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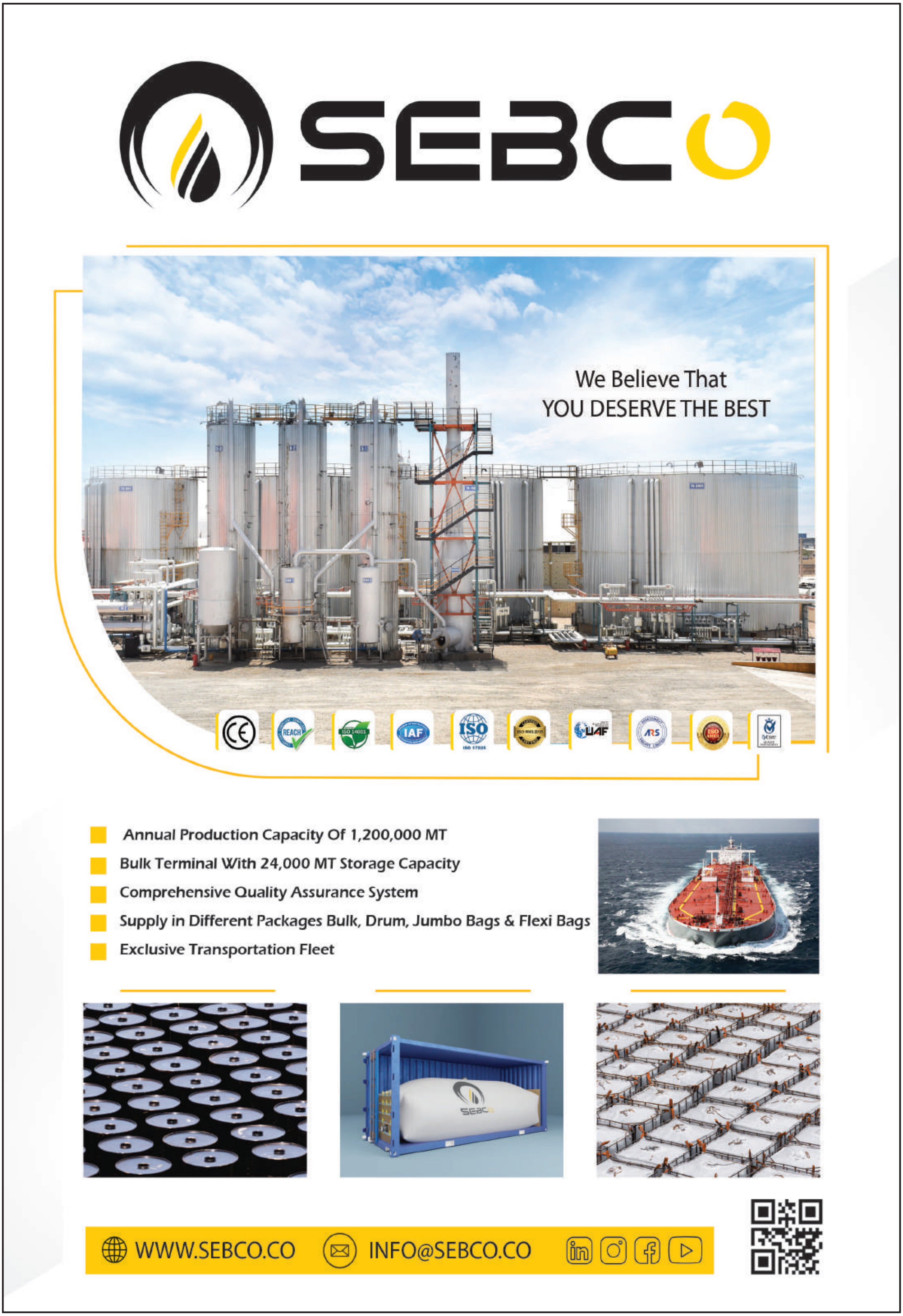
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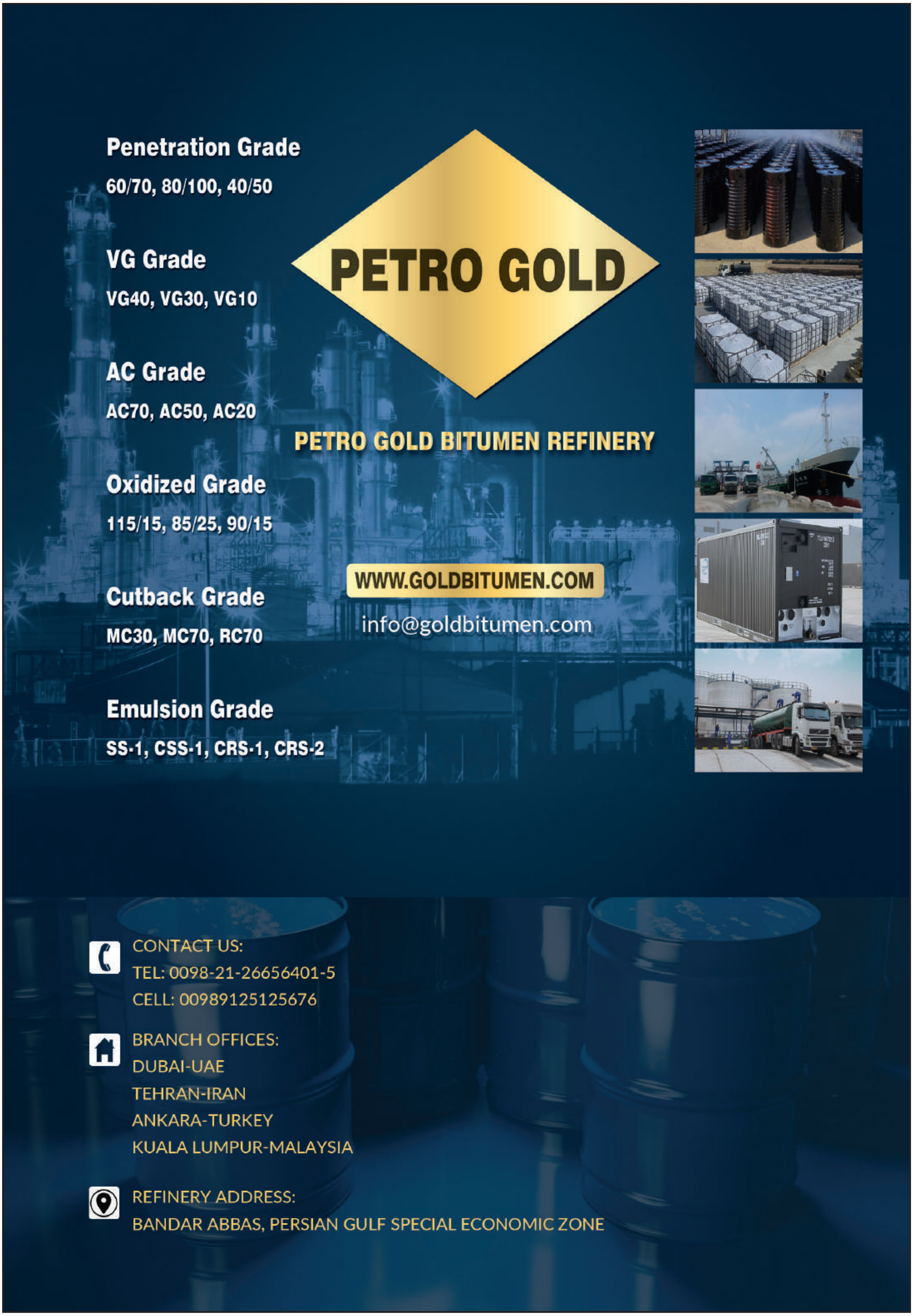
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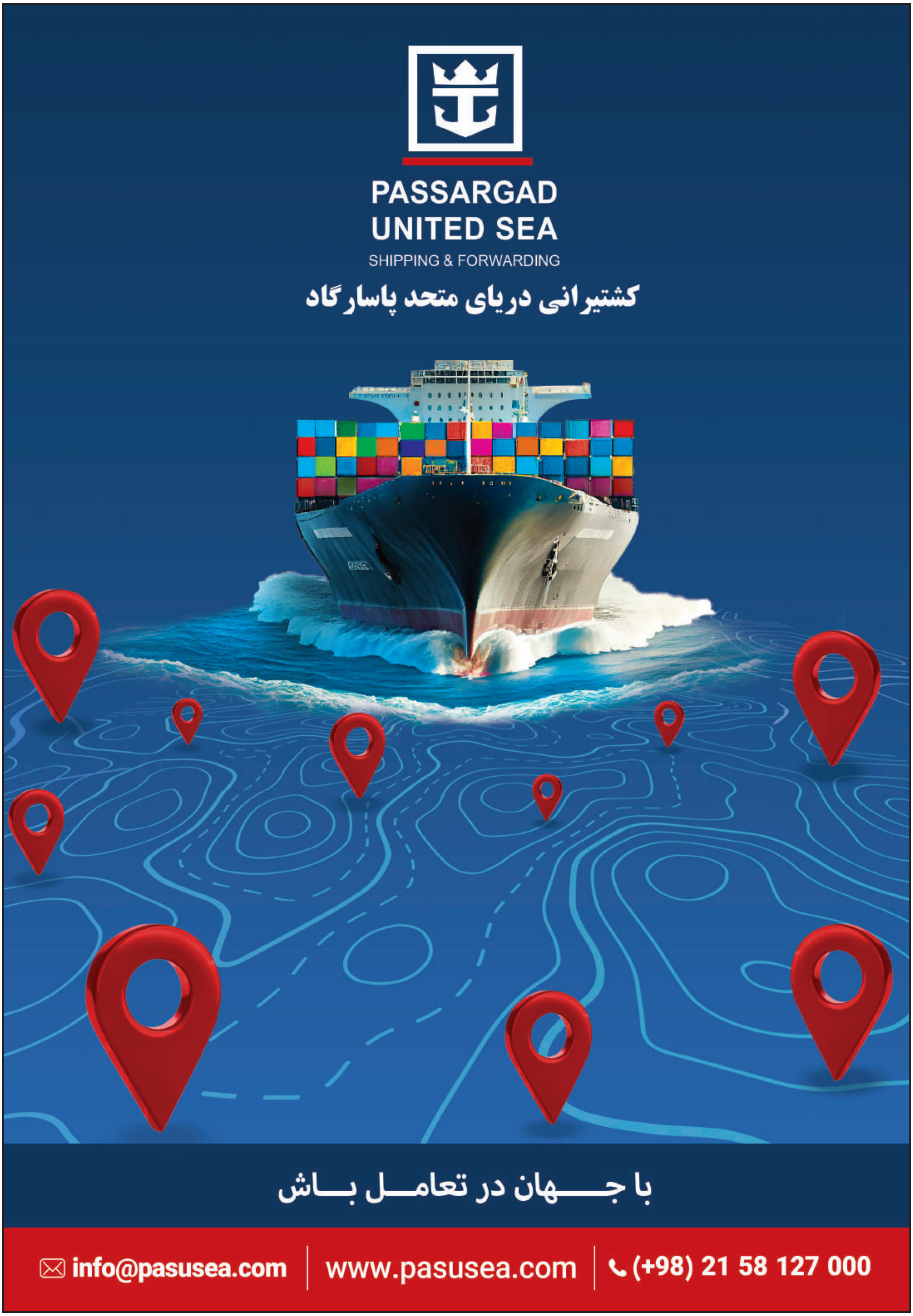
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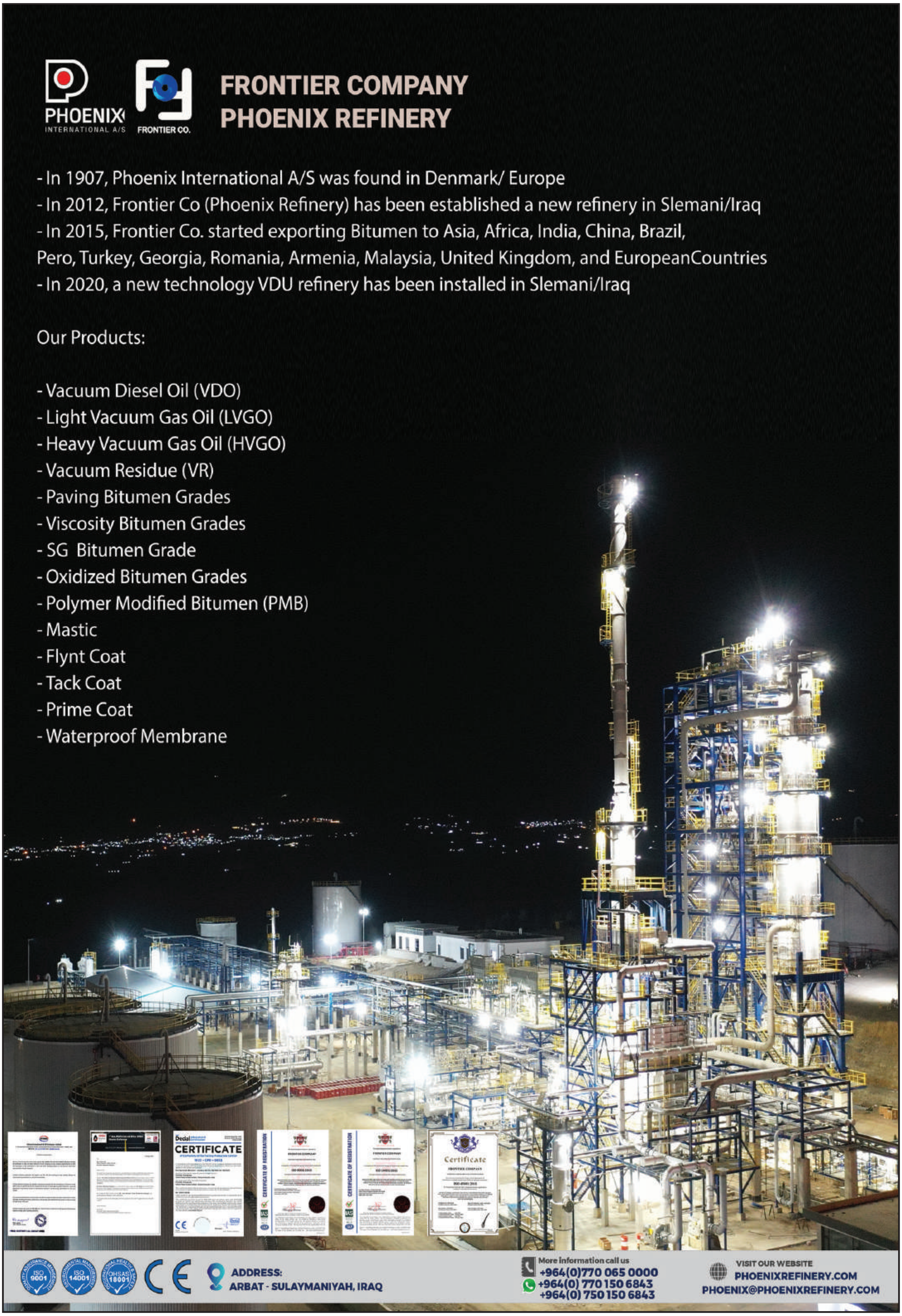
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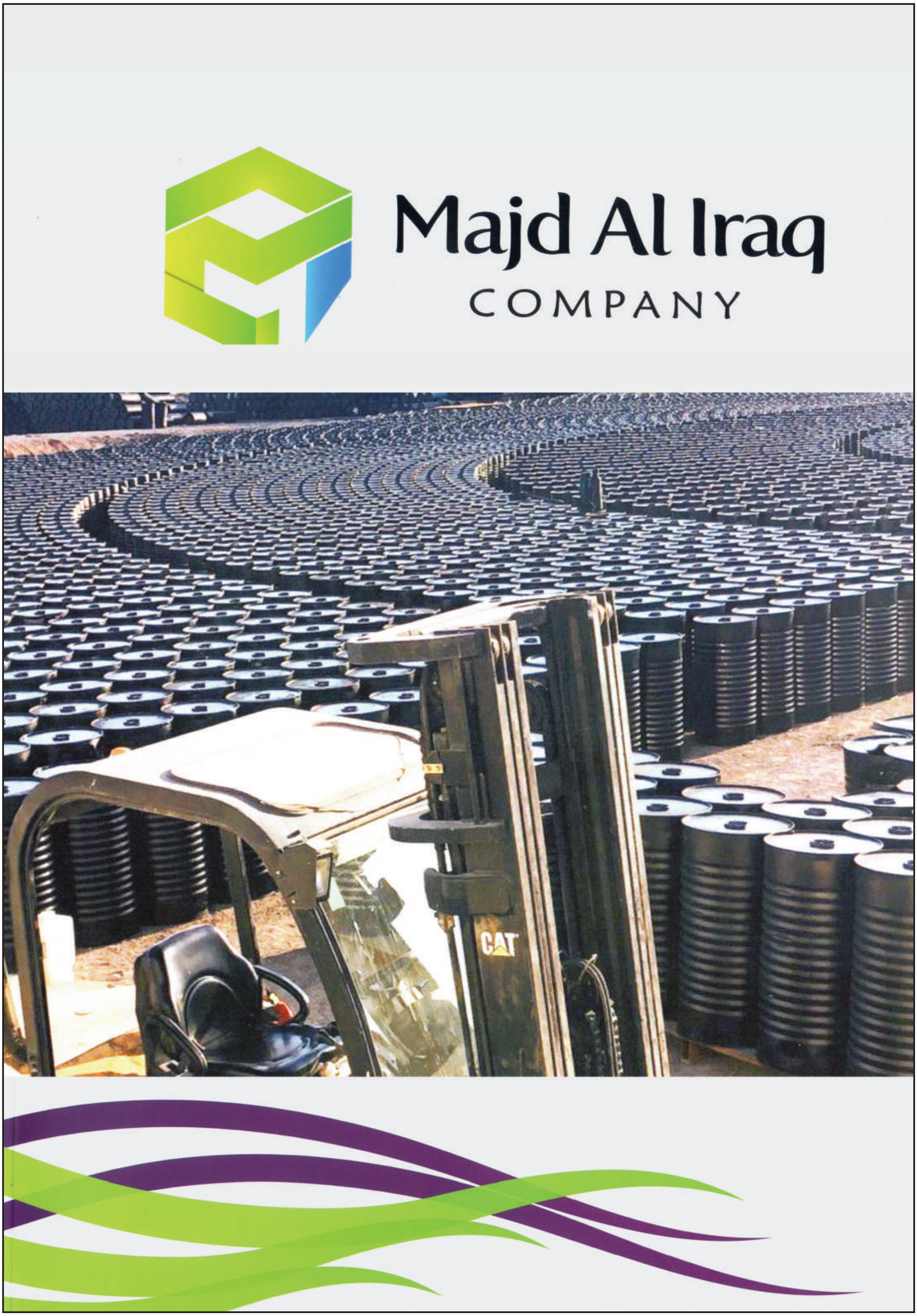
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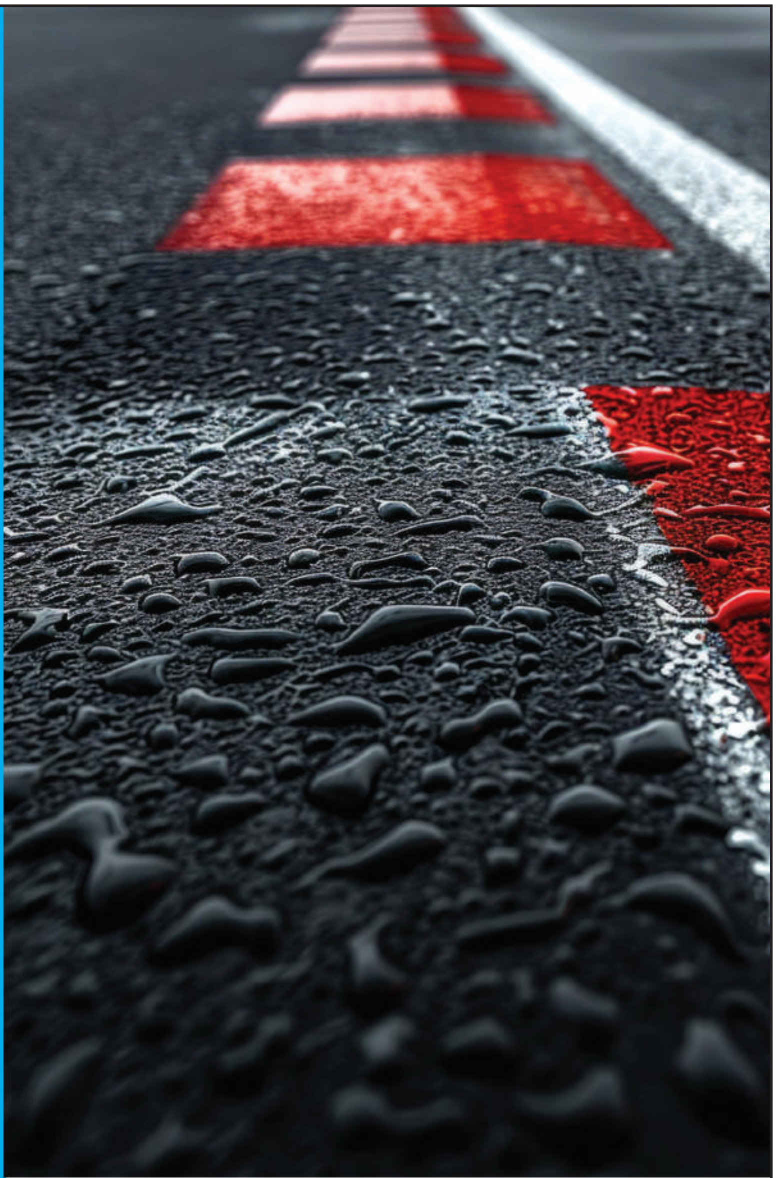
EDITOR'S MESSGAE

With a decade of activity in the bitumen and petroleum derivatives industry in the field of printing and publishing specialized news and selected scientific articles from conferences, symposiums, research centers and universities, and introducing brands and companies producing petroleum and bitumen, the World of Petroleum and Bitumen Journal has been able to gain the trust of more than 6000 permanent audience in such a way that they would like to receive the print version of the journal every month.

Ali farjam



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Iranian The World of Petroleum and BitUMEN jOURNAL

Phone: +98 2633524014 – +98 2166988059 – +971 562634384

Managing Editor
Alireza farjam
Master's degree in structural engineering
Email: farjam@bitumenmag.com

Commercial Manager
Hoda Khoeiniha
Email:hkhoeiniha@bitumenmag.com

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SHELL BROADENS ITS BITMEN MARKET REACH TO VIETNAM

BITUMEN IS A BY-PRODUCT OF PROCESSES IN OIL REFINING, WHICH IN TURN COULD BE USED AS RAW MATERIAL IN INFRASTRUCTURE DEVELOPMENT SUCH AS ROOFING OR ROAD SURFACING, AMONG OTHERS.

Pilipinas Shell Petroleum Corporation, a publicly-listed firm, has expanded its presence in the bitumen market by entering Vietnam. This move allows the company to generate additional revenue from bitumen exports, which began in the final quarter of the previous year. Jose Jerome Pascual III, Shell's Vice President for Finance, revealed that the company's first shipment of finished bitumen within the ASEAN region was made to Vietnam during that period.

Bitumen, a by-product of oil refining, is primarily used for infrastructure projects like road surfacing and roofing. According to Pascual, their bitumen facility has the capacity to serve both domestic and international markets due to its size.

Additionally, the company is looking to boost profits by completing the installation of a hydrogen unit, which will enable the refinery to handle a broader range of crude oils, particularly the more affordable "sour" types. This upgrade is also expected to enhance the refinery's bitumen output for local and regional distribution. Pascual pointed out that the hydrogen optimization will increase their production of both bitumen and diesel.

Cesar G. Romero, President and CEO of Pilipinas Shell, noted that the hydrogen unit, to be installed at the refinery in Tabangao, Batangas, will require an investment of ₱2.0 billion and is part of the company's ₱6.0 billion capital expenditure plan for the year. The project is expected to be completed by the end of next year, with commercial operations starting by the first quarter of 2021. Romero emphasized that this development will enable the refinery to process a wider variety of crude grades, including potentially cheaper and more unconventional ones.

Furthermore, the company's capital expenditures are focused on expanding its retail network, enhancing refinery operations, and upgrading its supply chain, which includes 27 terminals across the country.

INDIA POISED TO CONTRIBUTE 35% TO GLOBAL ENERGY DEMAND GROWTH IN THE NEXT DECADES

India is projected to contribute up to 35% of the global surge in energy demand over the next two decades, according to petroleum minister Hardeep Puri, who made the statement during the Gastech conference in Houston.

“If global demand rises by 1%, India’s will grow at three times that rate,” Puri remarked, noting that India's share in the overall increase will reach 35% in the coming years.

While addressing energy needs, Puri emphasized that India is also committed to transitioning towards cleaner energy. “We will manage and succeed in achieving the green transition,” he stated, expressing his confidence in the country's efforts.

India is already a major force behind the rise in energy demand and ranks as one of the top energy importers. Earlier in the year, the U.S. Energy Information Administration (EIA) predicted that India’s industrial growth would drive a significant rise in natural gas consumption, potentially tripling in the near future.

In 2022, India’s daily natural gas consumption stood at 7 billion cubic feet, with more than 70% of it used by the industrial sector. The EIA forecasts this figure to more than triple by 2050, reaching 23.2 billion cubic feet per day.

The nation’s oil demand is also experiencing an upward trend, prompting the government to make plans for a substantial expansion in refining capacity. By the end of 2022, the petroleum ministry outlined a strategy to boost capacity by 1.12 million barrels per day annually, continuing through 2028.

As a result, India’s refining capacity is anticipated to increase by 22% within five years, rising from the current 254 million metric tons per year, or approximately 5.8 million barrels per day.

Despite this focus on fossil fuels, India remains keen on advancing its energy transition. The country has set an ambitious goal to install 500 gigawatts of renewable energy capacity by 2030, a significant leap from its current 153 GW capacity.

Additionally, India’s Renewable Energy Minister, Pralhad Joshi, recently disclosed that various banks have pledged a combined $386 billion to support the expansion of the nation’s renewable energy sector.

BRO and IOCL discuss improving road infrastructure in Northeast India

Harendra Kumar, Additional Director General (ADG) of the Border Roads Organisation (BRO) for the Eastern Zone, announced that around 33,327.64 KL of key oil products and 11,572.39 KL of bitumen will be necessary for BRO projects in Northeast India, with Indian Oil Corporation Limited (IOCL) expected to supply a significant portion of these materials.

A BRO-IOCL Coordination Meeting was held to deliberate on both ongoing and upcoming infrastructure initiatives in the region.

ADGBR (East) highlighted that IOCL currently provides 70-80% of the primary oil and bitumen required by BRO, a critical contribution to the timely completion of essential road infrastructure in Northeast India. In the previous year, IOCL delivered over 84% of the High-Speed Diesel (HSD) needed for regional projects and over 51% of the bitumen.

Looking ahead to the current year, the required amounts for oil and bitumen remain high, with IOCL expected to continue playing a major role in meeting these demands.

Despite difficulties in transportation—especially during the monsoon, which limits road access to remote areas—both organizations are determined to enhance delivery routes and address these challenges head-on.

The coordination meeting aimed to strengthen the partnership between BRO and IOCL, resolve outstanding issues, and plan for the seamless execution of future projects. Special attention was given to improving supply chains, particularly the use of smaller Bulk Petroleum Lorries (BPLs) to access more isolated areas.

In his closing remarks, the ADGBR (East) urged all attendees to actively engage in productive discussions to guarantee the smooth continuation of infrastructure projects across the region.

The collaboration between BRO and IOCL remains a key factor in improving connectivity and infrastructure development in the Northeastern states. The meeting ended on a positive note, with optimism for future projects and enhanced cooperation. Representatives from IOCL, including Satyendra Sahai, CGM (MCO), Debabrata Bandyopadhyay, GM (IB) WBSO, R.K. Shahab, GM (IB) AODSO, and senior officials from BRO, were present.

CHINA'S OIL IMPORTS FROM RUSSIA HAVE SURGED BY 25% AS BEIJING LOOKS FOR MORE AFFORDABLE CRUDE.

In August, China's crude oil imports from Russia surged by 25.6% compared to the previous month, marking the highest monthly intake of the year so far, as Beijing capitalized on more affordable oil supplies.

According to data from the Chinese General Customs Administration, China brought in 2.21 million barrels per day (bpd) of crude from Russia during the month. Malaysia ranked as the second-largest crude supplier to China, bolstering the belief that Beijing hurried to secure discounted oil, especially as global benchmark prices dropped. It is widely thought that Malaysia serves as a transit point for crude from Iran and Venezuela on its way to China, which has not hesitated to purchase sanctioned oil at reduced rates.

Chinese imports of crude from Iraq also saw a significant jump, increasing by 43.1% in August from July. Meanwhile, oil deliveries from Saudi Arabia to China declined by 17.4%, as reported by Interfax.

China's total crude oil imports in August were the highest for the year, with the country seeking low-cost supplies from Russia, Iran, and Venezuela, based on customs data detailing imports from Russia and Malaysia.

The country's crude imports reached 11.56 million bpd last month, the highest since August 2023, representing a sharp recovery from the July figure of 9.97 million bpd, which had been the lowest in two years. Despite this rebound, August's imports were still 7% below the levels recorded in August 2023.

China's August import figures do not fully clarify whether the increase was driven by rising domestic demand or a strategic move to secure more oil while prices were low. The contracts for these imports were likely made in May and June, when international crude prices were declining.

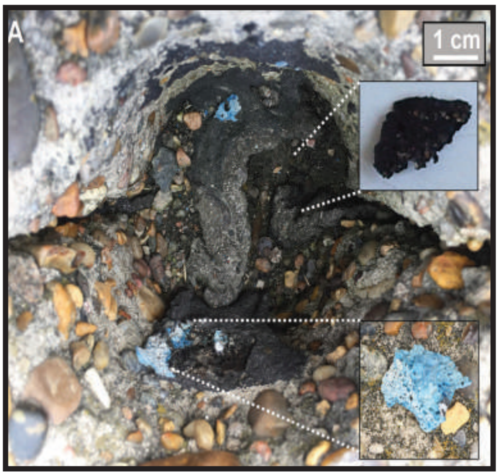
China imported 2.21 million barrels per day (bpd) of crude from Russia in August, according to data from the Chinese General Customs Administration cited by Russian news agency Interfax.

A NEW PLASTIC VARIANT IN TERRESTRIAL SETTINGS

BITUMEN-BASED PLASTITAR

Plastitar, a type of plastic embedded in oil residues, has been found in numerous marine environments worldwide. This form of plastic, known for undergoing both chemical and physical changes, is believed to result from interactions between plastic and crude oil due to ocean currents. In this study, a novel variant of plastitar, derived from bitumen, was identified in terrestrial settings such as marina walls, riverbanks, and road surfaces. Using Fourier-transform infrared (FTIR) spectroscopy, plastic fragments, including bottle caps, liners, and paint chips, were detected in bitumen joint sealants. These materials were confirmed to be composed of polymers such as polypropylene and polyester.

The joint sealants were made from a bitumen-mineral mixture, commonly utilized in construction, particularly for road repairs. The plastic fragments embedded in the bitumen displayed signs of melting, including bubbles and holes, indicating their partial combustion, thus qualifying them as pyroplastics. These fragments were either embedded during the application of heated bitumen or later pressed into hardened bitumen surfaces. Observations showed that after 608 days, up to 66% of the bitumen-based plastitar had degraded, releasing microplastics into the surrounding environment.



This study highlights, for the first time, that plastitar forms can originate from materials other than crude oil, and that such variants can also develop in non-marine environments. It is hoped that this research will raise awareness of the processes by which plastics are unintentionally fixed within bitumen, which could assist in minimizing their occurrence during future construction efforts.

Introduction

Recently, plastitar, a form of plastic embedded in tar, has been identified on coastlines, particularly around the Canary Islands in the Atlantic Ocean. Although plastitar has been previously recorded globally, it has been described under various names. Early reports of tar containing plastic materials date back to the 1970s, such as the discovery of tar-bonded

Fourier-transform Infrared Spectroscopy (FTIR)

beach conglomerates on Bermuda. The spread of plastitar to multiple locations worldwide, including the Mediterranean and Indian Oceans, underscores its pervasive presence in aquatic environments.

The harmful effects of plastitar are still under investigation. Plastics and tar, such as crude oil or bitumen, are known to release harmful chemicals into their surroundings, which can impact marine life and ecosystems. However, research on the occurrence and persistence of plastitar in terrestrial settings remains scarce. This study aims to explore whether plastitar occurs in non-marine environments, particularly focusing on the role of bitumen—a material widely used in construction—as a source of plastitar. Additionally, the longevity of plastitar in various environments will be assessed.

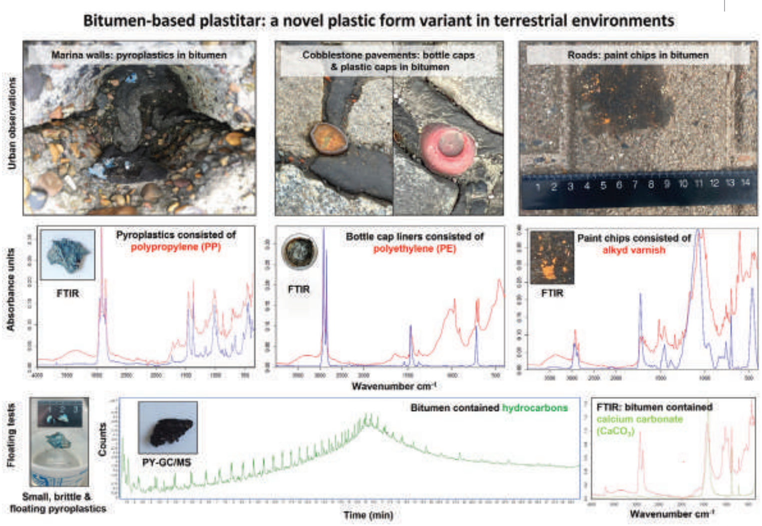
Field Surveys

Field surveys were conducted in Cuxhaven, Bremerhaven, and Helgoland in Germany. During these surveys, blue fragments were observed embedded in black joint sealants along marina walls, riverbanks, and roadways. For instance, in Cuxhaven's marina, blue plastic fragments were found in recessed areas of the walls. Beer bottle caps were also observed embedded in bitumen-based sealants along cobblestone pavements in Bremerhaven. These caps, which contained plastic liners, were re-inspected after a period of over 500 days.

In Helgoland, fragments of blue and orange materials were also identified in joint sealant stains on roads. The materials were collected and analyzed to determine their composition.

Fourier-transform Infrared Spectroscopy (FTIR)

The blue fragments found in Cuxhaven were analyzed using FTIR spectroscopy to identify their chemical composition. This analysis confirmed that the fragments were made of polypropylene, a common polymer. FTIR was also used to analyze other samples, including the black joint sealant found at the field sites. The findings indicated that the black material was derived from bitumen, a substance that origi-



BITUMEN

MICRO- AND MACROSCOPIC EXAMINATIONS

Bitumen-based Plastitar in Cobblestone Pavements in Bremerhaven

nates from crude oil.

Pyrolysis-Gas Chromatography/Mass Spectrometry (PY-GC/MS)

The black joint sealants were further analyzed using pyrolysis-gas chromatography/mass spectrometry to confirm their origin. The results indicated that the bitumen used in construction projects was the likely source of the plastitar identified in the terrestrial environment.

Micro- and Macroscopic Examinations

The physical characteristics of the blue fragments from Cuxhaven were examined under a digital microscope. The fragments showed signs of degradation, such as bubbling and melting, suggesting that they had been exposed to high temperatures, likely during the installation of the bitumen sealant.

Field observations were also used to assess the persistence of plastitar over time. A loss of 66% of the plastic cover was recorded in Cuxhaven after 608 days. This indicates that plastitar can degrade, releasing microplastics into the environment. A similar phenomenon was noted with the orange fragments found in Helgoland, which decreased by 27% in number after 35 days.

Results and Discussion

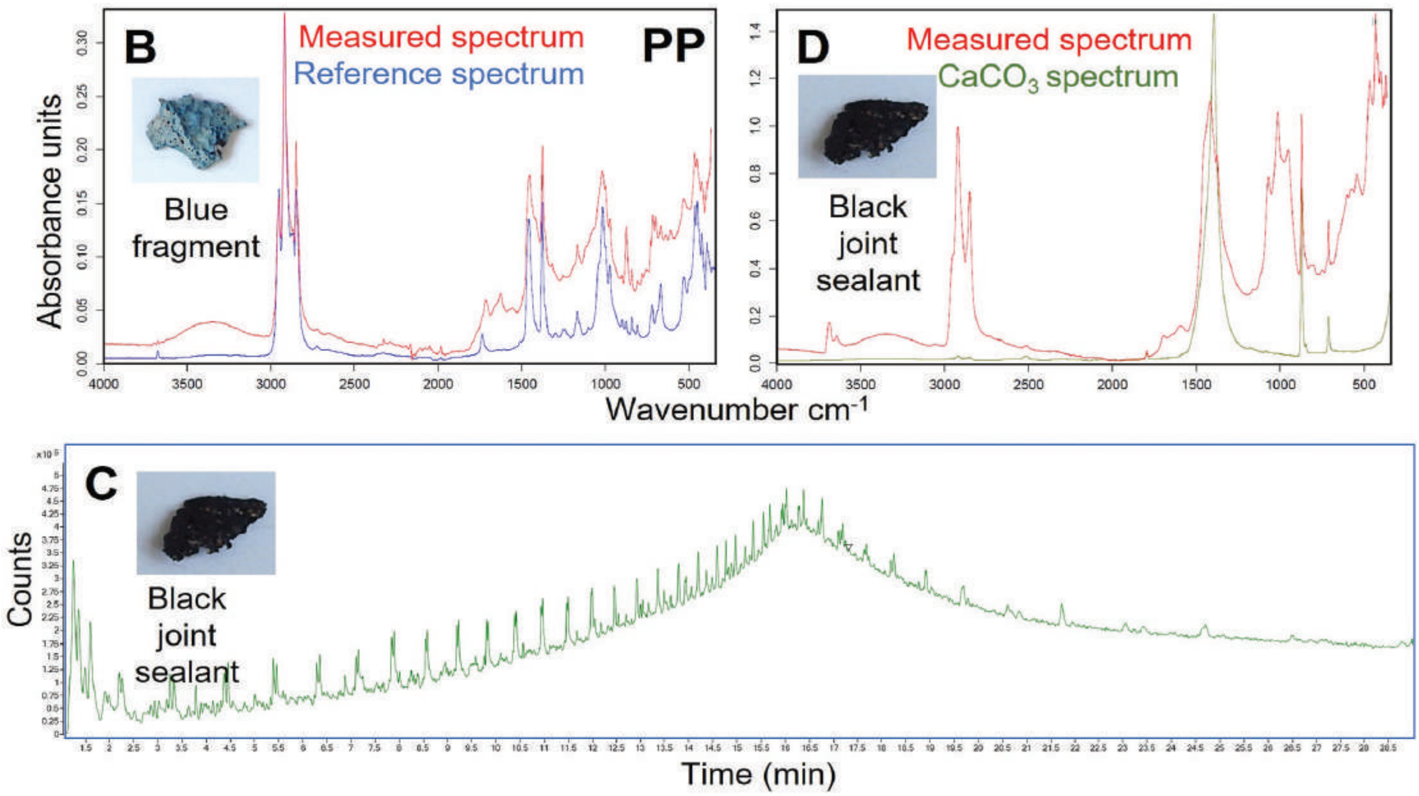
Bitumen-based Plastitar in Marina Walls in Cuxhaven

In Cuxhaven, plastitar was found embedded in black bitumen sealants along marina walls. The plastic fragments, identified as polypropylene, were found to have been incorporated into the bitumen either during its application or later through physical pressure. The presence of melted plastic fragments suggests that high temperatures during the installation of the bitumen may have contributed to the formation of plastitar.

Bitumen-based plastitar differs from marine plastitar, which is typically found in ocean habitats and is formed by interactions between plastic and crude oil residues. In Cuxhaven, the plastitar was sheltered from wind and wave activity, which may have contributed to its formation and persistence. Over time, the plastitar degraded, releasing small plastic particles back into the environment.

Bitumen-based Plastitar in Cobblestone Pavements in Bremerhaven

In Bremerhaven, beer bottle caps embedded in bitumen sealants were observed along riverbank pavements. The caps were found to contain plastic liners made of polyethylene. These plastitars were likely formed by pedes-



trians or vehicles pressing the bottle caps into the bitumen, as confirmed by a penetration test performed during the study.

Although the caps had rusted, the plastic liners remained intact, demonstrating the persistence of plastitar in terrestrial environments.

The degradation of the bottle caps over time indicates that plastitar may persist for extended periods before breaking down and releasing microplastics into the environmen.

Bitumen-based Plastitar Containing Paint Chips on Helgoland Island

In Helgoland, fragments of paint chips embedded in black bitumen were discovered on road surfaces. The chips, composed of polyester and alkyd varnish, were likely deposited due to pressure from passing vehicles. These paint chips, a common yet often overlooked source of plastic pollution, contributed to the formation of plastitar in the area. Over time, a portion of the paint chips degraded, further adding to microplastic pollution.

Summary and Conclusion

This study provides the first documented evidence of plastitar formation in terrestrial environments. The findings demonstrate that plastitar can develop from bitumen-based materials commonly used in construction, as opposed to solely crude oil residues. The plastic fragments embedded in bitumen ranged from pyroplastics to packaging materials and paint chips, highlighting the variety of sources contributing to plastitar formation.

The persistence of plastitar in urban environments, particularly in locations with high pedestrian or vehicle traffic, suggests that human activity plays a key role in its formation. The degradation of plastitar over time releases microplastics, which poses a significant environmental concern.

This research emphasizes the need for increased awareness of plastitar formation in both marine and terrestrial environments. Preventive measures should be considered during construction and maintenance activities to reduce the occurrence of plastitar.

Additionally, further studies should investigate the frequency and persistence of plastitar in urban settings, as well as the environmental factors influencing its degradation.

ANALYSIS OF FUNDAMENTAL FACTORS INFLUENCING BITUMEN PRICES IN THE MIDDLE EAST, PARTICULARLY IRAN, IN 2024

AHMAD REZA YOUSEFI- RAZIEH GILANI

Ahmad Reza Yousefi, the managing director of Infinity Galaxy and a PhD candidate in international entrepreneurship, has over ten years of experience in the export of bitumen and petrochemicals. Leading a dynamic young team, he is dedicated to serving his country through exports. He believes that once customers place their trust in his company, it is essential to provide them with exceptional service. For the past four years, he has been proactively updating customers on the latest market changes, trends, and insights to help them maximize the benefits of their transactions.

Razieh Gilani, the export manager of Infinity Galaxy is a seasoned bitumen market analyst and consultant with over seven years of experience in export, trade, and shipping, focusing on bitumen and petrochemical exports primarily in markets such as China, India, East Asia, and Africa. For more than 200 weeks, she has been producing detailed market analyses to assist industry stakeholders in making informed decisions based on the latest trends and developments. She collaborates with a dedicated team of professionals who possess extensive commercial experience and profound insights into market challenges.

Introduction:

In 2024, multiple past factors, primarily influenced by events following the COVID-19 pandemic, have directly impacted bitumen prices in the Middle East, especially in Iran. These include inflationary effects stemming from the Russia-Ukraine war, the October 7, 2023 Hamas attack on Israel, fears of recession in the world's second-largest economy, concerns regarding fluctuations in interest rates in the United States, and Houthi attacks on various commercial vessels in the Red Sea, along with many other fundamental factors. These elements, in addition to regional and domestic factors within Iran, have influenced bitumen prices as well as supply and demand.

Overall, if we consider domestic factors as well, their number may exceed ten influential factors. Among them are significant fluctuations in currency rates, container shortages in Bandar Abbas, a lack of vacuum bottom from summer onward, and various logistical issues that have contributed to stagnation or rapid price changes in 2024 in the Persian Gulf.

Infinity Galaxy, with over ten years of export experience as a bitumen supplier and four years of expertise in weekly bitumen market analysis, has published more than 200 weekly reports by the time this article was printed. This article aims to examine the factors influencing bitumen prices since the beginning of 2024 by reviewing these weekly reports.

The tables below summarize the important factors for each week during the first nine months of 2024, with a more detailed analysis of the most significant influencing factors.

The Effective Factors on Bitumen Price in 2024,Based on Infinity Galaxy Weekly Bitumen Reports

Jan-24			
Week 1	Week 2	Week 3	Week 4
Russia Ukraine War	Houthi Attacks on Commercial Ships in the Red Sea	Israel Hamas War	Israel Hamas Ceasefire
Israel Hamas War	Iran Stopped its Crude Oil Export to China	Iran's Missile Attacks on Some Regions of Iraq, Syria, and Pa	The Middle East Tension
Crude Oil Demand Reduction	OPEC Reduced its Production to Increase Crude Oil Pri	The Middle East Tension	A Balanced Condition of Crude Oil Price in 2024
Disruption in Crude Oil Supply of the Middle	Fall in India Bitumen Price	China's Economic Concerns	Fall in Crude Oil Price
Vacuum Bottom Competition in Iran	Rise in Iran Vacuum Bottom Price	Fall in Singapore's HSFO	Russia Ukraine War
		Fall in Singapore's Bitumen Price	Fall in Singapore's HSFO
		Fall in India Bitumen Price	Fall in Singapore's Bitumen Price
			Rise in India Bitumen Price
			Vacuum Bottom Competition in Iran
Feb-24			
Week 1	Week 2	Week 3	Week 4
Rise in Crude Oil Price	Israel Hamas Ceasefire	The Middle East Tension	Israel Hamas Ceasefire
Russia Ukraine War	Stable Crude Oil Price	Russia Ukraine War	Negative GDP in Japan and Great Britain
The Middle East Tension	The Middle East Tension	Russia, the Biggest Crude Oil Supplier of China	US Interest Rate
China's Economic Concerns	Quite Market in East Asia due to Lunar Year	Unprecedented Rise of U.S Crude Oil Inventories	Fall in Singapore's HSFO
Fall in Singapore's HSFO	Fall in Singapore's HSFO	Rise in Crude Oil Price	Logistic issues in Iran
Exchange Rate in Iran	Exchange Rate in Iran	Slow Uptrend of Iran Bitumen Price	Exchange Rate in Iran
		Exchange Rate in Iran	Extension of Voluntary Crude Oil Production Cuts
Mar-24			
Week 1	Week 2	Week 3	Week 4
US Election	Israel Hamas War	Israel Hamas War	Continuation of Production Cut of OPEC+
Logistic issues in Iran	Israel Hamas Ceasefire	Putin Reassigned as President	China's Economic Concerns
China's Economic Concerns	China's Economic Concerns	Rise in Crude Oil Price	India Election
Rise in Singapore's HSFO	Rise in Crude Oil Price	Houthi Attacks on Commercial Ships in the Red Sea	Rise in Iran Vacuum Bottom Price
Logistic issues in Iran	Rise in Singapore's HSFO	Fall in India Bitumen Price	
	Export Pressure in Iran		
Apr-24			
Week 1	Week 2	Week 3	Week 4
Rise in Crude Oil Price	US Interest Rate	The Middle East Tension	Israel Hamas Ceasefire
China's Economic Concerns	Russia Ukraine War	Growth in Ratio of Crude Oil Demand and Supply	Rise in India Bitumen Price
The Middle East Tension	The Middle East Tension	Reduction of Crude Oil Production and the Global Oil Rese	Insignificant Changes in Iran Bitumen Price
Rise in India Bitumen Price	Rise in Singapore's HSFO	Implementation of New Sanctions against Iran by America	
	Vacuum Bottom Competition in Iran	China's Economic Concerns	
		India Election	
		Logistic issues in Iran	
May-24			
Week 1	Week 2	Week 3	Week 4
US Interest Rate	Israel Hamas Ceasefire	Israel Hamas War	Iran Presidential Changes
Israel Hamas Ceasefire	Inflation Rate of the European Union	Russia Ukraine War	Russia Ukraine War
Fall in Crude Oil Price	Houthi Attacks on Commercial Ships in the Red Sea	Stable Crude Oil Price	Russia, the Biggest Crude Oil Supplier of China
Rise in India Bitumen Price	Increase in Bahrain Bitumen Price	Uncertainties about the Level of Global Crude Oil Demand	Increase in Bahrain Bitumen Price
Rise in Iran Vacuum Bottom Price	India Election	Fall in India Bitumen Price	Fall in Crude Oil Price
	Rise in Iran Vacuum Bottom Price	Exchange Rate in Iran	Continuation of Crude Oil Production cut by OPEC+
			Monsoon in India
			Export Pressure in Iran
Jun-24			
Week 1	Week 2	Week 3	Week 4
Russia Ukraine War	Israel Lebanon War	Rise in Crude Oil Price	US Election
Israel Hamas Ceasefire	Russia Ukraine War	Russia Ukraine War	Iran Presidential Changes
Fall in Crude Oil Price	Houthi Attacks on Commercial Ships in the Red Sea	The Middle East Tension	The Middle East Tension
Monsoon in India	China's Economic Concerns	China's Economic Concerns	Rise in Crude Oil Price
Export Pressure in Iran	Fall in India Bitumen Price	Fall in India Bitumen Price	Logistic issues in Iran
	Logistic issues in Iran	Iran Presidential Changes	
Jul-24			
Week 1	Week 2	Week 3	Week 4
US Election	Iran Presidential Changes	Russia Ukraine War	Biden Withdrawal from US Election
Iran Presidential Changes	Biden withdrawal from US Election	Israel Hamas War	The Middle East Tension
Vacuum Bottom Competition in Iran	Rise in Crude Oil Price	Slow Economic Growth in China	China's Economic Concerns
Logistic issues in Iran	Rise in Singapore's HSFO	Rise in Crude Oil Price	Monsoon in India
	Logistic issues in Iran	Rise in India Bitumen Price	Rise in Iran Bitumen Price
		Rise in Iran Vacuum Bottom Price	
		Exchange Rate in Iran	
Aug-24			
Week 1	Week 2	Week 3	Week 4
The Middle East Tension	The Middle East Tension	The Middle East Tension	Israel Hamas Ceasefire
Rise in Crude Oil Price	Economic Crisis in the US	Russia Ukraine War	US Election
Decline in US Dollar Index	Crash in Japan Stock Exchange Market	Economic Crisis in the US	Fall in Crude Oil Price
Israel Hamas Ceasefire	Rise in India Bitumen Price	Rise in Crude Oil Price	Crude Oil Demand Reduction
Rise in India Bitumen Price	Fall in Iran Vacuum Bottom Price	Fall in Bahrain Bitumen Price	China's Economic Concerns
Exchange Rate in Iran	Logistic issues in Iran	Stability in India Bitumen Price	Rise in India Bitumen Price
Economic Crisis in the US		Rise in Iran Bitumen Price	Logistic issues in Iran
		Logistic issues in Iran	Monsoon in India
			Fall in Iran Vacuum Bottom Price
Sep-24			
Week 1	Week 2	Week 3	Week 4
The Middle East Tension	US Election	Israel Lebanon War	Israel Lebanon War
China's Economic Concerns	Fall in Crude Oil Price	China's Economic Concerns	China's Economic Concerns
Fall in India Bitumen Price	Fall in India Bitumen Price	US Interest Rate	Vacuum Bottom Competition in Iran
Logistic issues in Iran	Stability in Iran Bitumen Price	Fall in India Bitumen Price	Shortage of Vacuum Bottom
	Shortage of Vacuum Bottom	Shortage of Vacuum Bottom	
	Logistic issues in Iran	Vacuum Bottom Competition in Iran	

1. Inflationary Effects from the Russia-Ukraine War:

The Russia-Ukraine war, which began in 2022, has significantly impacted global markets, including energy. The increase in oil prices and other essential commodities has led to rising inflation worldwide. This high inflation has increased production costs, subsequently affecting the overall price of bitumen.

2. Hamas Attack on Israel:

The Hamas attack on Israel on October 7, 2023, in addition to its extensive humanitarian and political impacts, also affected energy markets. The rising tensions in the region heightened concerns about disruptions in the supply of oil and other energy products, thereby influencing bitumen prices.

3. Fears of Economic Recession in China:

As the second-largest economy in the world, China plays a crucial role in the global economy. Any disruption in China's economy can impact global markets, including the bitumen market. Fears of an economic recession in China have decreased demand for essential commodities, including crude oil and bitumen, thus affecting prices.

4. Concerns Over Rising or Falling Interest Rates in the U.S.:

The monetary policies of the U.S. Federal Reserve, particularly interest rates, have a direct impact on the value of the dollar and consequently on the prices of essential commodities, including bitumen. Concerns regarding increases or decreases in interest rates have created uncertainty in the markets, influencing bitumen price volatility.

5. Impact of Houthi Attacks in the Red Sea on Bitumen Prices:

Houthi attacks on commercial vessels in the Red Sea, a vital artery for global trade, have had widespread effects on global markets, including the bitumen market. These attacks have influenced bitumen prices for several reasons:

- Supply Chain Disruption: Attacks on oil tankers and other petroleum products have disrupted the global oil supply chain. Since bitumen is a derivative of crude oil, any disruption in crude oil supply directly impacts bitumen availability.

- Increased Insurance Costs: Marine insurance companies have raised premiums due to increased transportation risks in the Red Sea. These higher costs affect the overall price of products, including bitumen.

- Decreased Investment: Investors in the energy sector are showing less willingness to invest in crude oil and bitumen-related projects due to rising risks from attacks. A decrease in investment can impact long-term bitumen supply.

Forecast for Bitumen Prices in 2024:

It seems that the following factors are among the most significant influences on bitumen and energy prices throughout 2024 globally:

1. Results of the U.S. Presidential Election

2. Peace or Continuation of War between Israel and Hamas, and the Outcomes of Israel's Attacks on Lebanon
3. Ongoing Crises in the Middle East, especially if the war spreads to other regions
4. Economic Instability in the Second-Largest Economy in the World
5. Continued Attacks in the Red Sea by Houthis
Finally, the following recommendations are made for market participants:

1. Continuous Monitoring of Global Developments: Bitumen market participants should consistently monitor political, economic, and social developments at a global level.

2. Thorough Analysis of Fundamental Factors: A detailed analysis of fundamental factors affecting the bitumen market, including supply and demand, production costs, and government policies, is essential.
3. Utilization of Forecasting Tools: The use of forecasting models and statistical analysis tools can enhance the accuracy of bitumen price predictions.

4. Risk Management: Bitumen market participants should identify risks arising from price fluctuations and plan strategies to manage them.

Notes:
This report is merely a general analysis of the factors influencing bitumen prices in 2024, and for investment decisions, it is recommended to refer to more credible information sources and specialized analyses.
Please note that this report is based on information available up to the date of writing and may change with new information.

Why Choose Infinity Galaxy?

At Infinity Galaxy, along with making the experience of a safe and pleasant bitumen journey as a bitumen supplier for our valued customers, our secondary mission is to keep key players in the bitumen market informed about the latest developments. Our weekly reports are prepared with the purpose of providing valuable insights that help our esteemed clients make well-informed decisions during negotiations.
Our weekly newsletter is a testament to the dedication of our team. Anyone interested in receiving the latest market updates can easily reach out to us at news@infinitygalaxy.org, and our team will guide you through the next steps.
Our operations team in Bandar Abbas ensures that we receive real-time updates on the loading status of every shipment, keeping our clients informed throughout the process. Our primary goal is to export bitumen and other commodities in the most efficient manner possible, ensuring that our valued clients enjoy a secure and successful transaction.

Navigating the complexities of this volatile market is no small feat. However, with our commitment to 24/7 service, Infinity Galaxy strives to remain resilient amidst all market fluctuations.

To Prevent Shoving, Ultra-Thin Wearing Courses Need Modified Bond or Tack Coat

BY BRIAN CANCIO

s road owners continue to work to improve cost efficiency and lane-mile network health year over year, preserving pavement using specialized hot mix asphalt (HMA) treatments has become increasingly common.

Among these are thin overlays, including ultra-thin bonded wearing courses (UTBWCs, involving specialized bond or tack coat and spray paving equipment and defined as HMA mixes below 2 in.
in thickness) and ultra-thin overlays or "Thinlays" (defined as HMA mixes below 1 in. in thickness).
The National Asphalt Pavement Association defines Thinlays™ as a suite of asphalt mixes that can be placed at a depth of 5⁄8 inch or more.
NCHRP Synthesis 464 collated national factors leading to successes and failures in these thin overlay treatments. That synthesis highlighted bond or tack coat applications as a critical factor in early slippage failures, especially in braking areas.

POLYMER MODIFICATION NEEDED

Ultra-thin bonded wearing courses include a bond or tack coat that differs from current products such as CRS-1h, CSS-1h & CNTT, or non-tracking tack, in that it uses a more adhesive asphalt binder that is polymer modified to improve binder performance, and has a specialized formulation to be compatible with the unique paving operation.

The softer binder, fortified by polymer modification, recovers from stress and strain over the life of the pavement due to its viscous and elastic properties. These specialized performance characteristics, combined with the more adhesive nature of the bond coat's base asphalt, lend themselves to greatly extending the life

of UTBWCs.

Further examination of the specialized synergy between the UTBWC bond coat and the open-gr ded mix it is traditionally paired with allows for di cussions that lend the principles of the application to generalized HMA applications.

All tack or bond coats are adhesives — bituminous adhesives to be sure — but adhesives, nonetheless. Think about Elmer's glue used in a child's craft project compared to the Gorilla Glue used to fix everyday items at home, which can be further compared to the spray sealants used to seal the house itself.

When thinking about bond or tack coats, the principles are similar even though the means and methods are not. The fundamental principle is use of the correct adhesive for the correct project.

As standard HMA mixes (which are usually paired with standard or non-tracking tack coat products) and UTBWC (which has the tack coat explained earlier) have demonstrated, the toolbox of tack or bond coats has significantly broadened in the last few decades.

Considering the work done to create the best possible outcomes when paving standard HMA lifts, and the further specialization to produce performing thin-lift and ultra-thin-lift applications, it makes entirely too much sense that a specialized tack coat for non-UTBWC thin overlay and ultra-thin overlay applications should exist. Let's look at this unmet need further before we discuss solving it. SUSCEPTIBLE TO SHOVING Thin overlay pavements are exceptionally susceptible to shoving, delamination, and similar stress and strain-related failures at the interface of the lift and the substrate. These failures areprimarily due to the energy of the stress and strain of traffic, particularly start/stop traffic, to translate quickly and effectively through the thinner- than-normal pavement to the substrate interface and the thin overlay pavement.

The additional wear on the interface and the pavement necessitates a bond or tack coat that reinforces the pavement and the interface between the pavement and the substrate.

While traditional tack coat is capable of this reinforcement to a limited but effective degree, recent developments in tack or bond coat technology allow for improvements on all counts.

The resilience of non-tracking tack coat products has been demonstrated in the handling, application and performance of tack coat emulsions. The UTBWC bond coat emulsion discussed earlier expands in a different direction of development, increasing viscous-elastic properties and using a more polymer-compatible asphalt binder in the tack coat emulsion.

While it lacks the non-tracking properties due to the softer binder base, the elastic

POLYMER MODIFICATION NEEDED

recovery of the binder and its ability to penetrate the open-graded pavement and expel its moisture through the pavement to the open air offers unique advantages. Further developments along these ideas have allowed for softer binders, higher degrees of polymer modification, new and improved polymer types, and improved controls for non-tracking properties, surface adhesion, cure times, and other properties.

The lower viscosity of the "softer" (high penetration value) asphalt binder allows for improved flow into both the pavement and the substrate as it experiences the heat and compaction of construction and traffic in addition to surviving temperature shifts overnight more effectively.

As NCHRP Report 712 demonstrated when looking into the rheological and performance grading of asphalt emulsion tack or bond coat residues, the effective viscosity and performance grading of an SS-1 or SS-1h differs greatly from non-tracking products. These non-tracking products do not have an effective low-temperature PG grade as measured by the testing used in the Superpave PG grading testing methods, or are too brittle to test effectively at comparable temperatures.

Keeping the ease of PG measurement and the broader measurable PG profile of the "softer," traditional tack coats such as SS-1 & SS-1h or CSS-1 & CSS-1h as an easily measurable performance point, extending their performance with polymer modifications greatly improves their ability to support Thinlay applications.

ELASTICITY = RECOVERY

The elasticity of the polymer modification allows for recovery, and the emulsification of the modified binder allows it to penetrate the substrate and pavement effectively, thanks to the forces involved in pavement compaction.

The result from a SS-1hP (emulsified softer binder with polymer modification) is a more potent bond between pavement and substrate without the brittleness of trackless tack.

The support of the pavement by the bond coat, as an adhesive and a reinforcement of the mix, is easily attainable with existing and widely available bond or tack coat products.

Market needs will create further niches for bond coats with further improved performance and enhanced properties such as pavement penetration during compaction, improved high and low-temperature properties, increased adhesion to pavement and substrate, and increased viscous-elastic recovery of the binder as it supports the pavement.

Forward-thinking pavement engineers should ask what value they can extract from the glue that is used to hold the road layers together.

Modified tack or bond coats with improved substrate and pavement adhesion properties will help extend the life of thin overlay pavements.

Further fortifying these materials with viscous-elastic modification will help road owners extract maximum lifecycle cost value from a thin overlay pavement application.

Edited by Pavement Preservation Journal from material contributed by Russell Standard. Russell Standard is a family- owned company focused on asphalt products, pavement preservation and asphalt maintenance, serving the East Coast and Midwest. Cancio is senior technical director of The Lab at Russell Standard, a nationally certified, AASHTO-accredited laboratory that tests asphalt binders, emulsions and cutbacks with an eye on developing future solutions

European Bitumen Modifier Market Set to Reach USD 2.27 Billion by 2034 with 4.5% Annual Growth Rate

The European market for bitumen modifiers is projected to expand from USD 1.46 billion in 2024 to USD 2.27 billion by 2034. Over this time frame, the demand for bitumen modifiers is expected to experience a compound annual growth rate (CAGR) of 4.5%.

In 2024, thermoplastic polymers/plastomers are predicted to account for the largest portion of the market, with a 38.1% share in terms of volume. However, the thermoplastic elastomers segment is anticipated to grow at a faster pace, with a CAGR of 5.4% through 2034.

Several factors are anticipated to contribute to the growth of the bitumen modifier sector in Europe. These include strong infrastructure development efforts and a rising awareness of the advantages of bitumen modifiers. The shift towards sustainable pavement solutions in the European construction sector is also expected to boost demand. Additionally, stricter government regulations related to road safety, quality, and environmental impact are likely to drive the market forward.

Consistent demand for bitumen modifiers across Europe is predicted to persist, driven by their ability to enhance bitumen's performance. The increasing number of infrastructure projects, including roadworks and airport runway developments, is expected to fuel the need for these products. Bitumen modifiers offer improved durability, resilience, and overall performance, helping ensure the long-term reliability and sustainability of transportation and infrastructure networks.

Countries such as Germany and the UK are witnessing a surge in renovation projects, which is expected to generate significant demand for bitumen modifiers during the forecast period. The growing need for durable and eco-friendly infrastructure solutions, driven by rapid urban growth, is likely to further accelerate the market. Moreover, the rise in heavy traffic loads and extreme weather conditions is expected to boost bitumen modifier sales in Europe.

"The European bitumen modifier market is set to experience solid growth, driven by increasing demand for long-lasting road infrastructure, a surge in construction activities, and heightened awareness of the benefits of modified bitumen in enhancing road performance and durability. As industries continue to modernize and expand, the need for high-quality infrastructure to support economic development will only increase," an analyst noted.

GRAPHENE-ENHANCED ASPHALT TESTED ON UK ROADS TO IMPROVE LONGEVITY AND ECO-FRIENDLINESS

A new road surface material featuring a graphene-enhanced polymer additive, known as Gipave, is being trialed on British roads. Graphene, an extremely strong material (100 to 300 times stronger than steel), reinforces the bitumen film that binds the aggregates in asphalt.

The trial took place on the A12 stretch between Hatfield Peverel and Witham, using a mix containing 40% recycled asphalt. Previous research has demonstrated that Gipave increases asphalt's stiffness and resistance to deformation, while also enhancing its long-term durability.

National Highways intends to assess the performance of the material on the A12 over the next few years before deciding whether to adopt it more broadly. The government-funded organization, responsible for managing the UK's motorways and major A roads, stated that this trial is part of a broader initiative to test various low-carbon asphalt solutions.

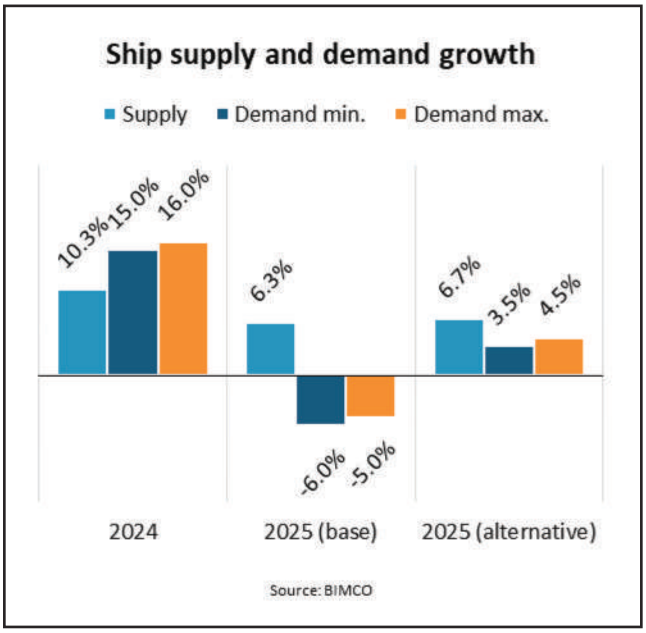
Gipave has already been applied internationally, including on the new San Giorgio bridge in Genoa, the runway at Treviso Airport, taxiways at both Edinburgh and Rome Fiumicino airports, and the F1 circuit at Imola in Italy.

Engineering consultancy AtkinsRéalis will carefully evaluate the 1km trial section, focusing on its carbon footprint and overall benefits, comparing it to a standard polymer-modified bitumen asphalt control section.

Umesh Parajuli, a senior pavement advisor at National Highways, stated: "We are continually looking for new ways to enhance our road network, prioritizing safety, customer satisfaction, and project execution.

"It is exciting to transition innovative road materials from the lab to actual use, as they offer potential for greater durability and efficiency, while ensuring road safety and reducing carbon emissions. This graphene-enhanced asphalt trial aligns with our 2040 net-zero goal for construction and maintenance, potentially offering significant long-term benefits for both local and national road networks."

CONTAINER SHIPPING MARKET OVERVIEW & OUTLOOK DISRUPTION REMAINS THE KEY DEMAND DRIVER



The disruption caused by ships being rerouted via the Cape of Good Hope remains the key ship demand driver. As a result, ship demand is forecast to grow three times faster than cargo volumes in 2024. Without it, ship supply would have grown faster than ship demand but instead we expect that the supply/demand balance will on average be tighter during 2024 than during 2023.

During the second half of 2024, we expect ship demand growth to weaken due to weaker cargo volume growth. On the other hand, supply will increase as the fleet continues to grow and so the supply/demand balance during the fourth quarter could approach the levels seen during 2023.

However, ship demand could end higher than projected during late 2024 and early 2025 due to disruptions caused by the redeployment of carrier alliances' services, particularly if negotiations between the International Longshoremen's Association (ILA) and the United States Maritime Alliance (USMX) are unsuccessful and lead to dockworker strikes in all US East and Gulf Coast ports starting on 1 October.

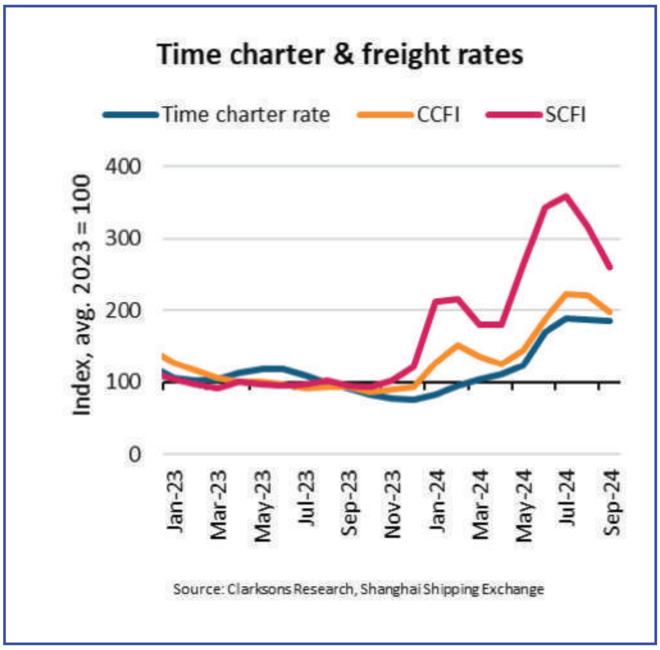
For 2025, we present two scenarios. In our base scenario we assume that ships could return safely to Red Sea and Suez Canal routings throughout 2025, whereas in our alternative scenario we assume no changes to the current rerouting pattern.

In both scenarios, the supply/demand balance would weaken compared to 2024, however it would remain stronger than in 2023 in the alternative scenario.

At present, we cannot judge which scenario is the more likely but as the Israel/Gaza conflict has expanded to include Hezbollah in Lebanon, it does appear increasingly likely that rerouting may partly impact 2025.

Spot freight rates from Shanghai (SCFI) peaked in early July but have since declined more than 30% due to lower cargo volumes and an increase in capacity deployed in some trade lanes.

Average export freight rates from China (CCFI) peaked



slightly later in July and have decreased only 15% since then. Despite time charter rates and the CCFI normally being very closely correlated, time charter rates have yet to react significantly to freight rate decreases because ship availability remains low and most continue to be renewed or find new time charter contracts.

As we move into the fourth quarter and into 2025, we expect further freight rate reductions and beginning time charter rate weaknesses, particularly if ships can return to normal routings.

The stable time charter rates have supported equally stable prices for second-hand ships and their development should remain aligned when the forecasted weaker supply/demand balance begins to impact time charter rates negatively.

On the strength of renewed container contracting, the global order book has increased another 5% during the last three months, leading to further price increases for newbuilds. The order book for bulk carriers and crude tankers remains low relative to the size of the fleets. Unless renewed interest in adding orders for these ship types underpins further expansion of the global order book, we expect prices to begin to fall along with the size of the order book.

Recycling prices are being pressured by cheap Chinese steel exports, and unless a pick-up in Chinese steel demand reduces those exports, we expect low prices to continue.

Much uncertainty remains in our forecast, not least because much of the demand side development is directly dependent on the current and potential future disruptions.

Risks to economic growth naturally also remain but at least appear less of a concern because lower inflation has allowed both the Federal Reserve and the European Central Bank to begin interest rate reductions.

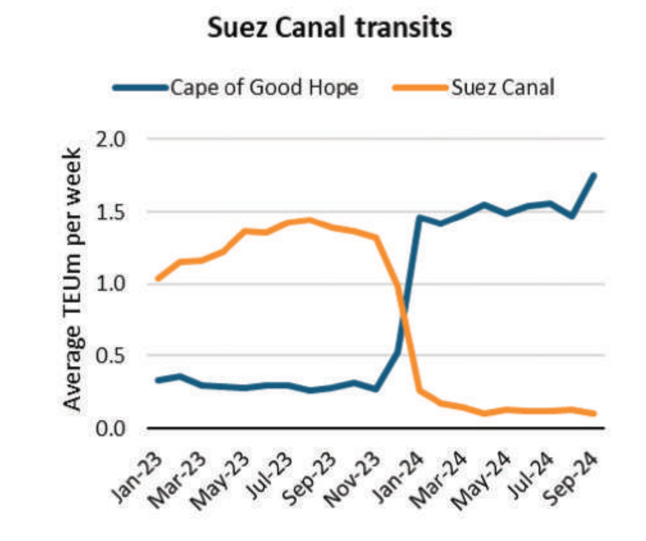
The result of the presidential election in November will meantime dictate US economic and trade policy from 2025 onwards. Should Donald Trump win a new term, his plans to impose new high import tariffs could disrupt US imports while increasing cost of living for consumers.

Macro environment

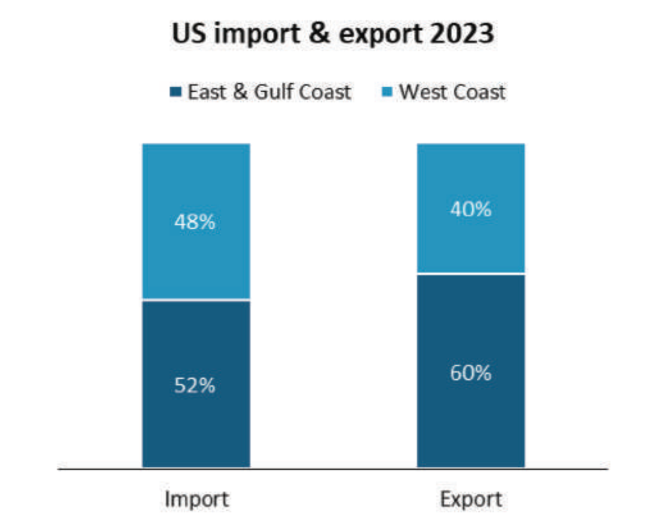
Houthi attacks on ships in the Red Sea continue to severely impact trade lanes that normally transit the Red Sea and the Suez Canal. Transits of the Suez Canal remain 90-95% lower than at the same time last year.

Though no resolution is in sight, we have in our base scenario chosen to assume that ships may utilise normal routings throughout 2025. However, we also offer an indication of the impact should ships continue to avoid the Red Sea.

Further disruption could occur if ILA and USMX fail to agree on a new contract before the current one expires on 30 September. If no agreement is reached, work stoppages could occur in all US East and Gulf Coast ports starting on 1 October. Though President Biden has the authority to intervene in labour conflicts that threaten national se-



Source: Clarksons Research



Source: US Port Authorities

curity, he has never done so, nor does he currently plan to do so to solve the potential dockworker strike.

More than half of all US container imports and export moves through US East and Gulf Coast ports and even short-term work stoppages could cause severe delays to ships and containers. Maersk has estimated that a one-week shutdown could take between four and six weeks to recover from.

Disruption could even occur in US West Coast ports if more ships and cargo are diverted to those ports during a shutdown. Congestion could build up and cause delays to ships and cargo moving through the West Coast.

Should a potential conflict be resolved quickly, the impact on the US economy will likely be minimal though a longer conflict could possibly lead to an increase in unemployment and inflation.

In its World Economic Outlook Update from July, the International Monetary Fund forecasts that the world economy will grow by 3.2% in 2024 and 3.3% in 2025.

The growth forecast for 2024 is only marginally lower than the 3.3% growth achieved in 2023, and regional growth forecasts are also in line with 2023. Despite only a small uptick in the global growth forecast, 2025 is meantime forecast to reveal larger shifts in regional growth patterns. Growth in the Chinese economy is expected to slow further in 2025 as the population ages and productivity growth slows, and thereby contribute to lower growth in the East & Southeast Asia region. Excluding the COVID years, 2025 is predicted to be the first year in a very long time that the region will contribute less than 40% of global growth.

In the Europe & Mediterranean region, growth in 2025 is forecast to finally show some upward momentum. Germany is normally a key driver of growth in the region but has experienced very weak growth during both 2023 and 2024, not least due to challenges in the manufacturing sector. Along with other major EU economies, improvements are expected in 2025.

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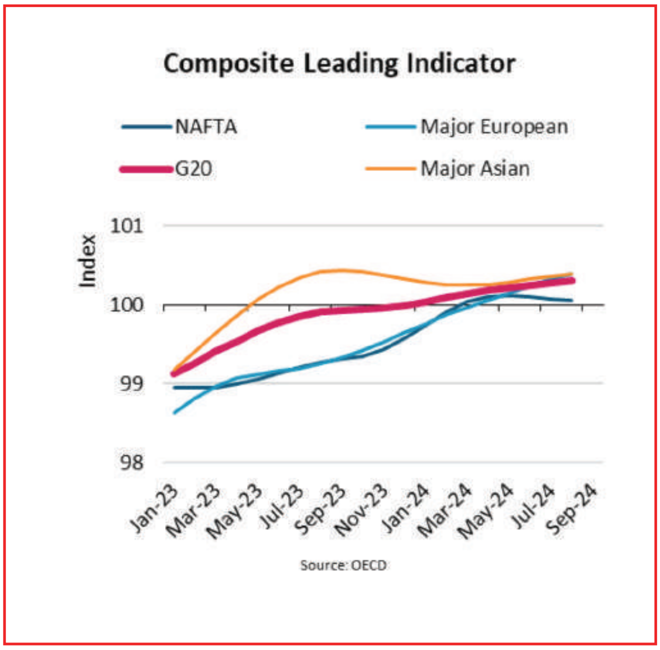
In the US, 2025 is forecast to show weaker growth as the labour market is expected to cool and consumption moderate which will drive growth in the North America region lower. A so-called "soft landing" is still forecast, and the recent interest rate reduction should contribute to

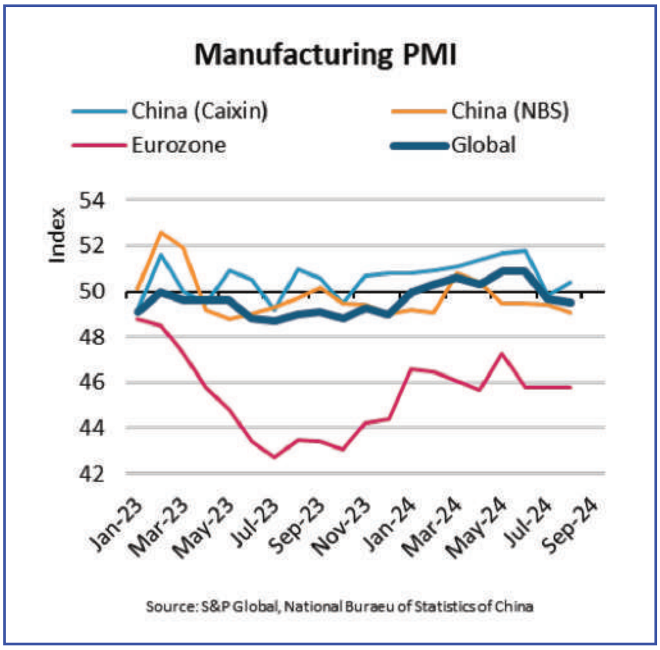
Source: IMF

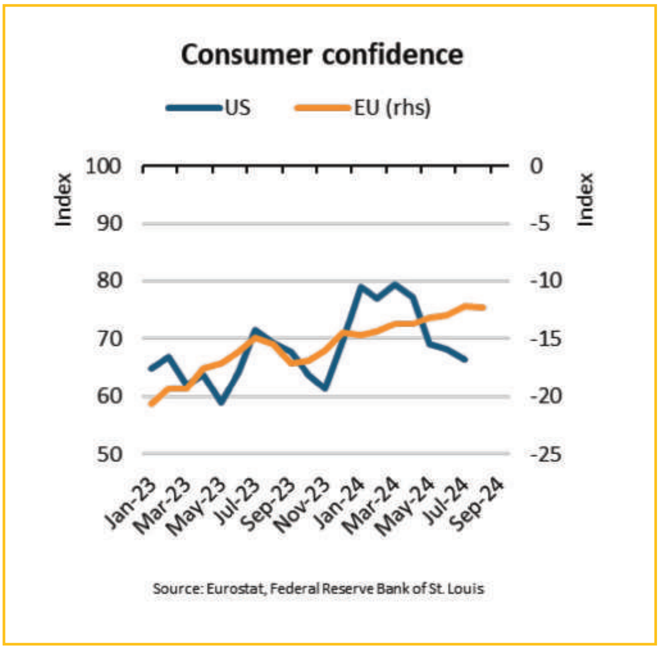
this. Other regions are expected to see faster economic growth in 2025 than in 2024 and combined they are forecast to contribute one third of global economic growth in 2025.

The OECD's Composite Leading Indicator (CLI) also points to relative growth stability in most regions. For nearly all countries and regions measured, the indicator hovers around 100.

It is meanwhile worth mentioning that the CLI for both the UK and Brazil is currently above 102 and thus indicates the largest increase in future growth of the countries measured.







Despite weakness in the eurozone, global manufacturing activity appears stable as the global Purchasing Managers' Index (PMI) remains within a very narrow band around 50. In the eurozone, however, manufacturing PMI is significantly below 50 indicating continuing contraction in the sector. The PMI has remained below 50 since mid-2022.

In China, slight weakness has recently been indicated as the manufacturing PMI from NBS (measuring large-scale state-owned companies) as well as the PMI for new export orders has dipped below 50 during the past four months. EU consumer confidence has, however, continued to improve, although it remains significantly below pre-COVID levels. In the US, an increase in consumer confidence in early 2024 has since been reversed.

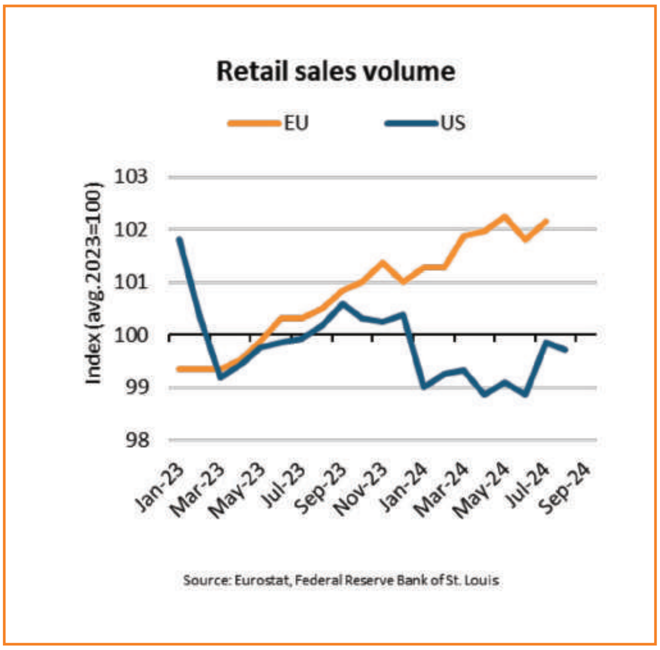
The shift in consumer confidence has had a direct impact on retail sales volumes in both regions. Whereas the EU has seen a slight increase in year-to-date retail sales volumes, the retail sector in the US has suffered a small decline in sales volumes.

Demand

We forecast that cargo volumes will grow 4-5% in 2024 and 3-4% in 2025. Volumes in head-haul trades are expected to grow slightly faster than the average.

We have lowered our cargo volume growth forecast for 2024 by 1 percentage point as second quarter volumes for some back-haul trades disappointed compared to our forecast, and because recent freight rate reductions indicate a faster weakening of head-haul trades than we had previously forecast.

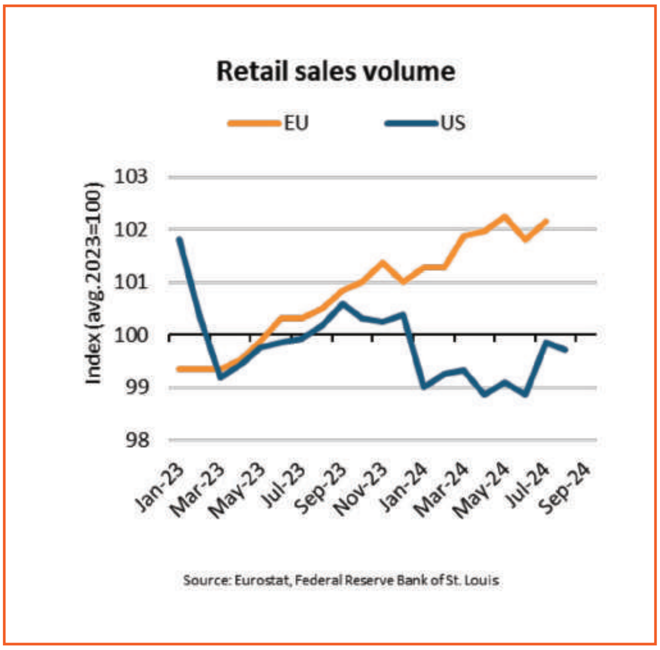
On the other hand, we have raised our ship demand growth forecast for 2024 by 0.5 percentage points to 15-16%. Trade lanes impacted by the rerouting away from the Red Sea and Suez Canal have been stronger than previously expected, increasing sailing distances and lifting

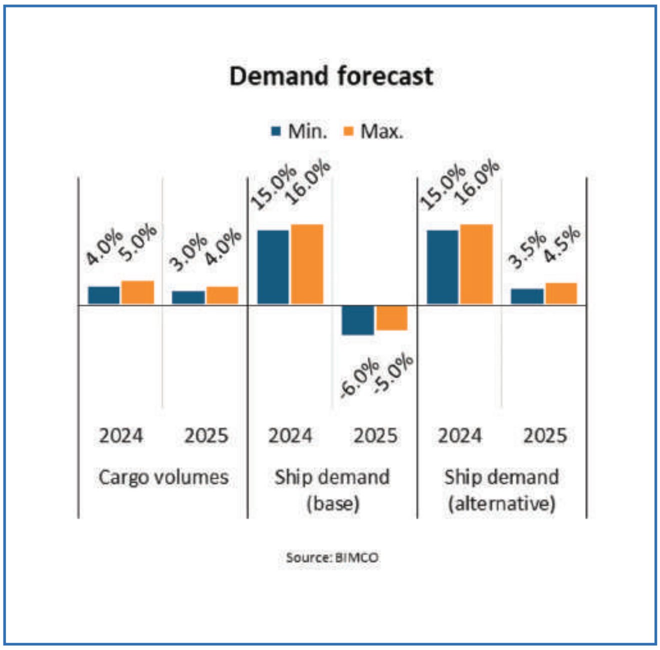


ship demand growth.

For 2025, we have included a forecast for both our base scenario and an alternative scenario. Our base scenario assumes that ships may return to normal Red Sea and Suez Canal routings throughout 2025, whereas our alternative scenario assumes no change compared to 2024. Should ships be able to return to normal routings, we forecast a 5-6% reduction in ship demand in 2025 whereas we forecast that ship demand should grow 3.5-4.5% if ships continue to be rerouted via the Cape of Good Hope. East & Southeast Asia is forecast to contribute 28% of import volume growth during 2024-2025, and North America 25%.

However, it is the South & Central America region that is forecast to post the fastest growth rate. In fact, despite expected disappointing growth into Sub-Saharan Africa during 2024, regions in the southern hemisphere





are forecast to post average annual volume growth of 5.5-6.5% during 2024-2025. Regions in the northern hemisphere are forecast to see lower average annual volume growth of 3-4% but should still drive nearly 80% of volume growth as they import 6-7 times more cargo than the regions in the southern hemisphere.

During the first half of 2024, cargo volumes into North America from East & Southeast Asia have grown particularly fast (14.7% y/y), partly due to a relatively weak first half of 2023 and partly because of peak season cargoes being shipped earlier than normal. The looming strikes in East and Gulf Coast ports along with longer transit times in some trade lanes have encouraged shippers to ship early.

However, it appears that second half volumes will suffer. Highlighting the unusual development, spot freight rates from Shanghai to the US have dropped by more than 30% between early July and mid-September. In the 2010s, before COVID, the spot freight rate fell a maximum of 10% during the same period but regularly saw a slight increase in rates.

Except for Durban, South Korea, West Japan and Oceania, spot freight rates from Shanghai to all other destinations have similarly developed much worse than was generally the case during the 2010s. In fact, the overall Shanghai Containerized Freight Index has also fallen more than 30% whereas it would normally fall a maximum of 5-10%. An increase in the capacity deployed may partly explain the adverse development in some trade lanes but we expect that this is mainly being caused by weaker volumes. Combined with a relatively stronger second half of 2023, we therefore forecast a lower annual growth rate during the second half of 2024 than during the first half.

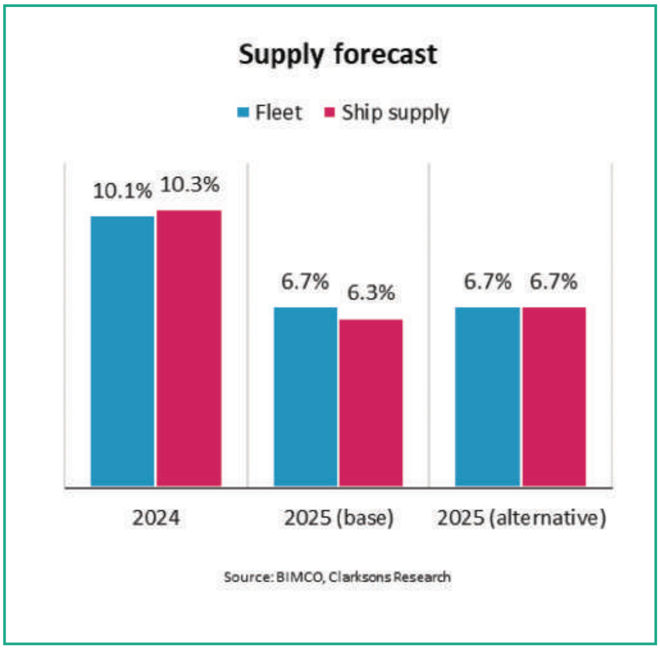
Ship demand growth may end higher than average during late 2024 and early 2025. MSC and members of Gemini

Alliance and the Premier Alliance may temporarily require additional ships to transition from the service patterns offered together with their current partner(s) to those planned with their new partner(s).

Similarly, if ILA and USMX cannot agree terms before 1 October, extensive port strikes in ports on the US East and Gulf Coast could temporarily lift ship demand.

Supply

We forecast that the average monthly fleet will grow 10.1% in 2024 and another 6.7% in 2025. Due to the longer sailing distances around the Cape of Good Hope, average sailing speeds have increased during 2024, and ship supply is therefore growing faster than the fleet. In 2025, our base scenario assumes a return to normal Red



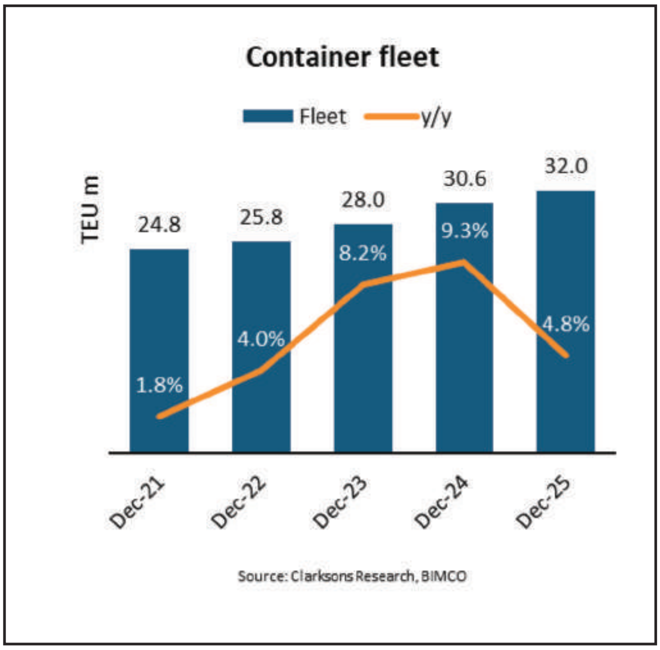
Sea routings, and we therefore assume that sailing speeds will reduce back to 2023 levels and cause ship supply to grow slower than the fleet.

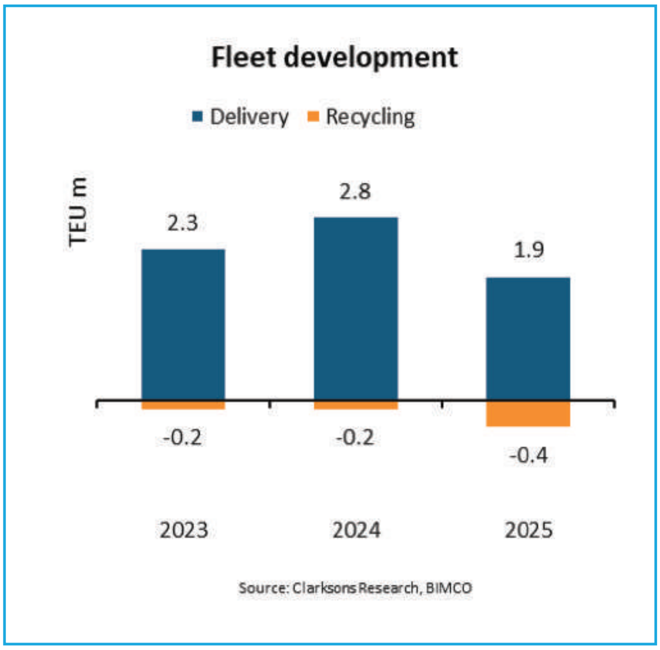
By the end of 2024, the fleet is expected to have grown to 30.6m TEU, an increase of 9.3% compared to the end of 2023. Another 4.8% growth is forecast to be added by the end of 2025 and the fleet will then hit 32.0m TEU.

This year is expected to see deliveries hit a new record high of 2.8m TEU whereas they should begin to slow down as early as 2025.

The increased demand for ships due to longer sailing distances has meant that ship recycling has remained very low. In both our scenarios for 2025, we expect that the supply/demand balance will weaken, and we therefore forecast that recycling activity will rebound.

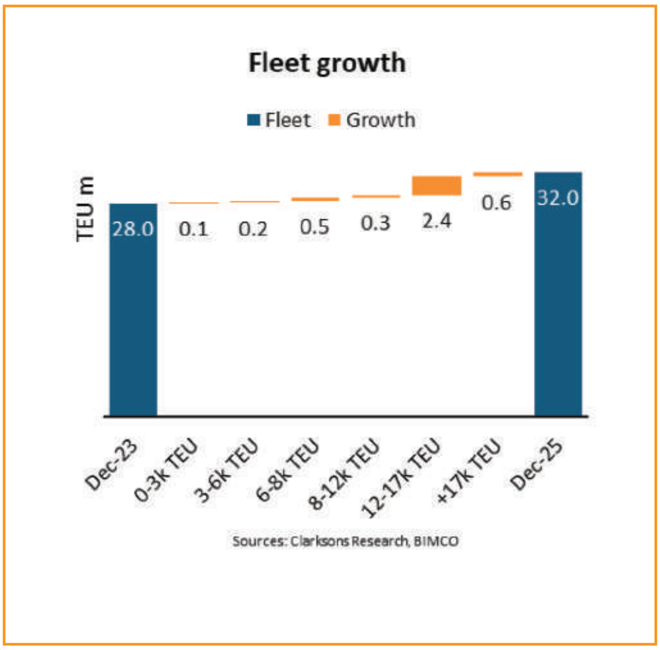
Ships in the 12-17k TEU size segment have continued to dominate new contracting during 2024, and they also make up nearly 50% of the capacity in the order book. Therefore, they are forecast to drive nearly 60% of the fleet growth between the end of 2023 and end 2025. Sailing speed has remained higher, as conditions in the

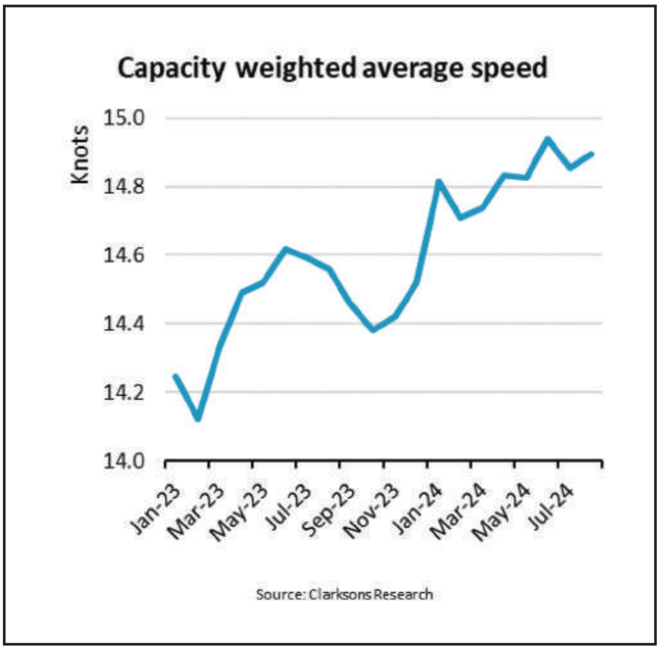




Red Sea have stayed unchanged. The increased average speed is driven by ships larger than 6,000 TEU which now regularly sail faster than 15 knots on average, whereas their average speed had dipped below 15 knots during 2023.

As mentioned, if the crisis is resolved we expect average speed to slow back down to 14.4 knots in 2025. Average speed could go even lower in 2025 as the Gemini Alliance aims to achieve 90% schedule reliability, which may cause them to slow ships down and increase buffers available to make up for delays.



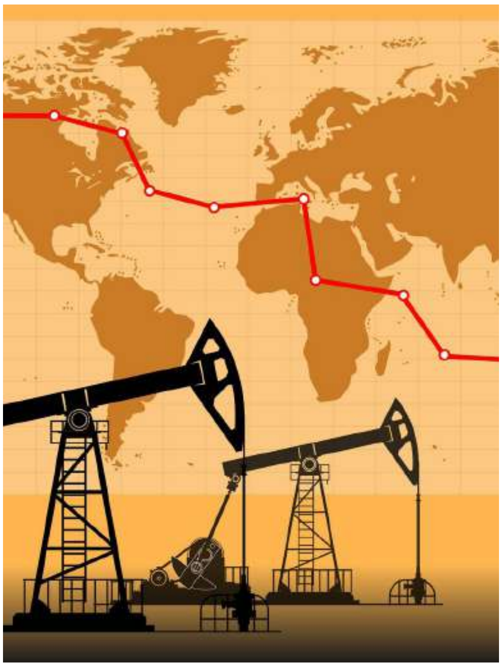


BIMCO is the world's largest international shipping association, with over 2,000 members in more than 130 countries, representing 62% of the world's tonnage. Our global membership includes shipowners, operators, managers, brokers, and agents. BIMCO is a non-profit organisation.

Petroleum price slump expected until the end of 2025

Analysts at the Wall Street bank Wells Fargo have predicted that petroleum prices will remain low until the end of 2025 due to the risk of an increase in global oversupply.

According to experts, a combination of factors, including the steady growth of U.S. shale oil production and a decline in demand from key economies, particularly China, are the main drivers behind the drop in petroleum prices. Wells Fargo notes that despite the current supply restrictions in the market, the anticipated easing of OPEC+ production limits by the end of 2024 will further support the likelihood of a supply surplus in 2025.



Wells Fargo forecasts that global petroleum supply will increase from 102.8 million barrels per day in 2024 to 104.8 million barrels per day in 2025, driven by growth in supply from non-OPEC producers like the U.S. and Brazil, as well as planned increases in OPEC production. Analysts have drawn comparisons between the current petroleum market situation and the conditions in 1998, when petroleum prices plummeted due to a global economic slowdown and a surge in new supply.

However, the growth of U.S. shale oil production is unlikely to play as significant a role in global oversupply as it has in recent years. U.S. petroleum production increased by only 0.1 million barrels per day by the end of the third quarter, which is much lower than the average increase of 0.6 million barrels per day seen in previous growth periods.

According to an Oil Price report, Wells Fargo has lowered its petroleum price forecast, estimating that the average price of Brent crude will be $70 per barrel in 2025, and the average price of West Texas Intermediate (WTI) crude will be $65 per barrel in the same year. However, Wells Fargo acknowledged that several factors could alter the trajectory of petroleum prices, including a faster-than-expected recovery in global demand, particularly from China and countries within the Organization for Economic Co-operation and Development (OECD).

Petroleum prices have fallen by over 2% due to reduced concerns about supply disruptions in Libya and ongoing worries about weak fuel demand from China.

Russia's use of sanctioned tankers accelerates

An increasing number of tankers that were sanctioned due to their role in transporting Russian petroleum have become active again, undermining Western efforts to restrict Moscow's access to petroleum revenues.

Since late April, at least 17 shipments of crude oil and refined petroleum products have been sent from Russian ports on ships sanctioned by the U.S., the U.K., or the European Union. Most of these shipments were carried on tankers that, at the time of the sanctions, were owned by the Russian shipping giant Sovcomflot.

Immediately after the sanctions were imposed, the vast majority of these sanctioned tankers became idle, with some remaining inactive for up to eight months.

However, shipping companies have gradually increased the use of blacklisted vessels after successfully delivering cargo to China. These shipments were carried at least partially on Western-sanctioned tankers that had turned off their tracking systems. Now, the tankers no longer try to conceal their movements, as shipments are openly delivered to China and India.

Sovcomflot, also known as SCF, has no ties with the sanctioning countries and is therefore not subject to actions from the U.K., EU, or U.S. Thus, Sovcomflot cannot be regarded as a violator or a tool for undermining the sanctions. The use of sanctioned tankers accelerated in August, and is expected to rise further this month.

If this trend continues, it could ease the logistical restrictions that have been in place. Nevertheless, Russia had generally been able to find the ships it needed, even when more vessels were out of commission.

Acceleration of petroleum shipments

In the past month, six ships that were under sanctions from the U.S., U.K., or EU loaded Russian petroleum cargoes. This number is nearly equivalent to the tally for September.

Sanctioned tankers that previously hid their movements from digital tracking systems are once again delivering petroleum with more transparency. With 11 more sanctioned tankers anchored near the Pacific port of Kozmino, seven idle tankers off the coast of Ust-Luga, three more that have been in the Black Sea for months, and two tankers near Murmansk,

In the past month, six ships that were under sanctions from the U.S., U.K., or EU loaded Russian petroleum cargoes. This number is nearly equivalent to the tally for September.

ACCELERATION OF PETROLEUM SHIPMENTS

WPB

there are numerous opportunities to bring more sanctioned ships back into operation in the second half of September.

Increase in Russian fuel exports

Russian exports of petroleum products rose in the first half of this month due to increased shipments of diesel and fuel oil, alongside a rebound in refining rates.

Data collected by Bloomberg, based on information from the analytical firm Vortexa, showed that the export flow of petroleum products by sea in the first 15 days of September reached about 2.2 million barrels per day, nearly 10% higher than the daily average for the previous month.

Refined fuel exports have increased as refining rates recovered after a Ukrainian drone attack on a Russian refinery. In August, shipments fell to a four-month low due to reduced exports of diesel and fuel oil, which together account for about 70% of all refined fuel shipments from Russia.

According to Bloomberg, diesel and gasoil exports totaled around 807,000 barrels per day, a 10% increase from the previous month. Naphtha shipments fell by nearly 5% to 401,000 barrels per day. Gasoline and blending component shipments increased to 79,000 barrels per day. Fuel oil shipments rose by 13%, reaching 749,000 barrels per day, the highest level this year. Exports of refinery feedstocks, such as vacuum gasoil, reached 149,000 barrels per day, the highest in four months.

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Russian exports of petroleum products rose in the first half of this month due to increased shipments of diesel and fuel oil, alongside a rebound in refining rates.

THE U.S. REMAINS THE WORLD'S LARGEST GASOLINE EXPORTER

The U.S. holds its position as the largest gasoline exporter in the world, accounting for over 16% of global exports.

A review by the U.S. Energy Information Administration (EIA) showed that last year, U.S. exports of motor gasoline (finished gasoline plus blending components) averaged 900,000 barrels per day. This amount is equivalent to about 10% of domestic consumption and could fill the tanks of over 1.5 million SUVs daily, assuming an average tank size of 24 gallons.

Although China and India have increased their refining capacity and boosted their exports, the U.S. remains the top gasoline exporter. According to the EIA, the gasoline exports of other major exporters like Singapore and the Netherlands have never exceeded 700,000 barrels per day.

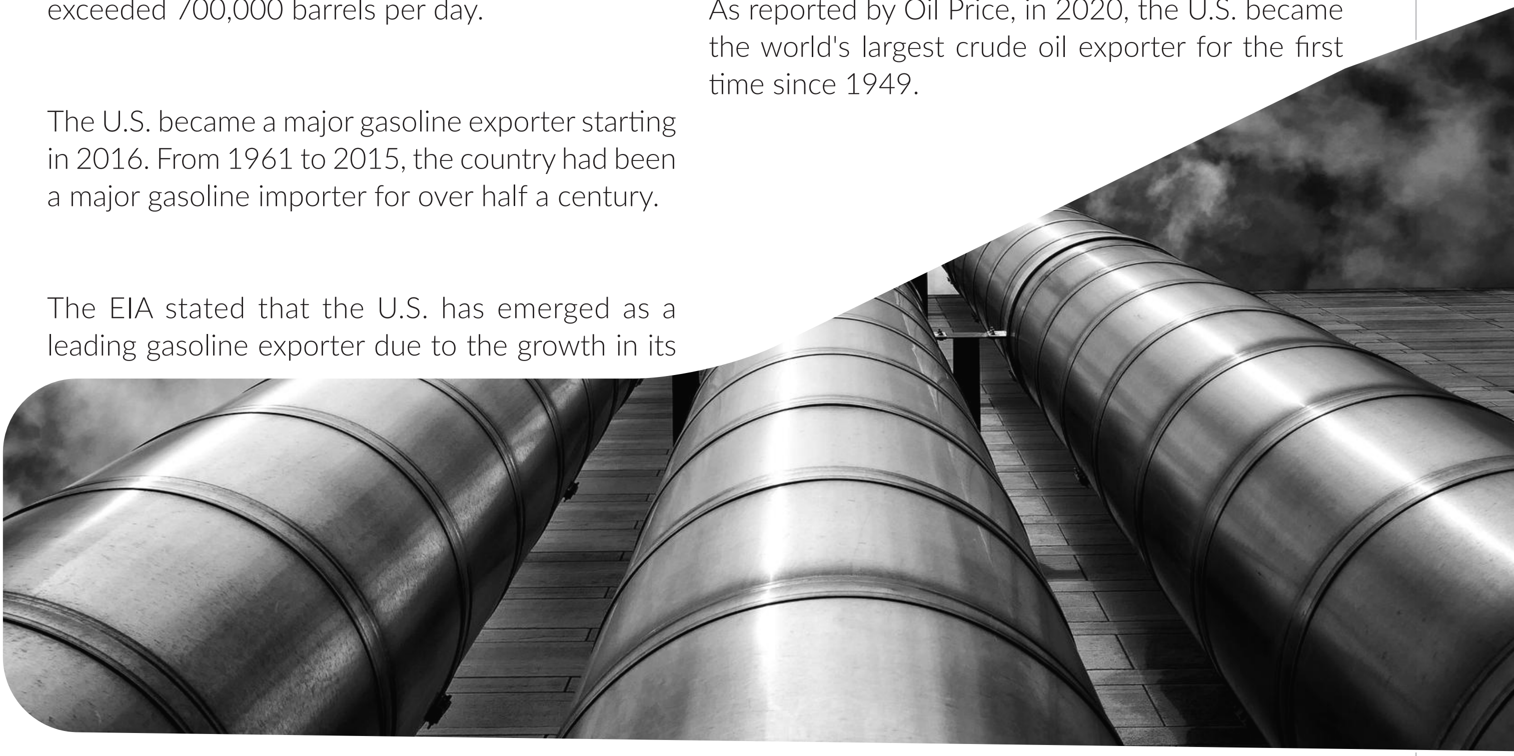
The U.S. became a major gasoline exporter starting in 2016. From 1961 to 2015, the country had been a major gasoline importer for over half a century.

The EIA stated that the U.S. has emerged as a leading gasoline exporter due to the growth in its refined petroleum product exports, which reached record levels in 2022 and 2023. Increased refinery utilization and expanded refining capacity have been key factors in the growth of U.S. petroleum product exports, including gasoline.

Despite the increase in U.S. refining capacity, domestic gasoline consumption has not risen, resulting in more gasoline available for export. U.S. motor gasoline consumption in 2023 remained fixed compared to 2010 and was 400,000 barrels per day lower than its peak in 2018.

According to EIA data, U.S. petroleum product exports reached a record 6.1 million barrels per day last year, 2.5% higher than in 2022.

As reported by Oil Price, in 2020, the U.S. became the world's largest crude oil exporter for the first time since 1949.



SHIPPING INDUSTRY TRENDS: A SEPTEMBER 2024 OVERVIEW

The shipping sector has seen notable transformations throughout 2024, presenting both new possibilities and obstacles. As container demand continues to rise, the industry finds itself grappling with concerns over fuel usage, geopolitical instability, and evolving operational approaches. To maintain a competitive edge and mitigate potential disruptions, importers and logistics providers need to stay abreast of these industry shifts.

Ongoing Rise in Demand

Global container shipments have experienced a marked increase this year, showing a 10% rise in Q1, followed by an additional 7% growth during the first half of the year. This steady climb in demand is being fueled by robust market activity in major areas, including North and Latin America. Even regions facing economic uncertainty are seeing a boost in imports as businesses gear up for year-end sales. Despite ongoing geopolitical challenges, these patterns suggest a stable demand for shipping services will continue.

Expanding Capacity Amid Operational Setbacks

The global container fleet is projected to expand by 10% in 2024, with an additional 5% growth anticipated in 2025. This reflects the considerable increase in capacity, as new vessel deliveries are expected to reach 1 million TEUs by year's end. However, challenges such as rerouting due to geopolitical tensions, particularly in areas like the Red Sea, continue to disrupt schedules and overall capacity. These disruptions lead to delays and elevated operational costs, making fuel efficiency and adaptable strategies more crucial than ever.

Geopolitical Tensions and Supply Chain Challenges

Rising geopolitical tensions, especially in regions like the Red Sea, are having a significant impact on shipping operations. Frequent rerouting is leading to delays and higher fuel expenses. Labor disputes, such as those in India and along the U.S. East Coast, further threaten to upset supply chains. To handle these issues, companies must focus on building resilient logistics systems and keep a close watch on geopolitical events.

Volatile Freight Rates and Carrier Alliances

Throughout 2024, ocean freight rates have fluctuated, driven by capacity shortages and the costs of rerouting. While some trade lanes may experience rate drops, others—particularly those linking Oceania and the Atlantic—are expected to see continued high costs. Meanwhile, shifts in carrier alliances, like MSC's decision to leave the 2M partnership with Maersk by 2025, indicate changes in the competitive dynamics of global shipping. These alliances will likely play a key role in shaping the future of the industry.

Looking Ahead: Opportunities and Risks

Looking forward, the shipping industry faces a mix of prospects and uncertainties. Bimco forecasts a 5% increase in container demand during the latter half of 2024 and into 2025. However, challenges such as potential labor strikes and new environmental regulations could disrupt supply chains. Companies that emphasize capacity management, fuel efficiency, and strategic partnerships will be better equipped to navigate these challenges and seize future opportunities.

CONTAINER VOLUMES RISE AT KEY JAPANESE PORTS

Container Volumes Rise at Key Japanese Ports

Preliminary figures from Japan's transport ministry reveal that the nation’s six primary ports handled 1.17 million TEUs in July, reflecting a 3.3% rise compared to the same month last year. This marks the fourth consecutive month of year-on-year growth. Export volumes totaled 571,534 TEUs, up by 3.3%, while imports reached 594,158 TEUs, a 3.2% increase. Breaking down the numbers, the Port of Tokyo processed 346,740 TEUs, marking a 3.5% increase, with exports reaching 156,341 TEUs (up 2.3%) and imports totaling 190,399 TEUs (up 4.6%).

In contrast, Kawasaki experienced a notable drop, with container throughput falling 16.3% to 6,096 TEUs following five months of double-digit expansion. Kawasaki’s export volume plummeted 21.4% to 2,725 TEUs, while imports declined by 11.8% to 3,371 TEUs. Yokohama, however, showed steady improvement, seeing a 3.4% growth to 237,988 TEUs, with exports climbing to 126,093 TEUs (up 4.9%) and imports increasing to 111,895 TEUs (up 1.8%).

Nagoya also posted positive results, handling 219,028 TEUs, a 3.5% rise, with exports of 112,240 TEUs (up 3.6%) and imports of 106,788 TEUs (up 3.5%).

The Port of Osaka processed 172,573 TEUs, growing by 3.4%. Exports reached 76,818 TEUs (up 1.6%), while imports rose to 95,755 TEUs (up 4.8%). Similarly, Kobe handled 183,267 TEUs, a 2.9% rise, with exports hitting 97,317 TEUs (up 4.9%) and imports totaling 85,950 TEUs (up 0.9%).

Predicting odorous emissions from bitumen collected at 13 refineries: A combined GC–MS and supervised learning approach

ZACHARY DELLER [A], FILIPPO GIUSTOZZI [B], SUBASHANI MANIAM [A,*]

[A] Applied Chemistry and Environmental Science, School of Science, STEM College, RMIT University, Melbourne, Victoria 3001, Australia

[B] Civil and Infrastructure, School of Engineering, STEM College, RMIT University, Melbourne, Victoria 3001, Australia

ABSTRACT

During asphalt paving operations, bitumen emissions occasionally give rise to unpleasant odours attributed to volatile organic compounds. While infrequent, these odours can significantly disrupt community well-being, local air quality, and workers' productivity. Predicting odours from a bitumen source before its use in the field is an ideal strategy to address these challenges proactively.

This study introduces a novel Linear Discriminant Analysis (LDA) method, utilising data from headspace gas chromatography-mass spectrometry (HS-GC–MS) of bitumen samples to forecast the likelihood of odours in bituminous road binders.

The LDA model, developed using HS-GC–MS results from sixteen straight-run binders of known odour status collected globally, demonstrates high accuracy in odour prediction through two cross-validation techniques. This accuracy enables the rapid identification of odorous bitumen samples using GC–MS data. Furthermore, our method suggests a substantial contribution to odour from alkanes and arenes.

The proposed approach provides a simple and practical tool, offering the potential for selective use or pre-treatment of bitumen, thereby reducing the introduction of highly odorous binders into paving projects.

This methodology presents an innovative step towards proactive odour management in asphalt paving, contributing to community well-being, environmental quality, and the efficiency of paving operations.

Keywords:

Bitumen
Odour
Discriminate analysis
Emissions
Pollution

1. Introduction

Bitumen used as a binder in paving projects can occasionally produce significant malodours that can lead to disruption of local communities or the shutdown of a paving project.[1–3] Odour pollution is a substantial and often underestimated factor influencing air quality in local communities.

The disruptive odours that can emanate from bitumen not only pose challenges to workers on paving sites but also have far-reaching effects on the overall well-being of nearby residents and businesses.

[4,5] Although not necessarily indicative of harmful emissions, these odours can cause substantial discomfort and distress among local inhabitants,potentially impacting their quality of life and daily activities.
[1,6] Consequently, many countries have recognized the need for stringent air quality and odour emissions regulations.

These regulations serve as essential measures to safeguard the health and comfort of residents and maintain the air quality of local environments.[7]

There is significant literature on the emissions and toxicological aspects of bitumen.[8–32] However, odour is a largely unresolved issue in bitumen materials research, occupying little space in the literature relative to the bulk of bitumen research.[1–3]

Odour in relation to bitumen within this work refers to a distinctly poor odour that is significant enough to cause disruptions and complaints from personnel.[1,6]

This poor odour is distinctively different from fuming where large volumes of fume are emitted from bitumen. [33,34]

While many analytical measures of bitumen properties can be assessed quantitatively, odour is more subjective and susceptible to environmental conditions making its metrics largely qualitative.[35–39]

Specific chemicals that are known to be odorous can be quantified, but given the range of chemicals present in the emissions of bitumen, quantification of all these chemicals is a monstrous task and may still struggle to describe a clear picture of the odour produced from such a complex substance.

Consequently, there are many challenges in identifying odour in bitumen products due to this range of chemicals and, the techniques available to analytically assess odour.

[1,5,6,38,39]
In attempts to quantify odour from bitumen, some studies have sought to identify correlations between particular chemicals and odour, [1,6] the literature on odour from bitumen emissions is notably constrained.

These works have aimed to refine the list of chemicals influencing odour, however, the range of compounds contributing to poor odour is vast and encompasses hydrocarbons, aromatics, and heterocycles. Moreover, it must be noted that these chemical lists of
odorous compounds are yet to undergo thorough validation through additional research.[1,6]
Compelling methods to predict odour are yet to be presented in relation to bitumen emission odour.[1–3,6,40] Determining the odour potential of a bitumen before it is deployed in road construction operations may reduce the need for odour reducing or masking additives.[1]

A predictive method could reduce negative effects on air quality and the delays that a highly odorous bitumen may cause due to disruption to workers or communities.

Assessing odour from complex mixtures often requires human participants to form an audit panel, thereby limiting its application.[41,42]

Methods that consider odour by statistical means present a more simplified approach to considering complex mixtures of chemicals.

[2,3,40,43–46] Statistical analysis of bitumen emissions and odour has been investigated previously with limited application.[2,3,40]
The study by Autelitano and Giuliani[3] focused on characterising bitumen emissions and odours using handheld equipment capable of measuring the concentration of specific chemical classes from gases but not identifying specific chemicals. Their approach involved considering complex odorous mixtures by studying the relative response of various chemicals. The researchers incorporated principal component analysis to reduce dimensionality and separate samples based on the first two principal components, enabling the differentiation of samples based on the relative responses of a range of chemical classes.

This statistical treatment and analysis of bitumen emissions exemplify methods that can address the intricacies of odours within complex gaseous mixtures.
Importantly, it is worth noting that the study did not extend its research to predicting odorous characteristics in bitumen, highlighting a notable

gap in the literature that our work aims to fill.

Discriminant analysis is a statistical technique used to identify distinguishing characteristics in datasets that segregate samples into distinct classes. When using Linear Discriminate Analysis (LDA), often referred to as Fisher's LDA,[47] p variables are used to construct discriminate axes.

The p variables are the initial set of features within a dataset, such as the measurements taken for each sample. An axis is constructed using the p variables to maximise the separation between two or more data classes.[48] This is done by maximising the distance between the means of each group for a given variable while minimising the spread of values within each group.[49]

The application of LDA tailored specifically for odour assessment has proven successful in evaluating malodours associated with food products.[45,50–54]

LDA has emerged as a powerful tool for discerning complex odour profiles in these well-established areas, providing valuable insights into sensory perceptions, quality control, and product development.

Applying LDA to evaluate odours from bitumen emissions represents a largely uncharted territory[2,3,40] with potential for innovation in terms of predictive analysis. The perception of odour in bitumen can be considered a multifaceted phenomenon influenced by intricate mixtures of chemicals.[35,36,41,42,55] Considering not only chemicals known for their malodorous properties but all the chemicals that constitute the emission profile becomes pivotal when assessing odours within complex mixtures.

The amalgamation of seemingly inconspicuous chemicals may give rise to distinctly odorous mixtures. Consequently, a comprehensive model tasked with evaluating odour risk must also consider chemicals that may initially appear inconsequential to the overall odour potential of bitumen.

Although bitumen samples share many of the same chemicals in their emissions, the concentrations of these chemicals can exhibit significant variations among different samples.[56]

Here we examine chemicals present in bitumen emissions to predict odours based on wellestablished historic bitumen samples with a record of malodour. By adopting a comprehensive approach that considers various chemicals and their intricate mixtures within bitumen and its fumes, this research aims to provide valuable insights into predicting odour attributes linked to bitumen emissions.

2. Methods and materials

To prepare the sample, 1.00±0.01 g of bitumen was placed in a sealed headspace vial with an incubation time of 90 min to establish equilibrium.

The method was carried out on an Agilent 8890 GC/5977B GC/MSD instrument fitted with CTC PAL RSI 120 attachments, including a headspace sampler with sample heating and agitation.

Headspace sampling was completed automatically with the CTC PAL systems 8010–0265 2500 µL headspace sampler. The samples were heated at 150 ◦C for 90 min in the agitator before gas was extracted with the automated syringe. A headspace

sample volume of 500 μL was used.

The injection mode was set to split (1:10). The injection port was set to 250 ◦C and was fitted with an Agilent 5190–3983: 800 μL (single taper) linear. The GC was fitted with a J&W DB-624 GC Column (30 m, 0.25 mm, 1.40 μm).
Flow was 1.525 mL/min, and pressure was 12.685 psithrough the column.

This method was used for both scan and selective ion monitoring (SIM) runs. Using a scan mode with mass ranges between 33 and 300 m/ z a range of potential compounds that could be used to predict odour were analysed (Table S1) and the responses of the integrated molecular ion were recorded.

Using SIM, the analytes previously found to be predictive of odour were analysed, the molecular ions were integrated, this is found in Table 1.

The selected analytes were confirmed based on library matching from scan data and analytical standards two analytical standards: ASTM surrogate base gasoline (RGO-711–1) and benzene, toluene, ethylbenzene and m, p, o-xylenes (BTEX) standard (BTX-2000 N), both purchased from Agilent.

Sixteen unique bitumen samples were used in this work, they were provided by Puma Energy (Australia) Bitumen Pty Ltd and were taken from a library of samples with known performance spanning two decades.

The 16 samples were received from 13 different refineries across various international regions (Table 2). All samples were collected from a sealed tin containing the bulk sample, all samples had been stored indoors in controlled conditions since decanting on the scale of millilitres to litres.

None of the bitumen samples were modified bitumen.
The sample set contained 8 samples with no odour complaints and 8 samples that had confirmed odour status. The samples were acquired from a range of countries and were composed of a range of penetration grades (Table 3).

These were assigned to ‘No odour’ and ‘Odour’ groups by Puma as part of a survey reviewing problematic bitumen products, the complaints were assessed and substantiated by Puma Energy Bitumen.
The results were supplied for this work as qualitative binary data of ‘No odour’ and ‘Odour’. All samples were run in duplicates with sample 44771 being run four times to measure variance. The duplicates were not averaged but entered as two individual data points.

Table 1
Molecular ions of selected analytes using the SIM method.

No.	Analyte	M^+ ion
1	Pentane	72
2	Hexane	86
3	Benzene	78
4	Heptane	100
5	Octane	114
6	*m, p*-Xylene	106
7	Nonane	128
8	*o*-Xylene	106
9	1,3,5-Trimethylbenzene	120
10	1,2,4-Trimethylbenzene	120
11	1,2,3-Trimethylbenzene	120

Table 2
Bitumen sample source, names and status used this this study.

Refinery	Name	Penetration grade	Group
A	207	160/220	No odour
B	44,771	80/100	Odour
C	23,762	70/100	Odour
D	22,707	70/100	Odour
E	46,558	160/220	Odour
F	47,272	50/70	Odour
G	198	50/70	No odour
A	204	50/70	No odour
H	227	35/50	No odour
I	237	40/60	Odour
J	25,249	70/100	No odour
F	33,248	70/100	No odour
K	180	10/20	No odour
L	C170	70/100	No odour
M	49,585	70/100	Odour
M	49,586	160/220	Odour

Table 3
Leave-one-out cross-validation accuracy and kappa for LDA model.

Cross-validation accuracy rate	1.0000
Cross-validation error rate	0.0000
Kappa	1.0000

This was done using the HSGC– MS method, producing 34 data points, 16 'No odour' and 18 'Odour'. To prepare a sample 1.00±0.01 g of bitumen was collected using a metal spatula without heating so any emissions could be minimised from the bulk sample. This was then added to a headspace vial and sealed.

The reproducibility of the samples was very high despite the collection of cold bitumen.
The data used in this study consisted of the integration values of the molecular ions for each of the 11 analytes in Table 1, this was done using Agilent MS quantitative analysis build 10.1.733.0. Once processed the dataset comprised 30 data entries and 11 predictor variables.

The integration values for each analyte were computed as a fraction of the net area of the 11 peaks (Eq. S1). After this, the data was then normalised using vector normalisation (Eq. S2). Next, a series of feature ratios were computed from the dataset. These feature ratio values were calculated to capture the relationships between the features in the dataset, which represents pairs of analytes in the emissions.

This enables a greater focus on the relationships between features. The dataset consists of 11 normalized vectors, each corresponding to an analyte. These features are systematically divided by each other, yielding a total of 121 values.

Among these, 11 values result from identical divisions that are equal to 1, reducing the count to 110. Half of these values are reciprocals, such as 1/2 and 2/1, which convey the same information in this work. Consequently, this process culminates in the extraction of 55 variables, labelled V1-V55. This refined dataset was then integrated into the LDA model for further analysis.

All data pre-processing, model training, and statistical analyses were performed using the R Studio programming language (version 2023.06.0 + 421).[57] The 'MASS' package[58] was utilised for the implementation of the LDA model and permutation test.
The corrplot package[59] was used for generating correlation matrix plots. And the ggplot2 package was used for graphical manipulation.[60] To differentiate between the odour and non-odour groups, we employed LDA.

LDA is a supervised classification technique that finds linear combinations of the predictor variables to maximize the separation between predefined groups. The LDA model was trained using the LDA function from the MASS package in R Studio.

To evaluate the performance and generalization ability of the LDA model, leave-one-out cross-validation (LOOCV) was conducted. LOOCV is a technique that iteratively trains the model using all but one observation, and then evaluates the model's performance on the left-out observation.

This process is repeated for each observation in the dataset, resulting in an accurate estimate of the model's predictive performance.

To determine the statistical significance of the model's performance two cross-validation methods were used. LOOCV and 5-fold crossvalidation tuning the shrinkage hyperparameter for shrinkage linear
discriminate analysis (SLDA) with the lambda and diagonal tune grid set

between 0 and 1 with increments of 0.1. The 'caret' package[61] was used for the cross-validation (CV) methods.
The collinearity of variables was assessed using a correlation matrix generated using the corrplot package.

Collinearity refers to the correlation or interdependence between predictor variables, which can affect the reliability and interpretability of statistical models.[49,62–64]

3. Results and discussion
In the initial phase of selecting predictor variables, a comprehensive assessment was conducted on 32 analytes to evaluate their ability to predict odour in bitumen samples (Table S1).
These analytes were chosen not only for their potential to produce odour but based on their presence in all samples to varying extents.

Thiols and disulfides were excluded from this evaluation as they were present in only a subset of the samples, and when they did appear it was in both odorous and nonodorous samples.

Consequently, despite their known poor odour[65,66] no definitive conclusions could be drawn regarding their contribution to odour in these bitumen samples. During the assessment of the model and its prediction capabilities many of these compounds did not contribute to the separation of the samples into odour and non-odour samples.

Therefore, among these 32 analytes, a subset of 11 compounds were selected (Table 1), there included alkanes, benzene, and benzene derivatives, they demonstrated a high level of efficacy in predicting odour using LDA.

The analysis identified collinearity among the predictor variables. Collinearity indicates a linear relationship between pairs of predictor variables, which can be positive or negative. High positive or negative values of collinearity can obscure the individual effect that a predictor has on the prediction of the samples. Vector normalisation had some effect on reducing the collinearity but not significantly.

This collinearity therefore carried over into the feature ratios dataset (Fig. S1). This observation is not unexpected due to the underlying relationships between the chemicals that produce these variables.

Given that bitumen is derived from crude oil, it is reasonable to expect the concentration of an alkane to be relative to other alkanes in the mixture, and the same can be expected for benzene and its derivatives. While overall there is observed collinearity, when considering the GC–MS data there are still significant variations in the ratios of analytes present in samples. Typically, collinearity raises concerns in statistical modelling due to its potential to obscure individual variable impacts.[62]

Rather than seeking to isolate the effects of individual analytes, our primary focus lies in evaluating the model's efficacy. As a result, we have consciously chosen to retain these collinear variables in our analysis to pursue a pragmatic approach by prioritising the model's practical utility.

The analysis conducted with the LDA model unveiled a clear and significant separation between groups, as depicted by the linear discriminant value (LD1) in Fig. 1. This outcome underscores the model's ability in distinguishing between the odorous and non-odorous groups.

Notably, the limited variability observed within each group suggests that the predictor variables exhibit minimal fluctuations.

Given the smaller size of the sample set CV needs to be carefully considered. Two methods for CV were carried out and compare to assess the performance of the LDA model. Firstly, a LOOCV method was used to maximise the size of the training data set. Secondly, A 5-fold crossvalidation method was used to assess the model more pessimistically. demonstrated an excellent ability to distinguish between the odorous and non-odorous groups through LOOCV. Demonstrating a 100% accuracy rate in LOOCV, as detailed in Table 3. This high accuracy helps to validate the model's competence in classifying the bitumen samples and capturing vital data associations.

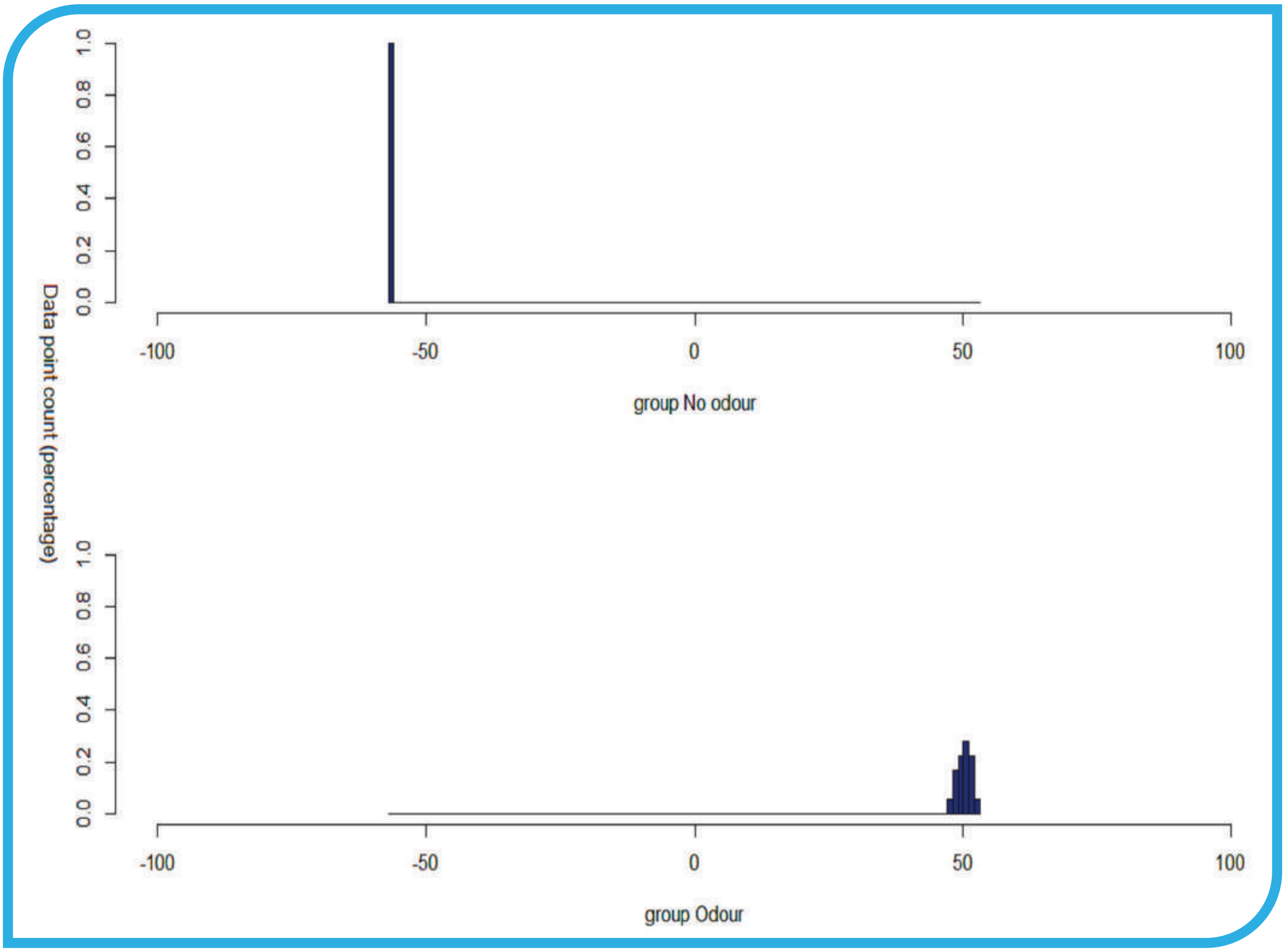


Fig. 1. LDA histogram of No odour and odour groups plotted on the first linear discriminate axis (LD1). The groups are separated along the LD1 axis, the group means are - 56.4 and 50.2 for No odour and Odour respectively, with minimal spread within each group where variance is 0.037 and 1.8 for No odour and Odour, respectively. The odour groups contain 18 samples, and the No odour group contains 16 samples.

Kappa values range from - 1 to 1 and where a kappa close to 1 indicates a good agreement between the model and the true labels of the samples, the obtained kappa value of 1 provides statistically solid evidence that the observed accuracy rate is significant and not due to chance.

Assessing the model when tunning shrinkage in LDA using a 5-fold cross-validation method yielded an equally high accuracy and kappa (Table 4).

that the LDA model demonstrated robust discriminatory power in predicting the groups. The high accuracy rate and kappa value support the notion that the observed predictions are unlikely to result from random chance.

Table 4
Five-fold cross-validation accuracy and kappa for SLDA model including optimisation metrics diagonal and lambda.

Cross-validation accuracy rate	1.0000
Cross-validation error rate	0.0000
Kappa	1.0000
Diagonal	0
Lambda	0.1

Thus, the LDA model exhibits reliable predictive capabilities for distinguishing between the odour and no odour groups.

Implementing methods for detecting odorous bitumen before deployment may minimise the occurrence of worker complaints, interventions by environmental regulatory agencies, and the need for deodorising and masking treatments.

These methods can result in cost savings and smoother project execution while reducing odour pollution in surrounding areas.
Given the intricate nature of odorous emissions in complex organic mixtures, it is essential to employ methods considering a range of organic chemicals and their interactions contributing to odour.

Statistical methods like LDA, in conjunction with analytical instruments, present a methodology capable of considering the complexity of odour in bituminous materials.

These approaches are particularly valuable when a training dataset is accessible, as they allow for a comprehensive examination of the complex relationships involved.

While the response of arenes and alkanes in bitumen do not correlate with odour directly based on their relative responses from GC–MS, when considering the ratios of these chemicals collectively with appropriate statistical methods, odorous samples can repeatably be distinguished from non-odorous samples using an LDA model.

This suggests that the 11 selected alkanes and arenes are significant contributors to poor odour in bitumen. While other VOCs that contain nitrogen, oxygen and sulfur and have various levels of saturation are likely to contribute to bitumen odour (Table S1), these findings suggest a previously unexplored association between bitumen odour and alkanes and arenes. Although novel in the context of bitumen, such association are not unprecedented in other industries, where these chemical classes have been contributors in the generation of poor odour.[67]

While isolated alkanes or benzene derivatives may exhibit relatively benign scents,[68] their presence in bitumen, combined with other volatile compounds, can give rise to complex odour profiles.

Their role as potential odour predictors in bitumen extends beyond their individual scent profiles.[67,69] The perception of odour is highly dependent on the mixtures' specific chemical composition.
Some mixtures may elicit the perception of distinct individual odours, exhibiting varying degrees of dominance and blending. Conversely, certain mixtures may present a homogeneous blend where only one component predominates the perceived odour. Furthermore, mixtures can generate a unique, collective odour attributed to the overall composition of the mixture.[55] Research has illustrated how mixtures of chemicals with each component below its respective odour threshold can still be perceptible by participants when combined. These mixtures can exhibit an additive or hyper-additive effect in regards to detectability and odour intensity, enhancing detectability beyond the contributions of the individual components alone.[41]

In this context, the alkanes and arenes measured in this work contribute significantly to the complex odour profile of bitumen where the synergy of various compounds, rather than the inherent odour of individual components, ultimately defines the odorous characteristics of bitumen. By considering these compounds not as direct sources of malodour but as contributors to a complex odour profile, we gain a more nuanced understanding of how bitumen emissions generate distinct odours. This perspective encourages the exploration of predictive models that consider the combinations of different chemical constituents, providing valuable insights into the factors contributing to odorous bitumen products.

4. Conclusion

This study employed LDA to predict odorous bitumen using chemical information from bitumen emissions. The proposed methodology demonstrated a high level of effectiveness in discriminating among eight odorous and eight non-odorous globally sourced samples, achieving a 100% accuracy rate when assessed using LOOCV and 5-fold crossvalidation SLDA. Our findings highlight the substantial contribution of alkanes and arenes to the manifestation of poor odour in bitumen emissions.

Integrating statistical tools, such as LDA, with analytical instruments provides a comprehensive approach to understanding the intricate odour profiles in bituminous materials. While individual compounds may not exhibit a direct correlation with odour, their collective interactions play a significant role in shaping distinct odorous characteristics. Further research is imperative to precisely understand how these compounds influence odour production in bituminous materials.

Implementing pre-deployment methods for detecting odorous bitumen can be a practical solution to alleviate worker complaints, mitigate regulatory interventions, and reduce the need for additional treatments. These measures can result in cost savings and contribute to smoother project execution and a notable reduction in odour pollution within the surrounding areas of paving projects. By prioritising the prediction of odorous bituminous materials, we can effectively limit the entry of poor-quality products into the market. This proactive perspective not only ensures the delivery of high-quality bitumen but also contributes to a substantial reduction in odour pollution from bitumen.

As our work provides a foundation for future investigations,
it is evident that ongoing research efforts are crucial to advancing our understanding of the complexities involved in bitumen odour and refining predictive models for enhanced industry practices.

Author Contributions.

Zachary Deller did the conceptualization and writing of the original manuscript draft. Filippo Giustozzi and Subashani Maniam did the supervision, funding acquisition and project development. The manuscript was written through contributions of all authors. All authors have given approval to the final version of the manuscript.

CRediT authorship contribution statement Zachary Deller: Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. Filippo Giustozzi: Writing – review & editing, Supervision, Project administration. Subashani Maniam: Writing – review & editing, Supervision, Project administration.

Declaration of competing interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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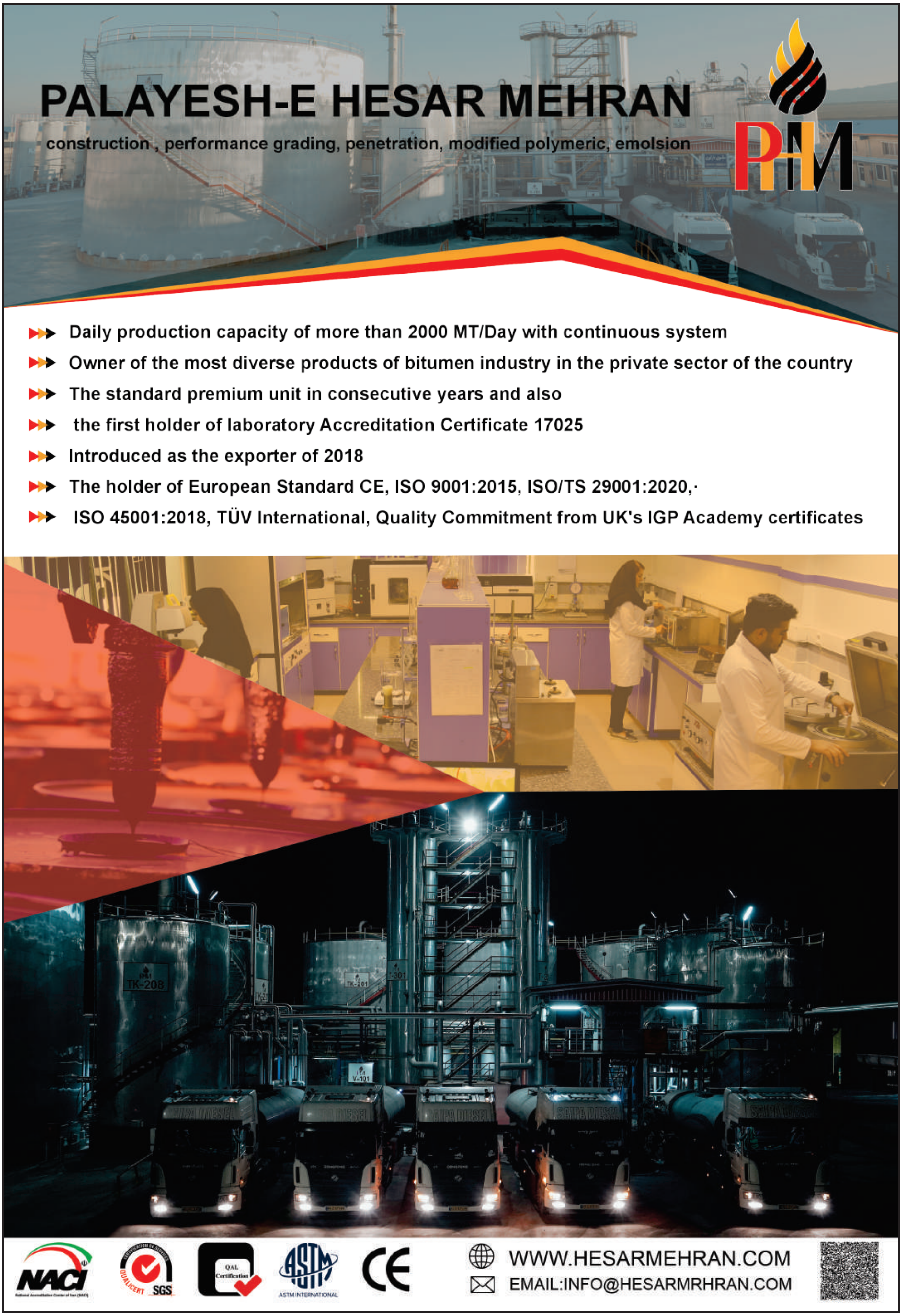
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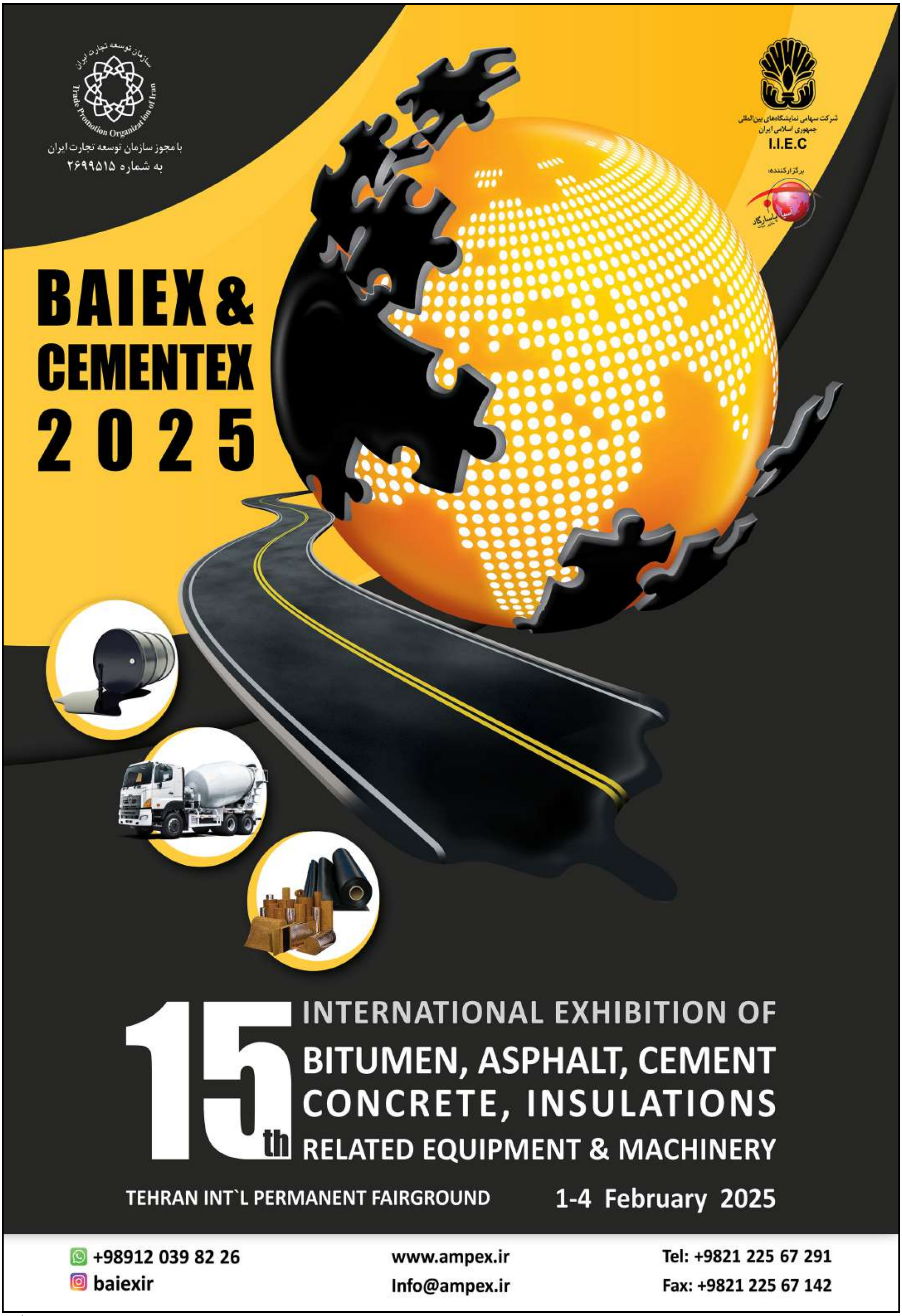
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