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Application of Operations Research in Oil Industry: A Systematic Literature Review

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Abstract: In the following bibliometric research paper, we have solely focused on applications of various methodologies of operations research focused on the addition, contributions, methodological focuses, and findings related to the oil industry. Starting from the 1940s to most recent publications available the authors and most relevant papers have been chosen and their contributions specified to provide complete information about their methodological work and the reasons they did it. To give a regressing brief about the paper our major findings include the MOEA, DOSC and Simplex methods and how they currently affect the oil industry along with what other questions our paper creates like how Covid-19 would affect the functioning/ working of these methods. To regress to the previous point that states a summary concluding our findings. Followed by the 4 most important methodologies and their applications in certain sectors within optimization withing the oil industry. This is then backed by our list of reviewed articles and what is stated within them to support the findings within the paper. Lastly the introduction consists of the issues and errors that created the need for these methods to be applied in the industry. This paper doesn't prove any hypothesis or work on filling gaps within the industry instead gives a competent collection of data over the years that have been slowly solving these problems and how they could help people identify other problems to solve after having detailed knowledge of most existing methods used within the oil industry.

Keywords: Optimization, Energy, Operations Research, Supply chain management, Oil industry, logistics, Transportation.

I. INTRODUCTION

According to the Council of Supply Chain Management Professionals (CSCMP), The transportation and transformation of goods from the extraction of raw materials to the end user, as well as information flows, are all operations that are a part of supply chain management.(Dawson & Fuller, 1999) (Handfield and Nichols, 1999); (Abduljabbar et al., 2013). And up to 50% of a product's overall logistics expenditures might be attributed to transportation expenses(Bauer et al., 2002);. One of the most important factors for oil firms to survive and maintain competitive advantages in a globally competitive climate is how to manage transportation operations effectively. From oil and gas exploration through refining and distribution, the oil industry engages in an excessively wide range of vertically integrated operations. The main oil firms typically locate their refineries near the depots, turning the depots into a hub for consumer distribution. The location of the consumers is mostly considered when deciding whether to establish a depot. Hill (2003) asserts that the sales and marketing divisions typically foresee the facility location strategy. The business will then consider its ability and capacity to meet the customer's needs (Abduljabbar et al., 2013)

To securely carry petroleum products, oil, and gas pipelines (OGPs) must be planned, designed, erected, operated, and maintained. However, several risk factors, including terrorism, sabotage, theft, corrosion, poor design and construction, environmental risks, operational mistakes, and many more, are endangering the security of these installations. Due to a lack of data and research on risk factors in developing nations, the present risk assessment tools are insufficient to analyze risk variables in OGP projects in these nations(Karadi & Kajjidoni, 2020). The distribution of petroleum products through oil pipeline networks is a major issue because it is a vital economic activity for all nations. Typically, the items are delivered to their destinations from refineries, ports, or storage facilities. The primary objective is to deliver the requested products on time to the destination places, but another crucial objective is to avoid shipping products of the same kind back-to-back because they could infect one another. In addition, a variety of restrictions must be met, including storage capacity restrictions, transportation network capacity restrictions, and capacity limits for delivering sources and receiving at destination.(De La Cruz et al., 2003).

Often the change in seasons, natural calamities, governmental regulations, imports pertaining to petroleum and other unpredictability-related issues, there are frequent shortages of refined oil in some nations or regions in daily life. Refined oil shortages are typically brought on by sudden events (such as government supervision or natural calamities) or ongoing issues (e.g., unethical business practices and holidays). To the greatest extent possible, the ODC anticipates meeting the demands of stations with greater levels while limiting operating expenses and overtime fines. When creating a distribution plan for vehicle allocation and route planning, focus lies on the absolute minimum requirements for safe operations and the priority levels linked with stations. Yet, few studies have been done on the distribution of refined oil that consider the possibility of a limited supply that can affect operation costs or operation time.(Goldbarg et al., 2009).(Chakrabortty et al., 2016)The optimality and even viability of an initial distribution plan could be undermined by considering the unpredictability caused by demand fluctuations(Ben-Ammar et al., 2019), transportation congestion, and weather changes (Adelzadeh et al., 2014),among other factors.(Xu et al., 2021)

II. LITERATURE REVIEW

In 1941, Hitchcock first developed the transportation model. Dantzig (1963) then uses the simplex method on the transportation problem. The modified distribution method is useful in finding the optimal solution for the transportation problem. (Ibrahim, 2008)Since then, transportation optimization in the oil industry has been analyzed in a variety of approaches. Fisher and Jaikumar (1981) developed a generic assignment for vehicle dispatching. They considered fulfilling customer orders with vehicles that transport goods kept at a central depot. To reduce overall delivery costs, the assignment decision entails deciding which of the needs will be supplied by which vehicle and what route each vehicle will take in satisfying its assigned demand. They assert that their heuristics will always guarantee a feasible solution (if possible), something unheard of for other heuristics up until that point. Additionally, the heuristics are easily adaptable to many more complex issue scenarios. (Ibrahim, 2008). A major American oil business employs dispatchers who oversee giving drivers the itineraries to pick up crude products utilizing homogenous capacity tank trucks and transport them to pipeline entry sites. Bixby and Lee (1996) used branch and cut processes on formulations of 0-1 IP (Integer Programming) to solve the problem to optimality with up to two thousandvariables (Ibrahim, 2008). Dynamic programming (DP) was used by Gigler et al. (2002) in the supply chain for agricultural commodities, or what they referred to as "Agri chains." In an example involving the supply chain of willow biomass fuel to an energy plant, they employed the DP methodology. In addition to transportation, the DP technique includes handling and natural drying of the biomass fuel at various stages.(Ibrahim, 2008)analyzed the optimum transportation of palm oil products in North Peninsular Malaysia. Keeping optimal distance minimization as the selected criteria, he considered a variety of central sites before concluding after his methods of research. Thus, he used transportation optimization to examine the best possible routes for oil products in a particular region. Similarly, E. Iakovou and C. Douligeris examined strategic transportation for oil in US waters(Iakovou & Douligeris, 1996)(Rossit et al., 2020)devised a three-stage practical heuristic to solve the oil transportation issue. This heuristic enables decreasing the time spent developing a schedule, increasing the company's adaptability to deal with changes in its clients' demands and boosting customer satisfaction(Joshi & Singh, 2019)(Rossit et al., 2020). The stages are focused on maximizing usage of the trucks with largest capacity and selecting routes to fulfil the largest demand present until each truck is assigned to a route using the complex algorithm of constructive heuristic procedure(Rossit et al., 2020). Optimization of oil transportation is also critically analyzed from the sustainable point of view(Dimić et al., 2016) (Rossit et al., 2020). They provide a strategic transport management model for the Serbian Oil Industry and identify transportation as one of the key components of a plan for sustainable growth. They demonstrate that this paradigm may be successfully applied in profit-making organizations for the implementation of sustainable strategies.

Porter (1985) primary activities are related to the production or delivery of products and services and can be clubbed into fiveprincipal areas. These are - inbound logistics, operations, outbound logistics, marketing, and sales and service.
Porter’s Five Pushes mainly are concerned with and analyze

- Obstacles to entrance
- Supply power
- Buyer power
- Availability of substitutes
- Competitive rivalry

In the end, when assessing the oil business, the Porter’s Five Pushes model is quite useful. This model can be used by the right business management to comprehend the vital oil industry context in which the company operates and gain an advantage over competitors. Planning downstream oil supply chains (DOSCs) is crucial to ensuring that the demand of retail markets can be met (Li et al., 2015). Pipelines are widely employed in several DOSCs as a cost-effective method of transporting refined oil. De Jong and others (2017) By building new pipelines in a DOSC, the distribution cost can be reduced, and the efficiency can be increased (Liu et al., 2015)(B. Wang et al., 2020). Mixed integer linear programming (MILP)(de Jong et al., 2017) is a model that Bohong Wang and colleagues created in 2019 to optimize a DOSC with novel pipeline route design. Planning restrictions for pipeline routes and the distribution of refined oil were also put forth. This model makes it possible for a DOSC to be used in China on a practical level by considering travel between storage depots (SDs). The locations of new pipes and supply chain planning following new pipeline construction can be determined using the present DOSCs. The two cases are compared after this strategy is used in an actual DOSC case from China. Additionally, using this technique, decision-makers can plan pipeline routes more effectively and develop distribution strategies for other DOSCs (B. Wang et al., 2020) The last year saw the petroleum sector endure two protracted crises: a supply glut brought on by the price war between OPEC and Russia, and a decline in demand brought on by Covid-19. Cost-effective techniques are a savior during such supply chain issues and disruptions, saving any industry from bankruptcy. In the expensive petroleum sectors, logistics is one of the best places to save costs. For the downstream supply chain of the petroleum industry,(Baraiya et al., 2021) introduced the multi-product multi-modal transportation cost optimization model. On AMPL software and the MINOS solver, the MILP model is proposed and resolved (de Jong et al., 2017). Various experiments and sensitivity analysis are used to determine the link between the demand and pipeline capacity, as well as the absolute and per-unit transportation cost. The authors discovered that a gain in pipeline capacity minimizes the overall and per-unit transportation cost, whereas a rise in depot demand maximizes it. The decision support system prototype was another suggestion made by the authors for the managerial application of this concept.

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III. RESEARCH METHODOLOGY

This section reviews the articles on various methods used in the Oil Industry, giving a brief about them. The scientific contribution and impact of publications in a study field are systemically reviewed and evaluated using bibliometric analysis, which employs simple to sophisticated mathematical and statistical methodologies. For analysis purposes we used various bibliographic databases which include Science Direct, EBSCO Host, Google Scholar, and Research Gate. The terms "Operations, Research, Oil Industry, Transportation and Optimization" were used while searching for data. The sample for the bibliometric study ranged from 200-250 papers. Academic Journals and English Language where some of the filters applied to the databases. For Bibliometric Analysis we used three methods which were :The number of publications published from 2010 to 2021, the co-occurrence of keywords in the chosen contributing papers, and the co-occurrence of the citation network from the chosen authors. The following methods were primarily used.

- Linear Programming
- DOSC method
- Nonlinear Planning Model
- MOEA

A. *Linear Programming*

When solving a type of programming problems known as linear programming (LP), the objective function that must be maximized as well as the relationships between the variables that relate to resources, or constraints, are linear. An LP model's formulation can be a time-consuming and challenging undertaking. The inappropriate collection of variables being used or the wrong connections between the variables being built might lead to an incorrect model. An effective model formulation follows several rules. A set of decision variables, a set of parameters, an objective function, and a set of constraints make up any LP.(Abduljabbar et al., 2013)

B. *DOSC method*

Oil is delivered from refineries to depots over the shortest possible distance according to the objective function. The two stigmas' following each other in the double summations signify that the multiplication of two variables take place before combining them together. The number of trips taken to deliver the oil between refinery I and depot j is multiplied by their distance to get the total transportation distance for the particular I and j. The total amount of oil produced by each refinery must equal the sum of the trips made from that refinery to the depots multiplied by the size of the tanker for the m equalities that make up the supply restrictions to be true. For these limits, the equal sign means that all the refined oil must be sent out. However, due to demand limits, which total n, the quantity of oil that may be processed by a given refinery cannot exceed its processing capacity. The These are the final constraints.

We solve this issue by presenting a superstructure-based model that uses mathematical programming to create the best energy development route for China's road freight transport. It has been demonstrated to be a useful technique for addressing the best planning of energy systems, including hydrogen infrastructure, polygene ration energy systems, and bioenergy processing systems [24e27]. Superstructure-based modelling is perfectly suited for its optimal planning because the mathematical programming allows a choice of alternative fuels and powertrains to choose for diverse types of trucks in different years. So, for this problem, we develop a COSM (cost-optimization model) utilizing the superstructure optimization approach.

Finding a solution that reduces environmental and transportation expenses is the fundamental goal of a DOSC operation. Refineries, storage facilities, or other retail markets may send refined oil to a retail market via rail, pipeline, or river. There are many additional routes available in a DOSC. The challenge creating a supply chain model and identifying the best operational strategy is performed using a P-graph.(B. Wang et al., 2020)The complex logic of several ship approaches to the platform, which is influenced by various weather conditions, was similarly captured by the model. The model now includes the capacity to run concurrent operations of several supply cargo kinds as well as unscheduled operations interruptions caused by weather window termination, vessel transition to another terminal, or vessel departure outside of the platform's three-mile border zone. The model also had a procedure for reducing local oil production when there was a possibility of an oil storage tank filling to capacity.

The procedure of distributing crude oil as efficiently as possible via land transportation using tanker trucks is covered in this study. An upstream oil and gas corporation operating in Indonesia's Sumatra is involved in the case. The producer moves the liquid throughout the supply-chain network using tank trucks and ground transportation.(Amelia et al., 2021)

Numerous constraints from the real world complicate the problem in this research. In response to the company's request to improve the travel time estimation formula (Eq. 1), the regional site distribution has been partially digitalized. It is improbable that the individual facilities and the network of paths between them will be fully digitalized due to the complexity of the components involved (the large quantity of sites can be seen in Fig. 1). The information, which took a lot of effort to obtain because these facilities change regularly, also soon gets out of date. Instead, the bases' more trustworthy locations were delocalized with QGIS. Due to the increasing Euclidean distance between bases when a route contained amenities supplied by more than one base, the first empirical formula for determining trip durations may be improved.(Rossit et al., 2020)

There are two objectives because This study's goal is to decrease overall risk and travel-related costs. As a result, this research employs the multi-objective programming approach. The primary aim function is to lower the overall annual cost of the crude transportation network. Transportation costs for pipeline transportation from the supply port to the port of transshipment or receiving, for seaborne transportation from the port of trans-shipment or receiving to the destination of consumption, and for pipeline transportation from the supply side to consumption are all included in the annual total cost.

Reduce the risk associated with the supply of crude oil and seaborne transportation as part of objective function two.(Y. Wang & Lu, 2015)

The main technique for analyzing the connections between sectors is Leontief's input-output matrix analysis (1951). The author is recognized as a pioneer in the investigation of inter-sector relations using linear algebraic matrix manipulations. Technical coefficients (which represent the direct connections between sectors in the form of each sector's percentage participation in each sector's production for a particular year) and coefficients derived from the inverse of the Leontief matrix are used to generate these matrices (which represent how much a sector demands from other sectors in first and higher order linkages). In 2009, Miller and Blair collated decades' worth of research on these topics.(Bouchain-galicia, 2000) the creation of a pipeline optimization model, as well as the introduction of relevant parameter calculation and limitation conditions. These computations are predicated on the idea that the pipe system has been simplified in this study to useful abstract mathematical terms.(liu et al., 2022)

The experimental strategy described in this study relies on selecting the critical parameters, which are subsequently varied one at a time in simulation trials. One can ascertain the outputs' sensitivity to and changes in each parameter by contrasting the effects of these changes on the given outputs. In 25% increments, the base-case parameters of shovel capacity, shovel cycle time, and GAP system throughput were increased from 50% to 150%. Because the GAP system's own progress cycle is the longest in this system, each replication takes four weeks (of 12 h operation days).(Que et al., 2016)

In this thesis, a particular case study was utilized. Hungary-based MOL Hungarian oil and gas PLC was chosen as the subject of the case study. A qualitative research methodology was used to conduct the study. Semi-structured phone and online interviews with employees of the organization were used to gather primary data. Additionally, the theoretical framework of reference for the thesis was constructed or built using secondary data from many sources, including books and journals.(SZUCS & HASSEN, 2012)

Since decades, professionals and academics have attempted to use the gradient approach, artificial intelligence method, linear approximation method, etc. to address the oil and gas pipeline optimization problem. However, the above-mentioned strategy is ineffective [2-4] for the presented problems because of the computing cost and optimality of the findings. The structural properties allow the oil and gas pipeline system to be converted into a multistage decision problem, which can then be solved using the dynamic programming method from optimization theory. The dynamic programming approach has the advantages of being insensitive to the objective function's nonlinearity and nonconvexity, adjustable computation time, and the ability to find the overall best solution.(Duan et al., 2021)

C. Nonlinear Planning Model

In 1998, A nonlinear planning model for refinery production by Moro et al. could serve as a universal topology representation. The refinery processing units that form the basis of the model's foundation are fully represented nonlinear equations. Blending relations and process equations make up the unit models. Additional limitations include operational variable caps, maximum unit feed flow rates, and minimum unit feed flow rates, and product standards must be followed by the unit variables. Various streams are created and blended in a typical oil refinery to produce a particular commercial product. Additionally, a range of products in various grades must comply customer needs. To achieve the desired output, it is assumed that there are multiple processing units, each of which generates a range of intermediate streams with unique attributes. Sets that show links between streams and units define the refinery's topology.(Joly et al., 2002)

D. MOEA

To address the problem, we use the multi-objective and multiple constraint optimization evolutionary algorithm (MOEA). You could consider constraint satisfaction to be a difficult objective. Thus, the degree of the constraints' violations in solutions is penalized, and constraints Cl, C2, and C3 are used as urgent goal-oriented operations. A mending function, on the other hand, takes care of the restrictions C4 and CS. This function tests each user to see if each transmitted packet complies with the specifications. If so, the person is preserved; if not, every erroneous the packet is taken out of the chromosome. As a result, this function makes sure that C4 and C5 are always satisfied.(De La Cruz et al., 2003)

Different researchers in our field have conducted bibliometric studies to discover and quantify the impact that particular authors, journals, and/or institutions have had on a given field of study (e.g., article outputs and co-citation metrics). The VOS viewer program was employed for the analysis in this study. A software program for creating and displaying bibliometric networks is called VOS viewer. These networks can be built via citation, bibliographic coupling, co-citation, or co-authorship relationships, and they can contain journals, researchers, or individual articles, for example. Additionally, the VOS viewer provides text mining capabilities that may be used to build and display co-occurrence networks of significant terms taken from a body of scientific literature. Using VOS viewer, a co-word analysis of the keywords found in the title, abstract, and author-provided keywords was carried out in order to understand the main study areas of the published papers by identifying the connections between the keywords. (Visualizing Scientific Landscapes, 2018). The co-occurrence of keywords serves to describe the article's substance, according to the theory of co-word analysis. Additionally, the co-Occurrence of keywords in a specific collection of articles illustrates how related terms are linked to one another (van Eck & Waltman, 2010). In order to generate a network map that shows the relationships between the research themes, the groups of keywords that come together most frequently are grouped together (research subjects). The bibliographic data was downloaded as a pdf file from several databases, converted to RIS format using Mendeley exporter, and then utilised as input for a co-word analysis in VOS viewer to conduct the co-word analysis. For additional examination, keywords that commonly appeared in the title, abstract, and author-provided keywords were chosen. A thesaurus file was provided to VOS reader during analysis, which assured keyword consistency and eliminated keyword inconsistency (e.g., singular vs. plural terms, UK vs. US English spelling). After all was said and done, a co-word network was created.

IV. BIBLIOMETRIC ANALYSIS

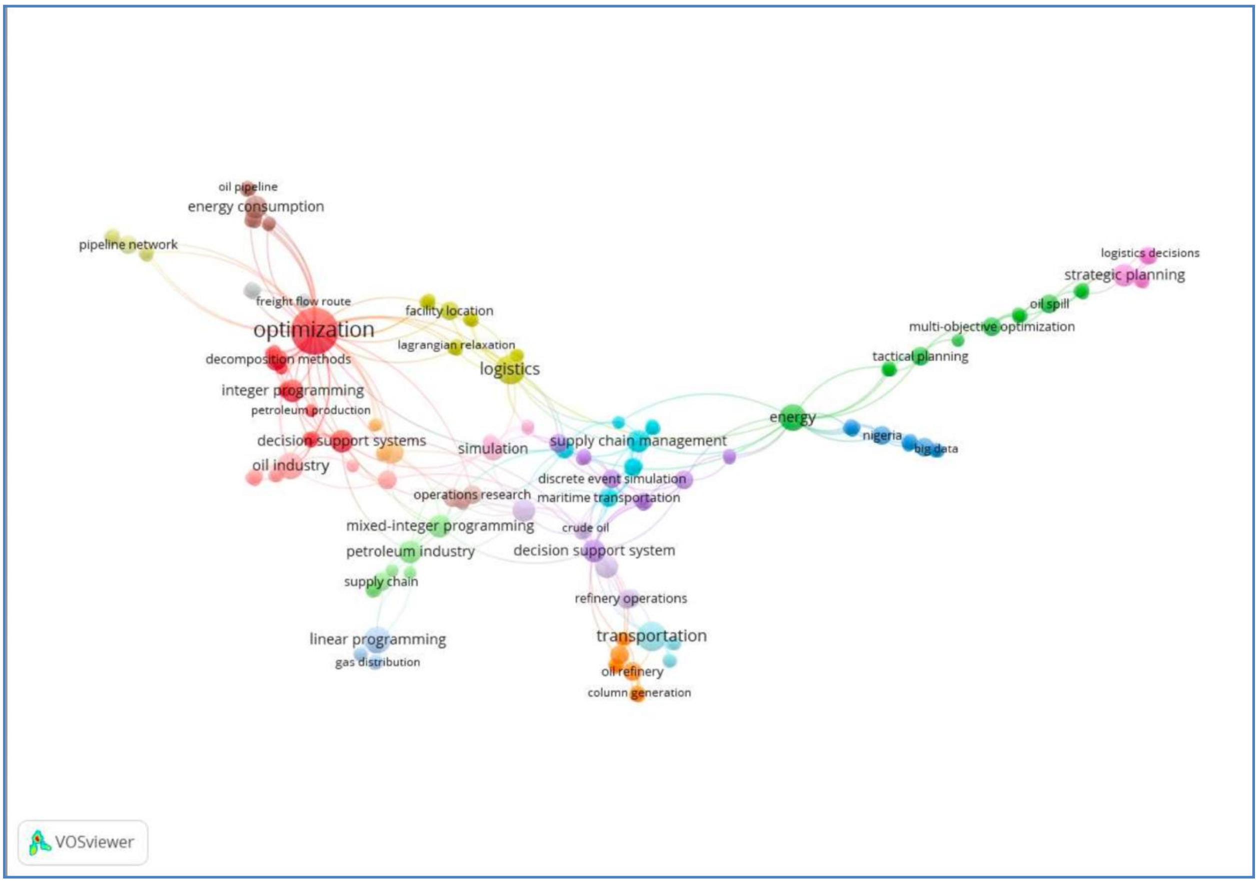

Fig. 1: Co-occurrence of keywords used in the selected contributing papers (source: VOS viewer)

This section presents a bibliometric analysis of different methods used to optimizeutilization in the oil industry. From the finalized literature search, we can see 4 topics stand out which are DOSC (Downstream supply chain operations), MOEA (Multi-objective evolutionary algorithm), Linear programming and Nonlinear programming.

There are more than 11 clusters found on bibliometrics analysis of the research papers. On analyzing a variety of topics like logistics, optimization, supply chain management, strategic planning and many more, it is seen that the number of links ranges from as low as 6 to as high as 45, with an average of 16.75. The lack of research, shown by lowest number of occurrences, is seen in multi objective optimization (2). Optimization is the most focused on element, with 13 occurrences.

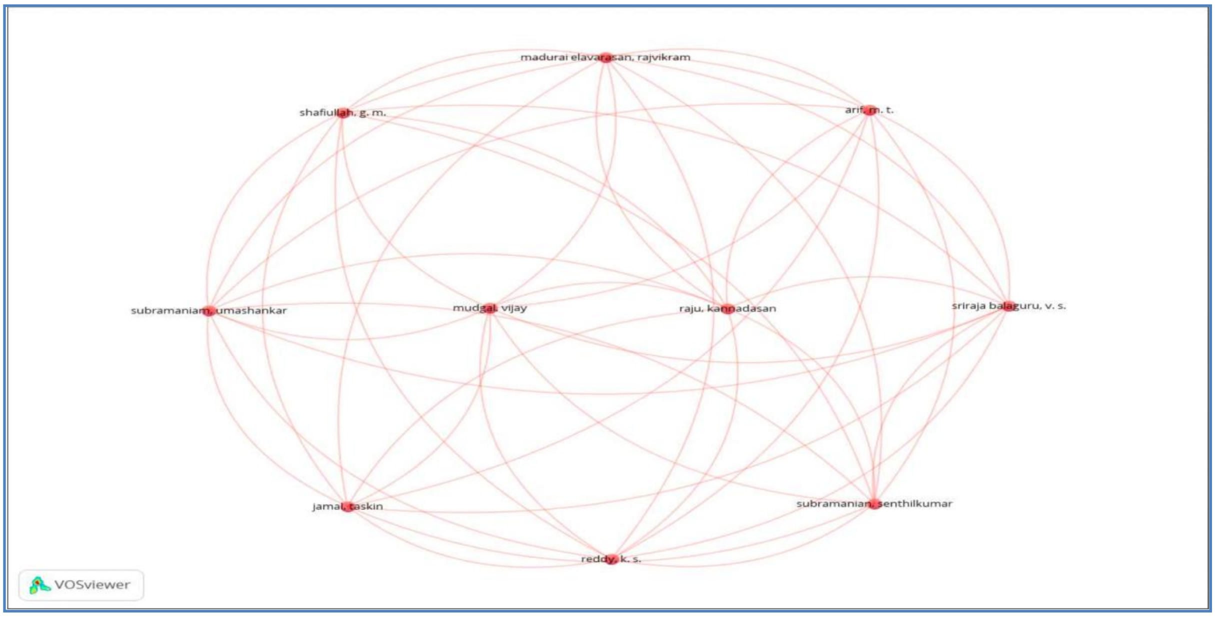

Fig. 2: Co-occurrence of citation network from the authors of the selected articles (source: VOS viewer)

In this paper Arif M. T., SrirajaBalaguru V. S., Subramanian Senthilkumar, Reddy K. S., Jamal Taskin, Subramniam Umashankar, Shafiullah G. M., Madurai Elavarasan, Rajvikaram, Raju Kannadasan, Mudgal Vijay have published the equal amount of research papers.

Here, the results of the computer-run integer programming models are displayed. Tables display the information needed as input for programming runs. The original refinery sites and depot are used to illustrate the output for the oil transportation problem. The findings demonstrate the ideal placement of refineries in relation to warehouses; that is, which depot should receive the refinery's oil and in what quantity, hence reducing the overall distance travelled.

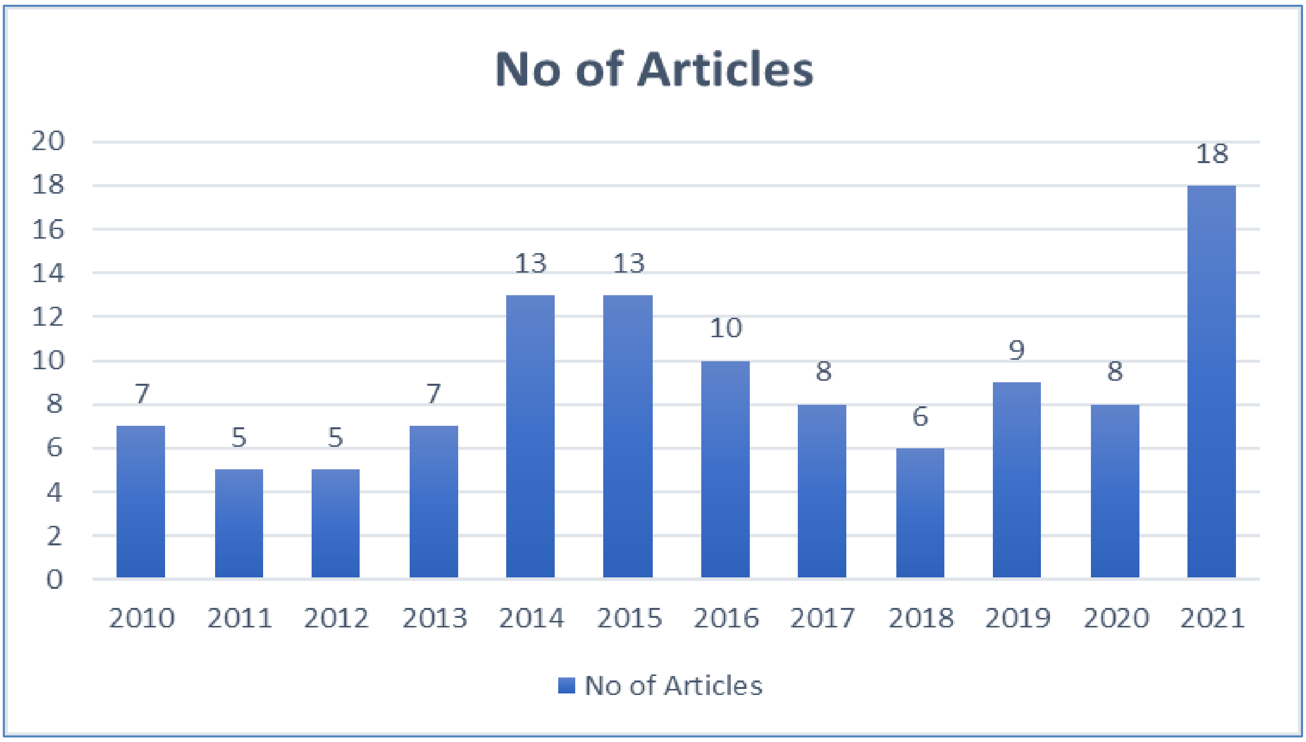

Fig. 3: Number of Articles published from 2010 to 2021

V. RESULTS AND DISCUSSION

The following key points provide a summary of the extensive literature review and its findings.

To begin with, in 1941, Hitchcock first developed the transportation model. Dantzig (1963) then uses the simplex method on the transportation problem. Bixby and Lee (1996) used branch and cut processes to solve the problem to optimality. Dynamic programming (DP) was used by Gigler et al. in the supply chain for agricultural commodities. DP technique includes handling and natural drying of biomass fuel at various stages.

Shamsudin Bin Ibrahim (2008) analyzed the optimum transportation of palm oil products in North Peninsular Malaysia. Diego G Rossit et al (2019) devised a three-stage practical heuristic to solve the oil transportation issue.

The Porter's Five Pushes model can be used to comprehend the vital oil industry context in which a company operates. Planning downstream oil supply chains (DOSCs) is crucial to ensuring that the demand of retail markets can be met. Pipelines are widely employed in several DOSCs as a cost-effective method of transporting refined oil. Cost-effective techniques are a savior during supply chain issues and disruptions. In the expensive petroleum sectors, logistics is one of the best places to save costs.

Lastly, Baraiya R. et al. (2021) introduced the multi-product multi-modal transportation cost optimization model.

To conclude, in order to resolve the oil transportation problem, Diego G. Rossit et al. (2019) developed a three-stage practical heuristic. To ensure that the demand of retail markets can be satisfied, downstream oil supply chains (DOSCs) must be planned. As a practical means of moving refined oil, pipelines are extensively used in a number of DOSCs.

VI. CONCLUSION AND FUTURE WORK

This essay provided an overview of the literature on the use of operations research to reduce costs in the oil and petroleum sector. Numerous articles linked to this and other relevant subjects have been published, but relatively few review papers have. A systematic literature analysis and review to identify and go through various methods to optimize cost in the oil industry was deficient. Contributing to the academic discussion on this topic, this paper is an effort to analyse the various ways to approach transportation and distribution of oil in the most cost efficient way possible while also taking into consideration the risk factors such as sabotage, theft, terrorism etc., natural calamities, government regulations and restrictions ranging from storage to, transportation to deliver restrictions.

Findings disclosed the following important methods used as the basis of previous studies:

- A variety of methods starting from the usage of simplex method in the 1940s to assignment problem in the 80s to the Integer Programming in the 90s to the Dynamic Programming model and so on were used to optimize cost of transportation of oil.
- A selection of 4 key methods were taken for this paper which are the Linear Programming, Planning of Downstream Oil Supply Chains(DOSC Method), Non-linear Planning Model, and the multiple constraint optimization evolutionary algorithm (MOEA). These 4 topics stood out from the final literature review as presented in the bibliometric analysis.
- Most of the individual methods focused on optimizing the transport of oil by minimizing distance, maximizing storage capacity of vehicles, reduce delivery costs, adapt to changing customer demands etc.
- A lot of attention is given to pipelines as they are widely applied in DOSC planning.
- It was found that logistics is the best place to implement cost effective techniques when it comes to the expensive petroleum industry especially during times of crisis which were face by this industry, namely the war between and OPEC and Russia and COVID-19.

Currently, there is a limitation in the scope of research on transport optimization in the oil industry. In the future, researchers can expand to more region focused research and analyze the best transportation routes based on the resources available for that locality. This is especially critical, and the difference is clearly seen between developing and emerging regions as compared to the fully developed ones, since the resources at hand vary drastically. The research can also be done by combining two or more of the various research methodologies to get more accurate results rather than just using one at a time.

Operations research is a vast field, with a variety of parameters to be analyzed like supply chain management, risk management, factoring in uncertainty, and many others. This aspect of optimization of transport along with bettering other aspects is a field that needs to be explored and researched upon to find the best ways to operate in any region and industry. There is also a lack of research considering the various barriers and challenges faced during transportation of oil products. Some of these factors could be oil leakages, extra safety measures taken due to flammability of these substances, specific temperatures to be maintained, and more. In future, the impact of other correlated factors such as drivers, enablers, barriers, and success factors could be connected to transport strategies and performance to better analyze the routes.

Integration of these research methodologies with other operations research techniques like mathematical modelling and optimization could also lead to more fruitful and optimal results. There could also be increased emphasis on sustainability of these supply chains and transportations toevaluate whether these strategies are beneficial in the long term. It would also be interesting to develop strategies about emerging local and global economies. Other upcoming technologies like the power of AI and digitalization, the widespread use of technology and various software’s and algorithms could be examined on how they could make the process less time consuming and more automated. The impact of COVID-19 pandemic could also be interesting to analyze as it affected all supply chains, across nations and sectors.

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