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Research Article

## Fuzzy AHP Approach to The Determination of Smart Port Dimensions: A Case Study on Filyos Port

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### ABSTRACT

As ports play a very important role in the national and international flow of goods, with the development of international trade, they face many challenges such as operational congestion, pollution, energy consumption and safety and security issues. Therefore, ports need to increase their operational efficiency and also pay attention to sustainability principles. The smart port is a digital transformation that adopts new technologies to improve efficiency and environmental issues. Existing ports and new ports have to be transformed into smart ports so that countries can get a share from international logistics. Smart port applications vary according to ports characteristics, as port needs are different. Thus, it is necessary to analyze ports to develop compatible smart port applications. However, in the literature, there is a lack of studies focuses on the smart port. The main purpose of this study is to examine smart port dimensions by considering Filyos Port. We have used fuzzy AHP for ordering each dimension and sub-dimensions to relative importance. The findings of the study show that operation is the most crucial factor, which is followed by environment, energy, finance and safety and security, respectively. Finally, we offered suggestions for each smart port dimensions.

**Keywords:** Smart port, Fuzzy AHP, Port digital transformation, Sustainability

## Akıllı Liman Faktörlerinin Belirlenmesinde Bulanık AHP Yaklaşımı: Filyos Limanı Örneği

### ÖZET

Limanlar, ulusal ve uluslararası mal akışlarında önemli bir rol oynamaktadır. Limanlar, operasyonel tıkanıklık, kirlilik, enerji tüketimi ve emniyet ve güvenlik sorunları gibi uluslararası ticaretin gelişmesiyle ilgili birçok zorlukla karşı karşıyadır. Bu nedenle limanların operasyonel verimliliklerini artırmaları ve sürdürülebilirlik ilkelerine dikkat etmeleri gerekmektedir. Akıllı liman, verimliliği ve çevre sorunlarını iyileştirmek için yeni teknolojileri benimseyen dijital bir dönüşümdür. Ülkelerin uluslararası lojistikten pay alabilmesi için mevcut limanların ve yeni limanların akıllı limanlara dönüştürülmesi gerekmektedir. Liman ihtiyaçları farklı olduğundan, akıllı liman uygulamaları limanlara göre farklılık göstermektedir. Bu nedenle, uygun akıllı liman uygulamaları geliştirmek için limanları analiz etmek gerekmektedir. Literatürde akıllı limana odaklanan çalışmalar yetersizdir. Bu çalışmanın temel amacı, akıllı liman boyutlarını Filyos Limanı'nı dikkate alarak incelemektir. Her boyutu ve alt boyutu göreceli öneme göre sıralamak için bulanık AHP yöntemi kullanılmıştır. Çalışmanın bulguları ise operasyonun en önemli faktör olduğunu ve bunu sırasıyla çevre, enerji, finans ve emniyet ve güvenliğin izlediğini göstermektedir. Son olarak, çalışmada akıllı liman boyutlarına yönelik öneriler sunulmuştur.

**Anahtar Kelimeler:** Akıllı liman, Bulanık AHP, Liman dijital dönüşümü, Sürdürülebilirlik

# **I. INTRODUCTION**

The globalization trend has enabled international trade to experience a rapid growth period. This situation has caused the logistics infrastructure of the countries to be insufficient [1]. Countries are building new logistics infrastructures or modernizing existing infrastructures to improve their logistics performance. Especially, the development in science and technology continually assistance the advances in logistics all around the world. Countries need to develop modern transportation networks to maintain their competitiveness in logistics. Therefore the modernization of ports, which have an important share in international trade, is very important [2].

Ports constitute one of the most important transaction locations in the logistics industry. Also, which play a vital role in international trade and global growth, connect different parts of the world [3]. 14 of the 20 cities with the largest economy and 36 of the 50 most competitive cities are port cities [4]. In the long term, sustainable management of the ports increasing transaction volume will be vital for the economic, environmental and political interests of the countries [5]. One of the development targeted to meet these expectations is smart ports. The smart port tries to develop environmental, operational, energy, finance, safety and security, using Information and Communication Technologies (ICT) to achieve the sustainability goals.

Although smart port literature has increased in the last few years, it is still limited [6]. The smart port term has been widely used, especially after smart port initiatives launched by the ports of Hamburg and Rotterdam. Initially, Mediterranean Ports Integration Project has focused on the smart port operation and created smart port dimensions. Buiza et al. [7] evaluated these dimensions with the Analytical Hierarchy Process (AHP) method. After that, Molavi et al. [8] has extended Med Mediterranean dimensions and added security and safety criteria. Chen et al. [6] has created an index to evaluate smart ports.

Turkey, despite having the longest coastline in the Black Sea, the existing infrastructure and port facilities have not enough capacity to be competitive in the international logistics environment [9]. One of the most important cost items for companies is logistics costs. As companies come near to the ports, logistics costs decrease. In this way, export companies, especially, contribute to the reduction of unemployment and poverty by gaining more competitiveness [10]. Turkey is planning to build ports in Blacksea, Marmara and Aegean Sea to increase logistics competitiveness. These ports will have higher integration with roads, railway and sea. Ministry of Transport has planned to establish Filyos port within the framework of the Filyos Valley Project in the Black Sea. Filyos is a coastal town near the Filyos River, in Zonguldak Province. In terms of location, the Filyos port can play an important role in national and international transportation. The ability of this port to compete with the world's leading ports depends on its development with sustainability principles. Therefore, it is inevitable to implement smart port applications in Filyos Port. The purpose of this study is to propose suggestions for the Filyos Port by evaluating the smart port dimensions and sub-dimensions. In this study, we gave information about the Filyos Valley Project, which constitutes the main material. We asked nine experts to evaluate the smart port dimensions taking into account the Filyos Port. We analyzed this data using the fuzzy AHP method and determined the weights of the dimensions. Finally, we offered smart port recommendations for Filyos Port.

The structure of the paper is as follows; the second section describes the smart port and its dimensions and sub-dimensions. The third section is an overview of materials and methodology. The fourth section shows the results. The final section is the conclusion, which proposes suggestions for building a smart port.

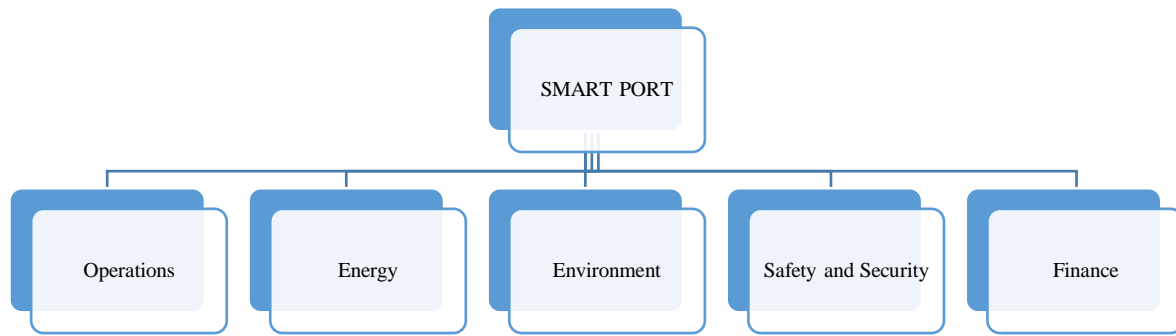
## **II. SMART PORT**

Maritime transport plays an important role in the world economy development. This role brings responsibilities beyond basic port services that ports provide to ships and cargoes. In addition to their roles as traditional marine/land connections, ports provide many services for value-added logistics, including industrial, trade, and finance. Therefore, ports are not only an integral part of the transportation system but also key players enabler production, trade and logistics processes [11]. The logistics infrastructure of a country explains most of the relative trade performance. Poor transportation and communication infrastructure isolate countries and prevents joining global production-transportation-distribution networks [12].

Ports deal with various activities, particularly the movement of ships, containers and other cargoes, loading and unloading of vessels and containers, customs process [13]. Although there have been various transformations in ports from containerization to automation over the past fifty years, due to globalization and competition, ports need to technological transformation to provide faster, more reliable and less costly port services [14]. In this context, the World ports, especially European ports aim to reach a sustainable, globally linked and competitive maritime transport sector through Research and Development (R&D) and innovation [15]-[16]. These technologies may contribute to solving environmental challenges and increasing operational productivity. The current innovation speed creates significant technological advances. However, determining which of these technologies will transform shipping, logistics, production and ports is a big challenge [15].

Technological transformation, which is different topics such as smart city and smart logistics, also emerges itself on ports as a smart port. Different definitions have been made about the smart port. The common point of these definitions is that they present a technology-centric perspective. Molavi et al. [8] definition is one of the most comprehensive definition. However, we define the smart port is “sustainable ports that use resources and port infrastructure in the most efficient way by benefiting from digital technologies in the port effectively, try to obtain maximum profit and minimum cost, care about the safety and security of the workers, ports and data, use renewable energy resources and adopt energy and environmental management [17]. Our definition has expanded to Molavi et al. [8] and added financial dimension and data safety and security subdimension.

Smart port aims a holistic improvement for the port via different technologies, especially information and communication technologies. Determining the smart port dimensions and goals is crucial. In the literature, smart port studies have used different smart port dimensions. Smart port dimensions and performance criteria formed by the Union of Mediterranean Ports are at the beginning point of these studies [18]. These criteria are grouped under three dimensions: operational, environmental and energy. Molavi et al. [8] has added safety and security in these dimensions. Chen et al. [6] proposed new dimensions, unlike these two studies; collaboration, agility, personalization and liberalization. In this study, we include the finance dimension in addition to the Molavi et al. [8] and Med Mediterranean [18]. Financial performance shows the financial strength for company managers and stockholders. Therefore, firms aim at profitability and financial stability regardless of their activity types. The main purpose of integrating finance into the smart port dimension is that smart ports have the same purpose as other ports. Therefore, finance is also decisive [19], [20].



**Figure 1.** The categorisation of smart port dimensions

## A. SMART OPERATION MANAGEMENT

Ports can provide service to many different vessel types according to their characteristics. Most of the port operations are to load and unload these vessels, transfer the cargo to the warehouses, road or rail transport. Ports can gain a significant advantage in terms of service quality by making this process at minimum cost and maximum speed [18]. Smart ports gain an advantage in operational efficiency and cost minimization by combining technology with innovative models [8]. Smart ports achieve higher competitiveness through a combination of productivity, automation and intelligent infrastructure improvement. The smart operation management sub-dimensions are shown in Table 1.

**Table 1.** Smart operations sub-dimensions [8], [18]

Operations	
Productivity	Port efficiency within time, budget, area and existing facility boundaries
Berth productivity	Infrastructure productivity
Land productivity	Size and use of maximum capacity
Lines calling at the port	Capacity for receiving large vessels
Level of intermodality	
Automation	Management of port management with autonomous technologies
Automated stack	Automated path
Automated rail	Automated lift
Automated trucks	Automated quay
Intelligent Infrastructure	Using hardware and software technologies for better port infrastructure
Integrated information systems and software hardware	Integration of information and communication technologies

## B. SMART ENVIRONMENT

Global warming and climate change pose a significant threat to the future of the world. Ports have a bad reputation for pollution as a significant part of the pollution in the seas is caused by port operations. Smart ports aim to reduce the negative impacts of ports on the environment and make an essential contribution to the emergence of preventive activities [6]. The increase in international trade also increases the operational workload on ports. This situation increases environmental problems

originating from the port. The ports, which connect different modes of transport and manage significant cargo volume, have critical environmental problems. Smart ports stand out by offering solutions to these problems. The smart port's environment dimensions include environmental management systems, waste management, water management [8].

*Table 2. Smart environment sub-dimensions [8], [18]*

<b>Smart Environment</b>	
<b>Environmental Management Systems</b>	Managing environmental performance of port by observing and controlling the environmental impacts of port operations.
<b>Emissions and Pollutions Control</b>	Air, noise and water pollution are the main causes of pollutions by ports.
<b>Waste Management</b>	Ports generate a high amount of waste during their operations.
<b>Water Management</b>	Water is a vital resource for both humans and other creatures. Therefore, its use by ports should be well managed.

### C. SMART ENERGY

Ports are one of the areas with high energy consumption due to their operations. The need to monitor and evaluate energy-related activities in the port hinterland in recent years, the public's awareness of energy and the environment, and studies on energy efficiency have cleared the importance of energy in the port [21]. The rise in energy costs and sources of energy are among the important issues for ports. In order to provide logistics services, ports must undergo an energy-efficient transformation. In this context, energy management is an important topic that should be adopted by port authorities in a smart and sustainable port formation process. Sub-criteria of the smart port's "smart energy" component include Efficient Energy Consumption, Energy Consumption by Containers, Energy consumption by lighting, Energy consumption by offices and companies, Producing and use of Renewables, Wind Energy, Biomass Energy, Efficient Use Of Solar and Electric Transportation is available [8].

*Table 3. Smart energy sub-dimensions [8], [18]*

<b>Smart Energy</b>	
<b>Efficient Energy Consumption</b>	Energy saving should be one of the main targets of ports in terms of both economic benefits and sustainability.
Energy consumption by containers	Energy consumption by fleet
Energy consumption by lighting	Energy consumption by terminal equipment for movement of containers
Energy consumption by offices and companies	
<b>Producing and Use of Renewables</b>	Ports' energy consumption of renewable energy will bring significant gains to the environment.
Wind energy	Solar energy
Biomass energy	Wave and tidal energy
Efficient use of solar and electric transportation	
<b>Energy Management</b>	Ports should review existing energy management and determine new strategies and activities.

### D. SMART SAFETY AND SECURITY

The rapid integration of information and communication technologies into ports creates a significant risk on ports. Port authorities need to pay attention to safety and security in addition to issues such as productivity, environmental awareness, energy efficiency within the smart port framework. Because smart ports have various security risks that can cause physical and data loss due to their activities [8],

[22]. Safety is “the state of being away from hazards caused by natural forces or human errors randomly. The source of hazard is formed by natural forces and/or human errors”. Definition of security is “the state of being away from hazards caused by deliberate intention of human to cause harm. The source of hazard is posed by human deliberately” [23]. In order to respond to smart ports, security and safety problems faster, it is necessary to make preparations such as employee training and simultaneous monitoring. Smart safety and security dimension include port safety management systems, security management systems, integrated monitoring and optimization systems, data security and privacy management.

**Table 4.** Smart safety and security sub-dimensions [8], [18]

Smart Safety and Security	
<b>Safety Management Systems</b>	These are comprehensive systems based on performing safety-related processes in ports.
<b>Security Management Systems</b>	Security management systems manage the entire process by proactively approaching all threats to ports.
<b>Integrated Monitoring and Optimization Systems</b>	Safety and security can be controlled easily with integrated monitoring and optimization systems.
<b>Data Security and Privacy Management</b>	It is important to protect data and system security with digital transformation.

## E. SMART FINANCE

Operational income and costs are very important for ports as well as for every business. Port managers should be aware of the financial situation of the port [11]. In addition to the other benefits, smart ports must have an economic value-generating structure, reduce costs, and create new sources of income [19]. Smart ports have to take into account the financial dimension when performing other dimensions. Especially one of the competition issues between ports is the service fees in ports.

**Table 5.** Smart finance sub-dimensions [8], [18]

Smart Finance	
<b>Revenue</b>	Total revenue from port operations
<b>Cost</b>	Total costs from port operations
<b>Contribution</b>	Difference between revenue and costs

## III. MATERIALS AND METHOD

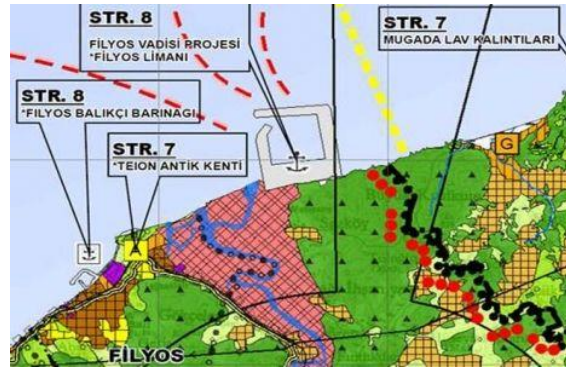
### A. MATERIALS

#### A.1. Filyos Valley Project-Filyos Port

Filyos Valley Project is located in the province of Zonguldak, Turkey's western Black Sea coast. Filyos Valley Project (Figure 2) has Filyos Port (25 million tons/year capacity), Filyos Industrial Zone (597 hectares), Filyos Free Zone (1166 hectares) and Free Zone Development Area (620 hectares) [24].

Turkey aims to be among the World's top 10 economies in 2023. Therefore, Turkey has focused on increase the industries competitiveness, its productivity, and to produce high-value and high-tech products. Consequently, Turkey has started new infrastructure and projects for an increase in production and international trade. Filyos, is one of the most important investments in Turkey, in terms of the first mega industry zone in Turkey. Filyos Port is planned as one of the largest ports in Turkey. Thus, Filyos Port is expected to create new transportation corridors, reduce the traffic load of the Istanbul and Çanakkale Straits, increase qualified production, and improve national and international transportation

and trade [24]. Filyos Port and Filyos Valley Project are expected to become an important trade and logistics center and contribute to the regional economy [25].



**Figure 2.** Filyos Valley Project in ZBK (Zonguldak-Bartın-Karabük) master plan

## B. METHOD

### B.1. Fuzzy AHP

Analytical Hierarchy Process (AHP) is one of the most preferred Multiple Criteria Decision Making (MCDM) method, which makes the dual comparison technique and creates priority weights, developed by Saaty [26]. Although the AHP method is an MCDM method that shows the emotions of the participants over certain numbers, in most cases, the decisions and linguistic evaluations of the participants contain uncertainty. Therefore, interim based judgments can be accepted as a better solution instead of net values applied in the AHP method. In Fuzzy AHP, Fuzzy Triangular Number (FTN) shown in Table 6 is used instead of real numbers obtained from AHP.

FTN was developed to mathematically represent data that is considered to be imprecise, a class of targets with FTNs, as shown in Table 6. A triangular membership function A is specified by three parameters {lA, mA, uA} as shown in figure 3.

Many methods have been proposed for the implementation of FAHP. Van Laarhoven and Pedrcyz's (1983) method, Buckley's (1985) method and Chang's extended analysis method (1996) are some of them. We used Buckley's (1985) method.

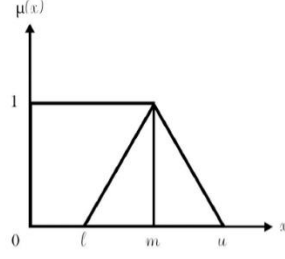
F-AHP method is seven-step method as follows [27]:

The first step is the comparison experts' score. The linguistic expressions shown in Table 6 indicate each factor's relative strength and the corresponding FTNs are used.

**Table 6.** Linguistic definitions FTNs of fuzzy scale

Value	Verbal expressions	Fuzzy number			Number reverse phase		
		l	m	u	l	M	u
1	Prefer to	1	1	1	1	1	1
2	Prefer low to moderate	1	2	2	0.333	0.5	1
3	Preferred medium	2	3	3	0.5	0.333	0.25
4	Preferred medium to high	3	4	4	0.333	0.25	0.2
5	Most preferred	4	5	5	0.25	0.2	0.166
6	Rather high to very high	5	6	6	0.2	0.166	0.142
7	Rather too much	6	7	7	0.166	0.142	0.125
8	Too much prefer to be quite high	7	8	8	0.142	0.125	0.111
9	Preference is quite high	9	9	9	0.111	0.111	0.111





**Figure 3.** A FTN's  $X$

Pairwise comparison matrix  $\tilde{a}_{ij}^k$  shows that the  $k$ th expert selects the choice of the  $i$ th factor over the  $j$ th factor.

$$\tilde{A}^k = \begin{matrix} & \tilde{a}_{11}^k & \tilde{a}_{12}^k & \cdots & \tilde{a}_{1n}^k \\ \tilde{a}_{21}^k & & \cdots & \cdots & \tilde{a}_{2n}^k \\ \vdots & & \cdots & \cdots & \vdots \\ \tilde{a}_{n1}^k & \tilde{a}_{n2}^k & \cdots & \cdots & \tilde{a}_{nn}^k \end{matrix} \quad (1)$$

The second step is the selection of each experts  $\tilde{a}_{ij}^k$  are averaged and  $\tilde{a}_{ij}$  is found using Equation (2).

$$\tilde{a}_{ij} = \frac{\sum_{k=1}^K \tilde{a}_{ij}^k}{K} \quad (2)$$

The third step is the pairwise comparison matrix is build to the average of the respondent.

$$\tilde{A} = \begin{matrix} a_{11} & \cdots & \tilde{a}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{a}_{n1} & \cdots & \tilde{a}_{nn} \end{matrix} \quad (3)$$

The fourth step is the use of the geometric mean technique as follows:

$$\tilde{r}_i = \left( \prod_{j=1}^n \tilde{a}_{ij} \right)^{1/n}, i = 1, 2, \dots, n. \quad (4)$$

The fifth step is the compute the total for each  $\tilde{r}_i$  of individual factors. Then compute the reverse of the vector obtained and do out the FTNs in an ascending sequence. Finally, Multiply each  $\tilde{r}_i$  with the reverse FTN value obtained to compute fuzzy weight:

$$\tilde{w}_i = \tilde{r}_i \oplus (\tilde{r}_i \oplus \tilde{r}_1 \oplus \dots \oplus \tilde{r}_n)^{-1} = (lw_i, mw_i, uw_i). \quad (5)$$

The sixth step is the de-fuzzy value of FTNs is computed via by the center of area method;

$$M_i = \frac{lw_i + mw_i + uw_i}{3} \quad (6)$$

The seventh step is the normalization of  $M_i$  ;

$$N_i = \frac{M_i}{\sum_{i=1}^n M_i} \quad (7)$$

### **III. RESULTS**

At this section, we evaluated each dimension and sub-dimension in a decision-making matrix and found results based on fuzzy AHP method. Table 7 shows that which areas should be prioritized when the Filyos Port is constructed based on smart port concept.

*Table 7. Normalized weights of smart port dimensions*

<b>Domain</b>	<b>Weight</b>
Operations	0.592
Environment	0.195
Energy	0.113
Finance	0.069
Safety and Security	0.031

In this study, experts drew attention to the operations. The main reason is increasing operational volume in ports and the indirect impact of improvements in operations on other dimensions [6]. The second important dimension is the environmental dimension. The population of cities is overgrowing and is expected to reach 7 billion by 2050 [28]. Increasing human awareness, developing a business approach towards sustainability and protecting green show that smart ports should be environmentally conscious. Increasing population will create a significant increase in the electricity need of the cities. At this point, it will become important how electricity is produced and consumed. Ports, which are an important part of cities, should also lead this change within the scope of the smart city. Therefore, energy is the third important dimension. One of the primary duties of the ports is to make the process in the logistics flows of other enterprises more efficient, as well as to control their costs as a private enterprise and increase their profitability and income. In this context, finance is ranked as the fourth important dimension. The last dimension is safety and security, which is important for the ports to carry out their operations without disrupting and creating a loss.

*Table 8. Normalized weights of smart port sub-dimensions*

<b>Domains in a Smart Port</b>	
<b>Operations</b>	<b>0.592</b>
Productivity	<b>0.354</b>
Berth Productivity	0.029
Infrastructure Productivity	0.020
Land Productivity	0.035
Size and Use of Maximum Capacity	0.064
Lines calling at the port	0.037
Capacity for receiving Large Vessels	0.039
Level of Intermodality	0.130
<b>Automation</b>	<b>0.175</b>
Automated Stack	0.062
Automated Path	0.012
Automated Rail	0.009
Automated Lift	0.046
Automated Trucks	0.009
Automated Quay	0.037
<b>Intelligent Infrastructure</b>	<b>0.063</b>
Integrated information systems and software hardware	0.063
<b>Environment</b>	<b>0.195</b>
Environmental Management Systems	0.100
Emissions and Pollutions Control	0.051
Waste Management	0.025
Water Management	0.019

**Table 8.** (continuation) *Normalized weights of smart port sub-dimensions*

<b>Domains in a Smart Port</b>	
<b>Energy</b>	<b>0.113</b>
<b>Efficient Energy Consumption</b>	<b>0.060</b>
Energy Consumption by containers	0,014
Energy consumption by lighting	0,005
Energy consumption by offices and companies	0,002
Energy Consumption by fleet	0,011
Energy consumption by terminal equipment for movement of containers	0,028
<b>Producing and use of Renewables</b>	<b>0.041</b>
Wind Energy	0,005
Solar Energy	0,007
Biomass Energy	0,004
Wave and Tidal Energy	0,021
Efficient use of solar and electric transportation	0,004
<b>Energy management</b>	<b>0.012</b>
<b>Finance</b>	<b>0.069</b>
<b>Contribution</b>	<b>0.042</b>
<b>Cost</b>	<b>0.017</b>
<b>Revenue</b>	<b>0.010</b>
<b>Safety and Security</b>	<b>0.031</b>
Safety Management Systems	0,002
Security Management Systems	0,002
Integrated monitoring and optimization systems	0,011
Data Security and Privacy Management	0,016

When operations sub-dimensions are examined, "productivity" comes to the fore. The main reason is that the ports want to increase the transaction volume in their existing operations. Automation and smart infrastructure follow this sub-dimension. In the environmental sub-dimension are examined, environmental management system, emission and pollution control, water management and waste management ranked respectively. In the sub-dimension of energy management, efficient energy use and utilization of renewable energy stand out as the two most important factors. This is followed by energy management. In the sub-dimensions of finance shows that ports gave importance to cost rather than profitability and income. In the sub-dimensions of safety and security, it is seen that data security and privacy management is the crucial point because of the importance of data in smart ports. Then is follows, respectively; safety management systems, security management systems and integrated monitoring and optimization systems.

## **IV. CONCLUSION**

Ports are the gateways of countries to each other. Trade is carried out between countries through these gates. The efficient operation of these gates directly affects the development of this trade. Digitization in many areas such as Industry 4.0 and smart cities has also accelerated the process in ports. The point that distinguishes the transformation in smart ports from a fundamental technology transformation is its focus on sustainability. Although digital transformation is the target of smart ports, this transformation is a sustainable digital transformation. Since each port has different structures, problems, developments and expectations, its solutions can be different. Therefore, ports need to create its own smart port strategies based on universal standards that benefit from technology.

In this study, fuzzy AHP is used to evaluate the dimensions and sub-dimensions of smart port adapted from Molavi 2019. The result shows that most important dimension is operations. We can conclude that main drivers of smart port transformation is operational productivity. Ports want to expand their operations and want to be competitive in a long term. Limitation of this study is smart port is a new and developing concept. Therefore, it may differ according to the experts' experiences and perceptions about

smart port and it has a subjectivity. In addition, the lack of detailed information about the Filyos Port has created a constraint for decision makers. However, the port operators may use these results to use in their port transformation process.

Smart ports are still in the beginning phase, especially Rotterdam, Hamburg and Antwerp Ports, produce long-term projections and carry out their plan within the framework of these projections. Although smart port applications may differ according to port needs, ports have similar targets. These targets, grouped with some dimensions, which are supported in different studies, are operations, environment, energy, security and safety and the finance we include in this study. In this study, first of all, information about the smart port was tried to be detailed and a broader and more comprehensive definition of the smart port was introduced. The weights of the smart port dimensions determined in the application part of the study are listed by the Fuzzy AHP method within the framework of Filyos Port. Finally, suggestions have made considering this order.

## **A. SUGGESTIONS FOR BUILDING A SMART PORT**

Conserving natural resources without destroying them is one of the main conditions of sustainable development. In this context, in order to protect and improve the environment, regional, basin and local area planning processes should be based on ecological basis [29]. Filyos Valley Project is an important area for economic development on a regional scale. Improvement of the environmental quality of the Filyos Valley, which is likely to deteriorate with the activities of the port and facilities planned in the project, can be achieved through plans and practices based on ecology. In order to ensure sustainable environmental protection and sustainable development, environmentally sensitive planning studies involving ecological planning approaches and methods on a local and regional scale are important [25].

In this part of the study, we have made suggestions within the framework of operation, environment, energy, safety and security and finance dimensions. The recommendations were determined primarily through the applications in the leading smart ports of the world, which are compatible with the needs of Filyos Port. Although this study was prioritized for Filyos Port and there was a relatively ranking difference, it was found that similar priorities were observed in both the works of Buiza et al. [7] and MedMediterran [18]. Therefore, an essential part of these recommendations can be considered for all smart ports. Digital transformation underlies the concept of the smart port. For digital transformation, there should be a data management structure that will collect, organize, process, analyze and propose solutions. Many of the smart ports' suggestions for different dimensions are based on technology and best management practices. In this context, recommendations for Filyos Port within the framework of smart port dimensions (operation, environment, energy, safety and security and finance) are presented below according to the prioritization in fuzzy AHP results.

### **A.1. Smart Operation Management**

- Irmak-Karabük-Zonguldak railway is beside the Filyos Valley Project and also there is the Adapazarı-Karasu-Ereğli-Bartın railway project, whose tender processes continue. For this reason, the port should be operated in an integrated manner with different modes, especially rail and road, and synchronization should be ensured between these transportation modes.
- Determining the estimated arrival time of the ships and calculating the time they will spend at the port ensures that the processes take place in a planned way and the inefficient points are determined. Therefore, internet applications should be developed and made available to all port users.
- Autonomous vessels are expected to launch in 2025, the port should prepare the infrastructure, where these vessels can successfully interact.
- The necessary infrastructure conditions must be provided for largest ships to dock at the port.
- Sensors should be used in the Filyos Port. Because sensors are the main data banks that make the ports smart. Sensors placed in various port equipment or points play a critical role in detecting problematic spots.

- 3D port digital twin application should be started. In this way, it will be possible to solve the problems by accessing real-time information proactively.
- In order to reduce the amount of emission arising from traffic density at the port, a truck appointment system (TAS) should be used.
- Terminal operations systems should be used to provide advanced planning and organizational capabilities to the ports.
- Projects should be carried out by collaborating with universities in the region.
- Turkey ports should establish a platform for the development of cooperation and information sharing. Also, international collaboration with other smart ports should be expanded.

## **A.2. Smart Environment**

- 1/50000 and 1/25000 scale Master Plans, including the industrial zone and interaction areas planned within the scope of Filyos Valley Project, should be prepared in more detail. Master plans should be an ecological master plan prepared based on ecological threshold analysis.
- Sub-scale plans should be prepared under the ecological master plan, and area decisions based on economic development should be made with an environmental approach.
- In order to location selections decisions into practice, protect the environment, prevent pollution, monitor environmental resources, and create healthy living environments; there should be area management centers that will provide coordination in the region, basin and local areas.
- A smart and ecological/green zone should be created both in using natural resources and in protecting nature by adding an environmental dimension to Filyos Port, where many facilities that will direct the economic development of the region will be located.
- Green areas should be created and afforested in the industrial zone.
- A green corridor should be created along the Filyos Stream and it should be ensured that it continues its ecological corridor function.
- Port operators should adopt environmental management systems.
- ISO 14001 and EMAS certificates should be obtained in order to provide a sustainable right to life for the living creatures around the port and nature and to minimize environmental impacts.
- To reduce greenhouse gas emissions originating from the port;
  - New generation machine systems should be adopted,
  - Quality fuel should be used,
  - Emission control systems should be used,
  - Operational improvement should be made,
  - Systems that reduce idle time should be created.
  - Main improvements should be made to equipment groups that cause the most carbon emissions.

## **A.3. Smart Energy**

- The management of the ports is to be created in an efficient energy-based environmental perspective. In this context, all renewable energy sources in the area should be evaluated before port construction and renewable energy types compatible with the Filyos ecosystem, which provides the most efficiency, should be used.
- The energy management system (EMS) should be implemented.
- New generation technologies that save energy should be used.
- Energy-saving systems should be used in field equipment.

#### **A.4. Smart Finance**

- Many of the operational improvements are expected to contribute to the profitability of the port financially. For this reason, the port management should establish its financial targets in the form of a win-win and adopt a management approach focused on cost reduction.
- Transparency is an essential quality for the development of ports. Therefore, supply chain management should be adopted. In this way, firms' sharing of information with each other will contribute to many issues, especially efficiency and cost reduction.
- Port management should use the data to create new revenue-generating services.

#### **A.5. Smart Security and Safety**

- Proactive solutions should be provided on cybersecurity to ensure data security and privacy.
- Employee safety should be supported by autonomous technologies.
- For the port security, camera, sensor, etc. technologies and automatic image and motion recognition systems should be used
- Blockchain-based information sharing should be used. In this way, paper, etc. While preventing costs, it will be ensured that the data can be monitored by all stakeholders increase the transparency among stakeholders and protection of data security.

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