ORIGINAL RESEARCH

Critical Success Factors of the Brazilian Offshore Support Vessel Industry: A Flexible Systems Approach

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Abstract The offshore support vessel (OSV) industry is essential to the successful exploration and production of oil and gas at sea. Understanding the factors that dictate this industry's success is crucial and can indicate the actions that must be taken by industry players to survive in this market. Despite the Brazilian OSV industry being part of an extensive supply network, decision-makers operating in this industry still do not know what the critical success factors (CSFs) are, which has implications for the flexibility of companies in this industry. In this context, this paper is devoted to the identification of the CSFs of the OSV industry in Brazil, a country that obtains 95% of its oil production from the sea and that has faced economic and political turbulence in recent years. In this study, nine macro CSFs and 25 micro CSFs were identified through a mixed-methodology approach. This study provides insights both for scholars and practitioners involved in not only the OSV industry but the entire oil and gas supply chain.

Keywords Critical success factors ·
Offshore support vessels · Oil and gas · Supply network ·
Latin America

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Introduction

Recently, Latin American countries have become increasingly active on the world stage (Mittal 2019), especially Brazil (Scaglione et al. 2019; World Economic Forum 2020), a country whose economy is considered one of the largest worldwide (Jabbour and Jabbour 2014), being among the top 10 economies in the world in 2019 according to the World Economic Forum (2020). Brazil is one of the most dynamic economies both in Latin America (Jabbour and Jabbour 2014) and globally (World Economic Forum 2020), with representative types of industries. One of the most important industry sectors is the oil and gas chain, in which Brazil is a leading player both in exploration and production, especially in deep and ultradeep waters, as in the case of the reservoirs of the pre-salt layer (Azevedo Filho et al. 2019). In this context, there are several types of services that support activities related to oil and gas exploration and production, including the offshore support vessel (OSV) industry.

The OSV industry is crucial to the exploration and production of oil and gas at sea (Kaiser and Snyder 2013b; Kaiser 2015). Throughout the entire life cycle of an oil field, specialised services must be executed by different types of OSVs, beginning with geodesic mapping, followed by drilling activities, installation of subsea systems, installation of production units, transportation of supplies, maintenance activities, and, finally, demobilisation of the production system. This vast range of services (Kaiser 2010; Kaiser and Snyder 2013b) is performed by specialised vessels hired from industry players, which constitute the OSV industry (Kaiser and Snyder 2010; Kaiser 2016). These companies strive to remain competitive, with their businesses being profoundly affected by the global

economy. In addition, there are several pressures concerning environmental impact (Li et al. 2016).

Due to the complexities of the oil supply networks, flexible systems management is critical to the success of offshore installations. Regular support services are also necessary (Aas et al. 2009; Da Silva Maciel et al. 2014). Offshore installations also require a set of specialised vessels (Kaiser and Narra 2014) to perform different and complex activities. In most cases, the associated costs of performing these services are prohibitive. It is therefore paramount to identify the factors that determine the success of this industry, but from its own perspective, rather than from that of the entire oil industry.

The oil and gas industry literature has addressed the planning of support operations at sea, including strategies to optimise resource utilisation through strategic, tactical, and operational research (Fagerholt and Lindstad 2000; Aas et al. 2007; Bassi et al. 2012; Halvorsen-Weare et al. 2012; Norlund and Gribkovskaia 2013; Norlund et al. 2015; Seixas et al. 2016; Fernández Cuesta et al. 2017; Cruz et al. 2019). Also, other approaches can be highlighted, such as sustainable operations in OSV (Silvestre et al. 2017), the relationship between innovation and performance in shipping firms (including OSV) (Jenssen and Randøy 2002, 2006), and the complexities of offshore oil spills (Li et al. 2016).

Regarding the critical success factors (CSFs) of the OSV industry, this paper focuses on the Brazilian oil and gas industry, where almost 95% of its production comes from oil reservoirs at sea. Moreover, the country has gone through several periods of economic and political turbulence, forcing OSV industry players to rethink their strategies. In Brazil, there has been a marked lack of government support in developing international strategic partnerships, especially those related to suppliers in the oil chain. Moreover, there are important opportunities in Latin American countries regarding a more in-depth understanding of management to promote sustainable development (Jabbour and Jabbour 2014). Thus, understanding this industry's CSFs is fundamental to the development of policies that can positively impact the entire oil supply chain, at both the operational and strategic levels.

Despite the recent advances in the OSV literature, no previous studies have identified and discussed CSFs in the context of the Brazilian OSV industry. To bridge this gap, this study aims to identify the CSFs in the Brazilian OSV industry. This study contributes by generating insights for Brazilian OSV decision-makers, which will hopefully support and enhance their strategies, goals, and decisions. Also, this work offers insights into the variables that could affect the system's flexibility.

The remainder of this work is organised as follows. Section 2 is devoted to a general review of CSFs, followed by an overview of the Brazilian oil supply chain, including pre-salt exploration, OSV industry dynamics, and the current Brazilian OSV industry. Section 3 presents our methodology. Section 4 displays the results. A discussion of the results is presented in Sect. 5, and conclusions and future research directions are presented in Sect. 6.

Theoretical Background

The Role of the Critical Success Factors (CSFs)

CSFs were introduced by Daniel (1961) and have been applied in several contexts since then. The main idea is to address the factors that are critical to a company's success and performance, aiming to identify those that the company should pay special attention to managing. CSFs are defined as "the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organization" (Rockart 1979, p. 85).

CSFs can differ from one sector to another (Hofer and Schendel 1978) but may also vary depending on the environment in which the organisation operates and, therefore, they cannot be considered immutable. In addition, CSFs must be compatible with the strategic planning of organisations and enable managers to focus on the most critical aspects of their business. Successful examples are found in lean manufacturing and Six Sigma projects (Al-huraish et al. 2017), total quality management (TQM) (Motwani 2001), ISO 9001 implementation (Psomas et al. 2010), the pharmaceutical sector (Inoue and Yamada 2013), knowledge in project environments (Ajmal et al. 2010), enterprise resource planning (ERP) systems implementation (Fui-Hoon Nah et al. 2001; Dezdar and Sulaiman 2009), IT governance (Alreemy et al. 2016), innovation technology in manufacturing industry (Su and Liu 2012), private and public sector collaboration (Ullah et al. 2016), and supply chains (Singh 2015).

Critical Success Factors (CSFs) in the Flexible Systems Management Context

Scholars have investigated CSFs in several flexible systems management contexts (Chowdhury et al. 2007; Ahmad et al. 2012; Goel et al. 2012; Shahu et al. 2012; Kulshreshtha et al. 2017). For instance, Ahmad et al. (2012) investigated CSFs in the context of enterprise systems in Indian organisations. The authors highlighted and reinforced that CSFs can depend on the country context. Regarding the ranking of the CSFs, the authors highlighted that "relationship" implementation strategy, system integration, technical tasks, training, and IT infrastructure,

among others, were within the most important from the Indian perspective.

In another interesting study, Goel et al. (2012) examined the CSFs for e-governance programmes. The authors found that leadership was a strong CSF, due to its relevance and influence in projects' implementation, considering mainly bureaucratic and political leadership. Also, communication was a CSF on account of the complexity of managing various stakeholders. Programme management, training, skills, knowledge, and infrastructure were also critical for e-governance projects. In a recent study, Kulshreshtha et al. (2017) identified the CSFs for the implementation of an urban metro system considering public–private partnerships (PPPs) in India. The authors underlined the need for an institutional and legal framework, government support and guarantees, good governance, and techno-economic feasibility, among others. Regarding flexibility, Shahu et al. (2012) approached CSFs from the construction projects perspective. The authors found that flexibility was a strong CSF, because it influenced the costs and benefits of the project.

CSFs have also been applied in the maritime industry (Stavroulakis and Papadimitriou 2016) and in the appraisal of port competitiveness (De Martino and Morvillo 2008). In the shipping industry, Cheng and Choy (2007) examined the use of CSFs in dealing with quality management by identifying four critical CSFs: top management commitment and participation; quality information and performance measurement; employee training and empowerment; and customer focus.

Overview of the Brazilian Oil Industry

The oil supply chain is divided into two groups: upstream and downstream. The upstream flow corresponds to oil exploration and production activities (E&P), which can be either onshore or offshore. However, the offshore industry is the most relevant in the case of this research. E&P activities are complex and require various support services from the initial stages of prospecting a potential field to the actual production. In this context, hundreds of companies are involved, each one specialising in a set of supporting activities. However, since resources are scarce, any variation in planning has negative consequences for the entire supply chain.

The Brazilian oil industry operated through a monopoly structure until 1997. The primary objective of ending the monopoly was to attract new entrants, reduce the flow of imported oil, and increase revenues. The model used is the concession model (companies that can explore fields of offshore oil for a determined period), which establishes a competitive process among those companies that demonstrate the technical/financial capacity to execute projects.

Regarding Brazilian production, in 2018, oil production (including onshore and offshore, pre-salt, and post-salt) reached 944.1 million barrels (Brazilian National Agency of Petroleum, Natural Gas and Biofuels 2019).

The Brazilian coast is extensive (Fig. 1); it lies in a sedimentary area of 7.5 million km^2 (Brazilian National Agency of Petroleum, Natural Gas and Biofuels 2017a) and poses many challenges (e.g. crew transportation, supplies, support services, etc.) to the offshore units. Brazilian offshore production is concentrated in eight states. Rio de Janeiro state accounts for approximately 70.2% of the total production, followed by Espírito Santo (12.95%), and São Paulo 12.34% (Brazilian National Agency of Petroleum, Natural Gas and Biofuels 2019).

The pre-salt layer (an oil and gas reserve below a 2000-m-thick layer of salt) comprises oil and gas reserves in the ocean floor that precede the dense salt layer. In October 2007, Petrobras officially announced the discovery of the pre-salt layer and, ever since, Brazil has been one of the principal world players in ultradeep E&P. It is estimated that there are more than 100 billion recoverable barrels in this layer, and this estimate is expected to be one-third of the actual total recoverable. The pre-salt area is approximately 800 km long and is up to 200 km wide in some places. As highlighted in Fig. 2, it corresponds to a total area of 149,000 km^2.

The distance of the oilfields from shore, approximately 300 km, is very challenging, as well as the reservoirs' depth, which are between 5300 and 7000 m deep. This challenging scenario indicates that the technical requirements of the support industry must keep up with the standards imposed by the oil companies if reliable services, with high productivity and low operational costs, are to be provided.

Offshore Support Vessel (OSV) Industry Dynamics

The offshore support industry is a diverse sector, operating with various types of vessels, performing different types of tasks. These vessels are highly specialised, being built according to the type of service that will be performed (Ritchie 2008). Figure 3 highlights the main stages in which OSVs are required, which are briefly explained below.

Stage 1: Geodesic mapping This consists of a geodesic survey to determine the potential existence of oil in a field that has not yet been explored. Using geophysical data, it is possible to analyse the structure of the subsoil and to determine the most probable sites for the accumulation of hydrocarbons (Bacon et al. 2007).

Stage 2: Towing and anchor handling rigs Previously identified promising locations are further explored by drilling rigs. Although drilling ships equipped with

Fig. 1 Brazilian coastal offshore area. *Source*: Brazilian National Agency of Petroleum, Natural Gas and Biofuels (2017b)

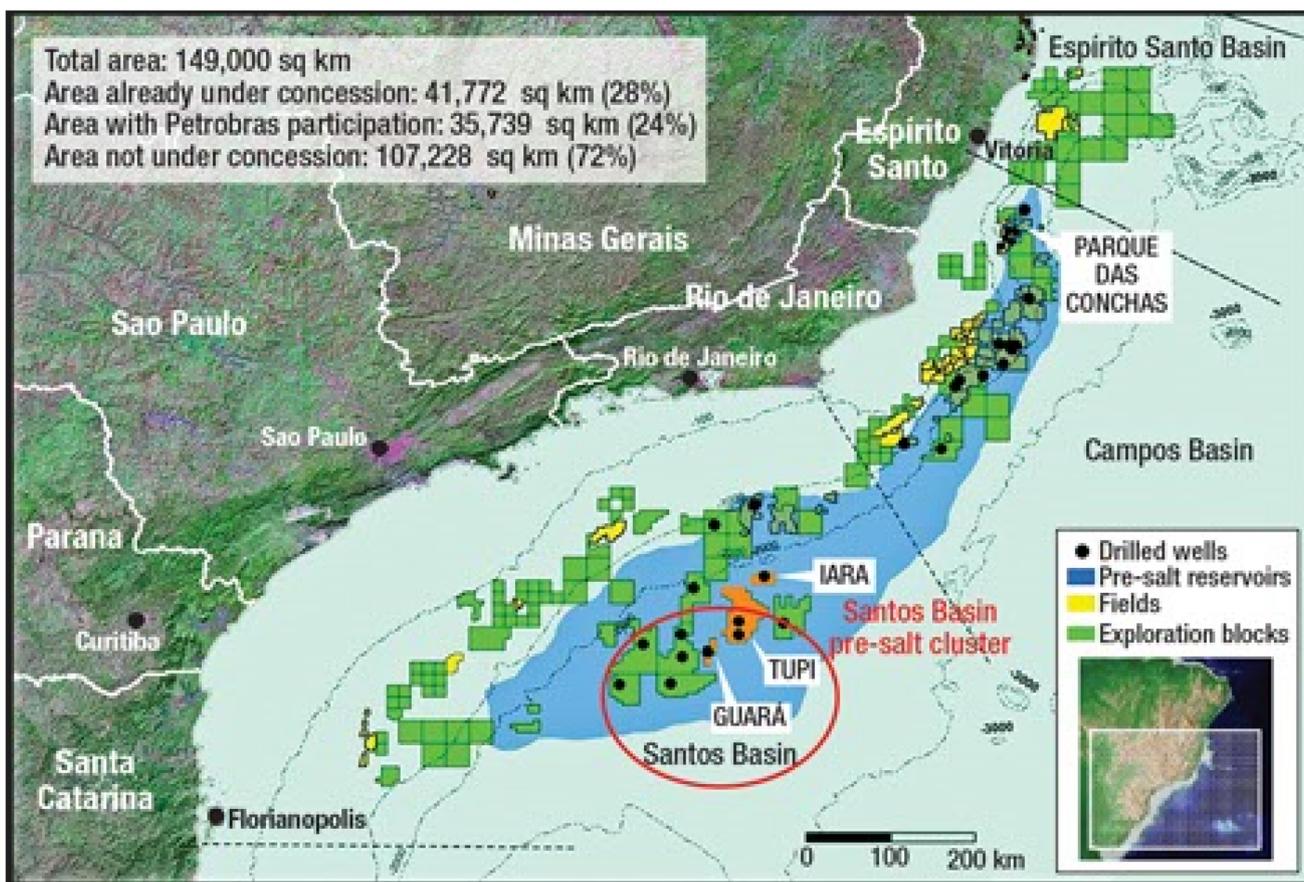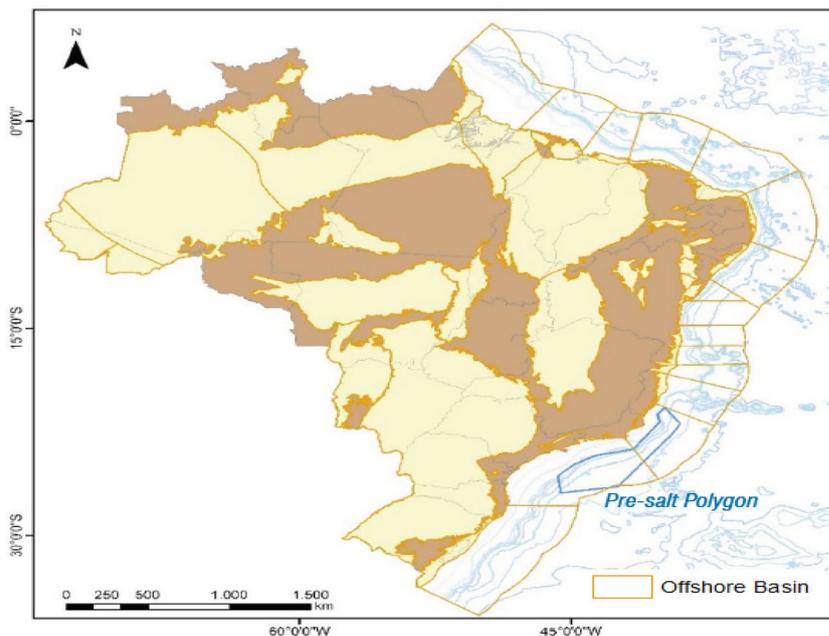Fig. 2 Brazilian pre-salt. *Source*: Estrella (2009)

dynamic positioning systems, which are propellers distributed along the hull of the vessel that, when activated, keep the floating system in a fixed position, do exist, many rigs are floating units that must be towed and anchored to their operating locations (Ritchie 2004; Shyshou et al. 2010), especially in the Brazilian market. Thus, these
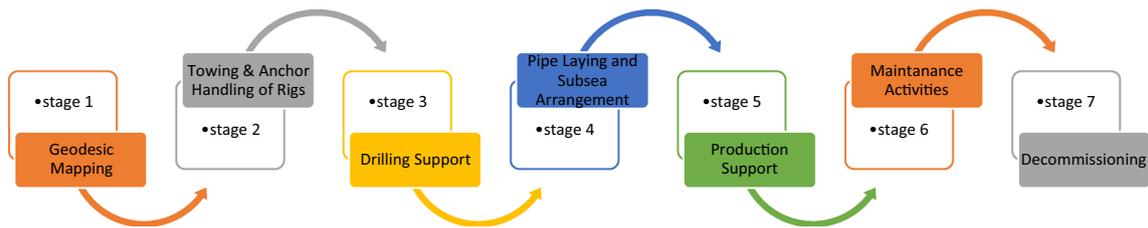
Fig. 3 Overview of the offshore support activities

activities are accomplished with the support of anchor handling and tug support vessels.

Stage 3: Drilling support The drilling process and preparation of a well for the production stage requires various materials, such as pipes of different diameters, cement, and mud. These materials are supplied from onshore bases by platform supply vessels (PSVs), which also provide potable water, industrial water, food, and diesel oil for onboard electric generators (Ritchie 2004).

Stage 4: Pipe laying and subsea arrangement A set of subsea equipment must be installed in an oilfield, such as Christmas trees, manifolds, jumpers, and other related equipment. Both the launching of this equipment and installation of pipes and risers and their connections are performed by pipe-laying support vessels (Bai 2012).

Stage 5: Production support Similar to drilling support, floating production units require materials, equipment, tools, consumables such as potable water, industrial water, diesel oil for generators, and food. These supplies goods are regularly transported to maritime units (Fagerholt and Lindstad 2000; Gribkovskaia et al. 2008; Halvorsen-Weare et al. 2012; Cruz et al. 2019) by PSVs.

Stage 6: Maintenance The underwater infrastructure requires a continual process of maintenance, either in a corrective, preventive or predictive nature. Scheduled inspections are also part of this type of service. Since the interruption in the production systems is likely to result in economic losses to the oil company, a quick response is expected if an intercurrence happens (Bassi et al. 2012; El-Reedy 2012). Remotely operated underwater support vehicles (ROVs) and diving support vessels perform these services, which are essential for the continuous and sustainable production of oil at sea.

Stage 7: Decommissioning This service has a critical dimension regarding the environment since there should be no risk of any leakage or contamination with the deactivation of an oil field. Therefore, this class of service also involves the demobilisation (withdrawal) of the equipment involved (Gerwick 2007; Martins et al. 2020) and is carried out with different support vessels.

The OSV activities generate a critical connection between offshore installations and the supply chain (Kaiser 2015). As shown in Fig. 4, this system can be divided into three parts: land; port; and offshore. The inland sector mainly consists of railroads and highways that are used to transport several types of materials to ports, where they are separated, collected, and stored before being transported to the offshore installations. Ports function as bases for maritime support companies, where it is possible to carry out a set of logistics services (e.g. materials receipt, storage, manufacturing, repairing and maintaining vessels, and waste management) (Kaiser and Snyder 2013b). The offshore part consists of several types of vessels specialised in different services, as listed above.

Regarding the Brazilian offshore support industry, it began in the late 1960s, with Petrobras importing 13 vessels. After almost 50 years, the Brazilian oil and gas industry has become a global player for E&P in deep and ultradeep water. Consequently, more specialised support vessels have become necessary. The OSV fleet has diversified, with the predominance of PSVs.

Methodology

In this work, we used a mixed-method approach (Deepali and Chaudhary 2017; Sushil 2018a, b). Mixed methodologies have acquired more visibility in the flexible systems literature due to their capacity for flexible systems modelling (Deepali and Chaudhary 2017; Sushil 2018a, b). Thus, we adopted a two-stage approach. First, supported by the literature (Deepali and Chaudhary 2017; Farooq and Raju 2019), we used content analysis (Kache and Seuring 2014; Roberta Pereira et al. 2014). Second, after the results from the content analysis, we used a questionnaire with experts to validate and ranking the CSFs (Sharma et al. 2015; Yadav et al. 2016; Apreda et al. 2019; Patil and Suresh 2019).

Content Analysis Step

Content analysis can provide insights about the hot topics and trends in a specific context (Kache and Seuring 2014; Roberta Pereira et al. 2014). Also, it signalises potential fields and theoretical gaps that require further research. From a flexible systems management perspective, the

Fig. 4 Offshore logistics dynamics. *Source*: Adapted from Kaiser and Snyder ([2013a](#))
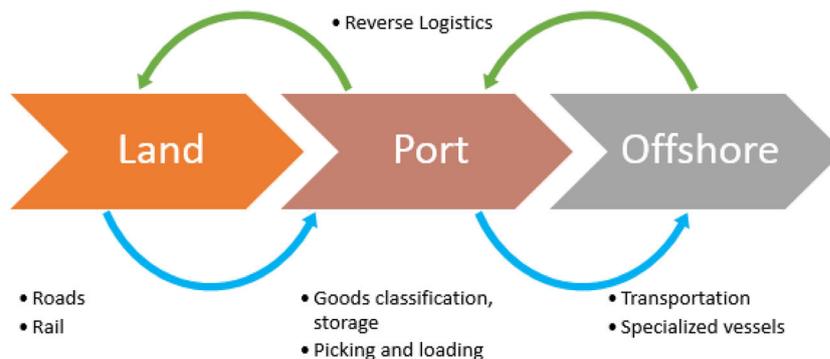
technique has the potential to highlight the main challenges and can suggest insights for scholars, practitioners, and decision-makers. The identification of CSFs for the OSV industry was based on the CSF literature as well as on the OSV literature; it also relied on industry yearbooks and company websites. Thus, to identify potential CSFs, three primary sources were integrated: extensive literature review (Phusavat et al. 2010); yearbooks from the sector; and secondary data based on the company websites searches. By triangulating these sources (Yin 2018), we found nine macro CSFs, comprising 25 micro CSFs (see Table 1).

The "policies" category comprises factors that are associated with industrial and governmental policies. The "financial" category, which usually represents an issue for organisations, comprises three factors. There are three "suppliers" factors, which seek to capture the integration of the offshore support industry with the rest of the oil chain. "Innovation" also has three factors, which highlight the current OSV industry innovations. The three micro CSFs in the "environment" category represent an essential dimension of the sector. "Competitiveness" comprises two factors, which seek to understand how companies are competitive. "Strategies" also comprises represented by two micro CSFs, expressing the main strategies adopted by the sector. The "workers" category comprises three factors, which are associated with workforce availability. Finally, the "productivity" category has two factors, emphasising the necessity of improving the sector.

Pilot Test and Data Collection

A questionnaire was developed to test the 25 CSFs using a five-point Likert-type scale, ranging from 1 (strongly disagree) to 5 (strongly agree). We employed a structured questionnaire to rank the CSFs. A pilot test was conducted with an experienced OSV industry professional and five oil and gas industry professionals. After feedback, consideration, and refinements, a final version of the questionnaire was generated that contained our 25 CSFs.

Sample

The National Agency for Waterway Transportation (ANTAQ) in Brazil lists 141 registered OSV-related companies. Preliminary screening was needed as their core business of some of the companies is not directly related to the scope of this research (e.g. tourism, recreation). Therefore, after eliminating 39 companies, the questionnaire was electronically sent to each of the remaining 105 companies, addressing decision-maker positions and managerial levels. We received 28 valid questionnaires (completed) from industry experts, representing a response rate of 26.67%. This rate is similar to that of Hu and Hsu (2010) and Zhu and Zhao (2015), who achieved a 28% response rate, which is superior to the studies of Cheng and Choy (2007) with 15.88% and Lin et al. (2002) with 20.27%.

Our sample size is very close to that of the studies of McKinnon (2014), who obtained 34 valid responses (27% response rate), and Zhu and Zhao (2015), who received responses from 39 companies regarding the "polluter-pays" principle in Hong Kong. The questionnaire was administered to the experts in 2017. Similarly to previous literature, it can be seen that our sample is representative and qualified. Moreover, our response rate (26.67%) is closed to one-third of the population, showing that it is sufficient to analyse the CSFs by employing descriptive statistics. Also, our sample is in line with the literature benchmark that supports a Pearson correlation test (Bonett and Wright 2000; Bishara and Hittner 2015).

Common Method Bias (CMB)

When a single respondent is used, CMB can inflate the variables' relationships (Podsakoff and Organ 1986; Doty and Glick 1998). A Harmon one-factor test was used to certify whether CMB was indeed a problem (Gunasekaran et al. 2017). The covariance was 42.58%, and since the threshold value is 50% (Gunasekaran et al. 2017), CMB did not significantly affect the results.

Table 1 Brazilian offshore support vessel (OSV) industry critical success factors (CSFs)

Macro CSF	Micro CSF	Description
Policies	CSF 1	Lack of political and economic information to support planning
	CSF 2	Current legislation and legal insecurity
	CSF 3	Taxation imposed by the government
	CSF 4	Bureaucracy in obtaining documentation for the bidding process
Financial	CSF 5	Difficulty in obtaining financing through National Bank for Economic and Social Development (BNDES)
	CSF 6	Difficulty in obtaining financing due to the rigour of the guarantees required by financial agents
	CSF 7	The average term to obtain financing to capture projects/bidding
Suppliers	CSF 8	Availability of high-quality suppliers
	CSF 9	Integration with the offshore supply chain (partnerships)
	CSF 10	The utilisation of the key performance indicators (KPIs) for qualification and evaluation of the suppliers
Innovation	CSF 11	Cooperation and partnership with universities
	CSF 12	The utilisation of computational packages to optimise the planning operations
	CSF 13	Tools and techniques to identify improvements
Environment	CSF 14	Specialists in environmental issues
	CSF 15	Environmental licensing costs
	CSF 16	Environmental certification ISO 14001
Competitiveness	CSF 17	Business intelligence to study bids
	CSF 18	Knowledge of the competitors (strengths and weaknesses)
Strategies	CSF 19	Strategies to avoid layoffs in times of low demand
	CSF 20	Strategies to optimise costs
Workers	CSF 21	Crew composition
	CSF 22	Availability of experienced and talented professionals
	CSF 23	Quality of the workforce
Productivity	CSF 24	Bidding bureaucratisation and its impacts on productivity
	CSF 25	Operational capacity

Reliability and Validity Analysis

Reliability concerns whether the test or procedure can yield the same results in repeated experiments (Carmines and Zeller 1979). To measure the internal consistency of the questionnaire, this study used Cronbach's alpha, following Hu and Hsu (2010). The literature considers scales with high internal consistency when Cronbach's alpha is higher than 0.70 (Landis and Koch 1977). In this study, Cronbach's alpha was 0.88, indicating high internal consistency for the questionnaire.

Results and Analysis

Distribution of the Respondents

The data obtained from the experts were analysed using IBM SPSS software (Zhu and Zhao 2015). Regarding the profile of the experts, directors accounted for the highest percentage of respondents (35.71%), followed by operations managers (28.57%), general and commercial managers (10.71%), and financial managers and consultants (7.14%). Company size, based on the number of employees, indicated that 17.86% of respondents worked in companies with fewer than 50 employees, 32.14% in companies with 50–99 employees, 10.71% in companies with 100–499 employees, 25.00% in companies with 500–999 employees, and 14.29% in companies with 1000 or more employees (Table 2).

Descriptive Statistics for Critical Success Factors (CSFs)

To measure the importance of the CSFs identified (ranked by the experts), this study used descriptive statistics based on the five-point Likert scale used. Table 3 presents the means of the CSFs and their correspondent ranking. As can be seen, two factors in the "policies" category [CSF 2 (current legislation and legal insecurity) and CSF 3 (taxation imposed by the government)] were ranked first and second. It is clear that both are significant to companies'

Table 2 Distribution of the experts

Profile of respondents	Frequency (N = 28)	Percentage
Director	10	35.71
Operations manager	8	28.57
General manager	3	10.71
Commercial manager	3	10.71
Financial manager	2	7.14
Consultant	2	7.14
Company size (no. of employees)		
< 50	5	17.86
50–99	9	32.14
100–499	3	10.71
500–999	7	25.00
≥ 1000	4	14.29

flexibility and operations, and in supporting their decision-making processes and planning.

Surprisingly, CSF 20 (strategies to optimise costs), in the "strategies" category, was ranked third. This reflects the necessity of the sector to utilise all resources efficiently given their high costs. Ranked fourth was CSF 23 (quality of the workforce), which represents a critical gap for all companies. CSF 15 (environmental licensing costs) was ranked fifth, indicating the considerable effort necessary to operate companies. The two lowest ranked CSFs were related to the "innovation" category: CSF 12 (utilisation of computational packages to optimise operational planning); and CSF 11 (cooperation and partnership with universities). However, innovation CSFs can affect all other factors.

Table 3 Mean and rank for critical success factors (CSFs) identified

Macro CSF	Micro CSF	Description	Mean	Standard deviation	Rank
Policies	CSF 1	Lack of political and economic information to support planning	4.2143	0.7868	6
	CSF 2	Current legislation and legal insecurity	4.6429	0.6785	1
	CSF 3	Taxation imposed by the government	4.6071	0.6853	2
	CSF 4	Bureaucracy in obtaining documentation for the bidding process	3.5000	1.2910	15
Financial	CSF 5	Difficulty in obtaining financing through National Bank for Economic and Social Development (BNDES)	3.0714	1.4639	19
	CSF 6	Difficulty in obtaining financing due to the rigour of the guarantees required by financial agents	3.7143	1.4365	12
	CSF 7	The average term to obtain financing to capture projects/bidding	3.8214	1.3348	11
Suppliers	CSF 8	Availability of high-quality suppliers	3.0714	1.1198	20
	CSF 9	Integration with the offshore supply chain (partnerships)	2.8929	1.1969	22
	CSF 10	The utilisation of the key performance indicators (KPIs) for qualification and evaluation of the suppliers	2.8214	1.6342	23
Innovation	CSF 11	Cooperation and partnership with universities	1.8571	1.3801	25
	CSF 12	The utilisation of computational packages to optimise the planning of its operations	2.5714	1.5013	24
	CSF 13	Tools and techniques to identify improvements	3.8929	1.1969	10
Environment	CSF 14	Specialists in environmental issues	3.3214	1.5647	17
	CSF 15	Environmental licensing costs	4.3571	0.8262	5
	CSF 16	Environmental certification ISO 14001	2.9286	1.3032	21
Competitiveness	CSF 17	Business intelligence to study bids	4.0000	0.9428	9
	CSF 18	Knowledge of the competitors (strengths and weaknesses)	4.0714	0.8997	8
Strategies	CSF 19	Strategies to avoid layoffs in times of low demand	4.1071	0.7373	7
	CSF 20	Strategies to optimise costs	4.4286	0.6901	3
Workers	CSF 21	Crew composition	3.6429	1.0616	13
	CSF 22	Availability of experienced and talented professionals	3.4286	0.9595	16
	CSF 23	Quality of the workforce	4.3929	0.7373	4
Productivity	CSF 24	Bidding bureaucratisation and its impacts on productivity	3.6429	0.8262	14
	CSF 25	Operational capacity	3.3214	0.4756	18

Table 4 Skewness and kurtosis for the CSFs

Category	Code	N	Skewness		Kurtosis	
			Statistic	Standard deviation	Statistic	Standard deviation
Policies	CSF 1	28	− 0.411	0.441	− 1.235	0.858
	CSF 2	28	− 1.712	0.441	1.631	0.858
	CSF 3	28	− 1.532	0.441	1.077	0.858
	CSF 4	28	− 0.723	0.441	− 0.554	0.858
Financial	CSF 5	28	− 0.056	0.441	− 1.213	0.858
	CSF 6	28	− 0.667	0.441	− 0.911	0.858
	CSF 7	28	− 0.856	0.441	− 0.169	0.858
Suppliers	CSF 8	28	0.362	0.441	− 1.442	0.858
	CSF 9	28	− 0.199	0.441	− 0.193	0.858
	CSF 10	28	0.144	0.441	− 1.740	0.858
Innovation	CSF 11	28	1.367	0.441	0.629	0.858
	CSF 12	28	0.170	0.441	− 1.518	0.858
	CSF 13	28	− 0.617	0.441	− 1.179	0.858
Environment	CSF 14	28	− 0.392	0.441	− 1.388	0.858
	CSF 15	28	− 0.780	0.441	− 1.062	0.858
	CSF 16	28	0.357	0.441	− 0.634	0.858
Competitiveness	CSF 17	28	− 0.857	0.441	0.149	0.858
	CSF 18	28	− 0.148	0.441	− 1.804	0.858
Strategies	CSF 19	28	− 0.174	0.441	− 1.058	0.858
	CSF 20	28	− 0.817	0.441	− 0.420	0.858
Workers	CSF 21	28	− 0.404	0.441	− 0.999	0.858
	CSF 22	28	0.625	0.441	− 0.638	0.858
	CSF 23	28	− 0.796	0.441	− 0.655	0.858
Productivity	CSF 24	28	0.780	0.441	− 1.062	0.858
	CSF 25	28	0.809	0.441	− 1.456	0.858

Skewness and Kurtosis

This study used skewness and kurtosis to test the normal distribution, i.e. whether the respondents have similar characteristics (Curran et al. 1996). Following the literature benchmark for skewness and kurtosis (Dubey et al. 2016), the maximum absolute values of skewness and kurtosis were 1.712 and 1.631, respectively. No significant deviance from the standard values was found. Table 4 reports skewness and kurtosis results.

Correlation Analysis

This study used Pearson correlation coefficients (Kess et al. 2010; Sharaan et al. 2017). Table 5 presents the results of the correlations. It is interesting to note that the relationship among the policies CSFs have a high correlation (> 0.77). The financial difficulties of the sector are emphasised by the high correlation of the "financial" CSFs with the "policies" CSFs, in which the correlations were more than

0.73. In the "suppliers" category, CSF 10 (utilisation of key performance indicators (KPIs) for qualification and evaluation of suppliers) had a low correlation with various other CSFs, as well as a negative relation with two CSFs from the "workers" category. In contrast, in the "suppliers" category, CSFs 8 and 9 demonstrated a high correlation with all three micro CSFs in the "financial" category: CSF 5 [difficulty in obtaining financing through National Bank for Economic and Social Development (BNDES)]; CSF 6 (difficulty in obtaining financing due to the rigour of the guarantees required by financial agents); and CSF 7 (the average term to obtain financing to capture projects/ bidding).

The "innovation" category presented low correlation with almost all CSFs. The only exception was CSF 13 (tools and techniques to identify improvements), which achieved a high correlation with some CSF from the "policies", "financial", and "suppliers" categories. The "environment" category achieved low correlation with practically all other categories, which suggests that

Table 5 Pearson correlations for the CSFs

	1	2	3	4	5	6	7	8	9	10	11	12
CSF 1	1											
CSF 2	0.77**	1										
CSF 3	0.78**	0.96**	1									
CSF 4	0.87**	0.88**	0.90**	1								
CSF 5	0.91**	0.73**	0.76**	0.92**	1							
CSF 6	0.94**	0.84**	0.86**	0.91**	0.89**	1						
CSF 7	0.88**	0.82**	0.85**	0.89**	0.84**	0.97**	1					
CSF 8	0.86**	0.52**	0.56**	0.76**	0.85**	0.84**	0.82**	1				
CSF 9	0.85**	0.77**	0.76**	0.89**	0.89**	0.82**	0.75**	0.75**	1			
CSF 10	0.29	0.47*	0.49**	0.43*	0.24	0.37	0.36	0.05	0.22	1		
CSF 11	0.64**	0.34	0.37	0.62**	0.77**	0.57**	0.56**	0.82**	0.73**	− 0.32	1	
CSF 12	0.18	0.24	0.19	0.09	− 0.04	0.11	0.15	− 0.11	0.04	0.64**	− 0.35	1
CSF 13	0.96**	0.77**	0.76**	0.82**	0.87**	0.86**	0.79**	0.75**	0.84**	0.27	0.59**	0.28
CSF 14	0.39*	0.39*	0.36	0.44*	0.33	0.37	0.43*	0.37	0.49**	0.41*	0.28	0.67**
CSF 15	− 0.12	− 0.09	− 0.01	− 0.13	− 0.14	− 0.07	− 0.11	− 0.07	− 0.30	− 0.01	− 0.28	− 0.41*
CSF 16	0.34	− 0.03	− 0.03	0.15	0.20	0.27	0.29	0.43*	0.14	0.32	0.16	0.55**
CSF 17	0.74**	0.81**	0.74**	0.70**	0.59**	0.73**	0.70**	0.52**	0.78**	0.29	0.34	0.39*
CSF 18	0.44*	0.17	0.11	0.32	0.33	0.36	0.29	0.47*	0.52**	0.21	0.31	0.35
CSF 19	− 0.04	− 0.07	0.01	− 0.02	0.03	0.03	0.13	0.26	− 0.11	− 0.53**	0.34	− 0.55**
CSF 20	0.03	− 0.29	− 0.18	− 0.08	0.04	0.02	0.09	0.39*	− 0.21	− 0.32	0.30	− 0.35
CSF 21	− 0.43*	− 0.34	− 0.35	− 0.35	− 0.32	− 0.36	− 0.28	− 0.13	− 0.21	− 0.82**	0.22	− 0.65**
CSF 22	− 0.13	− 0.43*	− 0.41*	− 0.27	− 0.08	− 0.23	− 0.29	0.18	− 0.06	− 0.80**	0.38*	− 0.71**
CSF 23	0.23	0.07	0.10	0.25	0.32	0.36	0.45*	0.54**	0.18	− 0.25	0.53**	− 0.34
CSF 24	0.12	− 0.10	− 0.19	− 0.17	0.02	− 0.03	− 0.09	− 0.05	− 0.04	− 0.40*	0.08	− 0.04
CSF 25	0.11	0.03	0.06	− 0.09	− 0.09	0.14	0.27	0.16	− 0.33	− 0.07	− 0.10	0.20

	13	14	15	16	17	18	19	20	21	22	23	24	25
CSF 1													
CSF 2													
CSF 3													
CSF 4													
CSF 5													
CSF 6													
CSF 7													
CSF 8													
CSF 9													
CSF 10													
CSF 11													
CSF 12													
CSF 13	1												
CSF 14	0.43*	1											
CSF 15	− 0.19	− 0.60**	1										
CSF 16	0.28	0.61**	− 0.45*	1									
CSF 17	0.78**	0.60**	− 0.29	0.18	1								
CSF 18	0.42*	0.61**	− 0.53**	0.73**	0.52**	1							
CSF 19	− 0.11	− 0.22	0.48**	− 0.34	− 0.16	− 0.51**	1						
CSF 20	− 0.08	− 0.13	0.50**	0.16	− 0.34	− 0.23	0.78**	1					
CSF 21	− 0.46*	− 0.26	− 0.02	− 0.44*	− 0.22	− 0.28	0.61**	0.22	1				
CSF 22	− 0.15	− 0.39*	0.36	− 0.24	− 0.25	− 0.04	0.56**	0.55**	0.59**	1			

Table 5 continued

	13	14	15	16	17	18	19	20	21	22	23	24	25
CSF 23	0.05	0.08	− 0.30	0.34	0.00	0.18	0.33	0.31	0.37*	0.07	1		
CSF 24	0.19	− 0.34	− 0.35	0.04	0.00	0.09	− 0.30	− 0.31	0.02	0.06	0.12	1	
CSF 25	0.06	0.01	0.26	0.22	0.00	− 0.32	0.53**	0.58**	0.02	− 0.07	0.26	0.02	1

$**p < 0.01$, $*p < 0.05$

companies find it challenging to manage factors in this category. The "competitiveness" category presented low correlation with "strategy", and, in some cases, a negative relationship. Non-significant relationships were found for the "workers" and "productivity" categories. However, CSF 17 (business intelligence to evaluate bids) achieved a good correlation with "policies", "financial", and "suppliers" CSFs, and with CSF 14 in the "environment" category.

The CSFs in the "strategies" category also demonstrated low positive and negative correlations, which were, in most cases, non-significant. However, CSF 19 (strategies to avoid layoffs in times of low demand) achieved significant a positive correlation with the "workers" category, showing a correlation of 0.61 with CSF 21 (crew composition), and 0.56 with CSF 22 (availability of experienced and talented professionals). CSF 20 (strategies to optimise costs) achieved a correlation of 0.55 with CSF 22 and 0.58 with CSF 25 (operational capacity) in the "productivity" category. In addition, CSFs 21 and 22 in the "workers" category showed a negative correlation with CSFs 12 and 13 in the "innovation" category. Finally, "productivity" CSFs demonstrated a non-significant correlation with the other categories, except for "strategies".

Propositions Derived from the Analysis of the Results

Based on the analysis of the results, this study formulates the following propositions:

P1 Policies CSFs → Financial CSFs: in the OSV industry, "policies" CSFs are positively related to "financial" CSFs, impacting companies' financial planning.

P2 Policies CSFs → Innovation CSFs: in the OSV industry, "policies" CSFs are positively related to "innovation" CSFs, impacting companies' innovation planning.

P3 Policies CSFs → Competitiveness CSFs: in the OSV industry, "policies" CSFs are positively related to "competitiveness" CSFs, impacting companies' competitiveness.

P4 Innovation CSFs → Competitiveness CSFs: in the OSV industry, "innovation" CSFs are positively related to "competitiveness" CSFs, impacting companies' level of competitiveness.

P5 Suppliers CSFs → Competitiveness CSFs: in the OSV industry, "suppliers" CSFs are positively related to "competitiveness" CSFs, impacting companies' integration.

P6 Environment CSFs → Competitiveness CSFs: in the OSV industry, "environment" CSFs are positively related to "competitiveness" CSFs, impacting companies' level of competitiveness.

Discussion

This work is one of the first studies to focus on the identification of CSFs in the OSV industry in Brazil, a highly representative economy from Latin America (Jabbour and Jabbour 2014; World Economic Forum 2020). We identified nine macro CSF, namely policies, financial, suppliers, innovation, environment, competitiveness, strategies, workers, and productivity. By using an expert respondents' strategy approach, we validated and ranked the CSFs. The two highest ranked CSFs were from the "policies" macro category [CSF 2 (current legislation and legal insecurity) and CSF 3 (taxation imposed by the government)], which impact the flexibility of the sector. This result is interesting and is in line with a recent study by Kulshreshtha et al. (2017) that identified the CSFs in the urban metro system in India and highlighted the influence of the institutional legal framework and government support and guarantees.

In third highest ranked CSF was CSF 20 (strategies to optimise costs) from the "strategies" macro CSF category, followed by CSF 23 (quality of the workforce) from the "workers" category, and, completing the top five, CSF 15 (environmental licensing costs) from the "environment" macro category. The result for CSF 20 is in line with the literature, due to flexibility directly impacting costs (Shahu et al. 2012). Also, the quality of the workforce is essential for a system to be flexible and responsive (Ahmad et al. 2012; Goel et al. 2012). In addition, CSF 15 is related to government support (Kulshreshtha et al. 2017).

It is fundamental to note that the CSFs vary according to the countries' particularities (Ahmad et al. 2012); our findings reinforce this behaviour. We found interesting similarities and differences from previous CSFs highlighted in the flexible systems management literature. For instance, our macro categories identified (policies, financial, suppliers, innovation, environment, competitiveness, strategies, workers, and productivity) are in line with the extant of the literature (Ahmad et al. 2012; Goel et al. 2012; Shahu et al. 2012; Kulshreshtha et al. 2017)

Thus, our results confirm the previous findings of the Ahmad et al. (2012), which found CSFs concerning systems integration, training, and IT infrastructure, among others. Although these CSFs were identified in different industries, this is an invaluable finding showing similarities in two BRICS (Brazil, Russia, India, China, and South Africa) countries. Our result regarding the "policies" CSFs also highlight the impact of the government bureaucratic processes (Goel et al. 2012) in the OSV field. Specifically, several CSFs identified emphasise the need for good governance and support from the government (Kulshreshtha et al. 2017) to promote sustainable growth of individual organisations and the entire oil chain. Also, the financial CSFs show that companies suffer from inflexibility in managing and planning at all levels (strategic, tactical, and operational). Previous literature (Shahu et al. 2012) has identified that flexibility impacts directly on the costs and benefits of projects.

Finally, comparing our results to previous CSFs from the maritime sector (Cheng and Choy 2007), our findings reinforce the need for adequate training for workers, information exchange between partners, and top management commitment to shifting this industry towards effective, flexible systems management.

Conclusion

Contributions to Literature

This study has identified the CSFs in the Brazilian OSV industry. By combining a mixed-methodology in two stages, we first identified nine macro CSFs, comprising 25 micro CSFs; in the second stage, these CSFs were ranked by industry experts. The results from the industry experts showed that policy-related CSFs were the most sensitive for the industry, followed by strategic and competitiveness CSFs.

Consequently, policy-related CSFs can impact significantly on companies' flexibility. In light of these findings, to improve competitiveness, understanding its antecedents is fundamental (Rosa Pires Da Cruz et al. 2013). The innovation dimension was ranked is the last position, based

on the mean, highlighting the urgent need for improvements in innovation policies by organisations and government. For example, "innovation" CSF 11 (cooperation and partnership with universities) emphasises this need, based on the low technical cooperation and the subsequent low innovation in this segment. Thus, for organisations to gain more flexibility, innovation is required.

Regarding the "financial" CSFs, virtually all OSV companies have difficulty dealing with these factors. For example, obtaining funds from a BNDES or the Merchant Marine program can be a complicated process. Regarding the relationships among the categories, a correlation test showed that "policies" CSFs have an interesting relationship with all other categories. Furthermore, "innovation" CSFs showed low or non-significant correlation with most CSFs. This suggests that although the Brazilian oil and gas industry is highly innovative, the Brazilian OSV industry should foster and develop more innovation, not only between the members, but also within the entire oil chain.

Moreover, the correlation test revealed essential relationships. For instance, in general, "financial", "suppliers", "innovation", and "competitiveness" CSFs were positively correlated with "policies" CSFs. However, the "environment", "strategies", "workers", and "productivity" categories presented some CSFs with a negative relationship. Thus, these results suggest that companies, the government, and all decision-makers involved in this supply chain need to pay attention to these variables and their associations to improve the flexible systems management both of the companies themselves and the sector as a whole. Consequently, a deeper understanding of these CSFs can support the development of more reliable planning.

Implications for Managers

This study is a valuable source of information for managers and practitioners involved in the Brazilian OSV industry as, by highlighting the CSFs, it consequently generates insights for decision-makers. All these CSFs require substantial attention from companies, due to their direct impact on flexibility, and consequently, on companies' performance.

Furthermore, the results provide valuable insights for managers by aiding their decision-making at operational, tactical, and strategic levels. The insights gained can also support decisions on investment in new vessels, the importance of workers' training, etc. Notably, although the "innovation" macro category of CSFs has been recognised by the literature (Chowdhury et al. 2007) as essential to organisations, our results show that substantial improvements are required in the Brazilian OSV industry. Specifically, the two lowest ranked CSFs were CSF 12 (the

utilisation of computational packages to optimise the planning of operations) and CSF 11 (cooperation and partnership with universities), which suggests that more actions related to flexibility are required both from managers and the government.

Limitations and Future Research

Concerning the main limitations of this study, we highlight the following. First, we cannot establish a comparison for our identified CSFs, due to the scarcity of similar literature. Also, caution must be taken in generalising the results due to the lack of benchmarks. These limitations, however, open avenues for future research. For instance, our CSFs can be used in other OSV networks (e.g. the Gulf of Mexico, Norway, etc.) and may also provide insights for other industries segments in Latin America. This study also suggests that future research investigates the CSFs identified in different oil and gas segments (e.g. exploration and production, distribution, etc.), as well as the enablers and barriers (Yuen and Thai 2017) to adopting innovations in the OSV industry. Futures studies could also investigate the effects of the Industry 4.0 and digital supply chain capabilities (Queiroz et al. 2019), as well as the requirements for moving to smart production systems (Queiroz et al. 2020). Finally, our suggested propositions open avenues and opportunities for further empirical studies.

Compliance with Ethical Standards

Conflict of interest The authors declare that there is no conflict of interest in publishing this paper. The authors state the clarification of the anonymisation of the data collection or for questionnaires (if any).

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Key Questions

1. Which are the main barriers and enablers to companies adopt and implement innovation policies for different horizons times?
2. Are the OSV companies prepared to adopt and implement Industry 4.0 technologies?

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