The impact of contemporary socio-economic and technological factors on container terminal performance

Received 10 March 2023
Revised 25 June 2023
Accepted 19 September 2023

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Abstract

Purpose – This present study uses political, economic, social, technological, legal and environmental (PESTLE) analysis and the strategic management theory to examine how external factors, namely the coronavirus (COVID-19) pandemic, the industrial revolution (IR) 4.0 technologies, the fuel price crisis and Sultanate of Oman Logistics Strategy (SOLS) 2040, affect the performance of container terminals in Oman.

Design/methodology/approach – A hybrid decision-making method that combined the analytical hierarchy process technique and Bayesian network model was used to achieve the objective of the present study.

Findings – The COVID-19 pandemic (54.60%) most significantly affected the performance of container terminals in Oman, followed by IR 4.0 technologies (19.66%), SOLS (17.00%) and fuel price crisis (8.74%). Container terminals in Oman were also found to perform "moderately," considering the uncertainty of external factors.

Research limitations/implications – This study enriches existing literature by using PESTLE analysis to assess the impact of the external business environment on firm performance in the context of the maritime industry as well as highlights how challenging external environmental factors affect the performance of container terminals in Oman.

The authors would like to thank all the expert respondents for their cooperation and willingness to participate in the survey and interview sessions. Their invaluable insights and contributions enabled us to produce good results, particularly in determining the performance of container terminals in Oman amidst emerging external factors.

Arab Gulf Journal of Scientific Research
Emerald Publishing Limited
e-ISSN: 2536-0051
p-ISSN: 1985-9899
DOI 10.1108/AGJSR-03-2023-0106

Originality/value – This study contributes to developing novel study models and determining the performance level of container terminals in Oman considering integrated uncertainties and external factors such as the COVID-19 pandemic, IR 4.0 technologies, the SOLS 2040 and the fuel price crisis.

Keywords COVID-19 pandemic, Port operations and management, Container terminal performance, Bayesian network method, Socio-economic, Maritime logistics

Paper type Research paper

Introduction

Oman is strategically positioned in the Middle East, in the south-eastern quarter of the Arabian Peninsula. Oman, which is a part of the Cooperation Council for the Arab States of the Gulf, which is also colloquially called the Gulf Cooperation Council (GCC), is the only GCC nation located outside of the Gulf (Oxford Business Group, 2020) and the only GCC nation that faces both the Arabian Sea and the Gulf of Oman (Calabrese, 2018).

To capitalise on its strategic location and to become a global logistics centre and an engine of economic diversification in the region, Oman has invested in its infrastructure (Oxford Business Group, 2020) and committed to development plans across the GCC (Ziadah, 2018), such as the expansion of marine ports, roads, railways, airports and logistics cities which are expected to change its economic landscape.

The ports of Salalah, Sohar and Duqm are the primary Omani container ports engaged in local and international cargo flow. While Sohar Port, in the north, and Salalah Port, in the south, aim to foster import–export market operations and attract foreign investments, Duqm Port is the political focal point for strengthening relations between Iran and the Arab world (Al-Wahaibi, 2019). As it has been operating since November 1998, Salalah Port is one of the world's leading container ports (Port of Salalah, 2020) and, therefore, plays a vital role in the economic future of the Sultanate of Oman.

Oman has experienced significant developments in infrastructure, policies and services that diversify its economy, especially that of its logistics industry. However, this has not rendered the Sultanate immune to the far-reaching impacts of global macroeconomic and structural challenges in other countries (Al-Wahaibi, 2019; United Nations, 2020) in the last few years.

Adopting technologies from the fourth industrial revolution (IR 4.0) technologies and implementing the Sultanate of Oman Logistics Strategy (SOLS) 2040 demand strong commitment and investment to create robust and inclusive economic growth. However, the country now faces significant pressure to commit to these adoptions due to unprecedented phenomena, such as the fuel price crisis and the coronavirus (COVID-19) pandemic, which have caused simultaneous supply and demand shocks, resulting in economic uncertainty (International Monetary Fund, 2020).

Therefore, given the limited availability of empirical studies, it is apt to examine the effect and magnitude of socioeconomic and technological factors, namely, the fuel price crisis, the COVID-19 pandemic, the SOLS 2040 and IR 4.0 technologies, on the performance of Omani container terminals.

Theoretical basis and literature review

Effect of external factors on port performance via PESTLE analysis

PESTLE analysis, formerly called PEST analysis (Aguilar, 1967), is a mnemonic listing of the sources of change, namely, political, economic, social, technological, legal and environmental, in the external environment of a firm. It extensively uses various socio-economic, business and strategic management contexts to examine and analyse how these factors influence the performance of a firm. Several studies on port management have used PESTLE analysis to examine the effects of external factors on throughput. For instance, Le and Nguyen (2020) investigated the influence of policy, operational and market conditions on seaport efficiency in Vietnam and concluded that these factors significantly impacted port performance. Meanwhile, Ojadi and Walters (2015) highlighted that policies by state agencies and government-appointed service providers were among the predictors of seaport efficiency in Lagos, Nigeria.

Yang *et al.* (2014), on the other hand, empirically studied port traffic data between 1952 and 2009 in China and examined the impact of politics, economic events and port policies. It concluded that institutional factors, such as the Great Leap Forward campaign and reforms in port governance, had long-lasting and positive effects on port throughput. Moreover, other economic and political factors, such as accession to the World Trade Organisation (WTO), were the primary drivers of port throughput in China.

Bergantino and Musso (2011) similarly concluded that governance-related factors and macro-economic conditions significantly affect change and management skills at Southern European ports. Meanwhile, Abdul Rahman *et al.* (2014) examined how the opening of the Northern Sea Route affected the Malaysian maritime sector and economy. A few years later, Abdul Rahman *et al.* (2016) used PESTLE analysis to examine the probable effects of Thailand's decision on Kra Canal project on market trends in Malaysia's maritime industry and proposed new maritime and logistics business strategies. Therefore, the literature review clearly shows that external factors significantly impact port performance, particularly throughput and efficiency.

Current external factors and port performance

Oman is a developing economy situated in Western Asia (United Nations, 2020). It faces challenges concerning robust economic growth, especially in implementing strategies, such as IR 4.0 technologies and the SOLS 2040, that strengthen the economy. Declining fuel prices and the public health response to the COVID-19 pandemic caused Oman's economy to shrink in 2020 (World Bank, 2020). While low fuel prices and the COVID-19 pandemic are key challenges that Oman will need to navigate in the short run, implementing IR 4.0 technologies and the SOLS 2040 are critical long-term challenges that the country must address to ensure sustainable economic growth. These four issues are discussed further in the following paragraphs.

The coronavirus (COVID-19) pandemic. Coronavirus (COVID-19) is an infectious disease caused by the Coronaviridae family of viruses. First detect at the end of 2019 (World Health Organization, 2020; UNDP, 2020), the resulting global health crisis is considered the greatest challenge the world has faced since Second World War (UNDP, 2020) as it negatively affected all sectors of business, especially retail, services and tourism (World Bank, 2020).

The COVID-19 pandemic decreased the volume of imports and exports at ports (Prabhu, 2020). For instance, the usually booming container terminal at the Port of Baltimore shortened its operating hours on 1 March 2020 due to fewer incoming cargo (Campbell, 2020). Container ports in India, however, predicted a double-digit decrease in volume (Mathew, 2020), while Mexican container ports braced for a slump in incoming cargo (Morley, 2020).

In Oman, the Port of Salalah expected the COVID-19 pandemic to negatively affect its primary transhipment sector and decrease its imports and exports by 20% that year (Prabhu, 2020). Although the future of Salalah Port appears optimistic in the short run, its long-term future remains uncertain as global demand has steadily decreased and the supply chain is unstable (Prabhu, 2020).

Fuel price crisis. Although plummeting fuel prices will, undoubtedly, impact the income of oil-exporting countries, their impacts on container terminal operations are varied as they depend on various other factors such as logistics and production activities that largely determine the trade volumes of ports. As the impacts of lower fuel prices on container terminals is not straightforward, its impact on other sectors, such as logistics (Loh & Thai, 2015; Meuller, Wiegmans, & van Duin, 2020; Gocmez, 2020) and manufacturing (Loh & Thai, 2015), significantly affect the performance of container terminals, especially the flow of import and export cargo at these terminals. In the container and logistics industries, fuel prices mostly affect bunker fuel prices and container freight rates as fuel prices are expected to be lower and more volatile during periods of sharp decline (Gocmez, 2020; Direct Drive Logistics, 2020). Therefore, fluctuations in fuel prices may indirectly affect the performance of container terminals, via the logistics industry, as the fluctuations in bunker fuel prices and container freight rates tend to affect the volume of trade traffic (Direct Drive Logistics, 2020).

Volatile fuel prices may also cause disruptions in port-related supply chains (Loh & Thai, 2015). For instance, fuel prices can influence production rates in the manufacturing sector, subsequently determining the volume of import and export cargo (Loh & Thai, 2015). According to Loh and Thai (2015), production rates are largely determined by fuel price, forecasted selling price and seasonal peaks contributing to consumer product demand. However, since the drop in global fuel prices coincides with the COVID-19 pandemic, there is heightened uncertainty due to a sharp reduction in demand. Hence, container terminals must be empirically observed based on the current situation instead of relying on previous data, particularly in the case of Oman.

The fourth industrial revolution (IR 4.0) technologies. IR 4.0 technologies emerged when Germany pioneered the fourth IR in 2012 (Foenna, Kamal, & Ating, 2020). The primary goal of the initiative was to support current high-technology industries which incorporate German technological leadership, promote digitalisation, enhance the goods supply chain, uphold the research industry and act as a benchmark for standardisation in that country (Zhou, Liu, & Zhou, 2015; Androniceanu, 2017; de Sousa Jabbour, Jabbour, Foropon, & Filho, 2018; Foenna *et al.*, 2020). The IR 4.0 technologies' framework originated because of the 2011 high-tech strategy of the German government, which promotes the computerisation of manufacturing in the long term (Klitou, Conrads, Rasmussen, Probst, & Pedersen, 2017; Foenna *et al.*, 2020).

Although the IR 4.0 system is much more complex than its three predecessors, the transition is taking place as more industries slowly shift towards more advanced technologies (Foenna *et al.*, 2020). In this regard, production rates will increase, and industries will operate in more diverse and automated environments.

As more countries transition to using IR 4.0 technologies, Oman, too, has developed a digital strategy with which to build a foundation that significantly benefits from the adoption of IR 4.0 technologies (Digital Oman, 2020). The goals of the Digital Oman 2030, or the e.Oman 2030 strategy, include:

(1) Increasing the gross domestic product (GDP) share of the information technology (IT) industry.

(2) Providing digitised, smart and inclusive public services.

(3) Becoming one of the top 20 e-transformation countries.

(4) Creating digital technology jobs.

(5) Creating digital technology start-ups.

(6) Positioning Oman within the top 10 countries for cybersecurity and trust, which it has currently achieved.

One of the main pillars of the e.Oman 2030 strategy is the growth of digital industry, which involves creating a digital marketplace and digital solutions for economic diversification. Research and innovation have also been identified as methods by which Oman can gain knowledge and become a digital leader (Digital Oman, 2020). Implementing IR 4.0 technologies in the superstructure and infrastructure of ports will enable them provide competitive and highly efficient services that will, in turn, attract more trade. For instance, the remote-controlled giant cranes at Oman's container terminals can handle the largest of container ships, which gives them a competitive advantage that attracts international shipping traffic.

Sultanate of Oman Logistics Strategy (SOLS) 2040. The development of the logistics industry is the key to integrating global trade in multiples modes of transportation. As such, most logistics companies are hard at work aligning their business with global practices to reap benefits in the future. This also applies to Oman's logistics industry. As such, the Oman Global Logistics Group (OGLG) has proposed a strategic plan to achieve the SOLS 2040.

The SOLS 2040 is a blueprint for transforming Oman into one of the top 10 logistics hubs in the world by 2040 (Oman Logistics Center, 2015) by integrating four different modes of logistics; namely, sea, air, road and rail transportation. Due to its geographical advantage, Oman is an important logistical leader in the Gulf and the Indian Ocean. The SOLS 2040, which was published in February 2015, identified the transport and logistics industry as one of the top five priority sectors of the country (Oxford Business Group, 2020). The Oman Logistics Centre (OLC) oversees the execution of the four main pillars of the SOLS 2040, namely, market segmentation, trade facilitation, human capital and technology applications. The SOLS aim to achieve the following goals by 2040:

(1) Increasing the contribution of real-time logistics to the GDP by more than nine-fold to account for 12% of the total GDP.

(2) Increasing employment by 10-fold and creating 300000 more job opportunities.

(3) To become one of the top five to 10 countries in relevant trade and logistics rankings.

(4) To be perceived as a global logistics hub by 2030.

Although external factors affect Oman's container terminals, the magnitude of their influence remains unknown as they have not been analysed or compared, especially in the context of Oman. Therefore, this present study examines how external factors, such as the COVID-19 pandemic, the adoption of IR 4.0 technologies, the fuel price crisis and the implementation of the SOLS 2040, affect the performance of container terminals in Oman as well as the magnitude of their influence.

Methodology

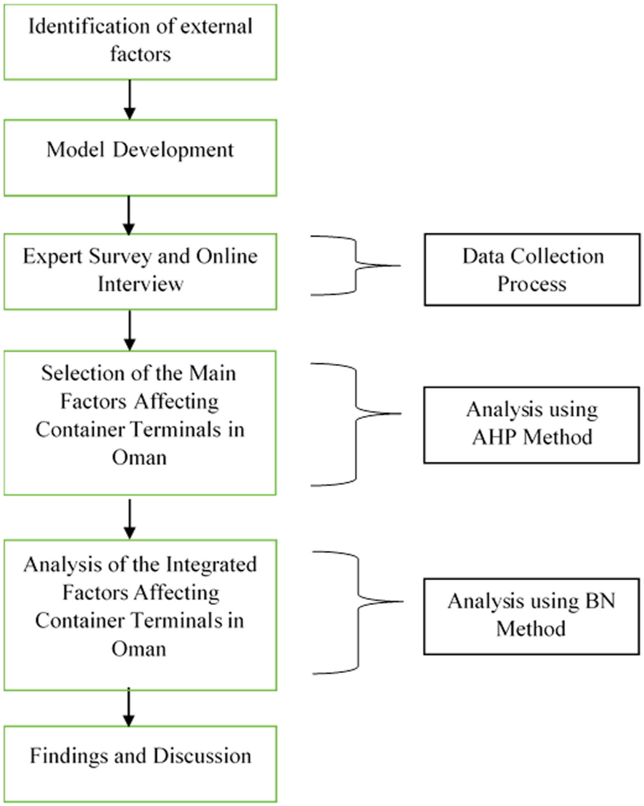
Figure 1 depicts the six steps of the systematic approach used to achieve the objectives of this present study.

External factor identification

As previously mentioned, the four external factors that affected ports in 2020 were the COVID-19, IR 4.0 technologies, the fuel price crisis and the SOLS 2040. These four factors were selected as they occurred in 2020 and may affect the performance of Oman's container terminal industry.

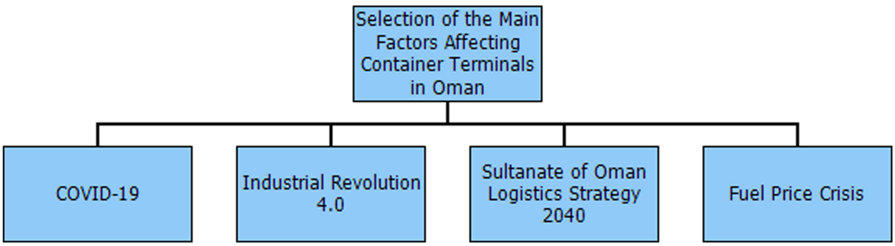
Model development

Two decision-making models were developed based on the findings of the literature review (Figures 2 and 3). Figure 2 depicts the structure of the analytical hierarchy process (AHP) that was used to select the main factors affecting the performance of the container terminal



Source(s): Figure by authors

Figure 1. Flow of this present study



Source(s): Figure by authors

Figure 2. The hierarchy of the AHP decision model used to select the main factors affecting the performance of container terminals in Oman

industry in Oman, while Figure 3 illustrates the Bayesian network (BN) model, which is a probabilistic graphical model, was used to analyse the combination of factors affecting container terminal performance in Oman.

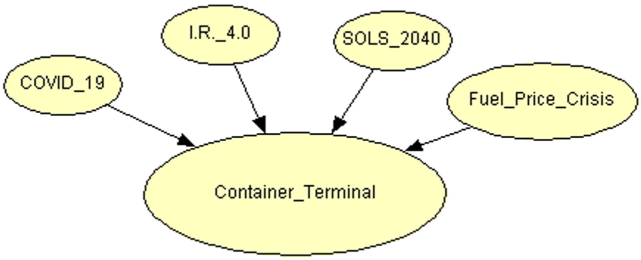
The nodes, or factors, of the BN model were “COVID-19,” “IR 4.0,” “SOLS 204” and “Fuel Price Crisis.” Each node in Figure 3 denotes the strength of causal dependence or “states.” These states aimed to determine the impact if a node was affected. Table 1 lists the nodes and states used in the BN model to measure the performance of container terminals.

Data collection
Purposive sampling, specifically nonprobability sampling, was used to identify industry experts to serve as respondents. Port operators, container terminal operators and academics with relevant knowledge, experience and perceptions of the container terminal industry of Oman were selected. The selection criteria included decision-makers, operators at or above supervisor positions, at least five years of experience working in the container terminal industry and possessing knowledge related to the container terminal industry. As such, 15 experts were sent online interviews and surveys to collect qualitative data. Of these, only 10 experts returned completed survey questionnaires with valid and reliable information, while two respondents overlooked the survey and the remaining three did not return the survey.

Data analysis
A hybrid decision-making method that combines both the AHP and the BN model was used to analyse the collected data. A detailed explanation of both methods is presented in the following sections.

Analytical hierarchy process (AHP). The AHP (Saaty, 1980, 1994) is a mathematical structure comprising compatible matrices and their corresponding vectors that can generate actual or estimated weights by comparing the parameters or alternatives of a criterion, such as the pairwise comparison model. The n parameters were first specified to implement the pairwise comparison matrix (Saaty, 1994; Abdul Rahman, Ismail, Othman, MohdRoslin, & Lun, 2018) before a ratio scale assessment was used to conduct a pairwise analysis of all the parameters (Saaty, 2001, 2008; Abdul Rahman & Ahmad Najib, 2017).

The qualified judgements on the A_i and A_j pair attributes were represented by an $n \times n$ matrix A, as seen in Equation (1) (Abdul Rahman *et al.*, 2018, 2023; Othman, Abdul Rahman, Ismail, & Saharuddin, 2020).



Source(s): Figure by authors

Figure 3. The BN probabilistic graphical model used to analyse the combination of factors affecting the performance of container terminals in Oman

No.	Nodes	States
1	COVID-19	maximum affect, minimum affect
2	Industrial Revolution 4.0 (IR 4.0)	maximum affect, minimum affect
3	Sultanate of Oman Logistics Strategy (2040; SOLS 2040)	important and urgent, important but not urgent
4	Fuel price crisis	maximum affect, minimum affect
5	Container terminal	good performance, moderate performance, bad performance

Source(s): Table by authors

Table 1. Nodes (factors) and states used in the BN model

$$A = (a_{ij}) = \begin{bmatrix} 1 & a_{12} & \ldots & a_{1n} \\ a/a_{12} & 1 & \ldots & a_{2n} \\ . & . & \ldots & . \\ 1/a_{1n} & 1/a_{2n} & \ldots & 1 \end{bmatrix} \quad \text{(Eq. 1)}$$

where $i, j = 1, 2, 3, \ldots, n$ and each a_{ij} is the relative impact of the A_i attribute to the A_j attribute.

Equation (2) was then used to calculate the weight value of this matrix (Othman *et al.*, 2018, 2020; Abdul Rahman *et al.*, 2023).

$$w_k = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}}\right) \ (k = 1, 2, 3, \ldots, n) \quad \text{(Eq. 2)}$$

where a_{ij} is the entry of row i and column j in a comparison matrix of order n.

For better accuracy, a consistency ratio (*CR*) was used to verify the weights of the pairwise comparison matrix via Equations (3) to (5) (Saaty, 1994; Abdul Rahman *et al.*, 2019, 2023):

$$CR = \frac{CI}{RI} \quad \text{(Eq. 3)}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad \text{(Eq. 4)}$$

$$\lambda_{max} = \frac{\sum_{j=1}^{n} \frac{\sum_{k=1}^{n} w_k a_{jk}}{w_j}}{n} \quad \text{(Eq. 5)}$$

where n is the number of items compared, λ_{max} is the for maximum weight of the $n \times n$ comparison matrix, *RI* is the average random index (Table 2) and *CI* is the consistency index (Saaty, 2008; Othman *et al.*, 2020).

If the *CR* exceeds 0.10, it indicates an inconsistency. The accuracy of the comparisons is only acceptable if the *CR* is ≤ 0.10 (Saaty, 1980). However, Park and Kim (2014) argue that the *CR* can still be accepted or considered to possess a permissible consistency, even if it is < 0.20. Therefore, a *CR* of 0.10 to 0.20 was considered acceptable. The AHP was used to select the main external factors affecting container terminals in Oman. The main factors were selected based on the highest weights of the four identified external factors.

Bayesian network (BN) model. Bayes' theorem is a mathematical formula used to measure *posterior probability* (Abdul Rahman, Yang, Bonsall, & Wang, 2012) and calculate logical confidence in probabilities. Equation (6) provides a representation of the fundamental rule of probability calculus:

Table 2. Average random index (*RI*) values

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Source(s): Table by authors

$$P(A,B) = P(A|B)\,P(B) \quad \text{(Eq. 6)}$$

In a simple version of Bayes' theorem, the $P(A,B)$ is called a *joint probability*. If the model parameter is a discrete variable, then the formal definition of Bayes' theorem can be simplified as:

$$P(A|B) = \frac{P(B|\,A)\,P(A)}{P(B)} \quad \text{(Eq. 7)}$$

where "|" means "given" or "on the condition of," $P(A)$ is the *prior probability* of A occurring, $P(A|B)$ is the *posterior probability* of A occurring under the condition that B has already occurred; $P(B|A)$ is the *conditional probability* of A occurring although B has already occurred; $P(B)$ is the *marginal probability* of B occurring and is effectively constant for the data at hand (Abdul Rahman, 2013).

This equation was used to analyse the effect of the four identified external factors, namely, the COVID-19 pandemic, IR 4.0 technologies, the fuel price crisis and the SOLS 2040, on the performance of container terminals in Oman.

Findings

Identifying the most significant factors affecting container terminal performance in Oman

This section discusses the first decision-making model, the AHP (Figure 2). Table 3 depicts the weight calculations for each factor using a pairwise comparison matrix. Factors with the highest weights had the most influence on container terminal performance in Oman.

Table 4 provides a summary of the *A(CISF)* performance matrix.

Equation (2) was used to determine the weight of all the main factors. The weight of the "COVID-19" factor was calculated as:

$$w_{COVID-19} = \frac{0.5802 + 0.6802 + 0.5078 + 0.4159}{4} = 0.5460$$

where the weight of the "COVID-19" factor was 0.5460. The weights of all the other factors were similarly calculated. Table 5 lists the results of the weight calculations. After obtaining the weight value of each factor, the value need to be multiplied with the pairwise comparison matrixas shown in Table 6.

The *CR* of the pairwise comparison was then calculated by multiplying each value in the pairwise comparison matrix column (Table 3) with the weight of each factor (Table 5):

	COVID-19	IR 4.0	SOLS 2040	Fuel price crisis
COVID-19 (C)	1	4.2	3.8	4.5
IR 4.0 (I)	1/4.2	1	2.4	1/0.5583
SOLS 2040 (S)	1/3.8	1/2.4	1	1/0.2833
Fuel price crisis (F)	1/4.5	0.5583	0.2833	1
SUM	*1.7235*	*6.1750*	*7.4833*	*10.821*

Source(s): Table by authors

Table 3. Pairwise comparison matrices of the main factors

COVID-19	1 ÷ 1.7235=0.5802	4.2 ÷ 6.1750=0.6802	3.8 ÷ 7.4833=0.5078	4.5 ÷ 10.821=0.4159
IR 4.0	1/4.2 ÷ 1.7235=0.1382	1 ÷ 6.1750=0.1619	2.4 ÷ 7.4833=0.3207	1/0.5583 ÷ 10.821=0.1655
SOLS 2040	1/3.8 ÷ 1.7235=0.1527	1/2.4 ÷ 6.1750=0.0675	1 ÷ 7.4833=0.1336	1/0.2833 ÷ 10.821=0.3262
Fuel price crisis	1/4.5 ÷ 1.7235=0.1289	0.5583 ÷ 6.1750=0.0904	0.2833 ÷ 7.4833=0.0379	1 ÷ 10.821=0.0924

Source(s): Table by authors

Table 4. The performance matrices of each main factor

Table 7 provides a summary of the above calculation.

Equation (5) was used to calculate the $\frac{\sum_{k=1}^{n} w_k a_{jk}}{w_i}$, where the total value of each factor (Table 7) was divided by its corresponding weight (Table 5):

$$\frac{2.4110}{0.5460} = 4.4157; \ \frac{0.8912}{0.1966} = 4.5331; \ \frac{0.7041}{0.1700} = 4.1418; \ \frac{0.3667}{0.0874} = 4.1956$$

The λ_{max} was calculated as:

$$\lambda_{max} = \frac{4.4157 + 4.5331 + 4.1418 + 4.1956}{4} = 4.3215$$

The CI was then calculated using Equation (4):

$$CI = \frac{4.3215 - 4}{4 - 1} = 0.1072$$

The CR was determined using Equation (3). As the analysis involved four factors, the RI was 0.9000 (Table 3) and the CR of the evaluated factors was:

$$CR = \frac{0.1072}{0.9000} = 0.1191$$

As previously mentioned, only CRs ranging between 0.10 and 0.20 would be considered to possess acceptable accuracy. As the four factors had a CR of 0.1191, they were deemed accurate. Therefore, the AHP analysis results indicated that COVID-19 pandemic was the

					Total	Weight value
COVID-19	0.5802	0.6802	0.5078	0.4159	2.1841 ÷ 4=	0.5460
IR 4.0	0.1382	0.1619	0.3207	0.1655	0.7863 ÷ 4=	0.1966
SOLS 2040	0.1527	0.0675	0.1336	0.3262	0.6800 ÷ 4=	0.1700
Fuel price crisis	0.1289	0.0904	0.0379	0.0924	0.3496 ÷ 4=	0.0874

Source(s): Table by authors

Table 5.
The weight values of the evaluated factors

	COVID-19			IR 4.0			SOLS 2040			Fuel price crisis
0.5460	1	+	0.1966	4.2	+	0.1700	3.8	+	0.0874	4.5
	1/4.2			1			2.4			1/0.5583
	1/3.8			1/2.4			1			1/0.2833
	1/4.5			0.5583			0.2833			1

Source(s): Table by authors

Table 6.
Calculations of each evaluated factor

					Total
COVID-19	0.5460	0.8257	0.6460	0.3933	2.4110
IR 4.0	0.1300	0.1966	0.4080	0.1566	0.8912
SOLS 2040	0.1437	0.0819	0.1700	0.3085	0.7041
Fuel price crisis	0.1213	0.1098	0.0482	0.0874	0.3667

Source(s): Table by authors

Table 7.
The total value calculations of each evaluated factor

most important factor affecting container terminal performance in Oman as its weight was 0.5460 or 54.60%. This was followed by IR 4.0 technologies (0.1966, 19.66%), the SOLS 2040 (0.1700, 17.00%) and the fuel price crisis (0.0874, 8.74%).

Analysis of the performance of container terminals in Oman

This section discusses the second decision-making model, the BN (Figure 3), and the calculations used to analyse the compounding effect of all four external factors on the performance of Oman's container terminal industry. Bayesian network (BN) software from HUGIN EXPERT was used to conduct the analysis. Table 1 provides a list of the abbreviations used. For instance, the scenarios in Figure 3 were analysed as follows:

The conditional probability table (CPT) of the *COVID-19 pandemic (without conditions)*

COVID-19 pandemic

maximum effect	0.7000
minimum effect	0.3000

For example, P(*COVID-19 = maximum effect*) = 0.7000

The CPT of *IR 4.0 technologies (without conditions)*

IR 4.0 technologies

maximum effect	0.6000
minimum effect	0.4000

For example, P(*IR 4.0 = maximum effect*) = 0.6000

The CPT of the *SOLS 2040 (without conditions)*

SOLS 2040

important and urgent	0.6000
Important but not urgent	0.4000

For example, P(*SOLS 2040 = important and urgent*) = 0.6000

The CPT of the *fuel price crisis (without conditions)*

Fuel price crisis

maximum effect	0.2000
minimum effect	0.8000

For example, P(*Fuel Price Crisis = maximum effect*) = 0.2000

The CPT of the *container terminals (with conditions)*

Container terminal

Fuel Price Crisis	maximum affect								minimum affect							
COVID-19	maximum affect				minimum affect				maximum affect				minimum affect			
SOLS 2040	important and urgent		important but not urgent		important and urgent		important but not urgent		important and urgent		important but not urgent		important and urgent		important but not urgent	
I.R. 4.0	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect	maximum affect	minimum affect
Good Performance	0.1000	0.2395	0.2680	0.2210	0.3815	0.3750	0.3911	0.5246	0.0755	0.2245	0.2217	0.1850	0.2719	0.2062	0.6570	0.7450
Moderate Performance	0.2020	0.3313	0.3402	0.4840	0.4639	0.5313	0.5124	0.4271	0.3581	0.2577	0.3251	0.5520	0.6210	0.6931	0.2630	0.2070
Bad Performance	0.6980	0.4292	0.3918	0.2950	0.1546	0.0937	0.0965	0.0483	0.5664	0.5178	0.4532	0.2630	0.1071	0.1007	0.0800	0.0480

For example, P(Container Terminal = Good Performance | IR 4.0 = maximum effect, SOLS 2040 = important and urgent, COVID-19 = maximum effect, Fuel Price Crisis = minimum effect) = 0.0755

The *conditional probabilities* that the CPT provided for each node were used to calculate the *prior probabilities*. For instance, Equation (6) was used to determine the *prior probability* of the "*Container Terminal=moderate performance*" node:

P(*Container Terminal=moderate performance*)=∑P(Fuel Price Crisis=*maximum effect*, Fuel Price Crisis=*minimum effect*, COVID-19=*maximum effect,* COVID-19=*minimum effect,* SOLS 2040=*important and urgent,* SOLS 2040=*important but not urgent, IR 4.0=maximum effect,* IR 4.0=*minimum effect*):

$$
\begin{aligned}
&= (0.2020 \times 0.6 \times 0.6 \times 0.7 \times 0.2) + (0.3313 \times 0.4 \times 0.6 \times 0.7 \times 0.2) \\
&\quad + (0.3402 \times 0.6 \times 0.4 \times 0.7 \times 0.2) + (0.484 \times 0.4 \times 0.4 \times 0.7 \times 0.2) \\
&\quad + (0.4639 \times 0.6 \times 0.6 \times 0.3 \times 0.2) + (0.5313 \times 0.4 \times 0.6 \times 0.3 \times 0.2) \\
&\quad + (0.5124 \times 0.6 \times 0.4 \times 0.3 \times 0.2) + (0.4271 \times 0.4 \times 0.4 \times 0.3 \times 0.2) \\
&\quad + (0.3581 \times 0.6 \times 0.6 \times 0.7 \times 0.8) + (0.2577 \times 0.4 \times 0.6 \times 0.7 \times 0.8) \\
&\quad + (0.3251 \times 0.6 \times 0.4 \times 0.7 \times 0.8) + (0.552 \times 0.4 \times 0.4 \times 0.7 \times 0.8) \\
&\quad + (0.621 \times 0.6 \times 0.6 \times 0.3 \times 0.8) + (0.6931 \times 0.4 \times 0.6 \times 0.3 \times 0.8) \\
&\quad + (0.263 \times 0.6 \times 0.4 \times 0.3 \times 0.8) + (0.207 \times 0.4 \times 0.4 \times 0.3 \times 0.8)
\end{aligned}
$$

$$
\begin{aligned}
&= 0.01018 + 0.01113 + 0.01143 + 0.01084 + 0.01002 + 0.00765 + 0.00738 + 0.00410 \\
&\quad + 0.07219 + 0.03463 + 0.04369 + 0.04946 + 0.05365 + 0.03992 + 0.01515 + 0.00795
\end{aligned}
$$

$$= 0.3894$$

The *prior probability* of the "*Container Terminal=moderate performance*" node was 0.3894. As seen in Figure 4, the BN software from HUGIN EXPERT can also be used to obtain these values.

The pre-posterior analysis calculated the *prior probability* of the "*Container Terminal*" node. The node "*Container Terminal=bad performance*" was then entered with a piece of data to define its updated *posterior probability*. Equation (7) was used to calculate the *posterior probability* of the "*Container Terminal=bad performance*" node with "*COVID-19=maximum effect*":

$$\mathrm{P(Container\ Terminal = bad\ performance \mid COVID-19 = maximum\ effect)}$$

$$= \frac{\mathrm{P(COVID-19 = maximum\ effect, Container\ Terminal = bad\ performance)}}{\mathrm{P(COVID-19 = maximum\ effect)}}$$

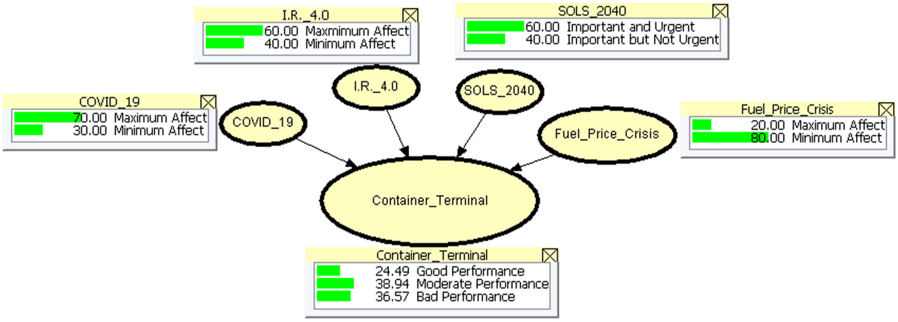
$$= \frac{\sum \mathrm{P(COVID-19 = maximum\ effect, Container\ Terminal = bad\ performance\ Fuel\ Price\ Crisis = maximum\ effect, Fuel\ Price\ Crisis = minimum\ effect, SOLS\ 2040 = important\ and\ urgent, SOLS\ 2040 = important\ but\ not\ urgent, IR\ 4.0 = maximum\ effect, IR\ 4.0 = minimum\ effect)}}{\mathrm{P(COVID-19 = maximum\ effect)}}$$

$$= \frac{(0.698 \times 0.6 \times 0.6 \times 0.7 \times 0.2) + (0.4292 \times 0.4 \times 0.6 \times 0.7 \times 0.2) + (0.3918 \times 0.6 \times 0.4 \times 0.7 \times 0.2) + (0.295 \times 0.4 \times 0.4 \times 0.7 \times 0.2) + (0.5664 \times 0.6 \times 0.6 \times 0.7 \times 0.8) + (0.5178 \times 0.4 \times 0.6 \times 0.7 \times 0.8) + (0.4532 \times 0.6 \times 0.4 \times 0.7 \times 0.8) + (0.263 \times 0.4 \times 0.4 \times 0.7 \times 0.8)}{0.700}$$

$$= \frac{0.33762}{0.7000}$$

$$= 0.4823$$

Therefore, the *posterior probability* of the "*Container Terminal=bad performance*" node increased from 0.3657 to 0.4823, while the probability of the "*Container Terminal=good*



Source(s): Figure by authors

Figure 4. Pre-*posterior probability* value of the "*Container Terminal*" node

performance" and "*Container Terminal=moderate performance*" decreased from 0.2449 to 0.1697 and 0.3894 to 0.3480, respectively (Figure 5).

Therefore, the proposed decision-making model facilitates proficiently dealing with the uncertainties faced by Oman's as well as the global container terminal industry. In Scenario 1, the probability of the "*Container Terminal=good performance, moderate performance, bad performance*" nodes was marginally updated with the "*COVID-19=minimum effect*", "*IR 4.0=minimum effect*", "*SOLS 2040=important but not urgent*", and the "*Fuel Price Crisis=minimum effect*" nodes. The probability of the "*Container Terminal=good performance*" node increased from 0.2449 to 0.7450 (Figure 6) while that of the "*Container Terminal=moderate performance*" node decreased from 0.3894 to 0.2070. Similarly, the probability of the "*Container Terminal=bad performance*" node decreased from 0.3657 to 0.0480.

Scenario 2 demonstrates the previously discussed AHP outcomes. In this scenario, the "*COVID-19*" node was categorised as having "*maximum effect*" on container terminals and, therefore, required immediate attention as its weight was >50%. Meanwhile, the "*IR 4.0*" and "*Fuel Price Crisis*" nodes were categorised as having "*minimum effect*," while the "*SOLS 2040*" node was categorised as "*important but not urgent*" and, therefore, required less attention in 2020 as the individual weights of these three nodes were <50%. Figure 7 illustrates the real-time conditions faced by Omani container terminals beginning in 2020, in which the *posterior probability* of the "*Container Terminal=moderate performance*" node was 0.5520 (55.20%). This scenario suggests a moderate performance value for container terminals in Oman after considering every uncertainty discussed in the literature review.

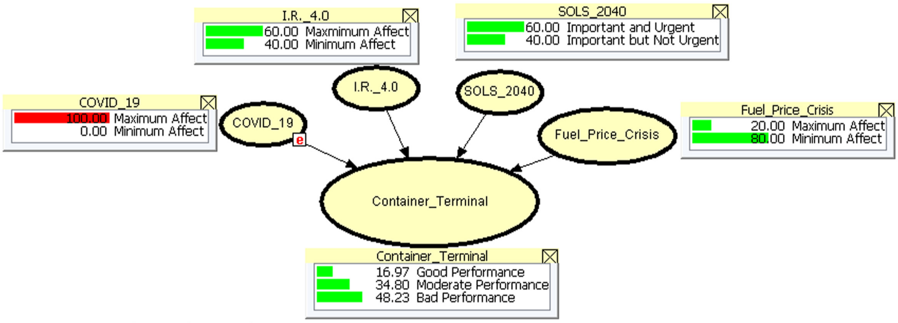


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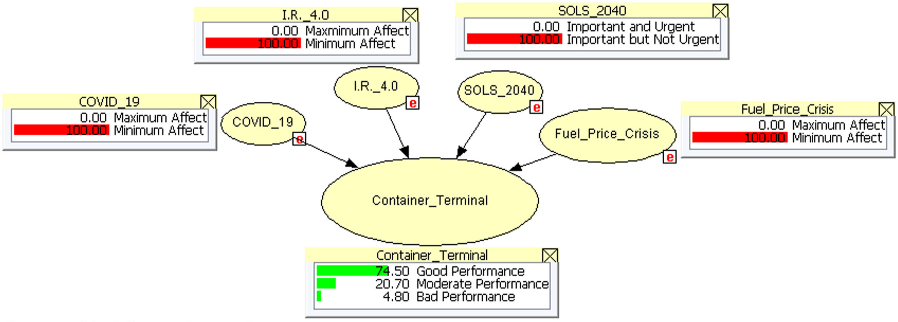
Figure 5. The "*Container Terminal*" node with 100% evidence of the "*COVID-19=maximum effect*" node

Discussion

The findings of this present study demonstrate the impact of each external factor on the performance of the container terminal industry and quantified them using posterior probability. For instance, the probability of "*Container Terminal=good performance*" increased after considering the external factors while that of "*Container Terminal=moderate performance*" and "*Container Terminal=bad performance*" decreased. Therefore, the proposed decision-making model can effectively address uncertainties and improve container terminal performance. This present study also used PESTLE analysis to investigate contemporary socio-economic and technological factors affecting container terminal performance. The AHP analysis revealed that the COVID-19 pandemic had the highest impact on container terminal performance in Oman followed by IR 4.0 technologies, the SOLS 2040 and the fuel price crisis. These findings provide valuable insights with which to allocate resources and prioritise strategies for container terminals in Oman and, potentially, ports in other countries facing similar challenges.

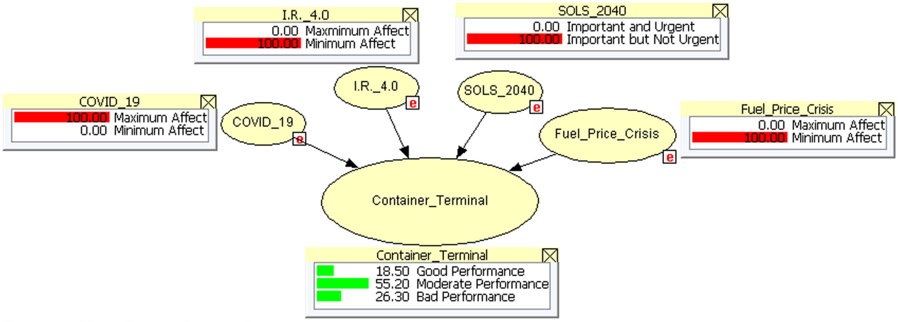
The integration of the AHP and BN models and the application of PESTLE analysis contribute to the existing body of literature on container terminals, particularly in the context of Oman. This present study surpasses the scope of extant studies as it comprehensively examined uncertainties caused by external environmental factors and developed an integrated decision-making model. Future studies may also use the theories of this present study as it can easily accommodate new variables that may arise in the future.

Therefore, this present study provides a valuable framework that the container terminal industry in Oman can use to plan their business strategies, manage resources effectively and



Source(s): Figure by authors

Figure 6. The *"Container Terminal"* node with 100% evidence to the "*COVID-19=minimum effect*", "*IR 4.0=minimum effect*", "*SOLS 2040=important but not urgent*", and the *"Fuel Price Crisis=minimum effect*" nodes



Source(s): Figure by authors

Figure 7. The "*Container Terminal*" node with 100% evidence to the "*COVID-19=maximum effect*", "*IR 4.0=minimum effect*", "*SOLS 2040=important but not urgent*", and "*Fuel Price Crisis=minimum effect*" nodes

address the uncertainties posed by external factors. The integrated decision-making model, as well as the findings of the AHP and BN analyses, can be applied in Oman and other ports facing similar challenges. The contributions of this present study to the literature and its unique approach make it a significant and pioneering research endeavour.

Conclusion

The objective of this present study was achieved by integrating two decision-making analysis methods, namely, the AHP and the BN. PESTLE analysis was then used to analyse the contemporary socio-economic and technological factors. The hybrid decision-making analysis method and its findings can be applied globally to any port experiencing changes in national visions or goals. The results of the AHP analysis show that the COVID-19 pandemic (54.60%) had the biggest impact on the performance of the container terminal industry in Oman followed by IR 4.0 technologies (19.66%), the implementation of SOLS 2040 (17.00%) and the fuel price crisis (8.74%). The BN analysis depicted the present situation of the container terminal industry in Oman as demonstrated in Scenario 2 of Figure 7. After accounting for uncertainties caused by the COVID-19 pandemic, the IR 4.0, the SOLS 2040 and the fuel price crisis, the performance of the country's container terminal industry was ranked "*moderate*." As the container terminal industry is vital to Oman's economy as well as the country's transformation into a regional logistics hub and GCC gateway, the government should provide industry players with low-interest loans and tax reductions as they would enable businesses to remain in operation and upgrade their services, which is crucial for the country's economy.

The contribution and novelty of this present study include the development of the proposed model and determining the performance level of container terminals in Oman considering compounding external factors, such as the COVID-19 pandemic, IR 4.0 technologies, the SOLS 2040 and the fuel price crisis. Oman's container terminal industry can utilise the outcomes of this present study to better plan business strategies, such as managing employees and operating expenses (OPEX) and centralising business activities for 2020 and 2021 according to the priorities discussed in the AHP. This present study also contributes academically to existing literature, particularly studies related to Omani container terminals. Moreover, an analysis of this scale has never been done before as it considered uncertainties caused by external environmental factors to develop a hybrid decision-making model using PESTLE analysis. External environmental factors that may arise in the future can also be easily applied to the theories of this present study. Although adding new variables will undoubtedly update the findings of this present study, the fundamental theory will remain the same.

The practical contributions of this present study include its applicability not only to stakeholders, such as container ports in Oman and other ports worldwide, but to other fields of research, such as logistics, terminal performance, warehousing, supply chains, organisations and management, to improve the implementation of theoretical information. The theory's practical utility satisfies social and organisational needs, particularly the uncertainty of external factors in the business environment. However, future studies may use "What-if Analysis" and "Rule-Based Bayesian Reasoning" to classify the operational status of a container terminal as either "Surviving with Minimum Impact," "Suffering and Struggling," or "Collapsing and Closing" when dealing with the aftermath of the COVID-19 pandemic, IR 4.0 technologies, the fuel price crisis and the SOLS 2040.

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