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Analysis of GPS Use for Determining Ship Course and Position on the MT New Winner

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ABSTRACT

The Global Positioning System (GPS) is the primary source of position for modern ship navigation, and its value depends on how well it is integrated with other bridge equipment such as RADAR/ARPA, the Electronic Chart Display and Information System (ECDIS), and the Automatic Identification System (AIS). This study analyses the use of GPS for determining ship course and position on the tanker MT New Winner, identifies the factors that hinder its optimal use, and proposes solutions. A descriptive qualitative design was applied over 12 months of sea service, using observation on the bridge, semi-structured interviews with four deck officers (the Master and the Chief, Second, and Third Officers), and a review of manuals and literature. While the vessel was sailing in the Makassar Strait, GPS1 (Furuno GP-150), the only receiver interfaced with RADAR/ARPA, ECDIS, and AIS, failed. Although GPS2 (GP-170) still displayed the ship's position, it was not connected to the other systems, so the Master had to plot the position manually every 30 minutes to avoid the risk of grounding. The failure was caused by a damaged GPS antenna and its mounting, broken antenna shock absorbers, poorly maintained cables and keys, and an inadequate power supply. The study concludes that GPS use on board was not optimal because of the lack of redundant integration and insufficient maintenance. Connecting both GPS units to all navigation systems, maintaining the antenna, cabling, and power supply regularly, and practising alternative position-fixing methods are recommended.

Keywords: GPS, Electronic Navigation, System Integration, Position Fixing, MT New Winner

ABSTRAK

Global Positioning System (GPS) merupakan sumber posisi utama dalam navigasi kapal modern, dan manfaatnya bergantung pada integrasinya dengan peralatan anjungan lain seperti RADAR/ARPA, Electronic Chart Display and Information System (ECDIS), dan Automatic Identification System (AIS). Penelitian ini menganalisis penggunaan GPS untuk menentukan haluan dan posisi kapal di kapal tanker MT New Winner, mengidentifikasi faktor-faktor yang menghambat penggunaannya secara optimal, serta merumuskan solusinya. Penelitian menggunakan metode deskriptif kualitatif selama 12 bulan masa layar melalui observasi di anjungan, wawancara semi-terstruktur dengan empat perwira dek (Nakhoda, Mualim 1, Mualim 2, dan Mualim 3), serta kajian buku manual dan literatur. Saat kapal berlayar di Selat Makassar, GPS1 (Furuno GP-150), satu-satunya penerima yang terhubung dengan RADAR/ARPA, ECDIS, dan AIS, mengalami kerusakan. Meskipun GPS2 (GP-170) masih menampilkan posisi kapal, perangkat tersebut tidak terhubung dengan sistem lain sehingga Nakhoda harus memplot posisi secara manual setiap 30 menit untuk menghindari risiko kandas. Kerusakan disebabkan oleh antena GPS dan tiang penyangganya yang rusak, peredam kejut (shock absorber) antena yang patah, kabel dan tombol yang kurang terawat, serta catu daya yang tidak memadai. Penelitian ini menyimpulkan bahwa penggunaan GPS di kapal belum optimal karena tidak adanya integrasi cadangan dan kurangnya perawatan. Disarankan agar kedua unit GPS

dihubungkan ke seluruh sistem navigasi, antena, kabel, dan catu daya dirawat secara rutin, serta metode penentuan posisi alternatif dilatihkan secara berkala.

Kata Kunci: GPS, Navigasi Elektronik, Integrasi Sistem, Penentuan Posisi, MT New Winner

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1. INTRODUCTION

Ship navigation is crucial to the safety and efficiency of shipping. The success of navigation depends largely on the navigator, who is responsible for directing the ship safely to its destination with the help of the navigation equipment provided on board. Under the International Convention for the Safety of Life at Sea (SOLAS) 1974, Chapter V, Regulation 19.2.1.6, every ship, irrespective of size, must carry a receiver for a global navigation satellite system or a terrestrial radionavigation system, or other means, suitable for use at all times throughout the intended voyage to establish and update the ship's position by automatic means (International Maritime Organization [IMO], 2020). Satellite-based equipment such as the Global Positioning System (GPS) is therefore vital and requires serious attention in ship operations.

Navigation equipment on board can be divided into conventional instruments and electrically powered electronic instruments. Almost all modern merchant ships rely on electronic instruments, and GPS is one of the most essential because it determines the ship's position, course, and speed accurately and in real time (Hofmann-Wellenhof et al., 2008). However, GPS signals are weak and vulnerable to interference, jamming, and spoofing (Wu et al., 2020; Zidan et al., 2021), and a false or lost GPS signal can mislead the bridge team and even allow a ship to be

steered off course (Bhatti & Humphreys, 2017). Because GPS supplies position data to RADAR/ARPA, the Electronic Chart Display and Information System (ECDIS), and the Automatic Identification System (AIS), a single GPS failure can disable several bridge systems at once (Awan & Al Ghamdi, 2019).

This study was conducted on the tanker MT New Winner, operated by PT Global Maritim Industri, a shipping company established in 1990 and headquartered in Jakarta. During the 12-month study period, it was found that although the ship was equipped with two GPS units, only one unit (GPS1) was connected to the other electronic navigation systems. During a voyage from Bitung to Balikpapan, the RADAR, ECDIS, and AIS lost their position input and could not be used normally. Although GPS2 (Furuno GP-170) continued to display the ship's coordinates, it was not connected to the other systems, so the Master had to plot the ship's position manually every 30 minutes to mitigate the risk of grounding.

National studies have emphasised the role of navigation equipment in preventing accidents and improving the safety of navigation (Sutryani et al., 2021; Syibli & Nuryaman, 2021), the optimal use of RADAR in narrow channels (Antoro et al., 2023), and the need to improve crew skills in using navigation technology (Purnomo et al., 2023). However, the effect of GPS redundancy and integration on position fixing during an equipment failure has received little attention. This study therefore analyses the extent to which GPS is used optimally for determining ship course and position on the MT New Winner, identifies the factors that hinder its use, and proposes solutions.

1.1. Navigation and the Role of the Navigator

Navigation is the process of determining the position, course, and track of a ship so that it reaches its destination safely, efficiently, and economically (Bowditch, 2017). In modern shipping, the navigator plans and monitors the voyage with the help of navigation equipment, keeps the ship on the safe track defined in the passage plan, and takes into account external factors such as weather, currents, and traffic. The introduction of ECDIS has changed position-fixing practices on the bridge, with implications for navigation safety (Car et al., 2020).

1.2. Global Positioning System in Marine Navigation

GPS is a satellite-based navigation system that allows users to determine their geographical position with high accuracy. At sea, GPS determines the ship's

position automatically and in real time, which supports monitoring and decision-making (Hofmann-Wellenhof et al., 2008). Its advantages include all-weather and around-the-clock operation, global coverage, and integration with other navigation systems such as ECDIS, AIS, and RADAR. Its accuracy can be further improved with differential corrections (DGPS), although the accuracy of positions recorded by onboard GNSS devices still varies in practice (Jung et al., 2023).

1.3. Electronic Navigation Systems and Their Integration

Modern navigation involves the integration of electronic devices such as GPS, RADAR, AIS, ECDIS, and the gyrocompass, with the aim of improving accuracy, efficiency, and safety (IMO, 2020). The effectiveness of such integration depends on the condition of the equipment, the connections between systems, and the competence of the crew. Integrated bridge and navigation systems contain digital components whose failure or manipulation can propagate through the whole system (Awan & Al Ghamdi, 2019; Oruç et al., 2022), and GNSS errors directly affect integrated navigation solutions (Liu et al., 2018). AIS also depends on GNSS for its position reports, so GNSS problems reduce the reliability of AIS data and of collision-avoidance assessments (Androjna et al., 2021; Engler et al., 2021).

1.4. Maintenance of Navigation Equipment

Maintenance is an important but often neglected aspect of navigation equipment. Lack of routine maintenance and periodic inspection is a major cause of malfunction, and maintenance includes calibration, checking the connections between devices, and updating the software of electronic navigation systems (Supriyono & Sulistyo, 2014; Syibli & Nuryaman, 2021). The manufacturer's manual for the GP-150 and GP-170 receivers also describes the installation, inspection, and troubleshooting of the antenna, cabling, and power supply (Furuno Electric Co., Ltd., 2014). Without adequate maintenance, navigation equipment is susceptible to technical failures that can endanger navigation.

2. METHOD

This study used a descriptive qualitative approach to describe and analyse the use of GPS navigation equipment on the MT New Winner. This approach was chosen because it is suitable for revealing facts, conditions, and obstacles in the field in depth and systematically. The study was carried out on board the MT New Winner, operated by PT Global Maritim Industri, during 12 months of active sea

service, with observation focused on the navigation systems and the operation of GPS during voyages. The study examined the use of GPS1 and GPS2 and its relationship with position fixing and with the connection of GPS to the other navigation equipment.

Primary data were collected through semi-structured interviews and observation. The interviews were conducted on 25 September 2023 on the bridge with four deck officers who were directly involved in the incident: the Master, the Chief Officer, the Second Officer, and the Third Officer. Each respondent was asked the same questions about the role of GPS in determining the ship's position, the problems encountered when using GPS, the causes of the GPS error, and the alternative methods of position fixing during a GPS failure. To protect their privacy, the respondents are identified only by their rank. Observation on the bridge was carried out using an observation checklist. Secondary data were obtained from the equipment manuals, ship documents, and relevant literature. The data were analysed descriptively by reducing and grouping the interview and observation data, comparing the two sources (triangulation), and drawing conclusions about the problems, their causes, and their solutions.

3. RESULTS AND DISCUSSION

3.1. GPS Failure Incident

During the voyage, while the MT New Winner was sailing in the Makassar Strait at 12:45 LT at a speed of 10 knots, GPS1 (Furuno GP-150) failed. The ship's position could no longer be displayed on the RADAR/ARPA, ECDIS, and AIS, which prevented these systems from functioning optimally. GPS2 (Furuno GP-170) still displayed the ship's coordinates correctly, but because it was not connected to the other navigation equipment, the Master decided to plot the ship's position every 30 minutes to avoid the risk of grounding. The GPS configuration on board is summarised in Table 1.

Table 1. GPS Configuration on the MT New Winner during the Incident

Unit	Model	Connected equipment	Condition during the incident
GPS1	Furuno GP-150	RADAR/ARPA, ECDIS, AIS	Failed (position error)
GPS2	Furuno GP-170	None (stand-alone display)	Functioning; position displayed only on its own unit

3.2. Interview Results

Four deck officers were interviewed to determine the causes of the problem. The respondents and their main responsibilities related to navigation are listed in Table 2, and a summary of their answers is presented in Table 3.

Table 2. Respondents of the Study

Respondent	Rank	Main responsibilities related to navigation
R1	Master	Overall responsibility for the safe navigation of the ship from port of departure to port of destination
R2	Chief Officer	Responsible to the Master for the safety of the ship and the deck department, including stability and cargo operations
R3	Second Officer	Navigational watchkeeping; checking all navigation equipment; preparing the passage plan approved by the Master
R4	Third Officer	Navigational watchkeeping; responsible for life-saving and fire-fighting appliances

Table 3. Summary of Interview Results

Respondent	Role of GPS	Problems encountered	Cause of the GPS error	Alternative position fixing
R1 (Master)	Provides position (latitude and longitude), speed, and distance run	Poorly maintained keys that no longer worked properly	Damaged antenna, first suspected to be caused by a short circuit in the cable	Bearings using RADAR/ARPA
R2 (Chief Officer)	Determines the ship's position very accurately	Poorly maintained antenna mounting pole	Broken antenna shock absorber identified from the error message in the manual	Terrestrial bearings: cross bearings, transit bearings, bearing and distance, bearing and sounding
R3 (Second Officer)	Used to create the ship's route	Insufficient power supply and voltage to the GPS	Poorly maintained navigation cables on the bridge	Celestial observations with a sextant
R4 (Third Officer)	Determines coordinates and monitors the route	Unstable signal affecting position accuracy	Antenna pole damaged by strong wind (position error alarm sounded twice); a bridge leak was first suspected	Cross bearings

All respondents agreed that GPS plays a very important role on board as the source of the ship's coordinates, speed, route, and distance to the next waypoint. The problems they reported point to two groups of causes. The first is physical damage to the antenna system, namely the antenna, its mounting pole, and its shock absorbers, caused by lack of maintenance and by strong wind. The second is inadequate maintenance of the keys, cables, and power supply on the bridge. The Master also advised that the GPS antenna should not be installed close to radio transmitting antennas, because their signals can be received by the GPS and reduce its accuracy. The Third Officer recommended keeping the antenna pole in good condition and connecting both GPS units to all navigation equipment to prevent the problem from recurring.

3.3. Observation Results

The observations on the bridge produced the following findings, which were consistent with the interview results.

a. Before each waypoint, the GPS sounded a turning alarm, set to two minutes before the planned course alteration. This function was lost when GPS1 failed, so the bridge team had to use RADAR/ARPA and visual lookout to keep the ship in safe water, even though the ship could not follow the plotted waypoints exactly.

b. During the GPS failure, the position could still be fixed with other equipment on board, particularly RADAR/ARPA, using bearing and bearing, bearing and distance, or distance and distance obtained with the electronic bearing line (EBL) and variable range marker (VRM).

c. Of the two GPS units on board, the unit that failed was the one connected to RADAR/ARPA, ECDIS, and AIS, so the own-ship position on RADAR/ARPA and ECDIS stopped moving and the position transmitted by AIS could not be read.

d. The officers regularly checked the ship's position against visual references such as bearings of islands and other landmarks. Position fixing is mandatory during a voyage because it shows whether the ship is in safe water, indicates the depth under the keel, and allows the ship to keep clear of obstructions and other dangers, in accordance with the safe navigation requirements of SOLAS Chapter V (IMO, 2020).

3.4. Discussion

The results show that GPS use on the MT New Winner was not optimal because the ship's two GPS units were not configured redundantly: only GPS1 supplied position data to RADAR/ARPA, ECDIS, and AIS, so its failure became a single point of failure for the integrated bridge. This is consistent with studies showing that the digital components of integrated bridge and navigation systems are interdependent and that faults or manipulation in one component affect the whole system (Awan & Al Ghamdi, 2019; Oruç et al., 2022; Liu et al., 2018). The loss of AIS position reports observed on board also illustrates how AIS data quality depends on GNSS input (Androjna et al., 2021; Engler et al., 2021). Although the failure on the MT New Winner was caused by physical damage rather than intentional interference, the consequences were similar to those reported for GNSS

spoofing and jamming, namely reduced situational awareness of the bridge team (Androjna & Perkovič, 2021; Radoš et al., 2024).

The second main cause was inadequate maintenance of the antenna system, cabling, keys, and power supply. This finding agrees with national studies that emphasise maintenance as a condition for the reliable use of navigation equipment (Sutryani et al., 2021; Syibli & Nuryaman, 2021) and with the installation and maintenance guidance in the manufacturer's manual (Furuno Electric Co., Ltd., 2014). The fact that the officers could still fix the ship's position using RADAR bearings, terrestrial bearings, and celestial observations shows the continuing importance of traditional navigation skills (Bowditch, 2017; Antoro et al., 2023). Studies of ECDIS use and human error, however, warn that dependence on electronic systems can erode these skills and create new risks (Car et al., 2020; Kayisoglu et al., 2022), and the growing use of information technology on the bridge also raises questions of responsibility when equipment fails (Tsimplis & Papadas, 2019). Regular training, including simulator exercises with degraded GNSS input, can help officers respond to such failures (Zalewski & Bilewski, 2019; Purnomo et al., 2023), while decision support tools should remain subordinate to the navigator's judgement (Aylward et al., 2022).

Based on these findings, the following measures are recommended: (1) connect GPS2 to RADAR/ARPA, ECDIS, and AIS, for example through a changeover switch, so that either unit can supply position data; (2) inspect and maintain the GPS antennas, mounting poles, shock absorbers, cables, and power supply according to the manufacturer's manual; (3) install GPS antennas away from radio transmitting antennas; and (4) practise alternative position-fixing methods regularly. This study is limited to a single ship and four respondents, so its findings should be confirmed by studies involving more ships and crews.

4. CONCLUSION

Based on the results and discussion, the following conclusions can be drawn.

1. GPS plays a very important role on board as the source of accurate position (latitude and longitude), speed, route, and distance to the next waypoint. On the MT New Winner, however, GPS was not used optimally because only GPS1 was connected to RADAR/ARPA, ECDIS, and AIS, so the failure of this unit

disabled the position input of the other navigation systems even though GPS2 was still functioning.

2. The GPS failure was caused by damage to the antenna system (the antenna, its mounting pole, and broken shock absorbers), which resulted from insufficient maintenance and strong wind, together with poorly maintained keys, cables, and power supply. Installing the GPS antenna too close to radio transmitting antennas can also reduce GPS accuracy.
3. When GPS fails, the ship's position can be determined using RADAR/ARPA, cross bearings, bearing and distance, and celestial observations. Connecting both GPS units to all navigation systems, maintaining the antenna, cabling, and power supply regularly, and practising alternative position-fixing methods are recommended.

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