units per port/berth
10. Turnaround time of the vessels at the port (including operation at berth + wait at berth + wait anchored + queue time for a berth)
11. The time between the arrival of the cargo at the port and the berthing of the vessel

The main parameters for maritime transportation are:

1. Number of vessels per offshore units
2. Fleet composition
3. Number of required visits per week for the offshore units
4. Number of offshore units per trip
5. Number of visits to the same offshore unit on the same trip
6. The rate of occupied area of the deck per trip
7. The rate of occupied volume of the tanks per trip, or the rate between the delivered volume and the volume of the tanks per trip

8. Duration of the trip and its composition according to each phase of the trip (the time between arrival and berthing / turnaround time at the berth / navigation time between the port and the cluster of offshore units and *vice versa*/ waiting time at the offshore units/ operating time at the offshore units/ navigation time between the offshore units/ waiting time for better weather)

9. The time interval between vessel departing from the port and delivery of the cargo (for the first visit, last visit and the average time)

Besides the productivity parameters, other characteristics of maritime transportation can be described, in order to gain a better understanding of how it works. These characteristics are:

1. Whether or not the vessels are specialized in terms of the type of cargo

2. Whether or not the vessels or the routes have fixed times of departure from the port

3. Which cargo is transported on the same trip

4. The method applied to select the cluster of offshore units for a trip, and whether or not the trips have fixed clusters

5. Whether or not the offshore units have a schedule to receive the vessel, that is, a specified day and time at which they know the vessel will arrive

6. Whether or not the offshore units have restricted time windows to receive the vessel or another type of restriction

7. Whether or not there are exclusive trips for emergency cargo

8. The plan to deal with the demand uncertainty

9. The plan to deal with bad weather conditions

10. Once the trip has been programmed, whether or not the route is changed during the trip and how often this happens

11. The method used to route the vessels

12. Whether or not the offshore units may require a vessel to serve as a floating warehouse

The main parameters to be calculated to serve as measures of the cargo consolidation are:

1. Area density (tons/m^2) of the general cargo

2. Size of the containers

3. The ratio between the cargo weight and the weight of the containers

4. Occupation rate of the containers

3.9 Offshore logistics in Brazil

The offshore basins located in the south and southeast of Brazil are Campos, Espírito Santo, Santos and Pelotas, as shown in Figure 3.10. Up to 2012, Pelotas Basin had no activities. The port configuration to support the logistics activities of the fields located in these basins and operated by Petrobras is shown in Table 3.10 and in Figure 3.10, as it was in 2012, the Port of Imbetiba being the most important one. The importance of each port in the south and southeast of Brazil in 2011, according to each type of cargo, is shown in Figure 3.11.

Figure 3.10: Map of the south and southeast of Brazil, including the port configuration to support the logistics activities of the fields located in the south and southeast of Brazil and operated by Petrobras

The Port of Imbetiba operates with all types of cargo and also with service vessels. It handled 54% of the deck cargo from the fields operated by

Table 3.10: Port configuration to support the logistics activities of the fields located in the south and southeast of Brazil and operated by Petrobras, as it was in 2012

Port	State	City	Deck cargo	Water	Diesel	Cement	Dry bulk[2]	Fluids
Angra dos Reis	Rio de Janeiro	Angra dos Reis					x	x
CPVV	Espírito Santo	Vila Velha	x	x	x	x		
Ilha d'Água Terminal	Rio de Janeiro	Rio de Janeiro			x			
Imbetiba	Rio de Janeiro	Macaé	x	x	x	x	x	x
Itajaí	Santa Catarina	Itajaí	x	x				
Rio de Janeiro	Rio de Janeiro	Rio de Janeiro	x	x	x	x		
Samarco	Espírito Santo	Anchieta					x	x
Santos Terminal	São Paulo	Santos			x			

Petrobras in 2011, 69% of the water, 78% of the fluids, 83% of the dry bulk and all of the cement. As the main Brazilian port for offshore support, it supplies not only Campos Basin but all of the Brazilian fields operated by Petrobras, although the focus is Campos Basin.

The Companhia Docas do Rio do Janeiro, usually called Port of Rio de Janeiro, nowadays operates with deck cargo, water, diesel and cement and supports the Santos Basin. Other ports located in Rio de Janeiro are used to load fluids and dry bulk with spot contracts (these are not shown in Figure 3.10), as well as ports located in Niterói (a city 8 km from Rio de Janeiro).

Most of the diesel is handled by two diesel terminals: the Santos Oil Terminal and the Ilha d'Água Oil Terminal (located in Rio de Janeiro). As explained in Section 3.2, tankers are loaded at the oil terminals and navigate to the basins where PSVs pick up the diesel and carry it to offshore units.

The Port of Samarco operates with fluids and dry bulk, while CPVV (Companhia Portuária de Vila Velha) operates with deck cargo, water, and services. CPVV supports mainly the Espírito Santo Basin. The Port of Itajaí operates with deck cargo and water and it supports the south of Santos Basin.

The operations in the Port of Angra dos Reis began in early 2012, and so this port does not appear in Figure 3.11.

The North and Northeast shown in Figure 3.11 is not a port, but a set of ports located in the north and northeast of Brazil. The major ports in this region for offshore support are Guamaré, Pecém, Paracuru and Aracaju.

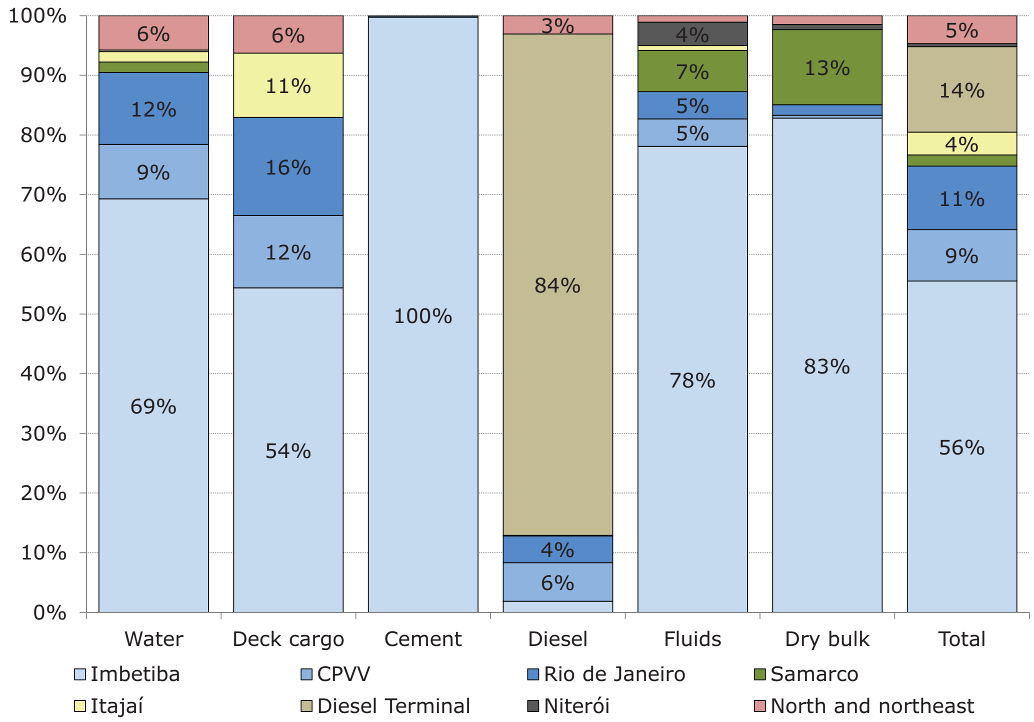


Figure 3.11: The importance of each port in 2011, according to each type of cargo