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EFFICIENCY OF HANDLINE TUNA FISHERMEN'S WORKING TIME USING THE PERT APPROACH

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ABSTRACT

Handline tuna fishing constitutes one of the key economic activities in coastal areas, particularly for small-scale fishermen. Efficient working time plays a vital role in improving fishermen's productivity and income. However, in practice, tuna fishing operations frequently encounter inefficiencies in both planning and the execution of daily tasks. Therefore, an analytical method is required to identify and evaluate each stage of the work process systematically. The Program Evaluation and Review Technique (PERT) provide a structured approach to mapping work activities, estimating the time required for each task, and identifying the critical path that determines the total project duration. This study aims to evaluate the efficiency of working time utilization among tuna fishermen using handline gear by applying the PERT approach. The research was conducted on 163 fishing vessels using the PERT (Project Evaluation and Review Technique) method, focusing on the analysis of actual time allocation for each activity. The results indicate that of the 24 analyzed activities, 17 (70.83%) fall within the critical path, while 7 (29.17%) have slack time. Critical activities such as loading supplies, traveling to the fishing ground, and retrieving the parachute anchor determine the project's minimum duration. Meanwhile, activities with slack time, such as preparing the parachute anchor and mooring the vessel to the fish aggregating device (FAD), can be performed flexibly without affecting the overall project timeline. Effective time management is essential to ensure that each operational phase is completed on schedule, thereby improving the efficiency and productivity of fishing operations.

Keywords: *critical path, handline, PERT, tuna.*

INTRODUCTION

Indonesia ranks among the world's leading producers in capture fisheries. In 2018, the FAO reported that Indonesia contributed 7.19% / 6.54 million tons per year) to global capture fisheries (Kusdiantoro *et al*. 2019). The growth in both the quantity and diversity of fisheries resources over time has driven the development of fishing methods and techniques to optimize catch efficiency and effectiveness. At the Cilacap Ocean Fishing Port, tuna fishing using handline vessels is a primary activity (Saputra *et al*. 2022). The Fisheries Management Area of the Republic of Indonesia (WPPNRI) 573, the Ministry of Marine Affairs and Fisheries (KKP) has identified Indonesia's marine potential, with a total fisheries resource potential of 1,922,857 tons and pelagic fish potential of 978,581 tons (Panggabean *et al*. 2023).

However, the high failure rate in marine fishing operations indicates that fishermen constantly face challenges in their fishing endeavors. To minimize the risk of operational failure, fishing activities must be effectively managed. The primary objective of fisheries operations management is to reduce costs, optimize time utilization, and efficiently allocate human resources to maximize revenue (Wiyono, 2022). Planning is a crucial task in achieving the desired goals and results. Scheduling is a vital role in balancing time, cost, and labor requirements, particularly in overcoming limitations. Proper scheduling and resource allocation enable effective utilization, preventing delays, failures, or abandonment (Winarso, 2018). Data indicate that ineffective time management can impact the productivity and sustainability of fishing enterprises. However, research has identified several challenges encountered by fishermen, with time management in fishing operations being a significant concern. Ineffective time utilization can reduce productivity and operational efficiency, ultimately impacting the earnings of both individual fishermen and fishing enterprises.

Handline fishing plays a crucial role in tuna fisheries due to its selective, environmentally friendly, and small-scale oriented characteristics. This method minimizes bycatch, maintains high fish quality, and supports the socio-economic sustainability of traditional fishermen. Nevertheless, inefficiencies in operational time management remain a major issue affecting fishermen’s productivity. To address this challenge, the Program Evaluation and Review Technique (PERT) is applied as a systematic analytical method to evaluate the sequence and duration of fishing activities, identify the critical path, and determine stages that potentially cause operational delays. In addition to PERT, the Productive, Effective, and Total Human Effort (PETH) approach is incorporated to assess the human-effort dimension of handline operations, particularly regarding fishermen’s physical workload, task-specific time allocation behavior, and individual productivity levels. The integration of PETH strengthens the analysis by revealing how human performance and effort distribution influence operational efficiency, thereby complementing the process-oriented evaluation provided by PERT. The implementation of both PERT and PETH offers a comprehensive framework for improving the time efficiency of handline tuna fishermen, enhancing operational management, and supporting the sustainable development of small-scale tuna fisheries.

External factors, such as the relocation of fishing areas at the direction of rumpon owners, also pose a significant challenge, resulting in wasted time and fuel from repeated trips. Unpredictable weather conditions, such as storms and high waves, further worsen operational efficiency. Furthermore, limitations in facilities and equipment conditions, including the lack of navigation aids and technical issues with fishing gear and vessel engines, hinder the smooth execution of fishing activities. Therefore, an enhanced time management strategy is essential to increase the efficiency of fishermen’s work, ensure each stage of the operation proceeds as scheduled, and reduce the impact of potential obstacles that could delay the tuna fishing process.

While numerous studies have explored working hours, health, safety, and the economic impacts on fishermen, specific gaps in the literature remain and warrant further investigation. Elliott *et al*. (2022) and Laraqui *et al*. (2022) have highlighted the impact of working hours on fatigue and fishermen’s health; however, they have not explicitly examined work time efficiency in fishing operations.

Other studies, such as those by Remmen *et al*. (2021) and Santiago *et al*. (2021), have explored ergonomic risk factors and fishermen’s safety; however, their research focuses more on the health impacts of work than on the efficiency of time utilization. Meanwhile, Indrayani *et al*. (2023) discuss safety among small-scale fishermen but do not examine how increased work-time efficiency could enhance safety and productivity.

Bagshaw (2021); Akan and Bayar (2022) have applied PERT and CPM methods in project management. However, their application remains limited to shipyards and has not been widely used to optimize fishermen's working hours. In addition, Sorensen *et al*. (2022) address fisheries governance and its associated health implications; however, their study does not specifically analyze the efficiency of tuna fishermen’s working hours using the PERT method.

Buana *et al*. (2023) examined fishermen’s perceptions of climate change and highlighted various external factors influencing the fisheries sector. However, their study does not explore how fishermen can improve their work efficiency in response to these challenges. Similarly, Abrahamsen *et al*. (2023) studied fatigue among North Atlantic fishermen, but their research lacks an evaluation of work-time optimization using quantitative methods such as PERT. Finally, Auliyah and Santoso (2022) examined the relationship among capital, working hours, and income, but their research focused more on economic impacts than on technical approaches to improving fishermen's work efficiency.

The research gap addressed in this study is the lack of analysis of the efficiency of tuna fishermen's working time using handline gear using the Program Evaluation and Review Technique (PERT) approach. This study aims to evaluate the efficiency of working time utilization among handline tuna fishermen using the PERT (Program Evaluation and Review Technique) approach.

Given these challenges, it is evident that all business operations, including fisheries, encounter difficulties in effective planning. This underscores the importance of accurate scheduling and resource allocation, even when initial estimates may not fully align with real-world conditions. The novelty of this research lies in its application of the Program Evaluation and Review Technique (PERT) to analyze and optimize the efficiency of handline tuna fishing operations. This study introduces a structured time management framework by identifying both critical and non-critical activities, thereby enhancing scheduling precision and resource utilization. By integrating PERT into small-scale fisheries, the research provides a systematic approach to minimizing delays, streamlining operational workflows, and increasing productivity. Furthermore, the study identifies key factors contributing to inefficiencies such as changes in fishing grounds, adverse weather conditions, and equipment malfunctions and offers practical recommendations to improve overall fishing performance. In alignment with this objective, the study investigates the time management practices in the operations of handline tuna fishing vessels.

METHODS

Location and Time of Research

The research was conducted from February to May 2024. Land-based data collection took place at the Nusantara Fishing Port of Cilacap fishing base, located in Cilacap Regency, Central Java Province. Sea-based research was conducted across 11 fishing grounds equipped with fish aggregating devices (FADs). The locations of both land and sea-based research activities are presented in Figure 1.

Research Instruments, Materials, and Procedures

This study used various materials, equipment, and procedures to support the smooth operation of tuna fishing with handlines and to ensure the accuracy of data collection and analysis. Some of the main materials used include live and artificial bait to attract tuna, fuel (diesel or gasoline) to operate the boat, as well as ice and fish storage containers to keep the catch fresh. Logbooks and survey forms are used to systematically record the allocation of time and fishermen's activities. In addition, stopwatches, cameras, writing instruments, and research data sheets are also used as additional equipment.

The main operational unit in this study was the tuna longline fishing boat. Of the total 274 active boats registered at the Nusantara Cilacap Fishing Port based on Fishing Port Information System (PIPP) data, 163 boats were selected as samples using the Slovin formula with a 95% confidence level. The fishing gear used consisted of longlines and hooks, while the GPS navigation system was used to determine the precise location of the catch. Stopwatches were used to record the duration of each activity, measuring tapes were used to measure the size of the tuna caught, and notebooks and cameras were used to document data and images.

Primary data was obtained through direct observation, structured interviews, and documentation of all activities on board the vessel, from departure, the fishing process, to returning to port to unload the catch. During the three months of research, observations were made systematically of every activity on the longline fishing vessel, recording the allocation of time and labor required. The volume of data from 163 vessels provides a solid basis for evaluating time management and operational efficiency in tuna fishing.

Secondary data was collected from scientific journals, websites, ship documents, and information from fishing companies operating in the Nusantara Cilacap Fishing Port, Central Java. Data analysis was carried out using qualitative descriptive methods using PERT (Project Evaluation and Review Technique), which aimed to identify and describe the scheduling and time requirements in tuna longline fishing operations.

Data Analysis

Time management analysis was conducted using the Program Evaluation and Review Technique (PERT), which serves as a planning and control tool to minimize operational constraints and obstacles. Additionally, it functions as a coordination tool,

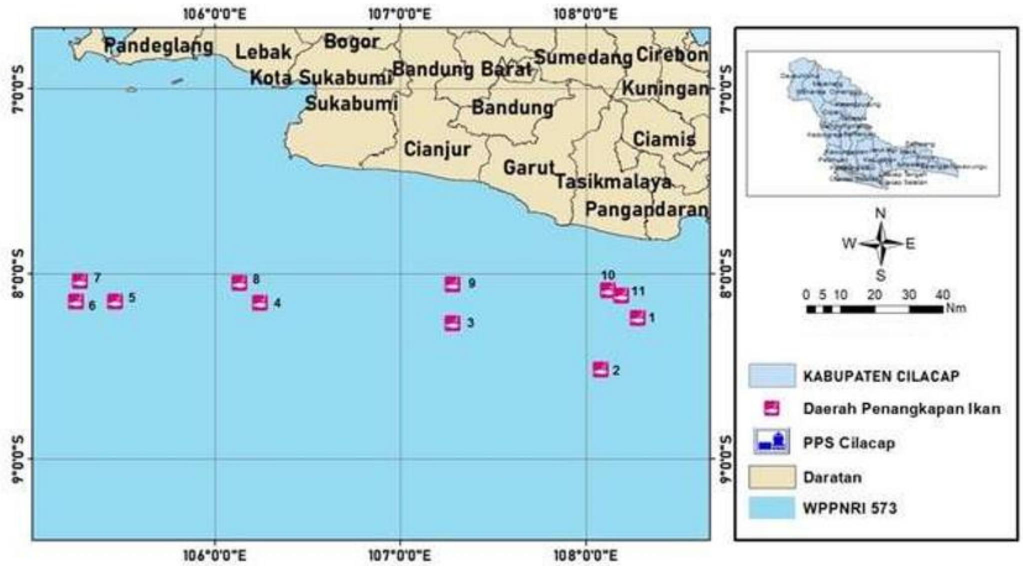

Figure 1 Map of fishing grounds and the data collection base at Cilacap Ocean Fishing Port (11 fishing grounds), Indonesia

integrating various components into an overall framework to ensure the successful completion of planned activities (Winarso, 2018). This method emphasizes data collection based on the time allocation required for each activity or through experience-based time utilization analysis. By determining the duration of all activities, it becomes possible to identify the critical path that governs the total operational time.

The analytical process included several sequential steps: (1) collecting time data for all fishing activities; (2) identifying each task and its logical relationships; (3) constructing a PERT network diagram; (4) performing a forward pass to calculate the Earliest Start (ES) and Earliest Finish (EF); (5) performing a backward pass to determine the Latest Start (LS) and Latest Finish (LF); (6) computing the Total Float (TF) for each activity; and (7) identifying activities with TF = 0 as part of the critical path. The results from this analysis were then interpreted to evaluate the efficiency of fishermen's working time and to identify operational bottlenecks that most influence the duration of tuna handline fishing operations. Mathematically, the PERT calculations are carried out through several computational steps, as follows (Winarso 2018):

1) PERT Formulas
   For each activity, PERT uses three time estimates:
   - a= optimistic time
   - m= most likely time
   - b= pessimistic time

   The standard PERT formulas are:
   • Expected Time (TE)
   $$T_E = \frac{a + 4m + b}{6}$$
   • Variance
   $$\sigma^2 = (\frac{b - a}{6})^2$$
   • Standard Deviation
   $$\sigma = \frac{b - a}{6}$$

2) Application of PERT Formula to the Dataset
   In this study, the three estimates (a, m, b) for each handline fishing activity were derived from the observed time data collected during field operations.
   The procedure applied was as follows:
   1. Observation of operational steps (e.g., bait preparation, fishing, retrieval, handling, chilling).
   2. Determination of PERT inputs:
      - a= minimum observed time
      - b= maximum observed time
      - m= most frequent or representative time (mode; or median/mean when the mode was not clearly identifiable)
   3. Calculation of T_E, variance, and standard deviation for each activity using the formulas above.
   4. Construction of the PERT network diagram based on the actual operational sequence of handline fishing tasks.

   A summary table (activity – a– m– b– T_E– variance) was then used to evaluate the entire operational workflow.

3) Linking the Formulas to Critical Path Analysis

For each possible operational path, PERT accumulates the time estimates as:

- Expected Time for a Path

$$T_{E,\text{path}} = \sum_{i=1}^{k} T_{E,i}$$

- Path Variance

$$\sigma^2_{\text{path}} = \sum_{i=1}^{k} \sigma_i^2$$

- Path Standard Deviation

$$\sigma_{\text{path}} = \sqrt{\sigma^2_{\text{path}}}$$

4) Short Numerical Example

Suppose two sequential activities were observed:

Activity A:

$a = 10,\, m = 12,\, b = 20$

$$T_{E,A} = \frac{10 + 4(12) + 20}{6} = 13$$

$$\sigma_A = \frac{20 - 10}{6} = 1.667 \Rightarrow \sigma_A^2 = 2.78$$

Activity B:

$a = 5,\, m = 6,\, b = 11$

$$T_{E,B} = \frac{5 + 4(6) + 11}{6} = 6$$

$$\sigma_B = \frac{11 - 5}{6} = 1 \Rightarrow \sigma_B^2 = 1$$

Path A → B:

$$T_{E,\text{path}} = 13 + 6 = 19$$

$$\sigma^2_{\text{path}} = 2.78 + 1 = 3.78 \Rightarrow \sigma_{\text{path}} = 1.94$$

In this study, the Program Evaluation and Review Technique (PERT) was applied to quantify the expected duration and variability of each handline fishing activity. Mathematically, the PERT calculations were carried out through several computational steps. For each operational activity, three parameters were determined based on the observed time data: the optimistic time (a), the most likely time (m), and the pessimistic time (b). These parameters were then used to compute the expected time (T_E) using the standard PERT formula $T_E = \frac{a+4m+b}{6}$, while the variance and standard deviation were calculated as $\sigma^2 = (\frac{b-a}{6})^2$and $\sigma = \frac{b-a}{6}$, respectively. In practice, the values of a, m, and $b$were derived directly from field observations, where $a$represented the minimum observed time, $b$the maximum, and $m$the most frequently occurring duration or representative central value. For each sequence of dependent activities, the expected time of the entire path was obtained by summing the individual expected times, $T_{E,\text{path}} = \sum T_{E,i}$, while the total path variance was calculated as the sum of individual variances, $\sigma^2_{\text{path}} = \sum \sigma_i^2$. The path with the highest total expected duration was identified as the critical path, representing the sequence of operations that determine the minimum completion time for the overall handline fishing process. This analytical approach enables the identification of delay-prone activities and provides a quantitative foundation for improving time allocation, operational efficiency, and workflow management in small-scale tuna handline fisheries.

RESULTS

Fishing Unit

The fishing operation in this study utilized the Handline tuna vessel, a handline fishing vessel with a gross tonnage (GT) of 30. Constructed from wood, this vessel was built in 2021 in Jakarta and is designed to accommodate a crew of 14 people. It has an overall length (LOA) of 21.7 meters, a width of 5.2 meters, and a depth of 1.65 meters.

The vessel is equipped with key navigational and fishing equipment, enabling efficient handline tuna fishing. Its size and design make it suitable for offshore fishing, providing adequate space for storing fishing gear, preservation, and accommodating crew members during fishing trips. The wooden structure offers durability and flexibility in handling various sea conditions, ensuring safety and stability during operations.

With a moderate gross tonnage, the Handline tuna vessel is classified as a small-scale commercial fishing vessel, capable of venturing into deeper waters while maintaining maneuverability. The vessel's operational efficiency is influenced by various factors, including crew coordination, fishing strategy, and time management, which are critical aspects analyzed in this study using the PERT approach.

Fishing Production Activities

The analysis of fishing production activities was conducted under the assumption of a 90-day fishing trip, reflecting the operational standards commonly applied to handline tuna vessels in Indonesia (Wudianto & Setyadji, 2018). Empirical evidence, however, indicates that only a fraction of this nominal trip duration is utilized for effective fishing operations, with productive fishing days typically representing only 40–50% of the total trip period (Purwanto, 2015). Accordingly, the PERT-based time efficiency assessment incorporated only the actual operational days to ensure that the estimated activity durations reflected real on-site conditions (Triyanti & Nurani, 2018). Within this effective operational window, the handline tuna fishery exhibited a multispecies catch composition dominated by skipjack tuna (*Katsuwonus pelamis*), which accounted for 96.73% of the total catch, confirming its role as the primary target species. The remainder of the catch consisted of tuna (*Thunnus* sp.) at 1.18%, mahi-mahi (*Coryphaena hippurus*) at 0.32%, and squid (*Loligo* sp.) at 1.76%, representing the characteristic species assemblage encountered in handline fishing grounds.

Although these species contributed a much smaller proportion compared with skipjack tuna, their presence nonetheless added to the vessel's total catch. The predominance of skipjack tuna suggests that the fishing operations took place within areas where this species is highly abundant and that the handline method employed was particularly effective in capturing skipjack relative to other species. Environmental factors such as water temperature, current patterns, and prey availability may also influence the species composition encountered during fishing activities. From an economic and fisheries-industry perspective, the substantial proportion of skipjack tuna provides notable advantages for both fishermen and processing sectors. Skipjack tuna commands high commercial value in domestic and export markets, particularly in the form of fresh, frozen, and processed products such as canned tuna. Its dominance in the catch therefore allows fishermen to maximize production and revenue. Nonetheless, the presence of other species, including tuna, mahi-mahi, and squid, remains important. A diversified catch supports ecosystem balance while supplying varied raw materials to the fisheries industry. Consequently, sustainable fisheries management is crucial to ensure that marine resources are utilized optimally without compromising the ecological integrity of the fishing grounds.

Fish Unloading Process

The fish unloading process is a crucial step in ensuring efficient storage and maintaining the catch's freshness. This operation is carried out on board or at sea, where chilled fish are transferred from the cold storage unit to the storage hold. By following a structured procedure, the crew ensures optimal use of space while preserving the quality of the fish. The unloading process begins with preparation, during which the crew members are assigned specific tasks, including retrieving fish from storage, recording catch data, placing fish into plastic bags, weighing, and lifting the fish. This division of labor helps streamline the operation, ensuring that the unloading process runs smoothly. Next, three crew members remove the fish from storage inside the hold. They pass the fish around in rotation to minimize prolonged exposure to cold. Since the crew does not wear protective cold-weather clothing, they rotate their duties as needed to maintain efficiency and comfort. Once removed from storage, the fish are wrapped for easier handling. Smaller fish are placed in plastic bags, while larger fish are tied with a string to facilitate unloading at the port. This method ensures that the fish remains organized and manageable throughout the process.

Following this, the fish undergo weighing on board. This procedure is vital for accurately recording catch data attributable to each fisherman. The recording process is handled by the captain, who logs each fisherman's catch based on marked fish. These records are then submitted to the vessel owner, who uses them to calculate the fishermen's wages. Finally, after weighing and recording, the fish are carefully stored in the cold storage unit. This step ensures that available space is used efficiently while maintaining the fish's freshness until they are ready for further processing or sale. By following these systematic steps, the fish unloading process becomes more efficient, helping to preserve the quality of the catch while optimizing operations on board.

The table is designed as a network activity diagram using the Program Evaluation and Review Technique (PERT) or the Critical Path Method (CPM), which helps plan, schedule, and analyze project activities. It provides a structured overview of various tasks and their interdependencies, ensuring efficient project execution. Each activity in the project is labeled with letters (A to X) and is linked to its preceding activity, indicating dependencies that must be completed before another task can begin. The estimated time required for each activity is measured in minutes and presented in Table 1, allowing for precise scheduling.

The tuna handline fishing operation is structured into three main phases: preparation, fishing, and handling and storage. During the preparation phase, various crew members carried out provisioning, refueling, and gear preparation, followed by a 15-hour voyage to the designated fishing ground. Upon arrival, anchoring and gear setup were completed. The fishing phase involved multiple settings and gear resets targeting squid, tuna, skipjack, and *mahi-mahi*, supported by regular breaks and anchor operations. Fishing activities occurred

across two fishing grounds, including areas around Fish Aggregating Devices (FADs), with precise scheduling and division of labor. During the handling and storage phase, catch processing, unloading, and storage were conducted efficiently, along with vessel repositioning and final anchoring. This sequence reflects a time-intensive, labor-intensive fishing operation, highlighting the complexity and organization of tuna handline fisheries.

Key scheduling metrics include the Earliest Start (ESi) and Earliest Finish (EFij), which determine the earliest times an activity can begin and complete, respectively, based on the project timeline. Similarly, the Latest Start (LSi) and Latest Finish (LFij) represent the latest possible times an activity can start and finish without delaying the overall project schedule. The Total Slack Time (TFij) is the difference between the latest and earliest start or finish times, indicating the flexibility available for each task. Activities with zero slack time are classified as critical tasks, meaning any delay in them would directly affect the project's completion. By structuring the table, project managers can efficiently monitor progress, identify critical activities, and allocate resources effectively. This approach enhances overall project efficiency, ensuring timely completion while minimizing potential delays.

Table 1 Operational activity breakdown, duration estimates, and labor allocation for handline tuna vessels based at Cilacap Fishing Port, Indonesia

Activity Type	Activity Description	Time Required (Minutes)	Activity Schedule		Workers Involved (Persons)
			Start	Finish	
	PREPARATION STAGE				
A	Stocking Supplies	90	15.00	16.30	14
B	Refueling and Water Refill	180	16.30	19.30	3
C	Sailing to FG 1	15(60)	20.00	11.00	7
D	Preparing Parachute Anchor	20	11.00	11.20	10
E	Deploying Parachute Anchor	10	11.20	11.30	8
F	Meal Break	270	11.30	16.00	14
G	Preparing Fishing Equipment	120	16.00	18.00	13
	OPERATION STAGE				
H	The setting, starting with squid bait fishing and tuna fishing	330	18.00	23.30	13
I	Meal Break	60	23.30	00.30	14
J	Resetting Fishing Gear	210	00.30	04.00	13
K	Retrieving Parachute Anchor	15	04.00	04.15	12
L	Sailing to FG 2 (fish aggregating device area)	465	04.15	12.00	5
M	Tying Ship's Rope to FAD	10	12.00	12.10	3
N	Rest	200	12.10	15.30	14
O	Fishing for lemadang Around Fish Aggregating Devices (FADs) That Appear on the Surface	120	15.30	17.30	7
P	Evening Meal Break	30	17.30	18.00	14
Q	Setting, starting with Skipjack, Lemadang, and Tuna Fishing	330	18.00	23.30	12
R	Rest	30	23.30	00.00	14
S	Squid Bait Fishing, followed by Tuna Fishing	210	00.00	03.30	12
	HANDLING, UNLOADING, AND STORAGE STAGE				
T	Tuna Catch Handling	30	03.30	04.00	12
U	Releasing Ship's Rope from FAD and Moving Away	215	04.00	07.35	3
V	Deploying Parachute Anchor	10	07.35	07.45	8
W	Meal Break	30	07.45	08.15	14
X	Onboard Fish Unloading (including unwrapping, weighing, and storing fish)	90	08.15	10.45	14

Critical activities have no slack time (TFij) and, therefore, affect the project's completion schedule. This table represents the critical path method schedule, a project management technique used to determine the sequence of activities that defines the minimum duration required to complete a project. The table lists various activities (A to X) along with their preceding activities, start and finish times, and total duration. Activities are classified as either Critical or Non-Critical (Slack) based on their impact on the overall schedule, as shown in Table 2 and Figure 2.

Table 2 indicates that the critical path activities include (A, B, C, F, H, J, K, L, N, O, P, Q, R, S, T, U, X). These activities determine the minimum duration required to complete the project. Non-critical activities, on the other hand, can be delayed without affecting the overall project timeline. The process of marine fish capture consists of an interconnected and sequential network. Based on field observations, the chronological time-series data for each fishing event in the WPPNRI 573 waters indicate that, among the three main stages of tuna fishing, there are 24 types of activities. Seven activities occur in the first stage, requiring a total of 1,590 minutes, while the second stage consists of 12 activities, totaling 2,010 minutes. The third stage, which involves handling and unloading the catch, includes five activities with a total duration of 375 minutes.

Thus, a complete tuna fishing cycle using the handline method requires 3,975 minutes per trip, whether in an area with or without fish aggregating devices (FADs), until unloading is completed on board. A detailed analysis and time allocation for each activity in the hand-line fishing operation are presented in Table 3.

This duration is primarily influenced by vessel speed, the distance between the fishing base and the fishing ground, the location of FADs, and environmental conditions such as weather, waves, and ocean currents, all of which affect the vessel's speed. Applying the Critical Path Method, a dynamic time-allocation approach is used to accommodate changes in environmental or mechanical conditions, ensuring the project remains effective and efficient despite unexpected disruptions. Addressing issues that may cause delays or setbacks is crucial to improving the efficiency and productivity of tuna fishing operations in WPPNRI 573. The causes of these delays in handline tuna operations on the handline tuna vessel are identified and detailed in Table 4.

Table 2 Calculation results of critical path and slack time analysis using the PERT method for tuna fishing operations at Cilacap Fishing Port, Indonesia

Type of Activity	Preceding Activity	Time Required (minutes)	Minute to		Menit ke		Total Slack Time (TF_{ij})	Remarks
			Early Start (ES_i)	Early Finish (EF_{ij})	Late Start (LS_i)	Late Finish (LF_{ij})		
A	-	90	0	90	0	90	0	Critical
B	A	180	90	270	90	270	0	Critical
C	A,B	900	270	1170	270	1170	0	Critical
D	A,B	20	270	290	1140	1160	870	Slack
E	D	10	290	300	1160	1170	870	Slack
F	C,E	270	1170	1440	1170	1440	0	Critical
G	C,E	120	1170	1290	1320	1440	150	Slack
H	F,G	330	1440	1770	1440	1770	0	Critical
I	H	60	1770	1830	1920	1980	150	Slack
J	H	210	1770	1980	1770	1980	0	Critical
K	I,J	15	1980	1995	1980	1995	0	Critical
L	K	465	1995	2460	1995	2460	0	Critical
M	K	10	1995	2005	2650	2660	655	Slack
N	L	200	2460	2660	2460	2660	0	Critical
O	M,N	120	2660	2780	2660	2780	0	Critical
P	O	30	2780	2810	2780	2810	0	Critical
Q	P	330	2810	3140	2810	3140	0	Critical
R	Q	30	3140	3170	3140	3170	0	Critical
S	R	210	3170	3380	3170	3380	0	Critical
T	R	30	3170	3200	3350	3380	180	Slack
U	S,T	215	3380	3595	3380	3595	0	Critical
V	U	10	3595	3605	3615	3625	20	Slack
W	U	30	3595	3625	3595	3625	0	Critical
X	V,W	90	3625	3715	3625	3715	0	Critical

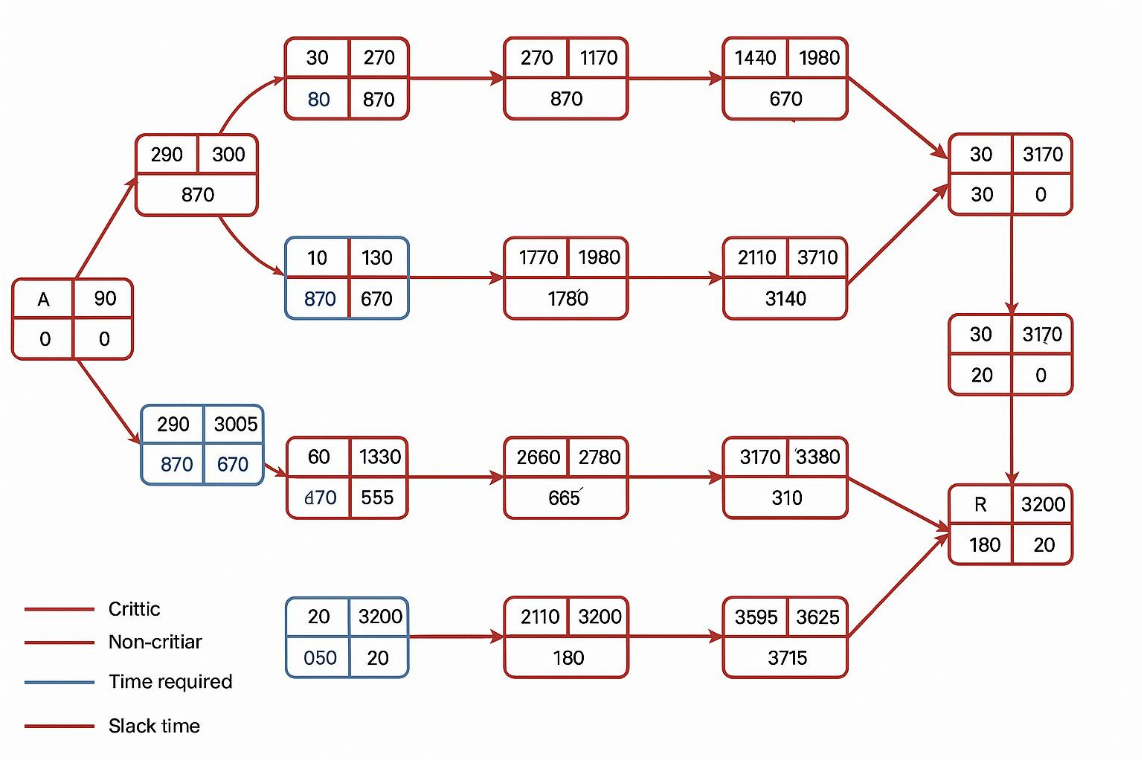

Figure 2 Project Network with Release Time as Activity

Table 3 Identification and description of critical path activities determining the total duration of handline tuna fishing trips based at Cilacap Fishing Port, Indonesia

No.	Critical activity	Description
1	Loading Supplies	Queuing with other boats
2	Refueling	Queuing with other boats
3	Traveling to FG 1	Must arrive before fishing operations begin
4	Rest	Resting during the afternoon-evening, working at night
5	Setting 1	Setting from 18:00 to 23:30
6	Setting 2	Setting from 00:30 to 04:00
7	Parachute Anchor Retrieval	Anchor must be pulled up immediately after setting to allow the boat to continue its journey
8	Traveling to FG 2	Must arrive before fishing operations begin
9	Rest	Resting during the afternoon-evening, working at night
10	Lemadang Fishing	Lemadang appearing on the surface in the afternoon must be caught immediately to prevent them from moving away
11	Rest	Dinner break at 17:30 before fishing operations at 18:00
12	Setting 3	Setting from 18:00 to 23:30
13	Rest	Meal break at 23:30 before fishing operations at 00:30
14	Setting 4	Setting from 00:30 to 03:30
15	Releasing FAD Rope	FAD rope is released after setting so the boat can continue its journey
16	Rest	Meal break from 07:35 to 08:15 before unloading starts at 08:15
17	Unloading	Unloading is done before the sun gets too hot to maintain fish freshness.

Table 4 External and technical factors causing operational delays in handline tuna fishing units based at Cilacap Fishing Port, Indonesia

No.	Cause	Description
1	Relocation of Fishing Area 1 to Another Fishing Area	Handline fishing vessels operating at fish aggregating devices (FADs) that do not belong to them are often instructed by the FAD owner to move to another fishing area, as they intend to operate their fishing gear at their FAD.
2	Repeated Vessel Trips	Due to the relocation from one FAD to another, the vessel has to repeatedly search for an effective fishing area, resulting in wasted time, energy, and fuel.
3	Weather and Storm Season	On March 6, additional issues arose in the form of bad weather and storm season, making vessel operations difficult and increasing safety risks for the crew.
4	Limited Equipment	The vessel is not equipped with adequate tools, such as binoculars, which could assist in locating FADs. This limitation hinders the crew's ability to find and reach the fishing location efficiently.
5	Fishing Gear Conditions	Fishermen often encounter problems when catching sizeable pelagic fish, such as broken fishing lines or tangled lines due to the aggressive pulling of fish taking the bait. These conditions frequently disrupt fishing operations.
6	Engine Condition	*Engine malfunctions cause operational delays, including late arrival at the intended fishing ground.*

DISCUSSION

Fishing Unit

Fishermen commonly use handline fishing to catch large pelagic fish (Marasabessy *et al.* 2021). Fishing gear, abbreviated as API, refers to the equipment and accessories used to catch fish (PERMEN-KP 18 2021). According to Pattiasina *et al.* (2020), *handline* is an active and environmentally friendly fishing method. It is easy to operate and does not require any additional tools. The success of hand-line tuna fishing is influenced not only by bait but also by the fishing technique used (Harding *et al*. 2022).

Traditional fishermen often use handline fishing at sea because it is an environmentally friendly method. This fishing gear is relatively easy to operate and does not require extensive equipment such as purse seines or other large fishing gear. A *handline* consists of several components: (1) a spool of fishing line, (2) a fishing line, (3) a fishing hook, and (4) a weight (Marasabessy *et al.* 2021).

Fishing Production Activities

Handline tuna vessel operates its fishing gear in the southern waters, specifically in WPPNRI 573. Technically, *handline* tuna fishing falls under the category of fishing gear that uses hooks and bait to attract fish, causing them to get hooked. A fishing ground is a designated area where fishermen operate their fishing gear. The handline tuna vessel conducts fishing operations in the southern waters within WPPNRI 573. The vessel's captain determines fishing locations by exchanging information with other fishermen via radio communication. They share coordinate points, which are usually locations of *rumpon*—fish aggregating devices owned by the company or individuals. *Rumpon* is a technology used to gather fish in a specific area (Hikmah *et al.* 2016). Additionally, the captain sometimes relies on instinct and experience to determine fishing spots by observing ocean conditions, such as when fish jump on the surface or seabirds fly low in search of food.

The operational principle of hand-line tuna fishing is similar to other hook-and-line methods. Bait is attached to the hook, which is tied to a branch line, and then lowered into the water. Upon detecting that a fish has likely taken the bait, the line is immediately hauled in for verification and potential catch retrieval. Fishing operations occur in the evening and early morning, usually before 3:00 AM (Tomasila *et al*. 2020). This timing aligns with the fish's feeding patterns, which occur around sunrise and sunset. Bait presence has a substantial impact on catch efficiency and overall catch rates. The process involves attaching bait to the hook and releasing it into the designated fishing area.

Proper catch handling is crucial to maintaining fish quality (Yusrizal *et al*. 2022). On the Handline tuna vessel, fish handling is essential for preserving quality, but fishermen still use basic equipment. The handling process includes pulling the fish aboard, killing it, gutting and removing the gills, and properly storing it. The analysis of time management needs for handline fishing on a handline tuna vessel uses the PERT (Project Evaluation and Review Technique) method. This method not only helps coordinate different parts of the work into a cohesive operation but also ensures the success of activities as planned (Winarso, 2018).

The Program Evaluation and Review Technique (PERT) is a detailed scheduling method used to allocate time estimates to each project phase, from the commencement of activities to their completion (Zhou *et al*. 2022). The purpose of this scheduling is to determine the critical path, which highlights the most time-sensitive activities. If the duration of all activities is known, it becomes possible to identify which activities form the "critical path". Therefore, if any activity on the critical path encounters delays, the overall operation will be affected. In other words, the success of an operation depends on the performance of all tasks along this critical path.

An organized schedule and disciplined execution of daily duties are vital for crew members to support the effective operation of a fishing vessel. This includes careful planning before departure, such as determining the right time to start and finish each activity. Additionally, setting priorities is a key part of effective time management. For example, it is crucial to process large fish catches immediately to maintain their freshness.

Good time management involves scheduling shifts with other crew members to balance work and rest periods. This ensures that each team member has enough time for rest and recovery, enabling them to stay focused and productive.

The Critical Path is the sequence of activities that determines the minimum time required to complete the project. In this table, the critical path is identified by activities labeled "Critical." These activities cannot be postponed without delaying the overall project timeline. Non-critical activities labeled "Slack" can be postponed without affecting the overall project duration.

Fishing Operation Process Overview

Fishing operations follow a structured sequence of activities that require careful planning, financial resources, human resources, and time management. The process can generally be divided into three main stages: preparation, fishing, and handling and unloading. The preparation stage is crucial to ensure a smooth fishing operation. This includes provisioning food supplies for the crew, refilling water and fuel, and preparing essential fishing gear such as parachute anchors, ropes, and other supporting equipment. Proper preparation helps optimize efficiency and reduce the risk of operational disruptions at sea.

The fishing process stage begins with identifying fishing grounds (FG) where the highest probability of a good catch exists. Fishermen then prepare their gear and conduct fishing operations, including catching squid for bait and deploying hand-line tuna gear. This stage consists of several steps, including setting the fishing line, submerging it, and eventually hauling the catch. Each step requires precision and experience to maximize the yield. The handling and unloading stage focuses on managing the catch to maintain quality and efficiency. Once fish are brought on board, they are carefully stored in the hold under optimal conditions. The unloading process involves wrapping, weighing, and systematically arranging the fish in the storage hold to maximize space utilization and preserve freshness. Proper handling at this stage ensures the catch remains in prime condition until it reaches the market or processing facility.

CONCLUSION

Based on an analysis using the Program Evaluation and Review Technique (PERT) method on handline tuna fishing operations, it can be concluded that:

1. Very High Operational Time Sensitivity: Of the total 24 activities analyzed, 17 activities (70.83%) were critical path activities (without slack time), while only 7 activities (29.17%) had time slack. This indicates that these fishing operations have a very tight schedule; a delay in any of the 17 critical activities will immediately cause a delay in the total duration of the trip and a decrease in efficiency.
2. The main critical activities that most determine the duration of the project include stocking supplies, traveling to the fishing

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ground (FG), setting fishing gear, and loading and unloading. However, the efficiency of these activities is often disrupted by external and technical factors that cause significant delays, namely: forced relocation due to the use of other people's fish aggregating devices (FADs), which requires boats to move around; limited facilities; and frequent damage to engines and fishing gear (broken ropes).

3. The application of PERT has proven effective in mapping real inefficiencies in the field by separating rigid (critical) and flexible (non-critical) activities, so that time management can be focused on points prone to delays.

RECOMMENDATION

To improve vessel operational efficiency and minimize delays on critical routes, fishermen are advised to equip their fleets with adequate navigation aids to speed up the search for fishing grounds and to implement strict preventive maintenance management on engines and fishing gear before departure. In addition, legal access to fishing grounds must be secured before setting sail.

Further research is recommended to integrate the PERT method with financial analysis (Cost-Benefit Analysis) in order to measure the real economic impact of the time efficiency achieved, as well as to examine the correlation between the speed of fishing operations and the quality (grade) of tuna landed. The development of comparative studies between fishing seasons is also essential to observe the consistency of critical paths under different weather conditions and fish stock availability.

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