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REVIEW

Progress in Offshore Oilfield Development Planning

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Abstract

This study examines the methods to plan the development of offshore oilfields over the years, which are used to support the decision-making on the development of offshore oilfields. About 100 papers are analysed and categorised into different groups of main early-stage decisions. The present study stands in contrast to the contributions of the operations research and system engineering review articles, on the one hand, and the petroleum engineering review articles, on the other. This is because it does not focus on one methodological approach, nor does it limit the literature analysis by offshore oilfield characteristics. Consequently, the present analysis may offer valuable insights, for instance, by identifying environmental planning decisions as a recent yet highly significant concern that is currently being imposed on decision-making process. Thus, it is evident that the incorporation of safety criteria within the technical-economic decision-making process for the design of production systems would be a crucial requirement at development phase.

Keywords Offshore oilfield development; Oilfield planning decisions; Production system design; Decision-making process

1 Introduction

Many technical challenges are driving the oil and gas industry to constantly evolve, develop new technologies, improve data collection methods and enhance decision-making processes to increase hydrocarbon recovery. Moving from onshore to offshore exploration and production elevates the project complexity, bringing more factors that influence the reservoirs exploitation, such as the water depth, the weather conditions and the distance from shore.

The development of an offshore oilfield is considered a critical phase, as it is responsible for defining the requirements of the production systems, the technical specifications and the feasibility studies, based on the data collected during the exploration and appraisal phases, for the physical implementation of the production system (Silva and Guedes Soares, 2021a). Thus, the operational stage appears to be a crucial phase, since it corresponds to the production and exploitation of the field itself, until the moment when the field is no longer economically viable for the oil company. Figure 1 presents the oilfield life-cycle phases.

In practice, many strategic decisions must be made during the development phase. Once the decision has been taken to develop an offshore oilfield, the decision-makers seeks for the most technically, economically, safety and environmentally appropriate system solutions that can be implemented and maintained throughout the remaining oilfield life cycle phases: operation and abandonment.

Therefore, the main goal of the present work is to analyse, based on the literature, three important questions that can provide a better understanding of the planning concerns of an offshore oilfield development:

1) What has been the status of decisions on the development of an offshore oilfield development over the years?

2) What are the main technical methods used to support the decision-making process of each development decision?

3) What are the prospects and gaps of decisions or technical approaches on each development category of offshore oilfields?

A substantial body of literature exists on the subject of field development planning, encompassing review articles on specific research topics, as well as the optimisation and mathematical programming methods applied to planning

Article Highlights

- The study examines the status of decisions and the main technical methods used to plan the development of offshore oilfields over the years.
- A temporal and spatial evolution of oilfield development decisions is presented.
- The work also provides the prospects and gaps of decisions or technical approaches that may be used to support the decision-making on the development of offshore oilfields.

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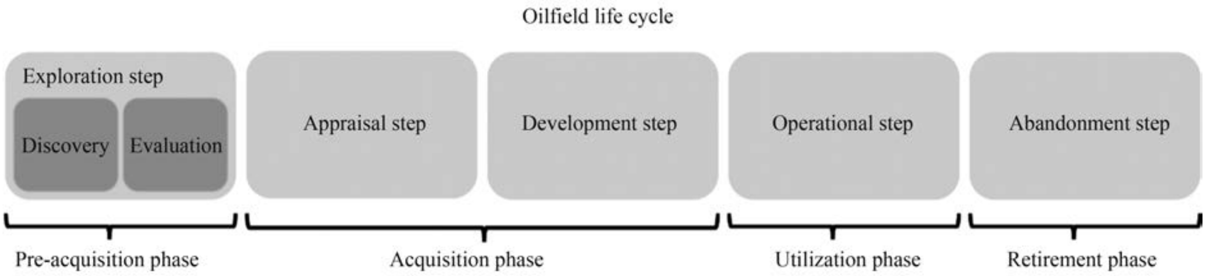

Figure 1 Oilfield life cycle phases

and development of an oilfield (Durrer and Slater, 1997; Khor et al., 2017; Sullivan, 1988). Other notable works include a review of the process system engineering perspective of field development planning (Tavallali et al., 2016), and a review of the evolution of subsea production systems worldwide (Hansen and Rickey, 1995).

The previous work of Durrer and Slater (1997) analysed the literature on operations research (OR), reviewing optimisation models to improve petroleum and natural gas production. They focused on drilling, reservoir simulation, production planning and operations, and enhanced recovery processes. Within the field of operations research, Sullivan (1988) focused on reviewing mathematical programming methods for long-term exploitation planning in oil and gas field development. The main goal of the study was to identify efficient optimisation models that integrate refined reservoir modelling and the decisions of drilling and recompletion planning; as well as the planning of surface separation; gas processing; oil, condensate and gas pipeline systems; export terminals and refineries, and more. Furthermore, the third review of development planning in the scientific area of operations research was carried out by Khor et al. (2017). The authors analysed numerical and mathematical programming optimisation methods for making decisions regarding reservoir development and oilfield planning and management. These include production rate and gas-lift allocation, as well as oilfield design and operations. Besides discussing research articles relating to onshore and offshore oilfields, the main focus of the proposed review articles are the operations research methods. Also, the authors do not cover all the decisions categorised in the present paper.

Tavallali et al. (2016) present a review article from the perspective of process system engineering, searching for deterministic methods for design and operational decisions, both separately and in an integrated manner. The authors analysed decisions relating to field planning, surface network design, well design and placement, and wells and surface networks, as well as field service. Not only does the author fail to distinguish between onshore and offshore oilfield papers, they also neglect to address the key offshore oilfield development decisions, such as those related to the subsea production system. Conversely, Hansen and Rickey (1995) only covered papers that addressed the subsea production system from a petroleum engineering perspective. The authors only described the evolution of the subsea development.

The present work contrasts with the contributions of operations research and system engineering articles on the one hand, and of petroleum engineering articles on the other. First of all, the present work does not focus on one methodological approach and tries to analyse all methods that can support the decision makers in the conceptual design phase. In addition to limiting the literature analysis to offshore oilfield development, the present work does not focus on the worldwide evolution of a system, looking for different technology implementations and configurations. Therefore, the main goal of the proposed article is to provide a systematic overview of the progress and prospects of offshore oilfield decisions categories and different technical solution and approaches used to support the decision-making process. About 100 papers are analysed and categorised into different groups of main early-stage decisions.

The remainder of this paper includes section 2, categorises and describes the most relevant offshore production system decisions and the general analysis of the papers.

2 General analyses of offshore oilfield development decisions

As the offshore oil production system aims to extract, produce, gather and transport the hydrocarbons from the reservoir to a pre-processing facility, which may be located onshore or offshore (Bai and Bai, 2010), in an attempt to maximise the recoverable amount of hydrocarbons from the reservoirs, it can be divided into two main subsystems: surface and subsea (Silva and Guedes Soares, 2025). According to Haugland et al. (1988), it includes mainly decisions related to the design of the production system, others related to the operation of the system and others appear as a mixed character of design and operation. In this respect, the decisions consider the relationship between the production system and the reservoir management (Wang et al., 2019). Moreover, nowadays, the environmental concerns of the oilfield project are imposing a significant impact on the decision-making process, requiring an extension on the early definition described by Haugland et al. (1988). Figure 2 shows the relation between the field design and production planning decisions.

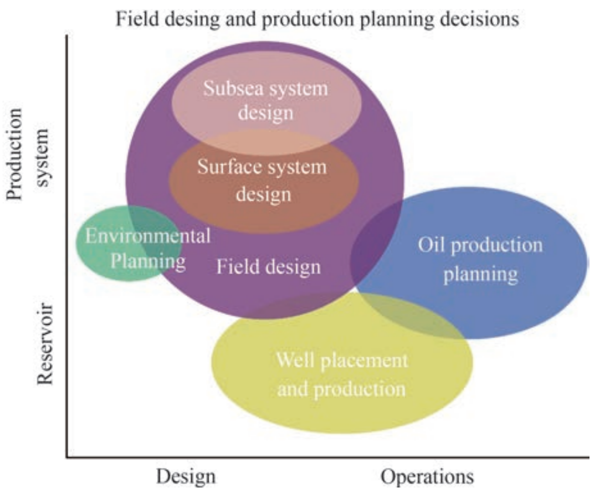

Figure 2 Relation between the field design and production planning decisions (adapted from Wang et al. (2019)). That field design and production planning may integrate two or a hybrid combination of the above categories

In the present paper, the planning and development decisions of an offshore oilfield are listed and classified as:

❖ *Oil production planning*:

• Identification of the reservoirs to develop and definition of the reservoir numbers, types (shared vs dedicated, production vs injection).

• Production and injection rates planning (medium/short-term production); production profile (long-term production); and scheduling and allocation planning.

❖ *Well placement and production*:

• Identification of where wells should be drilled; definition of the number, designs, locations, inclinations, trajectories, drilling schedules, and well' functionalities (production vs injection).

❖ *Surface system design*:

• Definition of the surface facilities' location-allocation; production and injection capacities; types, numbers and technology selection.

❖ *Subsea system design*:

• Allocation of the well's production; pipeline network (pipe connections, route, size of diameters); and subsea layout (locations, installation, capacities, and expansion of the subsea facilities).

❖ *Environmental planning*:

• Oil spill response planning; decommissioning planning; re-using planning, and decarbonisation strategies.

❖ *Field design and production planning*:

• Identification of the reservoirs to develop and definition of the reservoir numbers, types (shared vs dedicated, production vs injection).

• Production and injection rates planning (medium/short-term oil production); production profile (long-term production); and scheduling and allocation planning.

• Identification of where wells should be drilled; definition of the number, designs, locations, inclinations, trajectories, drilling schedules, and well' functionalities (production vs injection).

• Definition of the surface facilities' location-allocation; production and injection capacities; types, numbers and technology selection.

• Allocation of the well's production; pipeline network (pipe connections, route, size of diameters); and subsea layout (locations, installation, capacities, and expansion of the subsea facilities).

• Oil spill response planning; decommissioning planning; and decarbonisation strategies.

2.1 Evolution of the oilfield development decisions

On the basis of the papers analysed, Figure 3 shows the evolution of the number of papers published over the years. It was possible to identify that the first publications appeared in the 1970s, which is understandable as this was the time when offshore oilfield exploration and production moved from shallow to deep waters (5 papers were published between 1970 and 1990). Research and studies enabled rapid technological progress to overcome the technical challenges. Moreover, it can also be seen that the number of publications increased from 5 to 15 papers in the 1990s and 2009s as the oil industry moved further offshore into ultra-deep waters. In addition, 46 papers were published between 2010 and 2020, demonstrating that technological advances have reached new heights. Drilling tragedies, the development of new materials, technological innovations, and the development of new systems (e. g. subsea production systems) evidence that the oil industry's push for deeper offshore oil production is improving the efficiency and safety of offshore oil operations. Thus, the remaining 31 papers published nowadays (2021-2025),

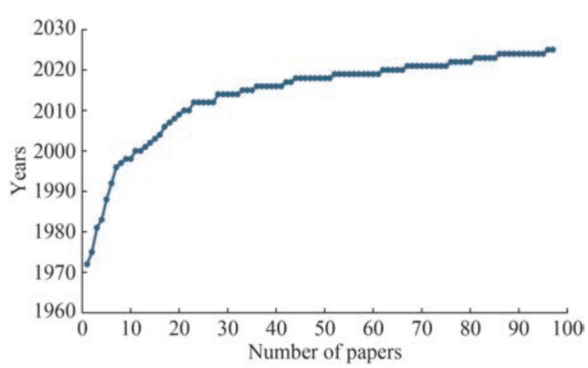

Figure 3 Number of papers published through the years

highlight that the challenges facing the offshore oil industry continue to evolve as new technologies, economic pressures, and environmental concerns shape its future.

Continuing with the general analysis of the papers, it was also possible to identify the evolution of oilfield development decisions over the years. Figure 4 presents the development categories and their respective starting dates. As it highlights, from the 1970s to the 1990s, field design and production planning were the main focus of the decision-making process, i. e. design and/or operation decisions were combined with the aim of improving the feasibility studies of field development. Subsequently, during the 1990s to 2010s, decisions such as estimating the production profile, location, number and drilling trajectories of wells, which can be considered as operational planning decisions, were taken, probably in an attempt to increase the recoverable volume of hydrocarbons while reducing the complexity of deep to ultra-deep-water operations. Thus, from the 2010s to present, the design decisions regarding the subsea production system and the environmental strategies and planning decisions also appear as main important issues discussed in the literature.

Another important analysis to be performed is that of the spatial and temporal evolution of the research articles. Firstly, 67% of the analysed articles were from the fourth most important offshore oil-producing countries, in terms of the number of articles published per country. Brazil published the most articles (20.61%), followed by China (16.49%), the United States of America (15.46%) and Norway (14.43%). Figure 5 presents a geographical distribution map based on the number of papers per country.

Brazil, China and Norway published articles in all development categories throughout the years (see Figure 6). The main research area of Brazil and the United States of America is field design and production planning. Norway focuses on two areas: field design and production planning, and oil production planning decisions. China's main research area is subsea system design. Furthermore, it is important

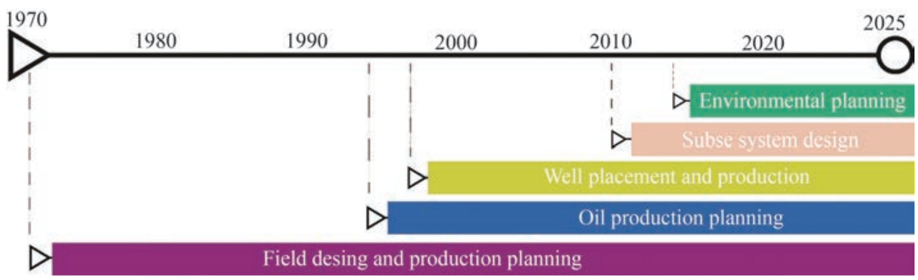

Figure 4 Evolution of the oilfield development decisions

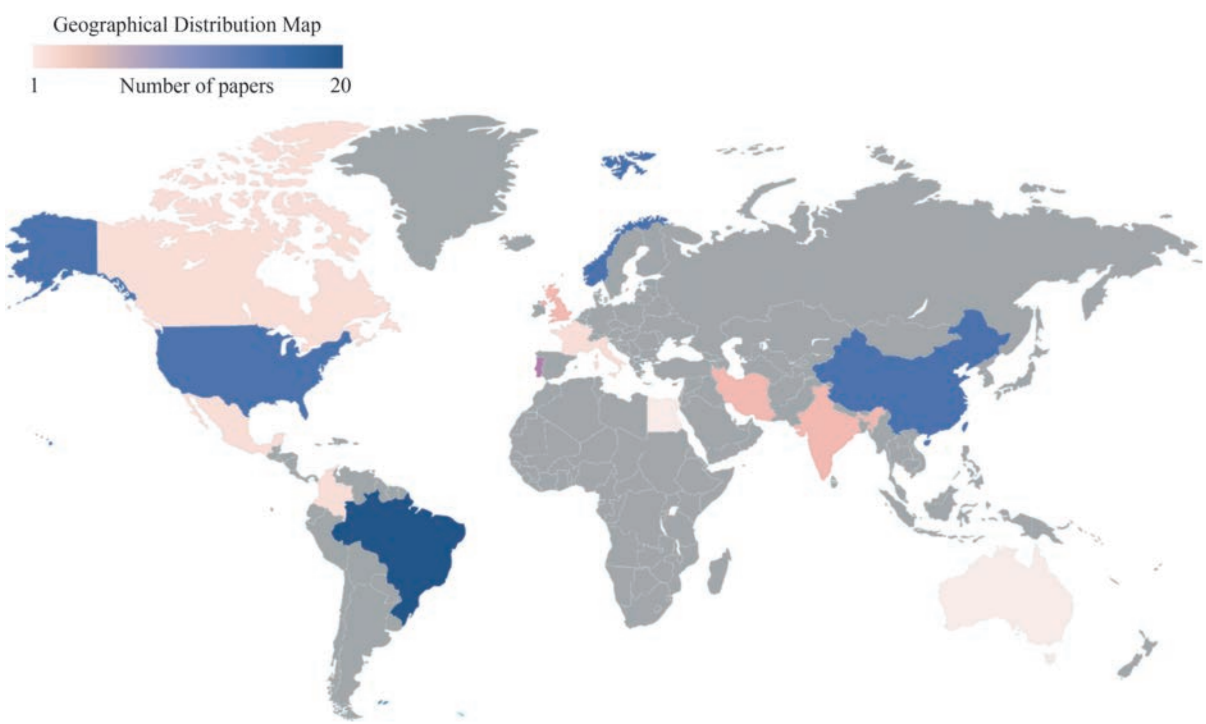

Figure 5 Number of scientific works concentrated by countries

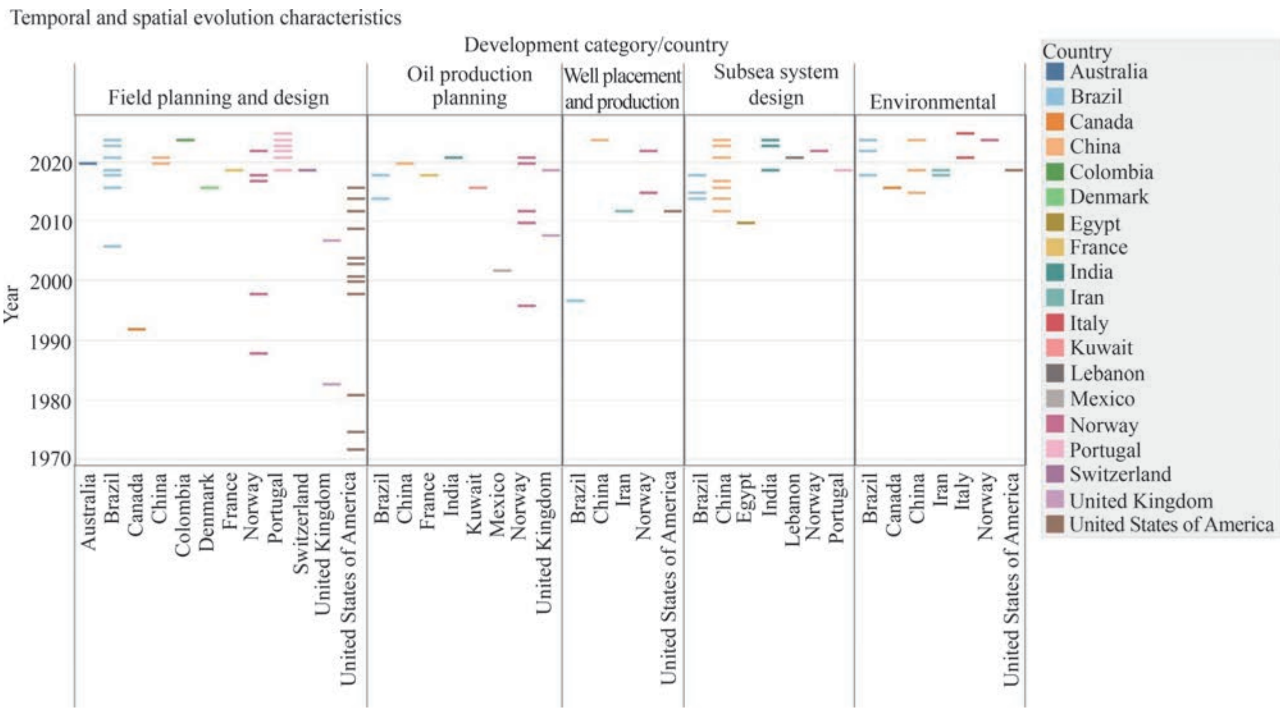

Figure 6 Temporal and spatial evolution characteristics of the development categories investigated per countries per year

to note that the United States of America was the first country to publish a scientific research article on offshore oilfield development, in 1972, followed by Norway in 1988, Brazil in 1997, and China in 2012.

All decision categories are analysed further in this paper. However, it is important to note that the surface design decisions related to the main development planning, such as the location and allocation of facilities, production and injection capacity, have not been studied as individual decisions in a single paper. Therefore, the surface category is not analysed separately.

2.2 Technical solution and approaches

The technical solution and approaches used to support the decision-making process was also analysed in all referenced papers (see Figure 7). Operation research approaches, such as mathematical programming models (45% of the papers) and algorithms (32% of the papers), were the most commonly used methodologies. This explains why there is a considerable number of review articles focusing on the study of the variety of mathematical models, pointing out their advantages, disadvantages and limitations. In addition, various numerical approaches were considered as valuable methods in 18% of the papers to help decision-makers during the development phase, such as probabilistic risk assessment. Nevertheless, conceptual methods were used in 5% of the papers, demonstrating that it can also be used as relevant approaches in the decision-making process.

In an attempt to improve the review analysis, the technical solutions and approaches most frequently used in all

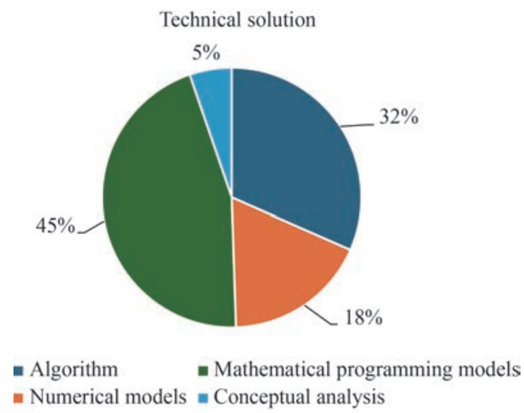

Figure 7 Technical solution and approaches used to support the decision-making process

the papers analysed are classified according to each development decision category (see Figure 8). Notably, most of the mathematical programming models are applied to enhance the decision-making process of the field design and production planning. Moreover, the field design and production planning appear as the only development category where all the technical solution and approaches are used, demonstrating that this category can be classified as the highly important.

The algorithm thus appears to be the most commonly used technical solution approach for subsea system design. Specifically, only the use of operations research methods (mathematical programming models and algorithms) has been reported in the subsea system design literature. Furthermore, algorithms are also highly applied to solve the well

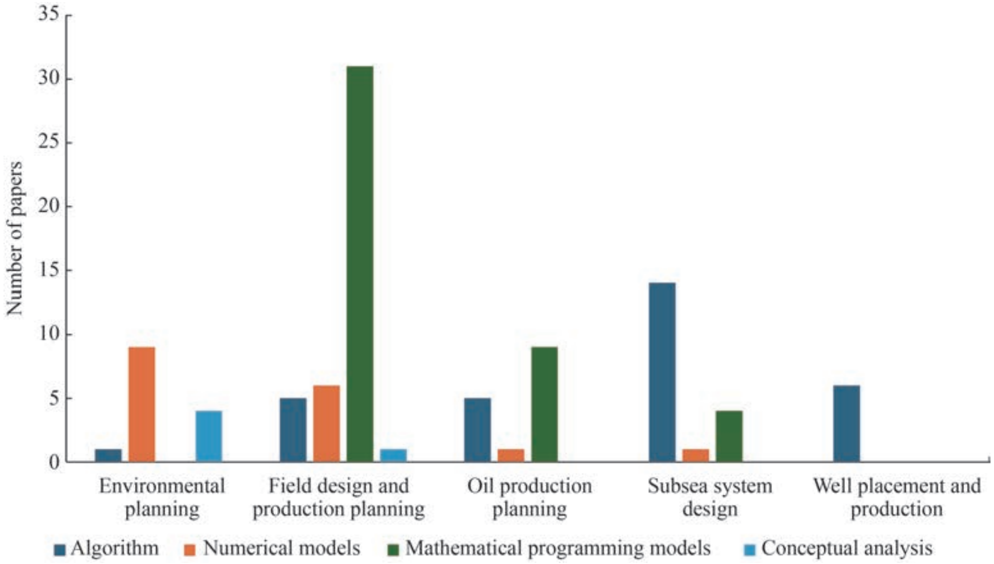

Figure 8 Relation of the technical solution approaches, the development decisions categories and number of papers published

placement and production decisions. In fact, it is the only technical solution approach used in this category. This is mainly because algorithms can be easily adapted to solve problems that do not fit neatly into the structure required by mathematical programming models, and can be used for non-linear, multi-objective or complex decision tasks that are difficult to formalise with mathematical models. It allows for a more refined real-world description of the system, as in the case of subsea system design, when considering the pipeline route, including, for example, the specific seabed bathymetry of an oil field, or, in the case of well placement and production, the detailed description of the trajectory of the wellbore into the reservoir layer.

2.3 Journal publications

The main goal of this study is to undertake a systematic academic review. To this end, the development decisions of each paper in the sample are correlated with the type of the published journal category. It is imperative to understand the category, description and subject area of an academic journal, as this ensures that the proposed work is disseminated to the intended academic audience.

In this regard, the list and description of the journal's categories are described below:

• *Petroleum engineering*: mathematical modelling, reservoir simulation, numerical and sustainable analysis of hydrocarbon production.

• *Ocean engineering*: structural, experimental and design engineering of ocean and naval systems.

• *Computer science*: experimental, computational and theoretical research on applied engineering.

• *Design and engineering*: design, engineering and system construction.

• *Safety engineering systems*: safety and reliability of complex technological systems.

• *Operation research*: theory and practice of systems' management.

• *Sustainable system*: climate action, planning and policy studies.

Accordingly, in consideration of the categorisation outlined, Figure 9 provides a comprehensive representation of the offshore oilfield development decisions, their respective journal categories, and the number of published papers of each category.

It is evident that the multifaceted nature of the of the "*field design and production planning*" decisions, has culminated in the dissemination of the respective works across a comprehensive array of journal categories. Whereas the "*subsea system design*" decisions were also published in a variety of journal categories. Mainly because the different perspectives that can be taken into consideration when designing a subsea system. Conversely, the particular characteristics inherent to the "*wells placement and production*" decisions necessitate the dissemination of associated works exclusively within the domain of petroleum engineering journals. Similarly, papers describing the "*environmental planning*" decisions were mostly published into the sustainable system journals. Furthermore, besides the essential characteristics of the hydrocarbon production, the respective papers concerning "*oil production planning*" decisions were primarily published in computer science, petroleum and operation research journals.

Further analysis of each paper category and its relationship with offshore oilfield development decisions is presented in subsequent sections of the paper. It is important to note that the subcategories are presented in order of the number of papers published. Moreover, of the total number of articles analysed, the most prevalent journal categories were the computer science, petroleum engineering,

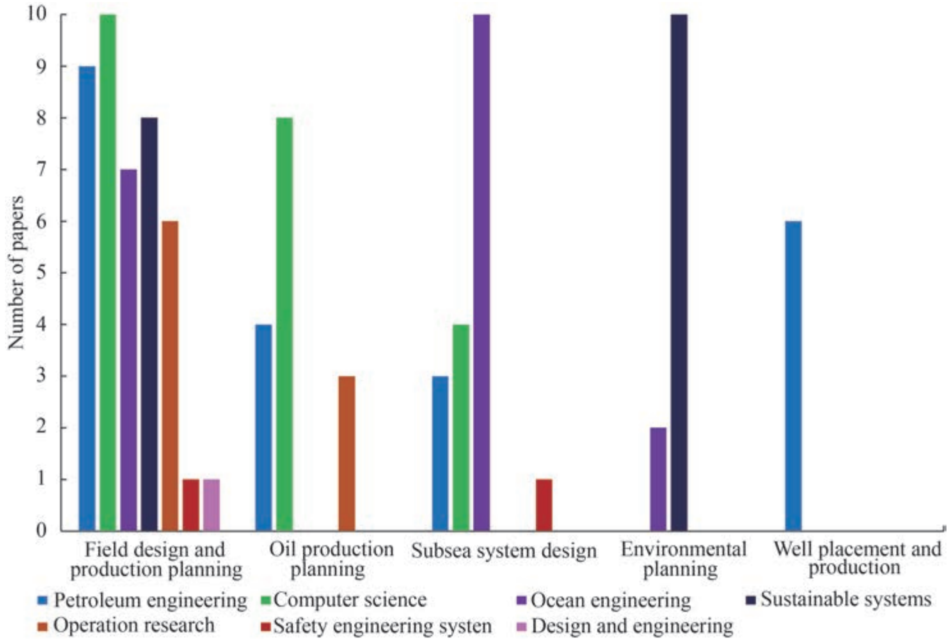

Figure 9 Relation between the offshore oilfield development decisions, journal categories and number of papers

ocean and naval engineering and sustainable systems, which collectively accounted for 87% of the articles analysed (see Figure 10).

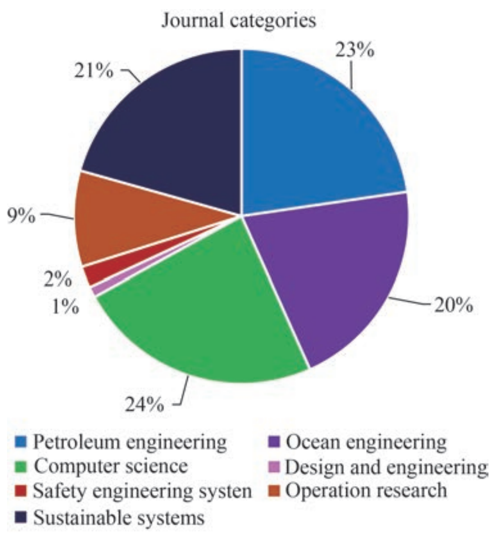

Figure 10 Journal categories of the published articles under analysis

3 Field design and production planning decisions

The main goal of this section is to further analyse the works presented in the literature, specifically considering the field design and production planning decision category. The three questions mentioned above (Section 1) are considered in detail. Thus, as described in Section 2.1, the first published papers appeared in the 1970s, and the main decisions addressed in the papers can be considered as the category of field design and planning decisions. From the 1972s to the 2025s, 43 papers analysed can be considered as part of this category.

The field design and production planning may integrate two or a hybrid combination of decisions categories. Therefore, in this regard, the sub-categories are listed below:

- Oil production and surface system design decisions;
- Oil production and subsea system design decisions;
- Oil production, subsea system design and surface system design decisions;
- Oil production and environmental planning decisions;
- Subsea system design and surface system design decisions;
- Well placement and production, subsea system design and surface system design decisions;
- Environmental planning and surface system design decisions;

Considering the above sub-categories, Figure 11 presents the number of papers for all subcategories. It can be seen that the integrated decisions of "*oil production and surface system design*" and "*subsea system design and surface system design*" are the most studied ones, accounting for about 50% of the papers presented in this category. "*Oil production and subsea system design*" and "*oil production, subsea system design and surface system design*" are equally studied in the literature. Furthermore, the "*environmental planning and surface system design*" decisions are well integrated in the literature, whereas the "*well placement and production, subsea system design and surface system design*" decisions and the "*oil production and environmental planning*" decisions are the least discussed in the literature.

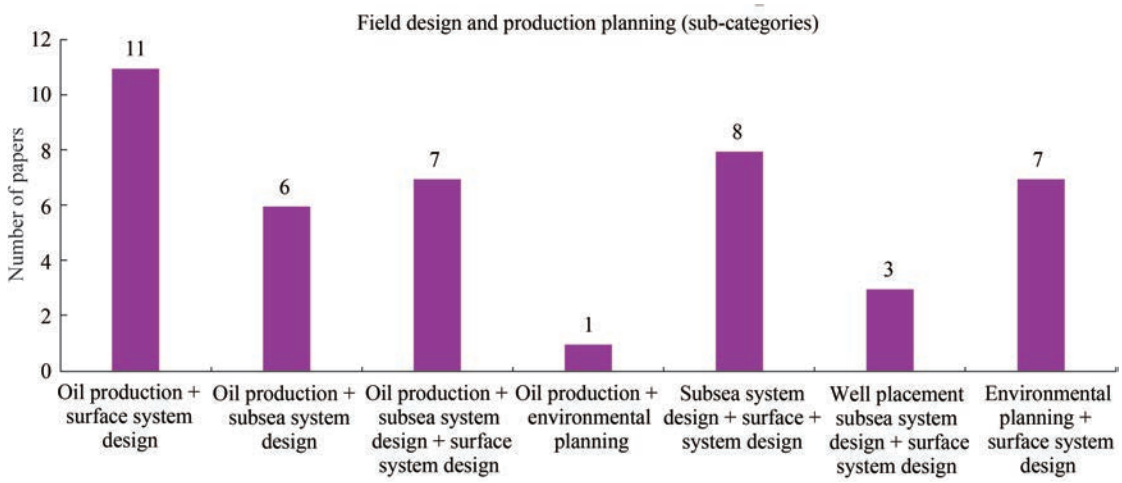

Figure 11 Published articles in field design and production subcategories

3.1 Oil production and surface system design decisions

Frair and Devine (1975), Haugland et al. (1988), Iyer et al. (1998), van den Heever and Grossmann (2000) and van den Heever et al. (2001) are some of the earliest works to consider "*oil production and surface system design*". Frair and Devine (1975), mainly attempted to determine the production time and schedule for each well and reservoir, and the number and location of the drilling platforms. Haugland et al. (1988), consider the well's production to determine the drilling scheduling and the facility capacity. Iyer et al. (1998), used the reservoir performance through time to determine the production planning and scheduling and, the respective drilling facility allocation considering the surface pressure and oil rig resource constraints. van den Heever and Grossmann (2000) and van den Heever et al. (2001) mainly treated a similar problem distinguishing the shallow-water platforms as production platform and well platforms, to analyse the production profile in each time period, by determining the platforms' installation and well's drilling scheduling, the platforms' capacity size and location-allocation.

Barnes et al. (2007), Tarhan et al. (2009), Gupta and Grossmann (2012), Gupta and Grossmann (2014), Grossmann et al. (2016), and Nguyen et al. (2019) are the remaining works of "*oil production and surface system design*". Barnes et al. (2007), consider the set of wells to be drilled to determine the drilling schedule and the platform location and capacity size. Tarhan et al. (2009), analyse the uncertainties of in the initial maximum oil flow rate, the recoverable oil volume and the water breakthrough time of the reservoir to determine the oil production rate, the number of wells to be drilled and the number of facilities to be built. Gupta and Grossmann (2012), adopted the production of multiple fields and the production of three major components (oil, gas and water) to determine the drilling schedule of wells and the production rates of oil, water and gas simultaneously in a multi-period setting, and thus the installation and expansion schedule of facilities and the respective oil, liquid and gas capacities. In the works of Gupta and Grossmann (2014) and Grossmann et al. (2016), the uncertainties of the field parameters are also considered, as well as the field size, oil deliverability, water-oil ratio, and gas-oil ratio, to determine the field production profile, the number of wells and drilling schedule, and the platform types and capacities. Nguyen et al. (2019) considered the production of hydrocarbons and water over time to establish the configuration, size and operating conditions of an offshore platform. The authors highlighted that the platform' modes of operation is directly related to the field characteristics and fluid properties.

3.2 Oil production and subsea system design decisions

Six works were published in the subcategory of "*oil production and subsea system design decisions*". Earlier work by Emanuel and Ranney (1981) and the work of Coats et al. (2004) used reservoir and piping network simulations to determine the well production rates. Nygreen et al. (1998), describe a production model that takes into account the field infrastructure, including the surface and pipeline networks, to define the production scheduling of the fields and the simultaneous design of the pipeline systems. Redutskiy (2017), utilizes the estimated hydrocarbon production to established the production operations variables, such as production rates, production pressures, oil cut values; the number, location and capacities of manifolds; assignment of wells to manifolds (connecting with jumpers); capacities of the jumpers; capacities of the flowlines connecting the manifolds to the riser base; sequence of wells in the daisy chain, and capacity of the daisy chain pipeline; assignment of each development activity (drilling wells, installing manifolds, jumpers and flowlines) during each time period of the deposit's lifecycle.

Darche et al. (2019) extended the idea of considering the simulation of the dynamics of the one reservoir coupled with a pipe network, to integrate four independent reservoir models and a properly subsea production system. This enabled the authors to define not only the production rate, but also to estimate the entire production profile. Wang et al. (2023) propose an integrated production model combining 3D reservoir equations and pipeline network equations to analyse the wax deposition in the subsea flowlines. This respective analysis can help the decision-makers to define the effectiveness of the subsea water separation.

3.3 Oil production, subsea system design and surface system design decisions

This respective subcategory presents seven works (Beale, 1983; Carvalho and Pinto, 2006; Lin and Floudas, 2003; Sales et al., 2018; Silva and Guedes Soares, 2022, 2021b; van den Heever et al., 2000). Beale (1983), considers a nonlinear dynamic for reservoir equations in order to define drilling schedules for new wells from a satellite platform, as well as pipeline installation planning. van den Heever et al. (2000), implement nonlinear reservoir behaviour to establish the production profile, the number and capacity of production and well platforms, and the number of pipeline connections, as well as complex investment planning. Similarly, Lin and Floudas (2003) explicitly incorporate non-linear reservoir dynamics and economic considerations to define the oil production profile, the number of platforms and the pipe connections. Carvalho and Pinto (2006) integrate reservoir pressure into the main reservoir equations to determine the oil and gas production, the platform installation and the well assignments.

Sales et al. (2018), consider the uncertainties in well deliverability to determine the well production allocation and pressure loss, the platform location and the manifold location. Silva and Guedes Soares (2021b) quantified the uncertainties of the decline curves approaches in an attempt of investigating the impact of production into the design of the subsea and surface systems, by determining the wells production assignment, the size and location of the manifolds, the pipeline connection, and the number, capacity and location of the platforms. Silva and Guedes Soares (2022) extended the previous work by establishing different production scenarios and their respective probabilities of occurrences, to determining the same design variables.

3.4 Oil production and environmental planning

As described in Section 3.1, only one paper integrates the "*oil production and environmental planning decisions*". Lei et al. (2022), considered two reservoirs produced with subsea wells in order to define the drilling planning and schedule, the production allocation, and the decommissioning time.

3.5 Subsea system design and surface system design decisions

The respective subcategory is one of the most important subcategories of the oilfield development considering the field design and production planning decisions. Eight articles are considered as part of this subcategory (Devine and Lesso, 1972; Hansen et al., 1992; Hong et al., 2021; Silva and Guedes Soares, 2019; 2023; 2024; 2025; Stape et al., 2023). Devine and Lesso (1972) and Hansen et al. (1992), were the earliest works to integrate both decisions. The papers intended to define the allocation of wells to platforms, as well as the number, capacity size and location of platforms.

Afterwards, Silva and Guedes Soares (2019) integrates the wells production assignment, the size and location of the manifolds, the pipeline connection, and the number, capacity and location of the platforms into a single model. Hong et al. (2021) developed a model able to determine the flowline routes, the well-head locations, the horizontal displacement of subsea wells, the FPSO sizes and the assignment of wellheads. Stape et al. (2023), presents a real-world bathymetry considering possible obstacles to define the flowline routing and facility location.

Whereas the works of Silva and Guedes Soares (2025; 2024; 2023) combined not only the technical-economic criteria of these systems, but the safety aspects. Silva and Guedes Soares (2023) and Silva and Guedes Soares (2024) integrated the risk of pipelines into the search of the most feasible subsea and surface production system designs, by determining the wells production assignment, the size and location of the manifolds, the pipeline connection, and the number, capacity and location of the platforms. The primary work analyses the risk of pipelines only considering the structural material of pipes as rigid, while the former work considers the structural material of the pipes as rigid and flexible. Silva and Guedes Soares (2025), besides considering the risk of pipes in accordance with the structural material of the pipes, the authors included the risk of manifold for designing the production system, by establishing the wells production assignment, the size and location of the manifolds, the pipeline connection, and the number, capacity and location of the platforms.

3.6 Well placement and production, subsea system design and surface system design decisions

There are three papers considered in this subcategory (Almedallah et al., 2020; Rodrigues et al., 2016; Wang et al., 2019). Rodrigues et al. (2016), integrated these planning decisions by developing a model able to define the number and positions of wells, and which sections of each well should be vertical or horizontal, and the number, locations and capacities of production platforms and the manifold locations. Wang et al. (2019), used an injection-production relationship matrix, to define the drilling schedule for both production and injection wells, the well assignment to the FPSO and the FPSO's oil and water production capacities and water injection capacity. Almedallah et al. (2020), take an integrated approach by finding realistic wellbore trajectories, planning of the pipeline route and the platform location.

3.7 Environmental planning and surface system design decisions

This subcategory is the final one to be considered as part of the field design and production planning process. The papers must analyse how environmental planning can enhance the design of the surface facility. Nguyen et al. (2016) analyses three different decarbonisation strategies-the implementation of waste heat recovery, the installation of a CO_2-capture unit and the platform electrification-to determine the most viable CO_2-capture processes, to maximise the platform power capacity and minimise the platform investment costs. Riboldi and Nord (2018), analyses the decarbonisation strategy of a combined cycle power plant integrated with a wind farm. The aim is to establish whether the combined cycle can supply heat and power to the processing block of a platform. Cavalcanti et al. (2021), assesses the environmental impact of a combined cycle power plant in an offshore field, by defining the stages of natural gas production, transmission, purification, distribution, and combustion.

Zhang et al. (2021), aimed to design a platform energy system that adopted wind power. The paper establishes the energy generation, conversion and storage devices for each form of energy (electrical, thermal and cold), considering three scenarios: a traditional energy system; a distributed energy system without access to wind energy; and a distributed energy system with access to wind energy.

Li et al. (2020) assesses the respective carbon footprint of a floating platform by determining the appropriate types of equipment and their energy capacities/consumptions. Blanco and Gallo (2024), diagnose greenhouse gas (GHG) emissions from a floating platform by identifying the sources of GHG emissions involved in the production process. Ferreira et al. (2024), assess the energy use and greenhouse gas (GHG) emissions to decide about the oilfield life extension.

3.8 Technical solution and approaches of the field planning and production decisions

Due to the intrinsically non-linear nature of reservoir dynamics, most of the technical solution and approaches adopted by the scholars to solve the "*oil production and surface system design*" were the mixed non-linear programming models, where some of them implemented with algorithms. However, the mixed-integer linear programming models are also adopted in conjunction with some decomposed problem strategy or when the size of the problem is limited. The adoption of algorithms is also presented in the literature as a valuable tool, to refine the reservoir model description and/or to enhance the computational effort for solving the problem.

Notably, the recent articles published in the "*oil production and subsea system design decisions*" subcategory (Darche et al., 2019; Redutskiy, 2017; Wang et al., 2019) describe a more complex reservoir and subsea system that considers not only the pipeline network, but also other subsea equipment and components. Furthermore, the works presented on this subcategory describe the most commonly used technical solution approach as integrated production modelling coupled with a reservoir simulator. However, an algorithm and a mixed-nonlinear programming model have also been developed.

It is worth noting that the papers integrating the subsea production system design developed after 2010 (Sales et al., 2018; Silva and Guedes Soares, 2021b; 2022), in the "*oil production, subsea system design and surface system design decisions*", extend the decision problem by investigating the reservoir interaction not only with the pipeline network but also with the subsea layout. In addition, most of the studies used operations research methods as the main technical solution approach. The published works adopt a linear programming, mixed integer linear programming, mixed integer nonlinear programming model, stochastic mixed integer linear programming model and evolutionary algorithm.

In the subcategory of "*oil production and environmental planning decisions*", the authors adopted the mixed integer nonlinear programming model as the technical solution approach. Moreover, in the "*subsea system design and surface system design decisions*", most of the works adopted as technical solution and approaches the mixed integer linear programming models. Only one paper of Stape et al. (2023) developed an algorithm due to the realistic nature of the seabed bathymetry to design the pipeline network. Also, because the uncertainty characteristic of the risk criterion, the works of Silva and Guedes Soares (2025; 2024; 2023) adopted the robust mixed integer linear programming model.

Whereas, in the subcategory of "*well placement and production, subsea system design and surface system design decisions*", the technical solution and approaches used are the integer linear programming model, the mixed integer linear programming model and the constrained optimization by linear approximation, respectively. Furthermore, multi-objective mathematical programming is the most adopted technical solution approach in the "*environmental planning and surface system design decisions*", but other numerical models were considered, as well as the lifecycle extension decision framework, process simulation, quantitative economic performance, and one conceptual environmental analysis.

Figure 12 shows the technical solutions and approaches most commonly used in the field design and production planning decisions. Figure 13, on the other hand, shows the journals' categories of the published papers.

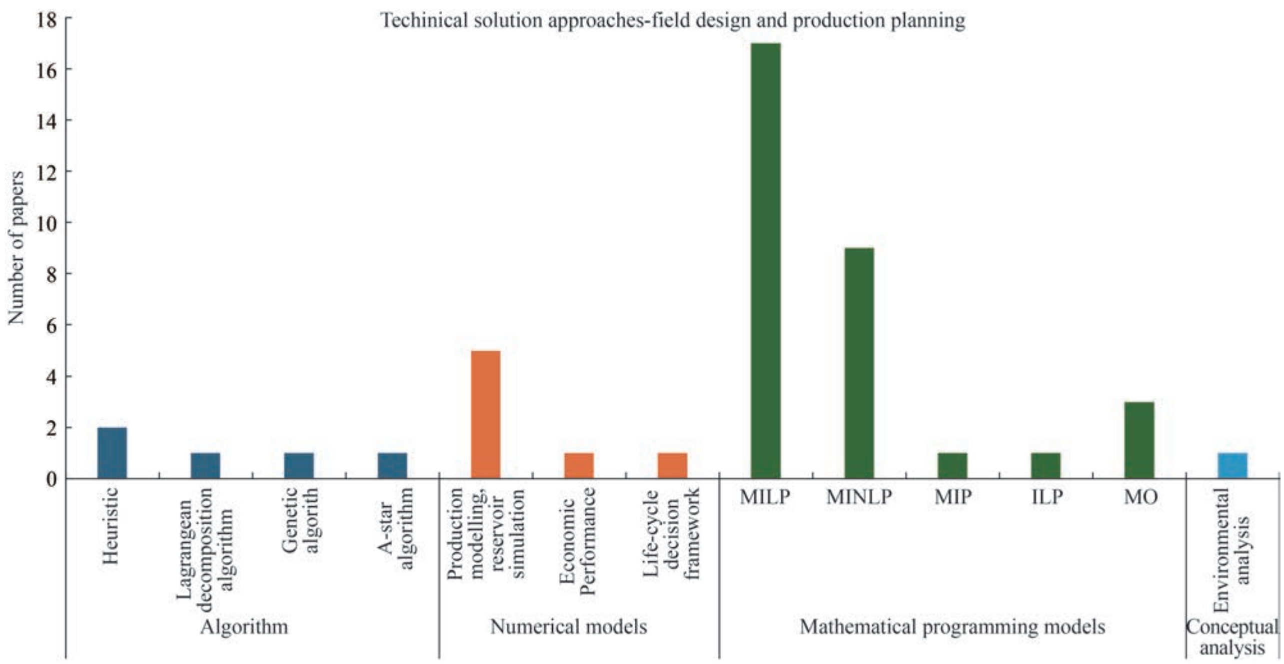

Figure 12 Technical solution and approaches of the field design and production planning decisions

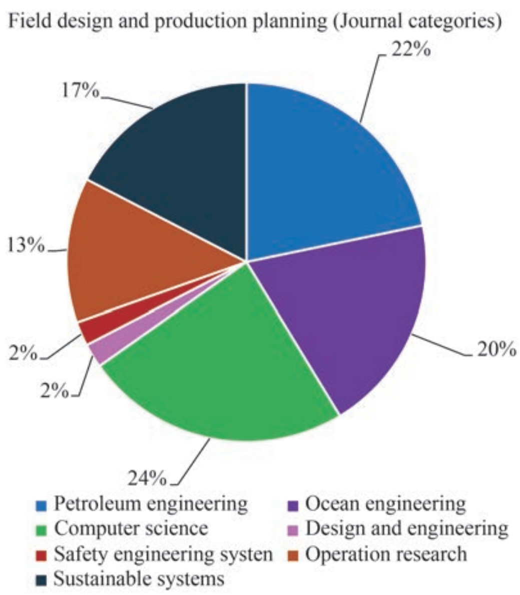

Figure 13 Journal categories of the field design and production planning decisions

Because of the variety of the decision analysis in this category, the papers were published in all journals' categories defined in the corresponding paper systematic analysis. Being the "*Computer Science*", "*Ocean Engineering*" and "*Petroleum Engineering*" journals the three most common journal' categories to publish in this respective area, and the "*Design and Engineering*" and "*Safety Engineering System*" the least common journal' categories. These two categories shall be an opportunity for new research perspective in an attempt of including on all aspects pertaining to a system engineering as well as the safety criterion of the system in the decision-making process.

4 Subsea system design decisions

The category of subsea system decisions is a relatively recent research topic that is already quite extensive, with 19 articles having been published. As described in Section 2, the main decisions regarding the design of the subsea system concern the allocation of subsea well production and the arrangement of equipment and components, including the design of an appropriate pipeline network. The subcategories are listed below, and Figure 14 presents the number of published articles in each subcategory:

- Pipeline network decisions;
- Subsea layout decisions;
- Subsea layout and pipeline decisions;

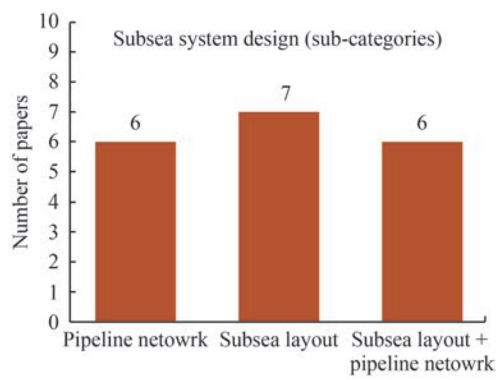

Figure 14 Published articles in the subsea system design decisions

4.1 Pipeline network decisions

Earlier work by El-Mahdy et al. (2010) assumes a predefined seabed topography, pipe length and type of pipe material, as well as related roughness and efficiency factors, in an attempt to establish proper pipeline diameters for complex pipeline networks.

Lucena et al. (2014), Rocha et al. (2015), Zhang et al. (2017), and Dbouk et al. (2021) enhance the decision-making process of the pipeline routing. Lucena et al. (2014) considered different design criteria, as well as obstacles, declivity, regions of interest, pipe crossing effects and minimum pipe radius curvature, in order to define pipeline routes within a pipe network. Besides the route design criteria of pipe length, bathymetric data and obstacles, Rocha et al. (2015) also considered the slop stability to define the most adequate pipeline route. Zhang et al. (2017), integrates the production flow assurance as pressure increment trough the pipes with the design criteria of terrain obstacles, pipe radius curvature to define the pipeline network. Dbouk et al. (2021) considered the topological complexities to find the shortest paths for the gathering and transmission pipeline systems.

Silva et al. (2019) offer an alternative perspective on pipeline networks. The authors considered the risk of pipeline failure in order to identify the pipe segments posing the greatest risk to the system, enabling them to rank the risk of each pipeline systems' alternative.

4.2 Subsea layout decisions

Decisions concerning the subsea layout are directly related to layout concepts. According to Bai and Bai (2010), there are four types of subsea layout: the satellite well system; the clustered satellite well system; the template manifold well system; and the daisy-chain well system. In a satellite layout, all the wells are spread out through the reservoir to maximise the amount of recoverable hydrocarbons, and the production from each well is transported individually to the offshore facility. The clustered satellite layout indicates that a group of satellite wells are connected by a cluster manifold, whereas the joint production is then transported from the manifold to the platform. In the template well system the wells are closely located and grouped by a template manifold, which have the function of housing the wells' subsea tree. Thus, in a daisy chain, two or more satellite wells are connected in series by the same flowline to the platform. This can be considered a special subsea layout, in which production engineers estimate flow assurance problems, such as hydrate and paraffin issues, that can minimise or block the pipe diameter. In this regard, pigging equipment can be used to clean the production line periodically. Only two types of subsea layout design are reported in the literature: the daisy-chain well system (Wang et al., 2014b) and the clustered satellite well system (Bhattacharyya and Cheliyan, 2019; Liu et al., 2022a; Wang et al., 2012; 2014a; 2016; 2019).

Wang et al. (2014b) analysed the daisy-chain layout concept in an attempt of defining the partition of subsea production loops, including the number of production loops, the approximate laying routes, and the lowest subsea layout cost. Wang et al. (2012) considered the layout of the clustered satellites in order to determine the number of cluster manifolds and their well slots, as well as their optimal initial locations and the minimum cost of pipeline connections. In their 2014 paper, Wang et al. (2014a) extended this work by using a pipeline end manifold (PLEM) to join the production of the cluster's manifolds for transport to the platform. A PLEM is a simple connection component that minimises pipeline length. As well as defining the manifold well slots and initial optimal locations and the minimal pipe connection cost, the new model aims to define the number of cluster manifolds using PLEMs.

Furthermore, rather than adopting a straight-line connection, Wang et al. (2016) improved the decision-making process of the clustered satellite layout by considering a more realistic subsea connection between the rigid pipelines. To this end, the authors considered three types of connection according to pipe length by using jumper, pipeline end termination (PLET) and infield flowlines. Thus, in addition to defining the number of cluster manifolds, their well slots and initial optimal locations, the model are able to establish three different connection types for jumpers between subsea wells and cluster manifolds. Wang et al. (2021) built on the previous approach by adopting an iterative searching method based on an unsupervised learning method and clustering algorithm. This allows the layout scenarios of cluster manifolds, wellhead grouping and the connection relationships between manifolds to be continuously adjusted.

Bhattacharyya and Cheliyan (2019) and Liu et al. (2022a) present a simpler approach regarding the subsea system design. Bhattacharyya and Cheliyan (2019) analyse the cost and reliability of the clustered satellite layout, represented by a fault tree model. The probability of failure and the cost of subsea equipment and components are considered to determine adequate overpressure in the well, as well as the number of jumpers, flowline pipelines, risers, wellhead connectors, manifolds, PLETs and PLEMs. Liu et al. (2022a) considers the clustered satellite design problem as a location-allocation of manifold aiming at to optimise the positions of the manifolds and the connection relationship between manifolds and wells so that the flowline costs are minimised.

4.3 Subsea layout and pipeline network decisions

This subcategory combines pipeline network and subsea layout decisions in an attempt to enhance the decision-making process by considering real-world limitations and constraints. For example, pipeline characteristics is considered alongside proper subsea layout connections to model a real-world system.

In addition to identifying pipeline routes based on subsea topology, Hong et al. (2018) consider the location of subsea facilities when designing a clustered satellite well system. Whereas Hong et al. (2023) enhanced the previous decision-making process for clustered satellite well systems by including subsea obstacles, restrictions on pipeline intersections, and limitations regarding manifold slot numbers. This makes the process closer to practical situations and establishes manifold positions, wellhead allocations to manifolds, manifold allocations to FPSOs, and flowline routes between facilities.

Furthermore, with the aim of designing a realistic subsea production network that also considers the clustered satellite layout, Rosa et al. (2018) integrate reservoir dynamics and estimate pressure drops in pipelines in an attempt to define pipeline routing, diameter, and manifold placement, as well as well allocation. Muhammed et al. (2023) aim to improve the design of flowlines by arranging them in a clustered satellite layout, considering both the route and network designs. To this end, the proposed work identifies the manifolds grouped into each flowline and determines the connections between them. It also establishes the diameter of each flowline and finds the route of each connection on the seabed.

Wang et al. (2024) integrate the clustering algorithm and the adoption of the pipeline end manifold (PLEM), as well as the realistic subsea connection between rigid pipelines previously described in Wang et al. (2016; 2014a; 2012) (see Section 4.2), into the pipeline routing which considers seabed topography. Beemaraj et al. (2024), decomposed the clustered satellite layout problem into four levels: drill centre clustering, manifold positioning, process host positioning, and flowline design. For each subsystem level problem, the authors developed various algorithms aiming to establish the wells associated with each drill centre, the manifold position corresponding to each drill centre, the process host position and riser type, and the shortest path between nodes, considering bathymetry.

4.4 Technical solution and approaches of the subsea system design

Figure 15 presents the technical solutions and approaches that are most commonly used for designing subsea production systems. Because of the refinement in modelling the seabed characteristics, which was an attempt to describe a real-world system, the most used technical solution and approach in the "*pipeline network decisions*" was the algorithm. The algorithms mostly considered are the genetic algorithm and the A-star algorithm. A mixed integer linear programming model and a probabilistic risk assessment were also adopted.

In an attempt to provide practical models that account for the real-world description of subsea connections and arrangements, most of the works published in "*subsea layout decisions*" adopt heuristic algorithms as the most suitable technical solutions and approaches. However, a mixed integer nonlinear programming model was also adopted.

Nevertheless, due to the high level of complexity and refinement required for the description of the subsea system in "*subsea layout and pipeline network decisions*", most authors combine two or more algorithms. Examples include the combination of simulated annealing and the Dijkstra algorithm, the Dijkstra algorithm and the Laplacian smoothing algorithm, the modified adaptive particle swarm optimisation (MAPSO) algorithm, the A-star algorithm the minimum spanning tree algorithm, and the K-means clustering algorithm and the genetic algorithm. Furthermore, the mixed integer nonlinear programming model (MINLP) and the mixed integer linear programming

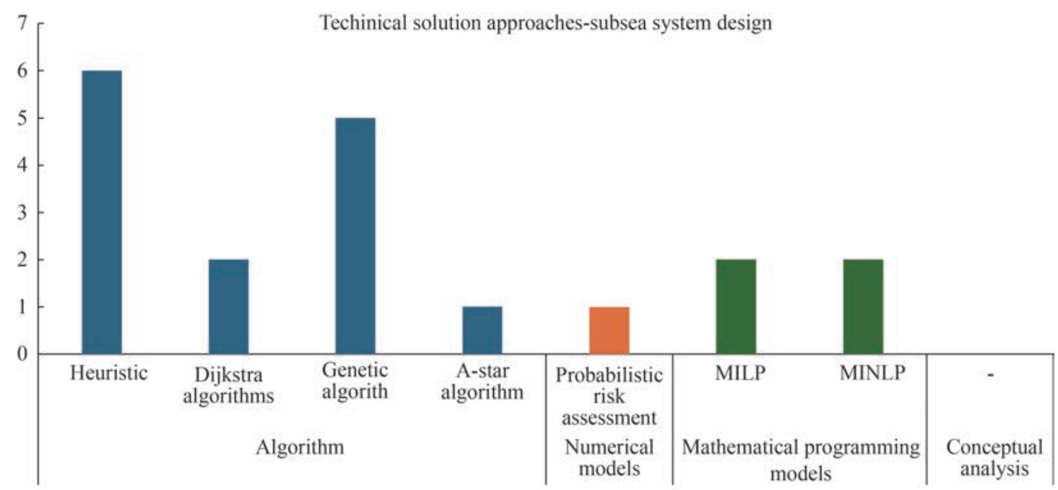

Figure 15 Subsea system design technical solutions and approaches

model (MILP) were also adopted.

Figure 16 shows the categories of the journals in which the published articles on subsea system design appeared. It can be seen that only three categories were identified. 61% of the papers were published in "*Ocean Engineering*" journals, 17% in "*Petroleum Engineering*" journals, and 22% in "*Computer Science*" journals.

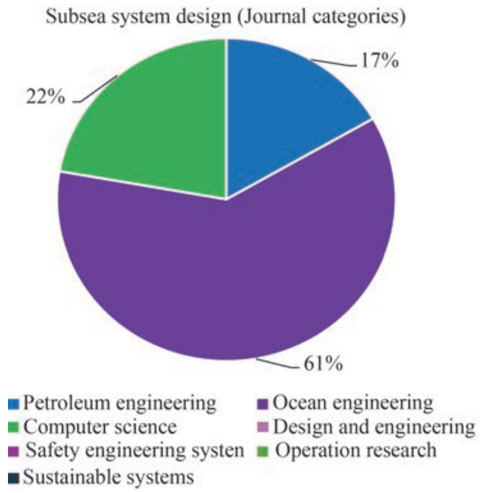

Figure 16 Journal's categories of the published articles of subsea system design decisions

5 Oil production planning decisions

The proposed category can be identified as the basis for decisions on oilfield development, as the main goal of an oilfield project is to increase the hydrocarbon recovery factor. However, as there are other remaining questions in offshore oilfields, it initially appears as a combination of decisions rather than a single group. Therefore, this category comprises 15 papers that aim to enhance the hydrocarbon production planning process (Figure 17). Section 2 described most of the decisions that fall into this subcategory, such as the identification of the reservoirs to develop and definition of the reservoir numbers, the production and injection rates planning (medium/short-term oil production), the production profile (long-term production), the flow assurance problems, and the scheduling and allocation planning, being listed below.

- Long-term production and scheduling;
- Long-term production;
- Medium/short-term production;
- Flow assurance problems;

5.1 Long-term production and scheduling decisions

Five articles are published in this subcategory (Epelle and Gerogiorgis, 2019; González et al., 2020; Haugen,

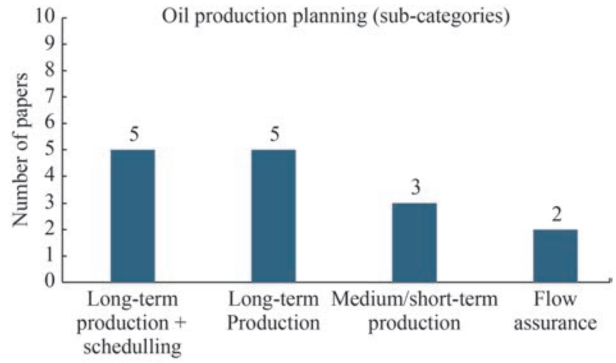

Figure 17 Published articles in oil production planning subcategories

1996; Hoffmann et al., 2019; Min et al., 2020). Haugen (1996) appears as the first paper to address the issue of "*long-term production and scheduling decisions*", aiming to define the most suitable production profile for a project under conditions of uncertain resources. Each estimated production profile is considered a stochastic variable in an attempt to minimise the expected deviation from the predicted contract profile. More recently, Hoffmann et al. (2019) proposed integrating all elements of the production chain (wells, production networks, and surface processes) into a single model to define the most appropriate schedule and forecast the production profile.

Epelle and Gerogiorgis (2019) adopted a water injection strategy as a secondary recovery method, aiming to maintain reservoir pressure over the long term. The study considers constraints such as surface processing capacity, pipeline pressure and water injection in order to establish a production profile and schedule water injection. In addition to considering the hydrocarbon production, Min et al. (2020) consider three other production strategies-water flooding, steam flooding and chemical flooding-to enhance oil recovery. The study attempts to allocate investment to these four production modes with the objective of maximising the net present value (NPV). The work also aims to determine the optimal composition of workloads for water and steam flooding oilfields, and the optimal project portfolio for chemical and hydrocarbon flooding, within the constraints of investment and production tasks. González et al. (2020) studied a series of steps for determining the optimal field production profile. These included the drilling schedule, the type of offshore structure, the method of reservoir pressure support and the selection of artificial lift.

5.2 Long-term production decisions

The works published in this subcategory are: Ortíz-Gómez et al. (2002), Mohammadzaheri et al. (2016), Camponogara et al. (2018), Sales et al. (2021), Bilal et al. (2021). All of these studies attempted to analyse and estimate oilfield production over the long term.

Ortíz-Gómez et al. (2002) considered the non-linear behaviour of reservoir dynamics in order to forecast well production in each time period, as well as the production profile of the reservoir, including operation and shut-in times. Mohammadzaheri et al. (2016) modelled a reservoir containing oil, gas and water to analyse the performance of an electrical submersible pump for enhanced oil recovery and to estimate the production profile of an oilfield.

Camponogara et al. (2018) planned the production and operation of a large offshore oilfield comprising multiple platforms, with the aim of maximising oil production and gas export pressure while minimising CO_2 concentration at the onshore facility. Sales et al. (2021) considered the impact of uncertainty in both the original volume of oil-in-place and the oil price on a non-linear reservoir, in order to determine the probability distributions of the number of wells, the plateau rate, and the project value. The work of Bilal et al. (2021) builds on the study proposed by Sales et al. (2021). The authors considered the same uncertainties, aiming to define the same decisions (the number of wells, the plateau rate, and the project value). However, in this study, the uncertainties were addressed using the mean of the distributions and Monte Carlo simulation.

5.3 Medium/short-term production decisions

For this specific subcategory, the main goal of the works was to analyse and plan the medium/short-term of the production. In the work of Gunnerud and Foss (2010), the authors modelled a semi-realistic reservoir, decomposing the nonlinearities of production in order to estimate production allocation and production and injection rates over shorter time horizons. Gunnerud et al. (2012) built on this previous work Gunnerud and Foss (2010) by advancing the methodological approach while maintaining the same reservoir characterisation and decision-making framework (production allocation and production and injection rates). Silva and Camponogara (2014) used non-linear characteristics of multidimensional well production and pressure drop functions to estimate daily gas-lifted oilfield production.

5.4 Flow assurance decisions

Only two papers included are in this respective subcategory (Gao et al., 2020; Luna-Ortiz et al., 2008). Luna-Ortiz et al. (2008) identified extreme oilfield conditions, such as high pressure and low temperature, and studied their respective impact on production planning. The authors modelled the flow dynamics of subsea pipelines to determine the potential for hydrate formation in multi-phase flow pipes. Gao et al. (2020) on the other hand, consider the state of well production, polymer flooding, energy consumption and platform inventory in order to estimate well operations and flow assurance.

5.5 Technical solutions and approaches of oil production planning decisions

Most of the works published in "*long-term production and scheduling decisions*" adopted the mathematical models such as the mixed integer linear programming model, the mixed integer nonlinear programming models and the stochastic mixed integer linear programming model. In some cases, these mathematical models were coupled with numerical models. Furthermore, a heuristic algorithm was also proposed.

For the "*long-term production decisions*", the most widely implemented technical solution was the algorithm, specifically the binary, derivative-free and differential evolution algorithms. The other most widely used approach was the mixed integer nonlinear programming model. It is comprehensive that these methodologies have been adopted due to the non-linear dynamics of an oilfield.

Because of the time horizon of the proposed works on "*medium/short-term production decisions*" is reduced compared to "*long-term production decisions*", this decreases the computational effort, allowing the mixed-integer linear programming model to be applied to all works.

Two different approaches were used in "*flow assurance decisions*" category. One approach coupled the hydrodynamic and thermodynamic models, while the other implemented a mixed integer nonlinear programming model.

Figure 18 and Figure 19 present the relationship between the number of papers and technical solutions, and the respective categories of the journals in which the papers were published in the "*oil production planning decisions*" category. As discussed above, the nonlinearities of reservoir dynamics make the computational modelling efforts discussed difficult, which prompts the authors to search for appropriate technical solutions to define the proposed decisions. In this regard, the mixed integer nonlinear programming model and heuristics account for eight papers together. This also justifies why most of the papers were published in the "*Computer Science*" journal category.

6 Environmental planning decisions

The category of environmental planning decisions accounts for 14 papers. The main objective of these works is to plan, analyse and evaluate environmental decisions relating to the development of an offshore oilfield. This includes planning the environmental response in the event of an oil spill, determining the most appropriate time for decommissioning oilfield infrastructure and planning logistics, implementing the reuse of infrastructure, and developing an adequate strategy for reducing the carbon footprint of an offshore oilfield development, These topics are classified as follows in the present paper, and

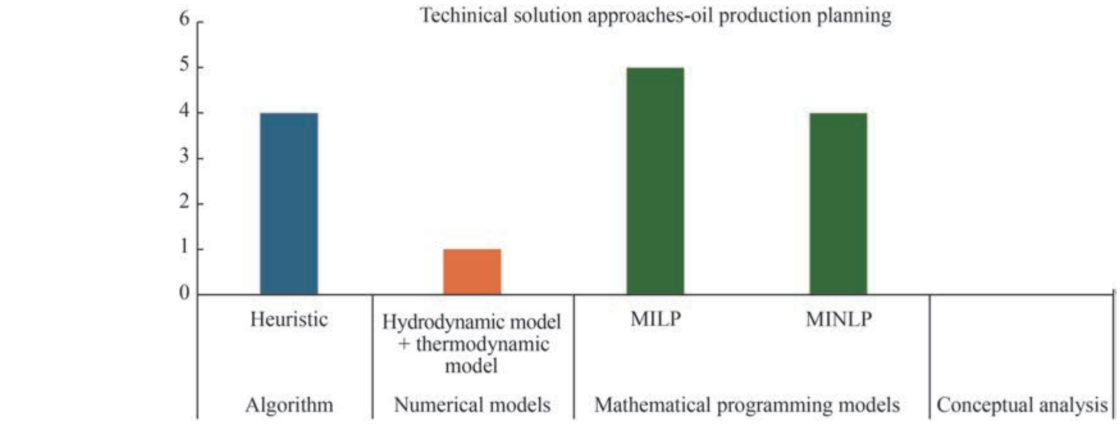

Figure 18 Oil production planning technical solutions and approaches

Figure 20 presents the number of papers published in each subcategory:

- Oil spill response planning;
- Decommissioning planning;
- Re-using planning;
- Decarbonisation strategies;

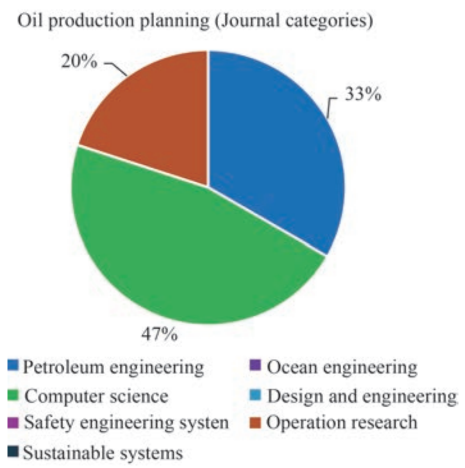

Figure 19 Journals' categories of the oil production planning papers

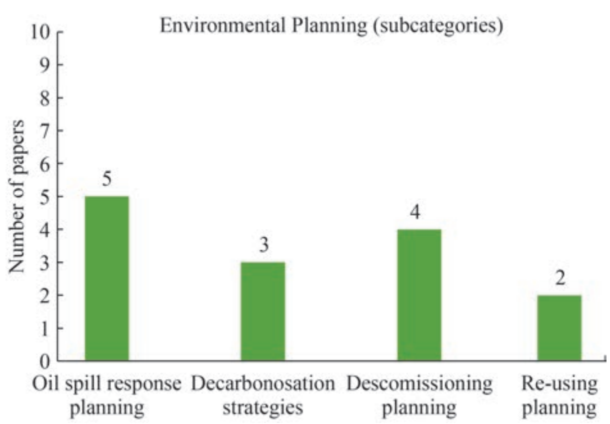

Figure 20 Number of papers published in each subcategory of the Environmental planning decisions

6.1 Oil spill response planning decisions

The catastrophic risk posed by an oil spill in an offshore oilfield makes response planning an important part of the development phase of an oilfield. Anticipating this decision-making process in the early stages of the project aims to reduce the potential impact on safety, the economy and the environment. Therefore, 5 papers were published in this respective category (Amir-Heidari and Raie, 2019, 2018; Guo et al., 2019, 2015; Li et al., 2016).

Guo et al. (2015) identified the key environmental sources of an offshore oil spills by analysing the full scope of pollution, including spills from ships and oil facilities. Their proposed work aimed to assess the risk of an offshore oil spill by taking into consideration the start time, volume and duration of the release. In contrast, Amir-Heidari and Raie (2018), only analysed oil spills from offshore oil wells. The authors considered different possible scenarios regarding release amounts and frequencies in order to assess the risk posed by each source of oil spill. Moreover, Guo et al. (2019) simulates various oil spill scenarios at twenty oilfields based on high-resolution oceanographic, meteorological, and geomorphological data to assess the risk of oil pollution in a sensitive marine environment. The proposed measure on oil spill risk combines conditional probabilities, environmental vulnerabilities and spatial area exposure.

In contrast, Li et al. (2016) conducted a thorough review of various new strategies and decision frameworks that can assist with diagnosing oil spills and support response planning. The main objective was to determine the most appropriate methodology and technology for oil spill response and countermeasures. Amir-Heidari and Raie (2019), meanwhile, proposed a decision-support system for response planning that integrates an oil spill model with high-resolution wind and sea current data. This integrated model can calculate the mean concentration and impact time of an oil spill in different areas, thus enabling optimal resource allocation and the optimal location of emergency response stations to be determined.

6.2 Decommissioning planning decisions

An important set of decisions concerning the oilfield development is how to decommission oilfield systems. Anticipating this group of decisions in the early stages of oilfield development enables decision-makers to develop a proper, sustainable plan and makes the decommissioning process more transparent and traceable, from planning to execution. This group of decisions is covered in four papers (Carneiro et al., 2024; Chen et al., 2024; Vidal et al., 2022; Zagonari, 2021).

Zagonari (2021) enhanced the decision-making process by integrating ethical concerns from a societal perspective into decision-making methodologies that aim to define sustainable planning. The work analysed the linear option of decommissioning versus the reusing planning by defining the economic, social, and environmental impacts of each decision. Vidal et al. (2022) analysed all the planning levels involved in the decommissioning process and their interconnection, with the aim of defining all the elements that comprise the decommissioning process and supporting strategic and operational decisions.

Chen et al. (2024) analysed and reviewed a specific decommissioning plan and process, searching for and defining the potential environmental impacts of an established strategy. The study also aimed to propose recommendations and environmental protection measures. Carneiro et al. (2024) analysed all the decommissioning alternatives for oil and gas structures, with the aim of assessing their environmental impact. The study presents quantitative indicators of technical features that enable the environmental sensitivity of each decommissioning option to be expressed as a numerical score.

6.3 Decarbonisation strategies decisions

In an attempt to align with current global environmental policies, this group of decisions seeks the most suitable alternative for developing oilfield systems that reduce the carbon footprint throughout the entire life cycle of the oilfield. This group of decisions describes three works (Bergmo and Holt, 2024; Coutinho et al., 2024; da Silva and de Oliveira Junior, 2018).

da Silva and de Oliveira Junior (2018) consider the lifespan of a well when analysing the operating conditions of the process and cogeneration plants of an offshore platform. The proposed work calculates the exergy and CO_2 unit costs of offshore platform products. Whereas Coutinho et al. (2024) considered not only the CO_2 emissions from the combustion of oil and gas products, but also CO_2 and CH_4 emissions from the oil and gas production. The work explored climate strategies for the entire upstream oil and gas sector, aiming to define the most cost-effective mitigation technologies. Bergmo and Holt (2024), in turn, analysed and ranked various alternatives for storing relatively small amounts of CO_2 captured from offshore petroleum production plants, in an attempt to define the most suitable alternative solutions for storing CO_2 captured from gas turbine power plants on offshore platforms.

6.4 Reusing planning decisions

The remaining group of decisions examined possible reuse alternatives for offshore platforms. Two papers considered the social, technical and economic aspects of these decisions (Kolian et al., 2019; Zanuttigh et al., 2025).

Kolian et al. (2019) analysed the socio-economic incentives, environmental impacts and regulatory issues associated with alternative uses of offshore platforms, such as carbon capture and storage, renewable wind energy and sustainable fisheries. These alternatives create employment opportunities in coastal areas. In contrast, Zanuttigh et al., (2025), evaluate the reuse of platforms for energy production, educational tourism and aquaculture, comparing it with decommissioning planning. The main objective of their study is to identify the most promising combination of reuse activities.

6.5 Technical solutions and approaches of environmental planning decisions

Most of the works in "*oil spill response planning decisions*" sub-category used a probabilistic risk assessment approach. The main goal of risk assessment is to identify the most critical aspect of the system in order to plan the response strategy properly, looking defining for preventive and corrective actions. Moreover, a strategic decision support framework was developed using an oil spill model to understand the possible environmental impact and allowing the definition of properly response actions. A comprehensive review is also proposed.

Furthermore, the set of decisions relating to "*decommissioning planning*" involves both numerical and conceptual analysis. The most important goal is to review the technical and societal features of a decommissioning plan and translate these into a numerical score. This will help decision-makers properly evaluate alternative options and reduce the gap between science and environmental policy.

On the one hand, as the primary objective of the "*decarbonisation strategies decisions*" is to evaluate alternatives, all of the studies adopted numerical analysis as a technical solution. For the "reusing planning decisions", however, both numerical and conceptual analyses are proposed. In this specific study, the main idea of the conceptual analysis is to examine the technical advantages of the proposed alternatives.

Figure 21 and Figure 22 present the technical solutions and approaches used in the respective subcategories, as

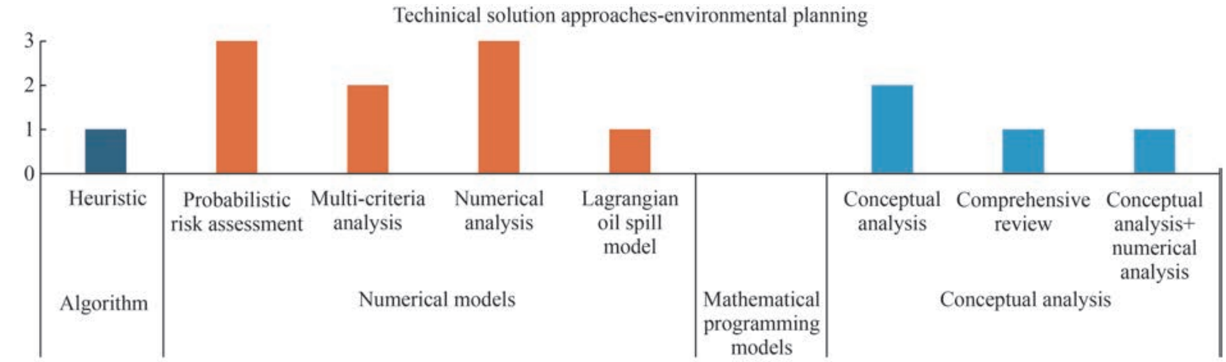

Figure 21 Technical solutions and approaches adopted in the environmental planning decisions

well as the number of papers and the categories of journals in which the published works appeared. Numerical models are widely adopted in most papers. The second most common approach is conceptual analysis, followed by algorithms. As can be seen, mathematical programming models are not used in the decision-making processes. Also, most of the papers were published in the journal' category of "*Sustainable Systems*". Followed by articles published in the "*Ocean engineering*" category.

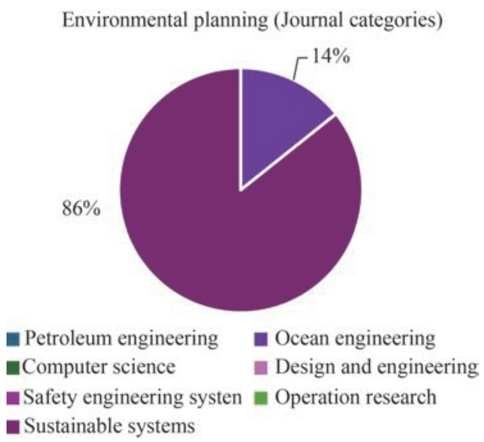

Figure 22 Journal categories of the published papers in the environmental planning decisions

7 Well placement and production decisions

The remaining category is the most difficult to identify as it is unclear whether the literature falls within the scope of this paper. This is because the field of study is not clearly defined in most of the articles; the primary objective is to explain the complexity of decision-making processes in relation to reservoir dynamics. Figure 23, shows that only six papers are categorised in this respective category (Bittencourt and Horne, 1997; Chang et al., 2015; Ebadat and Karimaghaee, 2012; Forouzanfar et al., 2012; Liu et al., 2022b; Wu et al., 2024). The subcategories are defined as follows:

- Well location;
- Well location and drilling trajectories;
- Well drilling;
- Well location and production scheduling;

In an attempt to improve the readability of the paper due to the reduced number of papers, the authors have decided not to present the papers according to the proposed subcategories, as standard.

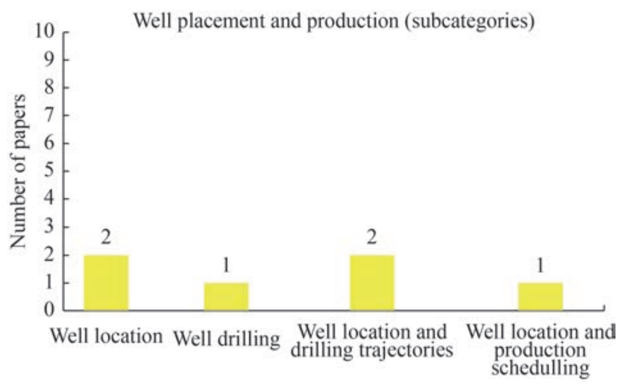

Figure 23 Subcategories of the well placement and production decisions

Specifically, the works of Bittencourt and Horne (1997), Liu et al. (2022b), Wu et al. (2024) address the well placement in a subsea production system. Bittencourt and Horne (1997) combine reservoir properties and production scheduling parameters to define the optimal location and type of drilling for a group of established wells. A second decision-making level involved reducing the cost of subsea pipelines to find the optimal platform location. Liu et al. (2022b) aim to establish the drilling site location and the trajectory between the drilling site to the completion interval in order to optimise the seabed facility layout. Wu et al. (2024) evaluate well-bore stability performance in order to determine optimal well locations and diameters in shallow water formations.

Forouzanfar et al. (2012), in addition to the 3D coordinates (x, y, z), considered the length of the well as an additional dimension in order to estimate the location of horizontal and vertical wells. Ebadat and Karimaghaee (2012) changed the well's placement approach by finding the optimal well locations that match the desired pre-specified production curve (field oil production total/rate), which is determined according to the industrial gas and oil companies' seasonal need. Chang et al. (2015) on the other hand, considered the geological uncertainty of the well productivity index in order to maximise the mean net present value (NPV) across all well placement scenarios.

Due to the intrinsic complexity of the reservoir characterisation problem, all papers in the respective category adopted the "*algorithm*" as the main technical solution. The genetic algorithm and the neural network were the most commonly used by the authors. A specific heuristic and a derivative-free algorithm were also adopted (see Figure 24). As expected, the journal category of all works published in this section is "Petroleum Engineering" (Figure 25).

8 Prospects for oilfield development decisions

In an attempt to better understand the planning concerns of an offshore oilfield development, this study aims to analyse three important aspects based on a systematic literature review: the status of decisions on the development of an offshore oilfield; the main technical methods used to support the decision-making process of each development decisions; and the prospects and gaps of decisions or technical approaches on each development category.

8.1 Status of decisions on the development of an offshore oilfield

The following decision statuses were identified by the above-described systematic research in brief:

• The main decisions regarding offshore oilfield development planning, "*field design and planning*", "*subsea system design*", "*oil production planning*", "*environmental planning*", and "*well placement and production*" are covered in 43, 19, 15, 14 and 6 papers, respectively.

• The first development category investigated was "*field design and planning*," which was studied by the United States of America, in 1972. Furthermore, Brazil, China, the United States of America and Norway are the four countries that contribute the most to this area of scientific research.

• The most commonly adopted technical solutions for the respective decisions are the mathematical programming models (45%), algorithms (32%), numerical models (18%) and conceptual analyses (5%).

• Most of the scientific papers were published in the following four areas of journals: Computer Science (24%), Petroleum Engineering (23%), Sustainable Systems (21%), and Ocean Engineering (20%).

8.2 Main technical methods used to support the decision-making process

One of the main contributions of the present systematic review is to identify the technical methods adopted by the scholars to support the decision-making process of each development category. Briefly, it can be summarized as follows:

• The papers included in the "*field design and planning*" category mostly used the mathematical programming models (32%), followed by the numerical models (6%), algorithms (5%), and conceptual analysis (1%). Mixed-integer linear programming models were the most commonly adopted mathematical programming models and were also implemented in conjunction with some decomposed problem strategies. Thus, due to the non-linear nature of reservoir dynamics, mixed non-linear programming models were also adopted, some of which were implemented with algorithms.

• For the "*subsea system design*" decision category, the technical solution most adopted by the scholars was the

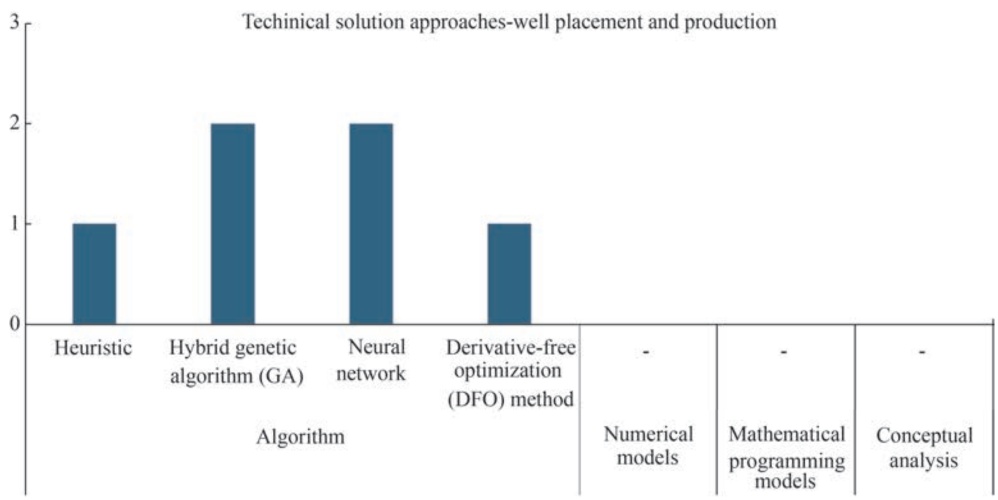

Figure 24 Technical solutions of the well placement and production decisions

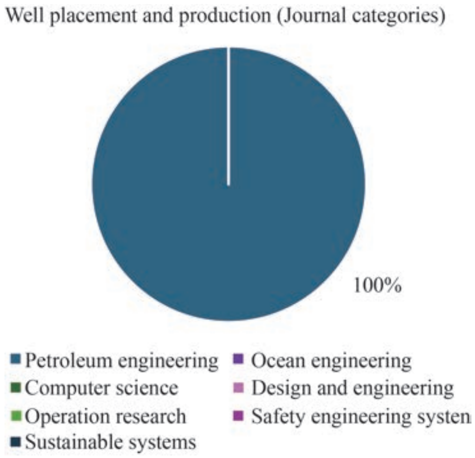

Figure 25 Journal categories of the published works in the "well placement and production decisions"

algorithm, presented in 74% of the papers. This was followed by the mathematical programming model (21%), numerical models (5%), and conceptual analysis (0%). The algorithms were mainly adopted to refine modelling of seabed characteristics in an attempt to describe a real-world system. Mixed integer linear programming models and probabilistic risk assessments were also commonly adopted.

• Research articles included in the "*oil production planning*" decision category mostly adopted the mathematical programming models (64%), followed by the algorithm (29%), numerical model (7%), and conceptual analysis (0%). The linear and the nonlinear programming models were commonly used. In some cases, due to the non-linear nature of reservoir dynamics, these mathematical models were coupled with numerical models. Furthermore, a heuristic algorithm was also proposed.

• For the decision category of "*environmental planning*" the published research mostly adopted the numerical models (74%), followed by the conceptual analysis (29%), algorithm (7%), and mathematical programming models (0%). The probabilistic risk assessment approach is commonly used to identify the most critical aspect of the system. Also, other numeral frameworks were developed using an oil spill model to understand the possible environmental impact and allowing the definition of properly response actions. Conceptual analyses were commonly adopted for decommissioning planning and decarbonisation strategies.

• The papers that studied the "*well placement and production*" decisions only adopted the algorithm (100%) as technical solutions, mainly because the intrinsic complexity of the reservoir characterisation problem.

8.3 Prospects and gaps of decisions on each development category

In this regard, it is possible to note that the "*field design and planning*" decisions are the development category that has the most articles published, accounting for 43 papers divided into seven subcategories. Thus, respective gaps in the literature can be highlighted as follows:

• "*Oil production and surface system design*": the majority of works used the well production and scheduling to determine the production allocation, the platform location and capacity size. However, few studies considered the impact of field parameter uncertainties on surface system design.

• "*Oil production and subsea system design*": the frameworks considered production in order to independently establish the pipeline network, subsea arrangement or analyse flow assurance problems. Therefore, a model that can use the production data to integrate all of these decisions in one framework would enhance the decision-making process, making it more representative of a real-world system.

• "*Oil production, subsea system design and surface system design*": papers considered production to independently define drilling schedules, pipe connections and installation plans, the number and capacity of platforms, production allocation and the location and size of manifolds. Few studies have incorporated uncertainties in field parameters when analysing the impact of production on these decisions. Nevertheless, integrating pipeline network decisions with flow assurance issues will increase the complexity of the problem but also improve the system description.

• "O*il production and environmental planning*": the studies coupled production with an analysis of environmental aspects. However, the only environmental concern considered by the works was decommissioning time. Therefore, integrating production with other environmental decisions would improve the decision-making process.

• "*Subsea system design and surface system design*": the subsea decisions are considered independently, including production allocation to platforms, subsea layout, flowline routes, and drilling trajectories, in order to determine the number, capacity, and location of platforms. While few studies have considered the risk of subsea equipment and components, incorporating a complete risk analysis of the entire subsea production system or flow assurance problems would provide valuable insights into the design of the production system.

• "*Well placement and production, subsea system design, surface system design*": few studies have considered the number and position of wells as well as the drilling trajectories, independently, in order to determine the location of manifolds, or the number, capacity and location of platforms. Other frameworks, however, adopted the production/injection relationship in order to define well assignment, oil/water capacity on platforms, or pipeline route. Nevertheless, the impact of reservoir uncertainties on the design of the production system (subsea and surface) would be considered for a precisely description of the system. The investigation of how the location of the wells may impact the design of different subsea layout concepts integrated with a proper pipeline network and surface system design is also important.

• "*Environmental planning and surface system design*": the works independently analysed different decarbonisation strategies for offshore platforms, such as the CO_2 capture processes, platform power, combined cycle power plants and other energy systems, and carbon footprint assessments. However, insights from other environmental decisions would be valuable for the planning and design of a sustainable oilfield production system. Furthermore, there are no environmental concerns associated with subsea system design, nor any integration of environmental planning, subsea system design, and surface system design, described in the literature.

Moreover, the "*subsea system design*" decisions analysed 19 papers categorised into three minor subcategories. The respective prospects of this group of decisions can be summarised as:

• "*Pipeline network*": the authors mostly focus on decisions relating to pipeline connections, diameters and routing. Few studies have incorporated flow assurance problems or risk assessment of pipes into decision frameworks. However, an integrated model that considers all these important aspects will not only increase the complexity of the problem but also improve the system framework.

• "*Subsea layout design*": most studies have considered clustered satellite and daisy chain layouts, aiming to reduce pipeline length (and therefore cost), and to define the number and size of equipment and components. However, only one study considers the probability of failure of subsea equipment and components, nor do they analyse other types of subsea layout concepts or the impact of flow assurance problems within subsea production systems.

• "*Subsea layout design and pipeline network*": the authors primarily considered the clustered satellite layout concept, incorporating a few subsea system design decisions, such as the location and number of equipment and components, as well as the clustering process of wells, to independently determine the pipeline network decisions mainly considering the pipeline routing issues, such as obstacles, pipe intersections and pressure drop in the pipeline. However, investigating different layout concepts or inserting analyses of flow assurance problems could improve the decision-making process.

The "*oil production planning*" decisions have considered 15 papers classified into four subcategories. From the respective works, the literature gaps can be highlighted as:

• "*Long-term production and scheduling*": most of the frameworks independently addressed production issues, geological uncertainty, elements of the production chain, reservoir pressure support and enhanced oil recovery independently, in order to estimate the oilfield production profile. However, none of the studies integrated all these aspects to determine the most appropriate production/injection schedule accomplished with the forecast of the production profile.

• "*Long-term production*": all studies considered the reservoir dynamics to have a non-linear behaviour, while some works independently considered a water drive mechanism to analyse enhanced oil recovery, or the impact of geological uncertainty on the estimation of the number of wells, plateau rate and project value. However, integrating reservoir pressure support with enhanced oil recovery to forecast oilfield production profiles would provide a valuable decision-making framework.

• "*Medium/short-term production*": most of the works consider the non-linearities of the reservoir and investigate production allocation, injection rates and pressure drop, separately. However, none of them have analysed the impact of uncertainties in field parameters on production estimation.

• "*Flow assurance*": all of the works investigate the impact of hydrate formation on production estimation. However, other flow assurance issues, such as wax, paraffin and sulphide formation, would be examined to provide a realistic view of production systems.

Thus, the "*environmental planning*" decisions accounts for 14 papers divided into four subcategories, where it is possible to highlight the following prospects:

• "*Oil spill response planning*": most studies considered different scenarios and sources of oil spills (e.g. ships or oil facilities) using high-resolution data (e.g. oceanographic, meteorological and geomorphological) to define the start time, volume and duration of an oil spill, assess environmental risk, or allocate response resources. However, analysing oil spill sources throughout the entire upstream phase, including drilling, production, logistics and decommissioning, appears to be a valuable decision-making framework.

• "*Decommissioning planning*": all of the works have considered the social, environmental and economic aspects to define the decommissioning plan, its interconnection and the decommissioning elements, as well as the potential environmental impact and environmental sensitivity. However, integrating two or more of these aspects could improve the decision-making process.

• "*Decarbonisation strategies*": the analysis of different decarbonisation strategies examined the exergy and CO_2 unit cost, CO_2 emissions (from combustion and/or production), and CO_2 capture and storage, separately. An enhanced analysis would consider how the uncertainties in CO_2 estimation impact on each respective strategy.

• "*Reusing planning*": the works have considered socio-economic incentives, the environmental impact, and regulatory issues when analysing the reuse of offshore platforms for purposes such as carbon capture and storage, renewable energy production, sustainable fisheries, educational tourism, and aquaculture. However, analysing the impact of oil price uncertainties on these respective strategies or environmental policies would increase the complexity of the decision-making framework.

The "*wells placement*" decisions only accounts for 6 papers included in the respective category. Therefore, due to the small number of papers, the subcategories do not provide a more systematic analysis. Therefore, in terms of the scope of the paper, it would be interesting to investigate how well placement decisions impact the design of the offshore production system, for example the subsea layout concepts or the location of the surface platform. Additionally, analysing how uncertainty in the drilling target, the volume of oil in place, and the oil price may impact the well drilling method (vertical or horizontal) would be worthwhile.

9 Conclusions

Decisions made in the early stages of oilfield development can impact the technical, economic and safety aspects of offshore oilfields. In this regard, systematically analysing the progress of the support methods may enhance the decision-making process in the conceptual phase by examining the evolution of offshore production systems, the various methods that could support decision-makers, and the valuable prospect of what can be implemented.

From the 1970s to the 1990s, field design and production planning were the main focus of the decision-making process, i. e. design and/or operation decisions were combined with the aim of improving the feasibility studies of field development, being the mathematical programming models the most adopted technical solution for solving these respective decisions. Subsequently, during the 1990s to 2010s, decisions such as estimating the production profile, location, number and drilling trajectories of wells, which can be considered as operational planning decisions, were taken, probably in an attempt to increase the recoverable amount of hydrocarbons while reducing the complexity of deep to ultra-deep-water operations. The mathematical programming models were the adequate approach for solving this development decisions. Thus, from the 2010s to present, the design decisions regarding the subsea production system and the environmental strategies and planning decisions also appears as main important issues discussed in the literature, being the algorithms and numerical models the technical solutions most used for these categories.

Therefore, the 97 papers analysed may provide valuable insights into what are the main prospects for the development decisions. However, due to the environmental policies and concerns imposed nowadays, these have presented a huge impact on the decision-making process, turning the planning of sustainable oilfields a recent yet highly important topic. Also, incorporating safety criteria into the technical-economic decision-making process for designing production systems may provide valuable insights at the oilfield early stage. Moreover, the integration of flow assurance issues into the oil production decisions and subsea system design may increase the complexity of the problem but also improve the system framework. Thus, the investigation of the impact of the wells placement into the subsea layout concepts and surface systems also may support the decision-makers.

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