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Resilience Strategies of Ports against Covid-19 in Terms of Chaos Theory

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ARTICLE INFO

Keywords:
Covid-19
Container ports
Chaos theory
Resilience
Fuzzy AHP

ABSTRACT

During the Covid-19 pandemic, all sectors experienced chaotic dynamics worldwide. For example, maritime transport, particularly ports as one of its main elements, had to continue operating in this chaotic environment. Ports developed their own strategies to provide resilience against these challenges. However, any study in the related literature has not been reached that reveals resilience strategies of ports by combining literature review and interviews with port practitioners. As a novelty of the study, it was tried to evaluate resilience strategies of ports by grounding chaos theory. Therefore, this study had two aims: (1) identifying the Covid-19 strategies of Turkish container ports; (2) prioritizing these strategies in terms of impact level. First, interviews were conducted with Turkish container port representatives to find out their resilience strategies. These strategies were then validated with a literature review and new ones were detected. Second, separate relation analyses of the strategies were conducted for the interviews and literature. Finally, ports' resilience strategies against Covid-19 disruptions were prioritized using Fuzzy Analytic Hierarchy Process (AHP) based on the port managers' evaluations. Fuzzy AHP is widely used and accepted in the maritime business literature. This method also diminishes inconsistencies and subjective evaluations by employing fuzzy logic. The results showed that 'Control Mechanism', 'Hygienic Measures', and 'Information Exchange' were the most effective resilience strategies. By using chaos theory, this study helped to theoretically clarify the role of port management approaches to the challenges of the Covid-19 pandemic. These findings can therefore guide container port practitioners in overcoming pandemic conditions.

1. Introduction

The Covid-19 pandemic spread worldwide very rapidly in the first months of 2020. The situation was declared an emergency on 30 January 2020 by the World Health Organization (WHO) before being declared a pandemic on 11 March 2020 \cite{23}. The pandemic and its accompanying preventive measures affected almost all sectors and world trade, and accordingly also the maritime industry \cite{16}. The maritime industry faced many challenges during the pandemic, such as, while sailing, disease management and social distancing on board, enforcing protective equipment use, interaction with port workers, crew changeovers, testing, accessing medical assistance overseas, and protecting mental health \cite{60}. During the first months of the pandemic, there was severe congestion, especially in Chinese ports, with 116 ports worldwide reporting disruption by July 2021 \cite{59}. The pandemic then reshaped global demand as a result of increasing restrictions. Accordingly, maritime transport had to adapt to these changes quickly, with ports staying in line with the new order.

The new order due to Covid-19 created a chaotic system for ports. In response, ports showed resilience by establishing a new order within this disordered situation through their successful strategies. This study therefore investigated how ports managed this chaotic situation and...
which strategies they implemented. To do so, it identified the ports’ resilience strategies and prioritized them by employing Fuzzy AHP in terms of chaos theory. At this point, Fuzzy AHP method is very beneficial and applicable for prioritizing the criteria in a specific problem. Study also employs fuzzy logic for refraining the subjective and sharp judgments of the experts [19,29]. Originality of this study comes from considering resilience strategies of ports within the chaos theory perspective.

The following section introduces the theoretical background before reviewing the literature based on port management applications during the pandemic. The methodology section describes the steps in applying the Fuzzy AHP method. Finally, the results are discussed in relation to similar studies in the literature.

2. Literature review

A traditional method was employed for the literature review. First, the Scopus database was chosen because it accesses a broader range of top-ranking journals. Second, a search was conducted using the following search string: TITLE-ABS-KEY (Covid-19 *) AND TITLE-ABS-KEY (port*) AND TITLE-ABS-KEY (maritime*). This identified 31 potential articles. Third, the abstracts of each article were reviewed. This indicated that four were irrelevant, so the remaining 27 articles were included in the literature review.

The effects of the Covid-19 pandemic on port throughput have been widely discussed in the literature. Menhat et al. [34] reviewed the effects of Covid-19 on maritime industries in terms of shipping, fisheries, maritime tourism, and the oil and gas sector in Malaysia. Mannan et al. [32] considered Chittagong port in Bangladesh, based on data from government agencies, policymakers, researchers, businessmen, port users, entrepreneurs, policy documents, scholarly articles, reports, and websites. Xu et al. [52] and Xu et al. [52] focused on import and export cargo throughput at 14 major Chinese ports from January to October 2020. Abous et al. [1] studied Morocco Tanger Med Port. Zhou et al. [57] investigated the economic impact of Covid-19 on Shanghai Port under 6 different scenarios. Other studies tried to predict the pandemic’s effects on port throughput. For instance, Tai et al. [48] considered three pandemic scenarios having a negative effect on the production and operation of world ports. Sarkar et al. [45] identified the risks of the pandemic for port logistics while Russell et al. [44] proposed strategies to increase the flexibility of container port capacity in response to the uncertain pandemic environment.

Several studies investigated the environmental effects of Covid-19 restrictions in port areas in terms of the Green Port concept. Mocerino and Quaranta [35], for example, conducted a case study of cruise ships berthed at the Maritime Station (Stazione Marittima) in the port of Naples to assess the production and saving of NOX, SOX, and CO2 emissions. The emissions fell dramatically from 2019 to 2020 after the cruise shipping sector stopped. Similarly, Shi and Weng [46] reported a reduction in CO2, CO, HC, NOX, SOX, PM2.5, and PM10 emissions from cargo, container, and tanker ships in Shanghai port waters in the first months of 2020 compared to the same period the previous year. Zabzbee et al. [56] analysed the air quality of different zones in Port Harcourt (Nigeria) over five days during the lockdown and found that disruptions in the air quality persisted though economic and transport activities were restricted. Curovic et al. [14] reported a reduction in noise pollution from the Port of Koper (Slovenia) and the adjacent residential areas during the pandemic. Although the pandemic is the main current source of disruption in the maritime industry, the most important issue for the future of shipping is the race to decarbonise. Lu et al. [30] therefore proposed a decision-making model to identify the optimal low sulphur marine fuel for the post-Covid-19 period.

One significant challenge for the maritime industry during the pandemic was crew changeovers because lockdown measures prevented ships’ crews from going ashore for months. Various studies addressed this crisis. For example, Luchenko and Georgievskyi [31] evaluated restrictive administrative measures in crew rotations during the pandemic while Gutsulik [21] attributed crew change problems to a lack of coordination between port authorities and ship owners.

Another significant challenge was ship control around ports. Tirrell and Mendenhall [49] clarified the tasks of port states and flag states under pandemic conditions by proposing a system of mutual responsibility to mitigate the difficulties. Choquet and Sam-Lefebvre [12] analysed the legal framework of coastal states regarding Covid-19 health risk management on cruise ships. Similarly, Faqiang and Ablakimova [18] identified practical approaches to ensure the safety of seaports and analysed national legislation, international agreements, case law, and time charter proforma regarding the legal category of a “safe port”. Yan et al. [54] assessed the impact of Covid-19 on port state controls in 2020 compared to between the years 2015 and 2019.

The unique challenges that the maritime sector faced during the pandemic will reshape it while newly acquired habits may determine a new order for the maritime community. One of these unique outcomes is an accelerating trend towards remote business communication and information technologies. According to Bocayuva [8], the pandemic accelerated digitalization, which in turn requires European Union ports to take strong measures against cyber-attacks.

The pandemic has also demonstrated the importance of risk management. Thus, van den Oord et al. [51] drew on crisis management and network governance concepts and applied network analysis to evaluate Antwerp Port Authority’s attempts to manage the crisis. Notteboom et al. [40] compared the resilience strategies that container shipping and container ports used in the 2008–2009 financial crisis and the Covid-19 pandemic. On the other hand, some authors tried to assess the vulnerabilities of ports or resilience levels against Covid-19 [4,42].

Finally, the pandemic has encouraged new governance approaches for the maritime industry. Notteboom and Haralamides [39], for example, evaluated contemporary port management challenges and called for research into port management governance models in the post-pandemic era. Cullinane and Haralamides [13] investigated how the pandemic may be creating a “new normal” through its effects on various aspects of the maritime industry, such as strategic alliances, container ports, and environmental regulations. Yi et al. [55] discussed how port management can be enhanced by considering public opinions and sentiment in the post-Covid-19 era.

According to the Table 1, studies in the literature were investigated the economic, social and environmental effects of the Covid-19 pandemic on port management. Furthermore, some of the studies assessed the resilience capacity or vulnerability levels of ports against Covid-19 disruptions. However, it has not been encountered any study that evaluated and prioritized resilience strategies of ports to the best of authors’ knowledge. This is the first study that reveals resilience strategies by interviewing with port practitioners, prioritizes them, and presents managerial implications for prominent strategies.

3. Chaos theory

Chaos, meaning disorder, confusion, and complexity, originated in ancient myths and has preserved its importance throughout history. While most scientific research deals with predictable phenomena, chaos theory addresses nonlinear phenomena that are impossible to predict or control [17,26]. According to the theory, chaos is a type of order with no periodicity or balance [24,25].

Chaos theory is thus concerned with dynamic systems that evolve irregularly [10]. It is a mathematics-based science that enables us to model the real world more closely and effectively by not following the traditional methods [41,47]. Chaos theory has attracted considerable attention in the management literature because it suggests that “a new order arises out of disorder and randomness” [2]. By clarifying the difficulty of predicting the future, chaos theory has affected organizational strategic results [33]. Thus, chaos theory qualifies to explain organizational behaviours in an uncertainty situation.
Chaos theory can explain the dynamic behaviour of non-linear systems that are disrupted by changes [37].

Ports are part of a network of organizations collaborating to provide value to end users through various logistics and transportation services [11]. Ports operate in a complicated, ever-changing dynamic environment [22], which is occasionally chaotic, such as during the Covid-19 pandemic. During this time, ports have experienced unprecedentedly unpredictable and chaotic situations. Fig. 1 shows how container ports during the pandemic can be considered as a chaotic system.

A system that is controlled by negative feedback can achieve stability as it reaches a new equilibrium after experiencing all of the challenges in this uncertain condition. To understand a stable system, it is necessary to distinguish between its actual state and the desired outcome. During the pandemic, the actual state of ports includes cost minimization and throughput maximization while the desired state targets minimizing cost and maximizing value. This difference shows that ports focus on their internal processes to survive rather than satisfy stakeholders.

A system that experiences both positive and negative feedback simultaneously in an imbalanced manner can be described as chaotic. Positive feedback tends to encourage initial change, which promotes instability, whereas negative feedback tends to maintain stability by countering initial changes. Each situation can have three different outcomes: the first two are predictable behaviours whereas the third is chaotic.

First, a system can be balanced if it is independent from time. This situation is known as the point attractor. In the container port sector, this can be matched with preventive measures, such as social distancing, crew changeover restrictions, remote teleworking, and mandatory face masks. This is because, as in other sectors, the first actions that ports took were to prevent the virus from spreading.

Second, the system can periodically reach equilibrium. This is known as the periodic attractor. Pandemic lockdowns were applied for varying time periods, which had particular effects on container ports. For instance, in the third quarter of 2021, the Port of Ningbo in China shut down its operations for two weeks because of a single Covid-19 case.

Third, the system can behave erratically due to the initial changes and the interaction of negative and positive feedback. This is known as the strange attractor. For the maritime sector, labour shortages due to quarantining caused varying levels of container port congestion worldwide. The ports of Los Angeles and Long Beach notably became container graveyards due to port congestion. This congestion made ports more strategic places for world trade because the number of ship movements decreased while container ship demand increased dramatically as a result of congestion. Growing demand and the rush to send orders increased freight rates and accordingly port tariffs. Non-pharmacological measures and rising port tariffs made container ports much more profitable than before the pandemic. Thus, container ports reached a new order in this chaotic situation. On the other hand, chaos theory brings many different dynamic solutions while providing resilience. This dynamic structure might be better complied with Multi-Criteria Decision Making (MCDM) problems. After this section, Fuzzy AHP which is one of the MCDM method will be introduced.

4. Methodology

This study combined expert interviews, a comprehensive literature review, and Fuzzy AHP. Fig. 2 shows the model of the methodology and application steps.

Fuzzy AHP is a technique for ranking and prioritizing criteria in a decision-making process. The method uses the fuzzy numbers to eliminate uncertainty, inconsistencies, and subjective evaluations from decision makers’ evaluations [6,15]. Fuzzy AHP is widely used and accepted because it allows scholars to incorporate many different research areas, such as personnel selection, port selection, location selection, safety, security, and competitiveness evolution [5,7,9,27,28,36,38,50,58]. Buckley proposed a Fuzzy AHP process of five main steps: pairwise comparison matrices; consistency ratio calculations for each expert; triangular fuzzy numbers; constructing fuzzy matrices; calculating fuzzy weights; defuzzification [20].

4.1. Step 1: Pairwise comparison matrices

In this step, pairwise comparison matrices were formed according to the experts' evaluations.

4.2. Step 2: Consistency ratio calculation of each expert

The consistency ratios of the pairwise comparison matrices were calculated. These ratios should be less than 0.10 [3]. If the comparison matrices are inconsistent, then the questionnaire form must be re-evaluated by experts. The consistency ratio can be calculated using Eq. 1. Table 5 shows the consistency rates of each expert that produced...
evaluations for this study.

\[ CI = \frac{(\lambda_{\text{max}} - n)}{(n - 1)} \]  

\( n \) refers to number of criteria.

4.3. Step 3: Triangular fuzzy numbers

Pairwise comparison matrices were made among all criteria. Linguistic variables were assigned to each comparison level, as shown in Table 2.

4.4. Step 4: Constructing fuzzy matrices and calculating fuzzy weights

In this step, fuzzy pairwise comparison matrices were formed and aggregated to each expert’s evaluations. The geometric mean of each parameter was then calculated before the fuzzy weights of each criterion were obtained.

4.5. Step 5: Defuzzification

Lastly, the fuzzy weights were converted into crisp numbers. There are many different ways to do this. In this study, the authors used the Centre of Area (COA) method to reveal the Best Non-fuzzy Performance (BNP) values of each criterion, using Eq. 2. The BNP values indicated that Covid-19 strategies of container ports during the pandemic period could be prioritized.

\[ BNP_i = \frac{[(u_i - l_i) + (m_i - l_i)]}{3} + l_i \]  

5. Application

This study analysed the resilience strategies of container ports in response to the Covid-19 pandemic. The study was conducted in two stages. First, the resilience strategies of Turkish container ports were identified. Turkish container ports were selected because they managed the chaotic situation effectively. Thus, while international seaborne trade tonnage fell by 3.8% and world container port traffic decreased by 1.2% from 2019 to 2020 [63], cargo tonnage at Turkish ports increased by 2.5% [62] and cargo throughput rose by 0.3% despite the blank sailing applications of container line operators and severe congestion at container ports worldwide. In 2021, Turkish container ports were performing 8.6% above pre-pandemic levels [61].

Accordingly, this study investigated how Turkish container ports outperformed the world throughput average during the pandemic through semi-structured interviews with Turkish container port representatives. Table 3 provides basic information about the participants.

Fifteen interviews were conducted between 17 June 2021 and 30 November 2021 using online video conferencing platforms because of the pandemic conditions. While most participants were senior managers in operations departments, their experience in their sectors varied between 5 and 26 years. The interviews revealed several strategies in response to the pandemic disruptions. The relevant literature was also examined to match against the strategies revealed by the interviews and to find additional ones. Table 4 presents and defines the container ports’
strategies obtained from the interviews and literature review.

In the second stage, the strategies were weighted by Fuzzy AHP according to expert evaluations. The experts were selected from among Turkish container port managers because they had directly relevant sectoral and managerial experience (see Table 5). The majority had at least 10 years professional experience and most had master’s degrees. Consistency index rates show the validity of evaluations. Based on this, the data from Exp 11 were excluded due to that expert’s inconsistent judgements, leaving 11 sets of expert evaluations for Fuzzy AHP analysis.

6. Findings

Several analyses were conducted on the data from the interviews and literature review. First, Figs. 3 and 4 present the frequency and code relation analyses of the ports’ strategies revealed by the interviews and literature review, respectively.

As Fig. 3 shows, the interviews revealed that ‘Hygienic Measures’,
Table 4 Strategies of Container Ports during the Covid-19 Pandemic.

| Code | Strategy                               | Definition                                               | Reference |
|------|----------------------------------------|----------------------------------------------------------|-----------|
| CR1  | Remote teleworking                     | Working from home and remote access to business meetings | Notteboom et al.[40], Cullinane and Haralambides[13], Curovic et al.[14], van den Oord et al.[51], Xu et al.[52], Interview |
| CR2  | Interdepartmental rotation             | Reinforcing inadequate departments from other departments | Mannan et al.[32], Notteboom et al.[40], van den Oord et al.[51], Interview |
| CR3  | Technological integration              | Using autonomous systems based on digital transformation  | Luchenko and Georgievsky[31], Sarkar et al.[45], Bocayuva[8], Notteboom et al.[40], Russell et al.[44], Notteboom and Haralambides[39], Faqiang and Abliakimova[18], Interview |
| CR4  | Personnel planning                     | Using labour more productively                           | Luchenko and Georgievsky[31], Sarkar et al.[45], Mannan et al.[32], Notteboom et al.[40], Interview |
| CR5  | Hygiene measures                       | Compliance with rules, such as cleanliness, masking, and social distancing | Luchenko and Georgievsky[31], Mannan et al.[32], Tirrell and Mendenhall[49], Notteboom et al.[40], Curovic et al.[14], Gutsuliak[21], Shi and Beng[66], van den Oord et al.[51], Faqiang and Abliakimova[18], Zabhey et al.[56], Xu et al.[52], Abous et al.[1], Interview |
| CR6  | Restricting crew-stevedore interactions| Practices to prevent physical contact between seafarers and port workers | Luchenko and Georgievsky[31], Mannan et al.[32], Tirrell and Mendenhall[49], Gutsuliak[21], Shi and Beng[66], Choquet and Sam-Lefebvre[12], Faqiang and Abliakimova[18], Abous et al.[1], Interview |
| CR7  | Change of business routine             | Changing the way of doing business                       | Luchenko and Georgievsky[31], Bocayuva[8], Notteboom et al.[40], Notteboom and Haralambides[39], van den Oord et al.[51], Faqiang and Abliakimova[18], Interview |
| CR8  | Information exchange                   | Knowledge sharing through training, seminars, and meetings to prevent disease spread | Luchenko and Georgievsky[31], Sarkar et al.[45], Mannan et al.[32], Tirrell and Mendenhall[49], Bocayuva[8], Notteboom et al.[40], Interview |

Table 4 (continued)

| Code | Strategy                               | Definition                                               | Reference |
|------|----------------------------------------|----------------------------------------------------------|-----------|
| CR9  | Technological device support           | Technological product support for home-working personnel, such as computers and internet access | Luchenko and Georgievsky[31], Faqiang and Abliakimova[18], Interview |
| CR10 | Adaptation to flexible working arrangement | Adaptation to the flexible working system of various stakeholders to have fewer employees in an office simultaneously | Luchenko and Georgievsky[31], Mannan et al.[32], van den Oord et al.[51], Interview |
| CR11 | Recruitment                            | Employing new port workers temporarily or permanently to fulfil declining workforce | Luchenko and Georgievsky[31], Cullinane and Haralambides[13], van den Oord et al.[51], Interview |
| CR12 | Control mechanism                      | Conducting checks to prevent disease spread, such as testing and temperature measurement | Luchenko and Georgievsky[31], Mannan et al.[32], Tirrell and Mendenhall[49], Curovic et al.[14], Tai et al.[48], Gutsuliak[21], Shi and Beng[66], Notteboom and Haralambides[39], Choquet and Sam-Lefebvre[12], Faqiang and Abliakimova[18], Interview |
| CR13 | Outsourcing                            | Outsourcing of labour for jobs requiring technical knowledge | Interview |
| CR14 | Joint tenancy procedure for equipment usage | Preparing instructions for using shared equipment to prevent disease spread | Interview |
| CR15 | Medical assistance for crew or passengers | Providing health services for sick seafarers on board a ship at anchor | Choquet and Sam-Lefebvre[12], Gutsuliak[21], Faqiang and Abliakimova[18], Interview |

'Remote Teleworking', and 'Personnel Planning' were the most frequently mentioned resilience strategies (as shown in Fig. 3 with dashed lines) against Covid-19 disruptions in Turkish container ports. Additionally, 'Remote Teleworking' was frequently coded with three other strategies: 'Technological Device Support', 'Adaptation to Flexible Working-Arrangement', and 'Technological Integration'. Similarly, 'Hygienic Measures' was associated with two other strategies: 'Information Exchange' and 'Restricting the Crew-Stevedore Interactions' (as shown in Fig. 4 with bold lines). As Fig. 4 shows, 'Restricting Crew-Stevedore Interactions', 'Control Mechanisms', and 'Information Exchange' were more frequently mentioned in the literature. In addition, these three were also more closely linked than other strategies.

Second, the strategies which identified from the interviews and literature were weighted with Fuzzy AHP, as shown in Table 6 and Fig. 5. The three highest weighted strategies were CR12, 'Control Mechanisms', with 0.117, CR5, 'Hygienic Measures', with 0.115, and
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The findings have several interesting implications. First, based on the interviews, one important resilience strategy for ports was hygiene measures. In contrast, the literature more frequently referred to

Table 5

| Number | Position                          | Educational Level | Professional Experience | Consistency Index | Result |
|--------|----------------------------------|-------------------|-------------------------|-------------------|--------|
| Exp 1  | Operations Manager               | MSc               | 8 years                 | 0.0479            |        |
| Exp 2  | Port Manager                      | MSc               | 9 years                 | 0.0967            |        |
| Exp 3  | Strategic Planning and Business Development Manager | Bachelor         | 13 years                | 0.0834            |        |
| Exp 4  | Port Manager                      | MSc               | 25 years                | 0.0706            |        |
| Exp 5  | Port Commercial Manager          | MSc               | 18 years                | 0.0636            |        |
| Exp 6  | Port Manager                      | MSc               | 25 years                | 0.0376            |        |
| Exp 7  | Port Manager                      | PhD               | 20 years                | 0.0260            |        |
| Exp 8  | Customer Relations Manager       | MSc               | 19 years                | 0.0359            |        |
| Exp 9  | Customer Relations Manager       | Bachelor          | 18 years                | 0.0728            |        |
| Exp 10 | Port Manager                      | Bachelor          | 17 years                | 0.0696            |        |
| Exp 11 | Operations Manager               | Bachelor          | 19 years                | 0.1885            |        |
| Exp 12 | Operations Manager               | MSc               | 8 years                 | 0.0819            |        |

Fig. 3. : Frequency and Code Relation Analyses of Strategies based on Interviews.

Fig. 4. : Frequency and Code Relation Analysis of Strategies in the Literature.

Cr8, 'Information Exchange', with 0.112. The two lowest weighted strategies were Cr2, 'Interdepartmental Rotation', and Cr11, 'Recruitment', with 0.023 and 0.019, respectively.

7. Discussion and conclusion

The Covid-19 pandemic affected almost every sector worldwide, including the maritime industry. Ports are the backbone of shipping and accordingly of world trade, so the pandemic’s impacts on ports directly affected global trade. Within the first months of the pandemic, ports had developed strategies to provide resilience against disruptions. This study identified and evaluated the resilience strategies of Turkish container ports. First, interviews were conducted with port representatives to discover the resilience strategies of Turkish container ports and the literature was reviewed to validate these strategies and reveal any new ones implemented in other container ports. Second, these strategies were coded and their frequencies examined based on both the interviews and literature review. Third, the strategies were transformed into criteria and included in a multi-dimensional decision-making problem and prioritized using Fuzzy AHP.

The findings have several interesting implications. First, based on the interviews, one important resilience strategy for ports was hygiene measures. In contrast, the literature more frequently referred to
restricting crew-stevedore interactions. Thus, both port representatives and scholars emphasized those strategies that especially prevent the virus from spreading. Second, the Fuzzy AHP analysis produced several interesting outcomes. The experts gave the highest weightings to ‘Contacting only vaccinated people’ and ‘Recruitment’. This indicates that Turkish container ports developed resilience against pandemic disruptions through strict controls in the port area by reducing interactions, increasing personal protection behaviours, and educating port personnel. The experts gave the lowest weightings to ‘Interdepartmental Rotation’ and ‘Recruitment’. This indicates that Turkish container ports are less disposed to employ new personnel or shift existing personnel to other departments as resilience strategies.

The literature review identified other studies discussing the pandemic-related strategies of ports. For instance, van den Oord et al. [51] took Antwerp Port Authority as a case study to evaluate pandemic disruptions in terms of crisis management. They underlined the importance of information exchange, hygiene measures, recruitment, remote teleworking, and interdepartmental rotation in crisis management, particularly during the pandemic or similar disruptions. Faqiang and Ablikimova [18] considered the strategies that ports should implement against the pandemic’s impacts from a legal perspective. They also emphasized UNCTAD’s recommendations for ports regarding the uncertainty generated by the pandemic. These includes restricting crew-stevedore interactions, technological integration in transactions, control mechanism, on-board medical assistance at anchorage, and changes in business routines. Moreover, Notteboom et al. [40] evaluated container ports’ resilience strategies during the pandemic in comparison to strategies in the 2008–2009 financial crisis. They emphasized hygiene measures, interdepartmental rotation, technological integration, and personnel planning. The findings of these studies thus align with the strategies identified in the present study.

Different from relevant literature, almost all port resilience strategies included disorganised in literature were systematically gathered together in this study. In addition, ports’ resilience strategies were identified by asking port representatives from Turkey, which had increased port throughput in 2020 and 2021 compared to previous years. Thus, this study makes an original contribution by including the best practices of ports and prioritizing their Covid-19 strategies.

The study has several limitations. First, it was only carried out with representatives of Turkish container ports, so the findings cannot be generalised. Second, the findings are limited to container ports, so the specific strategies for different cargo types or terminals were beyond its scope.

Nevertheless, the study makes two important contributions. First, it makes a theoretical contribution by, to the best of our knowledge, being the first to study together chaos theory, the Covid-19 pandemic, and container ports. Second, it makes a practical contribution by identifying best resilience practices during the pandemic. These can help container port managers to overcome disruptions, given that the pandemic’s effects continue. According to the results of the study, control mechanism and hygiene measures were evaluated as the most prior resilience strategies respectively. To prevent pandemic effects, port practitioners might use emerging technologies (handheld biometric devices, portable thermometers, etc.) for enhancing control mechanism in port area. Pandemic measures should be added on existing general control procedures in the port area. Besides, in some Ro-Ro terminals, gangs were held together while both operating and putting up at a hotel during the pandemic period. Similarly, container port managers could generate health corridor as applied in cruise shipping for their workers that allow contacting only vaccinated people. Our results show that in such chaotic situations, reliable and verified information exchange becomes utmost importance. This information can be shared via seminars, webinars, and trainings organized by port managers.

In future studies, the sample could be enhanced while other port types handling different cargoes could be included. The relation analysis could be conducted with different multi-criteria decision-making methods while different port types could be included as alternatives. In addition, several different econometric and Bayesian inferences methods could be employed for future studies to verify or bring different approaches to our results.

Table 6
Fuzzy AHP Analysis Results.

| Criterion Number | Criterion Name                     | Best Non-Fuzzy Performance (BNP) | Prioritization Ranking of BNP |
|------------------|------------------------------------|---------------------------------|-------------------------------|
| Cr1              | Remote teleworking                 | 0.049                           | 9                             |
| Cr2              | Interdepartmental rotation         | 0.023                           | 14                            |
| Cr3              | Technological integration          | 0.084                           | 5                             |
| Cr4              | Personnel planning                 | 0.082                           | 6                             |
| Cr5              | Hygiene measures                   | 0.115                           | 2                             |
| Cr6              | Restricting crew-stevedore interactions | 0.077                     | 7                             |
| Cr7              | Change of business routine         | 0.037                           | 13                            |
| Cr8              | Information exchange               | 0.112                           | 3                             |
| Cr9              | Technological device support       | 0.088                           | 4                             |
| Cr10             | Adaptation to flexible working arrangement | 0.045                      | 10                            |
| Cr11             | Recruitment                        | 0.019                           | 15                            |
| Cr12             | Control mechanism                  | 0.117                           | 1                             |
| Cr13             | Outsourcing                        | 0.040                           | 11                            |
| Cr14             | Joint tenancy procedure for equipment usage | 0.075                      | 8                             |
| Cr15             | Medical assistance for crew or passengers | 0.037                      | 12                            |

Fig. 5: Graphical Demonstration of Criteria Weights.

Credit authorship contribution statement

Ilke Sezin Ayaz: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. Umur Bucak: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. Mahmut Mollaoglu: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization. Soner Esmer: Validation, Data curation, Writing – review & editing, Supervision.
Declarations 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.

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