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Research Article

Evaluation of the technical feasibility aspects of the fishing structures: a case study of Izmir coast

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ABSTRACT

This paper was conducted by considering 28 fishing structures in Izmir Coast based on three aspects: inter relation with the fishing ground, technical aspects and market accessibility to determine technical requirements about infrastructure and superstructure facilities. The questionnaires and personal interviews with the main stakeholders were utilized to determine current situation of the fishing structures. The field observation covered the activities such as catch unloading, handling, auction, distribution and marketing of the catching fish. The data of fishing structures were evaluated by using Quality Function Deployment (QFD) Method. 13 customer requests and 19 technical requirements were considered for designing House of Quality (HoQ) matrix consisting of 7 sections. A mathematical model represented the relationship between fishing structure and boats was obtained by using Queuing Theory. The suitability of the model with Poisson arrival distribution and negative exponential service time distribution was checked using Chi-Square goodness of fit test. In the conclusion, the most important technical criteria were discussed. The features were identified which need to be improved most.

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INTRODUCTION

Fishing shelters are one of the most important points of juncture between increasing fisheries production. Recently, these shelters have been called as "Coastal fishing structures" with their natural-artificial harbors and harbor launches. The feasibility of land and water aspects are the main conditions which should be required by the fishing structures [1]. The basic criteria should be determined and the design must be done in accordance with these criteria for the technical feasibility of the coastal fishing structures for providing some essential conditions. The major

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improvements in planning, design, construction and operation of fishing ports were discussed by Agerschou (2004) [2]. Many researchers have investigated the technical facilities and inadequacies of fishing structures in different regions [3, 4, 5]. Chen and Zhang (2010) [6] described the current situation and technical progress of China's fishing port construction and the problems centering on the development were evaluated. The feasibility studies were examined by considering infrastructure in Jeppiar Fishing Harbor by Sampathkumar and Vanjinathan (2015) [7]. This study focused to upgrade this harbor to a higher grade by using observation results. Sharaan et al. (2016) [8] presented an over view about the current conditions of the existing natural and artificial Egyptian fishing ports. Nile Delta Coast of Egypt was selected to investigate the ability to of fishing facilities. Nurani et al. (2010) [1] evaluated some fishing ports and fish landing stations in the South Coast of Jav to discuss the functionality and accessibility of subsystems.

However, there are important problems in fishing ports and shelters built to serve fishermen in terms of the quality of the services received. Constructing these structures randomly on the coastal areas creates problems in terms of both coastal management and the desired efficiency cannot be obtained in terms of benefiting from these facilities [9]. The role of fishing ports cannot be ignored in the process from fishing to reaching the consumer. In order to achieve maximum productivity in the fishing sector, the adequacy of the fishing structures and the service they provide to the fishermen are very important [10].

In this study the infrastructures and superstructures which should be existed at the fishing structures were presented by comparatively according to the Regulation of Fishing Ports current in Turkiye [11]. Infrastructures are defined as structures that protect the fishing vessels from the impact of the wave, enable the water products obtained to be landed, provide navigation safety and facilitate the functionality of the harbor. The superstructures in the fishing coastal structures include the facilities which are required for fishermen's/seamen's (toilet, shower, canteen services, cooperative), wholesale fish market with the capacity to sell at least 10% of the haunting, boreholes and seawater systems, fish cleaning stations, workshops, dry docking areas, cold storage, ice production and repair areas, refueling systems, first aid services, fire extinguishing system [12]. The data which were collected from different sources as the personal interviews with the main stakeholders, questionnaires and visual observation, were used to determine current situation of 28 fishing structures in Izmir Coastal region. Structural aspects were examined according to the fishing vessel's characteristics and performances. Adequacy of the fishing ports was presented by taking into account the operating and marketing criteria. Quality Function Deployment (QFD) Method was utilized as a methodology for describing the inter-relationships between customer requirements and technical attributes. In the context of this paper, quality was viewed upon as the degree in which customer requirements were provided. 13customer requests and 19 technical requirements were considered for designing House of Quality (HoQ) matrix consisting of 7 sections. QFD Method is presented in a different field and the results were indicated that the most important customer request was "connection to the settlement". The additional facilities are proposed to upgrade the fishing structures in Izmir Coastal region to an ideal fishing port. A mathematical model was obtained by using Queuing Theory for Guzelbahce 1 fishing strıcture which has relatively more sufficient technical and structural equipment. The Poisson arrival distribution was derived considering single queue, multiple berthing place and priority queue conditions. The suitability of the vessel arrival distribution and service time distribution were checked with the Chi-Square goodness of fit test. The issues that should be prioritized for the improvement process of the fishing structures in Izmir Coast have been identified with this research.

MATERIAL AND METHODS

Materials

This study was accomplished to determine the adequacy of the infrastructures and superstructures of 28 coastal fishing structures in Izmir by conducting the questionnaires and discussions with 15 fishing port managers and 49 coastal fishermen. These fishing structures were presented in Table 1. The evaluation was utilized under three main headings as minimum requirements criteria, structural criteria [13] and operating and marketing criteria [14]. The minimum requirements were collected from the reports of the Ministry of Transportation General Directorate of Railways, Ports and Aircraft Construction [1]. The collected

Table 1. Izmir Coastal Fishing Structures

Number	Fishing Structure	Number	Fishing Structure
1	Dikili	15	Mordogan 1
2	Candarlı	16	Mordogan 2
3	Aliaga	17	Kaynarpinar
4	Yenifoca	18	Ambarseki
5	Semikler	19	Saipkoy
6	Karsiyaka	20	Karaburun
7	Narlidere Sahil Evleri	21	Yeni Liman
8	Guzelbahce 1	22	Ilica-Yildizburnu
9	Guzelbahce 2	23	Dalyankoy
10	Kalabak	24	Cesme
11	Urla (Pier)	25	Ciftlikkoy
12	Cesmealti	26	Alacati
13	Ozbekkoy	27	Sigacik
14	Balikliova	28	Ozdere

data were evaluated, listed in three categories and given in tables.

QFD method was used to provide product design quality based on surveys and questionnaire. Customer requests and technical requirements were defined. 28 coastal fishing structures given in Table 1 were evaluated according to HoQ matrices. The challenges relating to Izmir Coastal fishing structures were determined considering the values of absolute importance and relative importance.

The Study Area

Izmir coastal region was selected as the research area because of indented coast shape and narrow continental shelf of coastal fishing is commonly done [15] with an advantageous position in terms of fishing in Turkiye [16].

Izmir coastal area meets approximately 9% [17] of Turkiye's fisheries production is an important center in the Aegean Sea [18]. The location of the 28 coastal fishing structures in this region can be seen in Figure 1. Details of

Figure 1. The location of Izmir Coastal Fishing Structures.

Table 2. Assessment of Izmir Fishing Structures according to minimum requirements facilities

Fishing structure	Electricity	Water	Lighthouse	Net drying area	Dock
Dikili	•	o	•	•	•
Candarli	•	•	o	•	•
Aliaga	o	o	•	•	•
Yenifoca	•	•	o	•	•
Semikler	o	•	o	•	•
Karsiyaka	o	o	o	•	•
Narlidere Sahil Evleri	•	•	o	•	•
Guzelbahce 1	•	•	•	•	•
Guzelbahce 2	•	•	o	•	•
Kalabak	•	•	•	•	•
Urla (Pier)	•	•	•	•	•
Cesmealti	•	•	•	•	•
Ozbekkoy	•	•	o	•	•
Balikliova	o	o	o	•	•
Mordogan 1	o	•	o	•	•
Mordogan 2	•	•	o	•	•
Kaynarpinar	•	•	o	•	•
Ambarseki	o	o	o	•	•
Saipkoy	•	•	o	•	•
Karaburun	o	•	•	•	•
Yeni Liman	•	•	o	•	•
Ilica-Yildizburnu	o	o	o	•	•
Dalyankoy	•	•	•	•	•
Cesme	o	o	o	o	•
Ciftlikkoy	•	o	o	•	•
Alacati	o	o	•	•	•
Sigacik	•	•	o	o	•
Ozdere	•	•	o	•	•

"•" the requirement is provided, "o" the requirement is not provided

Table 3. Assessment of Izmir Fishing Structures according to structural design criteria

Fishing structure	The length of the main breakwater (m)	The length of the secondary breakwater (m)	The width of the harbor entrance (m)	Protected water area (ha)
Dikili	235.00	60.00	56.00	0.72
Candarli	458.50	-	280.00	4.25
Aliaga	289.00	73.00	**20.00**	1.85
Yenifoca	135.00	35.00	69.00	1.40
Semikler	235.00	-	40	0.70
Karsiyaka	**270.00**	**50.00**	-	5.50
Narlidere Sahil Evleri	**214.25**	40.00	**15.00**	1.40
Guzelbahce 1	270.00	70.00	**14.00**	0.99
Guzelbahce 2	320.00	50.00	30.00	1.20
Kalabak	160.00	55.00	**22.00**	0.60
Urla (Pier)	210.00	-	65.00	1.55
Cesmealti	200.00	-	187.00	3.00
Ozbekkoy	210.00	164.00	**28.00**	1.75
Balikliova	260.00	50.00	60.00	1.20
Mordogan 1	90.00	50.00	120.00	4.0
Mordogan 2	795.00	135.00	67.00	8.70
Kaynarpinar	133.00	30.00	**17.00**	0.56
Ambarseki	88.00	38.00	75.00	0.42
Saipkoy	177.50	83.50	35.00	1.25
Karaburun	115.00	12.50	**24.00**	3.70
Yeni Liman	198.90	45.00	147.00	1.15
Ilica-Yildizburnu	292.00	260.00	39.00	4.40
Dalyankoy	78.50	-	54.00	1.80
Cesme	108.10	28.00	**11.00**	0.18
Ciftlikkoy	273.00	67.00	**25.00**	1.12
Alacati	275.00	-	**22.00**	2.25
Sigacik	110.00	37.00	**20.00**	0.65
Ozdere	185.00	38.00	32.00	6.50

the existing facilities were obtained as a result of interviews with the administration by visiting these structures within the scope of the research for on-site observation.

Analysis of Technical Aspects of The Fishing Structures

In developed countries, coastal fishing structures are built as functional structures that can provide all kinds of services to fishing vessels and fishermen. Projecting should be done by determining the basic criteria for the technical feasibility of these structures. These criteria can be listed as main and secondary breakwaters that protect fishing vessels from wave effects, lighthouses providing safe access, docks where the fishing vessels can use regularly and safely, water, electricity facilities and net drying areas [19]. Technical due diligence on the viability of Izmir fishing structures including the evaluation of minimum requirements criteria was presented in Table 2.

As seen in Table 2, there are both electricity and water facilities in 16 fishing ports. The deficiency of net drying area was observed in two fishing structures in Izmir. Unfortunately, many fishing structures cannot even provide the minimum requirements. The interviews with fishermen indicated that water and wastewater systems are the most essential requirements in fishing structures. Water system operations are interdependent with other infrastructure systems.

Coastal fishing structures should meet certain criteria structurally as well as minimum conditions. The fishing structure can contain not only the main breakwater, but also secondary breakwater. The length of the breakwaters

Table 4. Assessment of Izmir Fishing Structures according to superstructures

Fishing structure	Administration building	Wholesale fish market	Cold storage	Ice production area	Rest room complexes	Refueling systems	Fire extinguishing system
Dikili	•	•	o	o	•	o	•
Candarli	o	o	o	o	o	o	o
Aliaga	•	•	o	o	•	o	o
Yenifoca	•	•	•	o	o	o	•
Semikler	•	•	o	o	•	o	o
Karsiyaka	•	o	o	o	o	o	•
Narlidere Sahil Evleri	•	•	•	o	o	o	o
Guzelbahce 1	•	•	•	o	•	o	o
Guzelbahce 2	o	o	o	o	•	o	o
Kalabak	•	o	o	o	•	o	•
Urla (Pier)	•	•	o	o	o	o	•
Cesmealti	•	•	•	•	o	o	o
Ozbekkoy	•	•	o	o	o	o	•
Balikliova	•	o	o	o	o	o	o
Mordogan 1	•	•	o	o	o	o	•
Mordogan 2	•	•	o	o	o	o	o
Kaynarpinar	o	o	o	o	o	o	o
Ambarseki	o	o	o	o	o	o	o
Saipkoy	•	o	o	o	•	o	o
Karaburun	•	o	o	o	o	o	•
Yeni Liman	•	o	o	o	o	o	•
Ilica-Yildizburnu	•	•	o	o	o	o	o
Dalyankoy	•	o	o	o	o	o	•
Cesme	•	•	o	o	o	o	o
Ciftlikkoy	•	•	o	o	o	o	o
Alacati	o	•	o	o	•	o	•
Sigacik	o	o	o	o	o	o	•
Ozdere	•	o	•	o	•	o	o

"•" the requirement is provided, "o" the requirement is not provided

belonging to the fishing structures in our study is calculated from site plan or aerial photographs. The width of harbor entrance varies depending on the size and capacity of fishing vessels and it is recommended to be in the range of 35-50 meters [20]. The water area protected by the breakwaters should be in a size that enables the fishing vessels to maneuver easily. While calculating the berth capacity, the width of the berth was accepted as 4 meters per fishing vessel. Number of docks and the size of the maneuver area are determined by in-port traffic and evaluating the number of registered fishing vessels respectively [21].

Insufficient width of harbor entrance causes the fishing vessels to wait for service, so fishermen's loss of labor occurs. For this reason, arrival and service times of the fishing vessels are also taken into consideration during the sizing phase. As seen in Table 3, the information in the column, which is considered to be inadequate and should be developed in the fishing structures, is written in bold.

As a result of various effects, such as the construction of the structures on sandy coasts, the entrances and basins of these fishing structures are exposed to great amount of shoaling, which affects the operations adversely [21]. The most effective solution to shoaling is seabed dredging [22]. Izmir coastal fishing structures which should be dredged with certain periods, were determined as Candarli,

Table 5. Assessment of Izmir Fishing Structures according to operating criteria

Fishing structure	Total capacity (the number of fishing vessels)	Capacity utilization rate	Density	Hinterland highway Connection
Dikili	61-115	**100.1-150.0**	**125.00**	Asphalt 4.5km
Candarli	116-185	50.1-100.0	90.30	Stabilized 22km
Aliaga	116-185	50.1-100.0	95.20	Asphalt (0.1 km)
Yenifoca	61-115	**100.1-150.0**	**131.60**	Asphalt (15 km)
Semikler	61-115	**150.1-200.0**	**167.00**	Asphalt (0 km)
Karsiyaka	116-185	50.1-100.0	77.40	Asphalt (0.05 km)
Narlidere Sahil Evleri	61-115	50.1-100.0	80.00	Asphalt (0.2 km)
Guzelbahce 1	61-115	**100.1-150.0**	**142.40**	Asphalt (0 km)
Guzelbahce 2	61-115	**50.1-100.0**	**95.70**	Asphalt (0 km)
Kalabak	22-60	**100.1-150.0**	**147.30**	Asphalt (0 km)
Urla (Pier)	61-115	**100.1-150.0**	**141.00**	Asphalt (0 km)
Cesmealti	61-115	**100.1-150.0**	**144.00**	Asphalt (0 km)
Ozbekkoy	116-185	**50.1-100.0**	**123.10**	Asphalt (4 km)
Balikliova	61-115	50.1-100.0	70.60	Asphalt (0.3 km)
Mordogan 1	186-275	**25.1-50.0**	**111.10**	Asphalt (1 km)
Mordogan 2	61-115	**100.1-150.0**	**25.60**	Asphalt (1.5 km)
Kaynarpinar	22-60	**50.1-100.0**	**60.00**	Asphalt (0.2 km)
Ambarseki	22-60	**100.1-150.0**	**125.00**	Asphalt (1 km)
Saipkoy	61-115	**25.1-50.0**	**25.60**	Asphalt (0.3 km)
Karaburun	61-115	50.1-100.0	70.80	Asphalt (0.7 km)
Yeni Liman	61-115	50.1-100.0	76.80	Asphalt (0.1 km)
Ilica-Yildizburnu	116-185	**25.1-50.0**	**31.80**	Asphalt (1 km)
Dalyankoy	186-275	50.1-100.0	84.70	Asphalt (1 km)
Cesme	22-60	**100.1-150.0**	**138.90**	Asphalt (0 km)
Ciftlikkoy	61-115	50.1-100.0	83.50	Asphalt (0.7 km)
Alacati	116-185	50.1-100.0	70.40	Asphalt (2.5 km)
Sigacik	22-60	**>200.1**	**291.70**	Asphalt (5 km)
Ozdere	22-60	**150.1-200.0**	**167.50**	Asphalt (24.6 km)

Aliaga, Yenifoca, Semikler, Karsiyaka, Guzelbahce 2, Urla, Cesmealti, Ozbekkoy, Mordogan 2, Kaynarpinar, Amberseki, Saipkoy, Yeni Liman, Ilica, Ciftlikkoy, Alacati and Ozdere.

Within the scope of structural criteria, it is not enough to examine the facilities only in terms of size. It is also necessary to examine the superstructure facilities that are expected to be found in order to increase the efficiency of the fishing structures. The superstructure facility inventory for 28 fishing structure was given by Table 4.

When Tables 3 and 4 are analyzed, it is seen that fishing structures are more sufficient in terms of infrastructure facilities, but they do not have many of the superstructure facilities. The absence of these facilities causes also economic loss. Interviews with managers revealed the fact that fishing structures were not delivered as specified in the project at the end of the construction process. The lack of superstructure to meet the needs continues due to the structures received only after the construction of the breakwaters before the superstructure facilities are completed. In addition, the lack of knowledge of the fisheries cooperatives about the facilities and services needed is an important problem [23].

Investigation of Conformity to Operating Criteria of The Fishing Structures

In this part of the study, the total capacity of the fishing structure, the capacity utilization rate, the ratio of the number of fishing vessels using during the fishing season to the total capacity (density) were examined. This ratio (density) shows the productivity of the fishing structure. In the evaluation of fishing structures in terms of operating criteria, besides these data, the distance of the fishing structure from the multi-lane connection roads (hinterland transportation connection) was also examined (Table 5).

Fishing structures, where the capacity utilization ratio and density are above 100%, are considered to be insufficient. As seen in Table 5, 7 fishing structures serve with more than 100% density (highlighted in bold). The interviews with authorities pointed that the yachts which use fishing structures are a source of income however negatively affect the fishing sector.

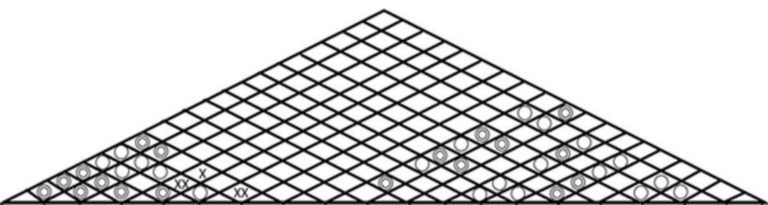
Structures where capacity and density are below 50% do not work with sufficient efficiency. As seen in Table 5 (highlighted in bold), there are fishing structures which are considered as redundant investments where the capacity utilization rate is below 50%. In line with the opinions received from the fishermen, it was concluded that the unproductive investments with low density are generally caused by the fishing structures located close to each other. In addition, the lack of security and financial conditions have been suggested as the reason for a less preferable fishing structure.

Application of Quality Function Deployment (QFD) Method in The Fishing Structures

QFD was developed as a design technique for executing product design and planning to answer customer needs and expectations [24]. This method has been popular in some engineering areas especially in the aerospace and automotive industry, but has slowly obtained concern among other disciplines [25, 26, 27, 28]. QFD was applied to determine the requirements of Izmir Coastal fishing structures and to meet these requirements technically within the scope of this study.

QFD has many stages, all of which are interconnected to form the House of Quality (HoQ) matrices [28]. HoQ provides that constituting targets of customer requirements and determining how these requirements are provided technically. Quality house is obtained by defining technical correlations, technical requirements, relationship matrix, customer requests, priority technical targets, importance of customer requests, planning matrix [29]. Customer requests (voice of customer) section is in the vertical part of the HoQ and this section responds to the question of "What". In this study, the feedbacks received from the fishermen and stakeholders through questionnaires were ensured to shape customer requests. Similarly, the technical requirements section answering the "How" question has been determined with the condition of adhering to the specifications as a result of the interviews with the managers [30]. The quality house created with 13 customer requests and 19 technical requirements considered to meet these requests is given in Figure 2.

28 fishermen structures evaluated in the quality house shown in Figure 2 were given a point value against each customer request. The averages of these score values were



Technical Requirements / Customer Requests	Main breakwater length	Secondary breakwater length	Port enterance width	Dock length	Dock depth	Number of docks	Protected water sea	Transportation connection	Electricity availability	Water availability	Lighthouse availability	Boat yard availability	Administration building availability	Fish selling place availability	Precooling availability	Ice production area availability	Net drying area	Rest room complexes availability	Fire extinguishing system availability	Importance Degrees	Compared options and point values (Table 6.)	Target Quality	Improvement Rate	Absolute Weight	Relative Weight
Protection against dominant waves	9	3	9	1	1	1	3													5		5	2.44	12.20	9.88
Effective infrastructure facilities									9	9										5		5	1.08	5.38	4.36
Settlement connection								9												5		5	3.68	18.42	14.92
Adequate size of land area												9	9	9	9	9	9	9		5		5	1.64	8.22	6.66
Adequate maneuver area in the protected water sea			9		3		9													5		5	2.70	13.46	10.90
Safe sea passing	9	3	9																	5		5	2.41	12.07	9.78
Regular and safe berthing				9	3	9	9													5		5	2.15	10.77	8.72
Adequate lighting on docks and piers									9		9									5		5	1.67	8.33	6.75
Adequate area for drying of nets and repairing																	9			4.67		5	1.06	4.95	4.01
Satisfying the essential needs of fishermen									9	9								9		3.67		5	1.51	5.52	4.48
Presence of the storage areas for putting the products									9	9						9	9			5		5	1.94	9.72	7.88
Presence of the product sales areas													3	9						4.67		5	1.37	6.41	5.19
Presence of emegency equipments																			9	4.33		5	1.84	7.98	6.46
Absolute Importance	218.43	72.81	339.58	109.12	84.89	109.12	254.68	165.79	260.68	185.68	75	73.99	93.22	131.68	161.49	161.49	118.57	123.72	71.79	Σ	2811.74		Σ	123.45	100.00
Relative Importance	7.77	2.59	12.08	3.88	3.02	3.88	9.06	5.90	9.27	6.60	2.67	2.63	3.32	4.68	5.74	5.74	4.22	4.40	2.55		100.00				

Figure 2. The House of Quality.

Table 6. Points of fishing structures accordig to customer needs

Customer Requests \ Fishing Structures	Dikili	Çandarlı	Aliağa	Yenifoça	Şemikler	Karşıyaka	Narlıdere	Güzelbahçe 1	Güzelbahçe 2	Kalabak	Urla	Çeşmealtı	Özbekköy	Balıklıova	Mordoğan 1	Mordoğan 2	Kaynarpınar	Amberseki	Saipköy	Karaburun	Yeni Liman	Ilıca	Dalyanköy	Çeşme	Çiftlikköy	Alaçatı	Sığacık	Özdere
Protection against dominant waves	2	2	2	2	2	3	2	2	3	2	2	2	2	2	2	4	2	1	2	2	2	3	2	2	2	2	2	2
Effective infrastructure facilities	5	5	1	5	3	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Settlement connection	1	3	1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	5
Adequate size of land area	4	2	4	4	3	3	4	4	3	3	3	4	3	3	3	3	2	2	3	3	3	3	3	2	3	3	1	4
Adequate maneuver area in the protected water sea	2	3	1	1	2	3	2	1	2	2	1	2	1	2	2	4	1	1	2	2	2	2	1	2	1	2	2	3
Safe sea passing	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	3	1	2	2	2	2	2
Regular and safe berthing	2	2	2	1	4	5	3	2	3	2	2	2	2	2	2	4	2	1	3	2	2	2	3	2	1	2	2	3
Adequate lighting on docks and piers	5	3	3	3	1	1	3	5	3	5	5	5	3	1	5	1	3	1	3	3	3	1	5	1	3	3	3	3
Adequate area for drying of nets and repairing	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	1	5	5	1	5
Satisfying the essential needs of fishermen	5	4	2	4	4	1	4	5	5	5	4	4	4	1	4	2	4	1	5	2	4	1	4	1	2	2	4	5
Presence of the storage areas for putting the products	3	3	1	4	2	1	4	4	3	3	3	5	3	1	3	2	3	1	3	2	3	1	3	1	2	1	3	4
Presence of the product sales areas	5	1	5	5	5	3	5	5	1	3	5	5	5	3	5	5	1	1	3	3	3	5	3	5	5	3	1	3
Presence of emegency equipments	5	1	1	5	1	5	1	1	1	5	5	1	5	1	5	1	1	1	1	5	5	1	5	1	1	5	5	1

used when calculating improvement ratios. Since these point values of the fishing structures will be difficult to display in the quality house, they are also given in Table 6.

In the application of this method, the aim is to determine the technical properties that can best meet customer needs before providing the product/service [31].

The strength of the relationships between the customer requests and technical requirements of fishing structures were evaluated by the values of improvement rate, absolute weight, relative weight, absolute and relative importance. These parameters are calculated by the following equations [32]. Improvement rate IR, is indicated by Eq. (1).

$$IR_i = \prod_{i=1}^{m} \left[\frac{TQ_i}{\left(\frac{A_{i_1} + A_{i_2} + A_{is}}{s} \right)} \right] \tag{1}$$

In Equation (1), TQ expresses target quality. A, B, C show different options in the planning matrix. The number of customer requests is given by m, the number of options by s. The i and j used in the equations are the number of rows and columns, respectively [33]. Absolute weight AW can be seen in Eq. (2).

$$AW_i = \prod_{i=1}^{m} \left(IR_i \times ID_i \right) \tag{2}$$

The ID given in the Eq. (2) indicates the degree of importance.

The relative weight RW, expressing the ratio of absolute weight to total absolute weight, is as in Eq. (3).

$$RW_i = \prod_{i=1}^{m} \left(\frac{AW_i}{\sum_{i=1}^{m} AW_i} \times 100 \right) \tag{3}$$

Relative weight is calculated in percent. The absolute importance AI and relative importance RJ which is total absolute importance ratio, is given in Eq. (4) and Eq. (5) respectively.

$$AI_j = \prod_{i=1}^{m} \left(\sum_{i=1}^{m} R_{ij} \times AW_i \right) \tag{4}$$

$$RI_j = \prod_{i=1}^{m} \left(\frac{AI_j}{\sum_{i=1}^{m} R_{ij} \times AW_i} \right) \tag{5}$$

The relationship between the customer need couple is calculated numerically and evaluated with the help of equations.

The correlation between stakeholder surveys and each customer requests/expectations is located in the roof matrix. Roof matrix provides technical properties that affect each other positively or negatively [34]. The relationships between the customer requests/expectations identified in this section are evaluated with the 5-point scale shown in Figure 3.

The relationship between customer requests and technical requirements were expressed and measured through a 9-point scale which was preferred by the Japanese Chan and Wu (2005) [35] such as seen in Figure 4.

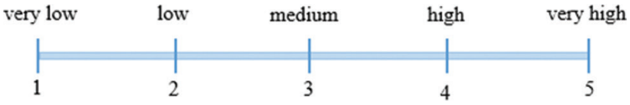


Figure 3. 5-Point sale of the correlation between customer needs/expectations.

Figure 4. 9-Point scale of the relationship between request and technical requirements.

Table 7. Degrees of relationship

Blank	No relationship
◎	Strong positive
○	Weak positive
XX	Strong negative
X	Weak negative

This scale uses 9-point scale from 1 to 9 to measure relative importance. The fact that if it is 0, it indicates that there is no relationship between request and requirement.

The degree of interrelation of the technical requirements in the roof of the Quality House is defined as shown in Table 7. In this technical relationship matrix that forms the roof, the aim is to reveal the relationship between technical requirements.

Mathematıcal Model of Coastal Fishing Structures with Queuing Theory

The dimensions of fishing structures and industrial facilities are the main factors that determine the investment cost and service capacity. The optimum design is only possible with the creation of the mathematical model that defines the relationship between the fishing structures and the vessels using the fishing structures and the correct planning of the number of berths. The most suitable models used for ports [36] and fishing structures are obtained by Queuing Theory [37] based on probability calculation principles. The number of vessels, number of berths, queue arrangement, vessel arrival distribution and vessel service time distribution are taken into consideration in the model to be created for the fishing structure.

In this study, single queue, multiple berthing place and priority queue order were used. The Poisson arrival distribution is given in Equation (6).

$$P_n = \frac{(\bar{n})^n e^{-(\bar{n})}}{n!} \tag{6}$$

In this equation P_n is the possibility of n vessels arriving to the fishing structure at the same time, $\bar{n}$ is the average number of arrivals within the specified time period, e is the Naperian logarithm constant. Negative exponential service time distribution is presented by the following equation.

$$P_b(t) = e^{-bt} \tag{7}$$

$P_b(t)$ is the probability of time spending at the docks, b is the average service speed and t time frame used for calculations. The suitability of the vessel arrival distribution and service time distribution were checked with the Chi-Square goodness of fit test. It is predicted that each vessel waits in the queue for a certain period of time with this model. The average waiting time t_w is calculated by Equation (8).

$$t_w = \frac{\psi^M}{b(M-1)!(M-\psi)^2\left[\sum_{i=0}^{M-1}\frac{\psi_i}{i!} + \frac{\psi^M}{(M-1)!(M-\psi)}\right]} \tag{8}$$

In this equation M is number of selected berth, ψ is traffic density and b is average service speed. Within the scope of the study, due to its close proximity to Izmir, a queue model has been created for Guzelbahce 1 fishing structure, which has a high traffic density and is suitable for meeting the basic requirements in terms of its technical and structural properties. Daily functional duration of Guzelbahce 1 fishing structure, daily number of vessels, number of vessels arriving per minute, time spent in service, number of vessels served per minute and traffic density are considered as $T=8$ hours, $N=120$, $a=0.25$ vessels/minute, $t_b=3600$ minutes, $b=0.033$ vessels/minutes and ψ = 7.5 respectively. The evaluated time interval is accepted as Δt= 30 minutes and the distribution of the vessel service time and the vessel arrival distribution are shown in Table 8 and Table 9.

It has been observed that the number of observed and expected vessels for the specified service intervals are consistent with the 5% probability of error.

It was observed that the model calculated the number of vessels coming to the fishing structure within the time interval of Δt= 30 minutes with the possibility of 7.5% error by checking the Chi-Square goodness of fit test.

RESULTS

As a result of the calculations made for Izmir Coastal fisheries structures, average values, target quality values and improvement ratios of customer requests are shown in Figure 5. The high ratio of improvement shows the demand that is most needed to be developed and the highest value is the most important.

Table 8. Fishing Vessel Service Time Distribution

Service Time (minutes)	Distribution by Vessel Length		Number of Observed Vessels	Attached Distribution		Theoretical Distribution		Number of Expected Vessels
	Length (m)	%		Number	%	Number	%	
0-15	12	50.0	60	120	100,0	120	100.0	76
15-30	12-15	20.0	24	60	50,0	44	37.0	18
30-45	15-16	15.0	18	36	30,0	26	22.0	26
45-60	17-20	10.0	12	18	15,0	17	13.8	7
60-75	20	5.0	6	6	5,0	10	8.4	10

Table 9. Fishing Vessel Arrival Distribution

Number of Vessels Arriving at the Same Δt Hour (n)	n Number of Vessel Arrivals at Δt Observed Value (t)	Arrival Probability of Vessels		Arrivals Number of n Number of Vessels at Δt Time Expected Value (F)
		Observed	Expected	
0	0	0.0000	0.0050	0.0080
1	1	0.0630	0.0041	0.0656
2	0	0.0000	0.0155	0.2496
3	3	0.1880	0.0389	0.6224
4	1	0.0630	0.0729	1.1664
5	2	0.1250	0.1094	1.7504
6	0	0.0000	0.1367	2.1872
7	2	0.1250	0.1465	2.3440
8	1	0.0630	0.1373	2.1968
9	2	0.1250	0.1144	1.8304
10	0	0.0000	0.0858	1.3728
11	1	0.0630	0.0585	0.9360
12	0	0.0000	0.0366	0.5856
13	1	0.0630	0.2110	0.3376
14	0	0.0000	0.0113	0.1808
15	1	0.0630	0.0057	0.0912
16	0	0.0000	0.0026	0.0416
17	1	0.0630	0.0012	0.0192
N=120	16			15.9600

The highest improvement ratios achieved among the 28 fishing structures were calculated as 3.68 and 2.69 for the "settlement connection" and "adequate maneuver area in the protected water sea" respectively. The criterion, where the improvement ratio has the lowest value, has been determined as "adequate area for drying of nets and repairing". Target quality value is 5.00 and average quality values vary between 1.36 and 4.71. The increase in the average quality value causes the improvement ratio to decrease.

13 customer requests that determine the properties of the fishing structures are listed in Table 10, sorted from large to small according to their absolute weight and relative weight.

The high absolute weight value indicates that the demand is high and there are criteria that should be developed as a priority. Relative weight values based on calculation of absolute weight ranging from 4.95 to 18.42 are between 14.92% and 4.01%.

Evaluation of technical requirements according to absolute and relative importance parameters is given in Table 11. The first five requirements are listed as port entrance width, electricity availability, protected water area, main breakwater length and water availability. It is seen that

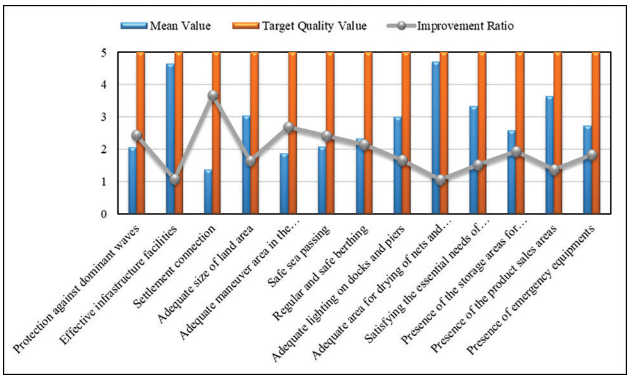


Figure 5. Mean Values, Target Quality values and Improvement Ratios.

Table 10. Customer Requests Ranking According to Absolute and Relative Weight Values

Customer Requests	Absolute Weight	Relative Weight (%)
Settlement connection	18.42	14.92
Adequate maneuver area in the protected water area	13.46	10.90
Protection against dominant waves	12.20	9.88
Safe sea passing	12.07	9.78
Regular and safe berthing	10.77	8.72
Presence of storage areas for putting the products	9.72	7.88
Adequate lighting on docks and piers	8.33	6.75
Adequate size of land area	822	6.66
Presence of emergency equipments	7.98	6.46
Presence of product sales areas	6.41	5.19
Satisfying the essential needs of fishermen	5.52	4.48
Effective infrastructure facilities	5.38	4.36
Adequate area for drying of nets and repairing	4.95	4.01

Candarli, Guzelbahce 1, Mordogan fishing structures are more equipped considering the order of importance. There is no electricity and water infrastructure in the fishing structures of Karsiyaka, Balikliova, where vessel traffic is high, and there is no electricity infrastructure in Mordogan 2. This lack of infrastructure adversely affects the operation of fishing structures.

As seen in Table 11, the highest value in terms of relative importance has been determined as the “port entrance width” with 12.08%. The port entrance width, which is an important design criterion in terms of operation and cost, affects the waiting time of the vessels in the model study made with the queue theory. The mathematical model made by considering Guzelbahce 1 fishing structure shows that t_w average waiting time should be reduced to 1.8 minutes in order to use the structure more efficiently. Thus, the structure can be used more functionally by 82.00%.

Table 11. Technical requirements ranking according to Absolute and Relative Importance

Technical Requirements	Absolute Importance	Relative Importance (%)
Port entrance width	339.58	12.08
Electricity availability	260.68	9.27
Protected water area	254.68	9.06
Main breakwater length	21842	7.77
Water availability	185.68	6.60
Highway connection	165.79	5.90
Precooling availability	161.49	5.74
Ice production area availability	16149	5.74
Fish selling place availability	131.68	4.68
Rest room complexes availability	123.72	4.40
Boat yard availability	118.57	2.63
Dock length	109.12	3.88
Number of docks	109.12	3.88
Administration building availability	93.22	3.32
Dock depth	84.89	3.02
Lighthouse availability	75.00	2.67
Secondary breakwater length	72.81	2.59
Fire extinguishing system availability	71.79	2.55

DISCUSSIONS

One of the contributions of this study is that Izmir Coastal fisheries structures present the data related to the infrastructure and superstructure facilities comprehensively by benefiting from the studies in the literature and on-site examinations. The information required for the research was obtained through the face-to-face survey method conducted with 15 port managers and 49 shore fishermen in May-October 2019. In addition, field studies have been carried out to determine the current state of the fishing structures. Evaluations have shown that 28 fishing structures have the necessary facilities for the supply of electricity and water with 64.30% and 67.90%, respectively. In addition to basic needs, 78.60% of fishing structures have an administration building, 53.60% have a wholesale fish market and 17.90% have a pre-cooling warehouse. On the other hand, ice production area with absolute importance value of 161.49 is present in only 3.60% of the structures. These data showed that fishing structures meet the need for protection of vessels in adverse weather conditions but do not have superstructure facilities to increase production. Another contribution of the study is to present the QFD Method in a different area, which is used to increase efficiency in many engineering fields. Customer requests and technical requirements have been put forward to improve fishing structures. Customer requests and technical requirements have been revealed to improve fishing structures. Absolute weight, relative weight, absolute importance and relative importance criteria and parameters that need to be improved numerically were determined. The highest value indicates the demand that needs to be improved the most. In the study, the most important customer request was determined as the "settlement connection" where the absolute weight is 18.42 and the relative weight is 12.92%. The most important technical requirement is "port entrance width" with 339.58 absolute importance and 12.08% relative importance. The subjects that should be prioritized for the improvement works to be carried out in the Izmir Coastal fisheries structures are specified with this research. Since the port entrance width and the number of docks are the main parameters affecting the waiting time of the vessels, a mathematical model based on Queuing Theory was created using the data of Guzelbahce 1 fishing structure. In the model, whose compliance was measured with the Chi Square test, it was observed that the waiting time of the vessels was reduced to 1.8 minutes, resulting in an increase of 82% efficiency. When the results are examined, although there are developed fishing structures according to their infrastructure, there is no ideal fishing structure in Izmir Coastal region.

AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] Nurani TW, Lubis E, Haluan J, Saad S. Analysis of fishing ports to support the development of tuna fisheries in the South Coast of Java. Indones Fish Res J 2010;16:69–78. [CrossRef]
[2] Agerschou H. Planning and design of ports and marine terminals. 2st ed. London: Thomas Telford Press; 2004.
[3] Israel DC. Analysis of fishing ports in the Philippines (No. 2000-04), PIDS Discussion Paper Series, 2000.
[4] Ceyhan T, Akyol O, Unal V. An investigation on artisanal fisheries in Edremit bay (Aegean Sea). J Fish Aquat Sci 2006;23:373–375.
[5] Boran M, Softa SA. An investigation on the coastal fishing structures located in Trabzon province. J Fish Aquat Sci 2016;33:307–311. [CrossRef]
[6] Chen ZR, Zhang JQ. An overview about the engineering technology of fishing port [J], Fishery Modernization 3, 2010.
[7] Sampathkumar V, Vanjinathan J. Feasibility study on upgrading infrastructure in Jeppiaar fishing harbor. Int J Oceans Oceanogr 2015;9:127–141.
[8] Sharaan M, Negm A, Iskander M, Nadaoka K. Egyptian fishing ports challenges and opportunities case study: Mediterranean Sea ports. In: Oates D, Burkhart E, Grob J, editors. 14th Triennial International Conference; 2016 June 12-15; New Orleans, Louisiana: American Society of Civil Engineers; 2016. pp. 540–549. [CrossRef]
[9] Avcı Softa S. An investigation on the coastal fishing structures located in Trabzon city. Master Thesis. Trabzon, Turkey: Karadeniz Technical University; 2014.
[10] Yıldız T, Karakulak FS. Current situation of fishing coastal structures in the Istanbul. Gümüşhane Univ J Sci Technol Inst 2013;3:16– 28.
[11] Ministry of Transportation General Directorate of Railways. Ports and Aircraft Construction, Fisheries Coastal Structures Situation and Needs Analysis Results Report 1-2, Ankara, 2011.
[12] RG Official Gazette. Regulation of fishing ports (in Turkish), 2016.
[13] Yıldırım D, Eren A, Gökkuş Ü. Criteria on technical feasibility of fishery harbors, The 16th National Aquaculture Symposium, Antalya, Turkey, 2011.
[14] Varol BY, Eren A, Gökkuş Ü. Availability of Izmir fishery harbors from aspect of the technical feasibility criteria. The 16th National Aquaculture Symposium, Antalya, Turkey, 2011.
[15] Yalçın E, Gurbet R. Environmental influences on the spatio-temporal distribution of European Hake (Merluccius merluccius) in Izmir Bay, Aegean Sea. Turkish J Fish Aquat Sci 2016;16:1–14.

[16] Unal V, Goncuoglu H. Fisheries management in Turkey. In: Tokac AC, Gucu BO, editors. The state of the Turkish fisheries.1st ed. Istanbul: Turkish Marine Research Foundation Publication; 2012. p. 263–288.

[17] Kınacıgil HT, Ilkyaz AT. Sea fishery in Aegean Sea. Ege Univ J Fish Aquat Sci 1997;14:351–367.

[18] TUIK Bulletin. Fishery products (in Turkish) 2008, Turkish Statistical Institute Publication, Ankara, 125, 2009.

[19] UDHB. Status and needs, analysis report results for fishing coastal structures. Volume-I, Volume-II, (in Turkish), Ministry of Transport, Directorate of Railway, Harbours and Air Ports Construction, Ankara, 2011.

[20] Tsinker GP. Port Engineering: Planning, Construction, Maintenance, and Security. 1st ed. New York: John Wiley & Sons; 2004.

[21] Sume V, Yuksek O. Investigation of shoaling of coastal fishery structures in the Eastern Black Sea coasts. J Fac Eng Archit Gazi Univ 2018;33: 843–852.

[22] Eisma D. Dredging in Coastal Waters. 1st ed. Florida: CRC Press; 2005.

[23] Belen S. Rehabilitation of fishery shelters, Master Thesis. İzmir, Turkey: Dokuz Eylül University; 2012.

[24] Yazdani M, Kahraman C, Zarate P, Onar SC. A fuzzy multi attribute decision framework with integration of QFD and grey relational analysis. Expert Syst Appl 2019;115:474–485. [CrossRef]

[25] Ahmed SM, Sang LP, Torbica ŽM. Use of quality function deployment in civil engineering capital project planning. J Constr Eng Manag 2003;129:358–368. [CrossRef]

[26] Dikmen I, Birgonul MT, Kızıltas S. Strategic use of quality function deployment (QFD) in the construction industry. Build Environ 2005;40:245–255. [CrossRef]

[27] Lam JSL. Designing a sustainable maritime supply chain: A hybrid QFD–ANP approach. Trans Res E: Logist Transp Rev 2015;78:70–81. [CrossRef]

[28] Bolar AA, Tesfamariam S, Sadiq R. Framework for prioritizing infrastructure user expectations using Quality Function Deployment (QFD). Int J Sustain Built Environ 2017;6:16–29. [CrossRef]

[29] Kelesbayev D, Kalykulov K, Yertayev Y, Turlybekova A, Kamalov A. A case study for using the quality function deployment method as a quality improvement tool in the universities. Int Rev Manag Mark 2016;6:569–576.

[30] Bode J, Fung RY. Cost engineering with quality function deployment. Comput Ind Eng 1998;35:587–590. [CrossRef]

[31] Kurt HS, Yenilmez G. Quality function deployment: an application on shopping malls. Organizasyon ve Yönetim Bilimleri Dergisi 2017;9:14–29.

[32] Govers CP. What and how about quality function deployment (QFD). Int J Prod Econ 1996;46:575–585. [CrossRef]

[33] Bouchereau V, Rowlands H. Methods and techniques to help quality function deployment (QFD). Benchmarking: Int J 2000;7:8–20. [CrossRef]

[34] Hauser JR, Clausing D.The house of quality. Harvard: Harvard Business Review; 1998.

[35] Chan LK, Wu ML. A systematic approach to quality function deployment with a full illustrative example. Omega 2005;33:119–139. [CrossRef]

[36] Dragu V, Dinu O, Ruscă A, Burciu S, Roman EA. Queuing theory models used for port equipment sizing. ModTech International Conference - Modern Technologies in Industrial Engineering; 2017 June 14-17; Sibiu, Romania: IOP Publishing; 2017. 012040. [CrossRef]

[37] Wolff RW. Stochastic Modeling and The Theory of Queues. 1st ed. Englewood Cliffs, New Jersey: Prentice Hall; 1989.