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ASSESMENT OF SUITABLE LOCATIONS FOR GREEN LOBSTER *(PANULIRUS HOMARUS)* AQUACULTURE USING THE VIETNAMESE CAGE SYSTEM (KJA) IN SUKABUMI AND PANGANDARAN REGENCIES

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ABSTRACT

The bays of Palabuhanratu and East Pananjung present promising potential for lobster aquaculture expansion. This study assesses the suitability of aquatic locales for the cultivation of sand lobsters (Panulirus homarus) employing the Vietnamese cage system (KJA) across the regions of Sukabumi and Pangandaran. Conducted between October and November of 2023, the research utilized field surveys, weighted analysis, and comparative descriptive evaluation. The collected data encompassed primary physical and chemical parameters such as water clarity, temperature, pH, dissolved oxygen (DO), salinity, current speed, and depth and biological factors, including plankton analysis, across the depths of 3, 5, and 7 meters. Findings from the suitability analysis indicated that Palabuhanratu Bay attained an 84% suitability score at each measured depth, whereas East Pananjung Bay achieved a higher suitability score of 92% at equivalent depths, designating both locations as Highly Suitable (SS). Planktonic assessment showed Palabuhanratu Bay with a total count of 33,800 individuals per cubic meter and a Simpson's index of 0.805, suggestive of light pollution levels. In contrast, East Pananjung Bay recorded a significantly higher plankton count of 124,500 individuals per cubic meter and a Simpson's index of 0.280, indicative of severe pollution or substantial plankton density. Comparative evaluations further delineate East Pananjung Bay as the more fitting site for sand lobster aquaculture using the Vietnamese cage system compared to Palabuhanratu Bay.

INTRODUCTION

Indonesia's marine aquaculture potential spans an impressive 12,123,383 hectares, yet the current rate of utilization is a modest 2.7% (Permen KP 2015). In managing the lobster sector (Panulirus spp), especially the juvenile stages known as pueruli, Indonesian regulations stipulate that these crustaceans must be captured and reared within the confines of the same province. The cultivation process must reach a stage where the lobsters attain a minimum weight of 5 grams before they are eligible for transport to other Indonesian provinces, contingent on certification of seed origin by local quarantine and natural resource conservation authorities (Permen KP 2021). Palabuhanratu Bay, with its substantial area of roughly 210 square kilometers, is a treasure trove of marine life, home to a diverse array of large and small pelagic and demersal fish species. This bay's physical and chemical properties render it highly conducive to the development of floating net cage aquaculture. Its rich biodiversity, which includes echinoderms, mollusks, crustaceans, and a habitat for various Panulirus species (Hartami 2008), only adds to its suitability. East Pananjung Bay, likewise, has been earmarked as a promising locale for lobster distribution, housing species such as the rock lobster (Panulirus penicillatus), sand lobster (Panulirus homarus), ornate lobster (Panulirus ornatus), and the long-legged lobster (Panulirus longipes) (Rahman et al. 2018). This bay, too, presents favorable conditions for the implementation of the Vietnamese cage system (KJA) for aquaculture (Supriyadi 2018).

Vietnam's lobster aquaculture has seen the adoption of three main types of cage technologies: floating cages, submersible cages, and fixed cages. The submersible cage design is celebrated for its superior survival rates (Nguyen Thi 2012) and is particularly advantageous for sand lobsters, which exhibit a remarkable resilience to environmental fluctuations. Palabuhanratu Bay and Pangandaran are acknowledged for their supplies of the sand lobster seed, a testament to the regions' aquaculture potential (Rahman et al. 2018). The waters surrounding Lombok represent one of the Indonesian regions implementing the Vietnamese cage methodology, although their yield has yet to parallel Vietnam's successful production. Notably, Vietnam's submersible cage technology is initiated during the seedling stage of lobster development (Jones et al. 2019).

The context provided underscores the necessity for a comprehensive assessment of potential sites for lobster aquaculture within the framework of the Vietnamese cage system (KJA), particularly between the locales of Palabuhanratu Bay and East Pananjung Bay. This study is designed to scrutinize and establish the suitability levels of each site, with the objective of pinpointing the most favorable locations for the cultivation of sand lobsters across these waters.

METHODS

Study Period and Location

The study was conducted from October to November 2023 at sampling points situated at latitudes 7°6'28.73"S and 7°42'12.15"S, and longitudes 106°28'47.20"E and 108°39'43.15"E, respectively. Selection of these stations was informed by the results of preliminary surveys. The processing of the water quality data, encompassing both physical and chemical parameters, relied on pre-existing datasets. Biological analyses of water samples were performed at the Ecology Institute Laboratory/PSMIL in Sekeloa, Bandung. The map depicting the research locations is illustrated in Figure 1:

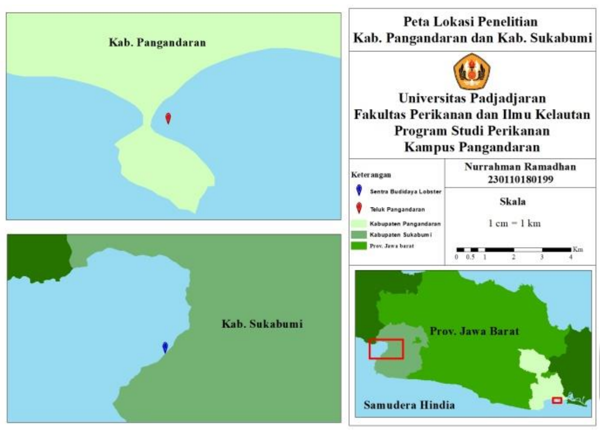

Figure 1. Map of Research Sites at Palabuhanratu Bay and East Pananjung Bay

Instrumentation

The array of equipment utilized for this research comprised a GPS, Secchi disk, pH meter, DO meter, life jacket, smartphone camera, outboard motorboat, logbook, dropper pipette, current meter, sampling bottles, refractometer, Lugol's solution, computer systems, a plankton net, microscope, and Nansen bottles.

Methodological Approach

A field survey approach was adopted to collect primary data, which included an array of water quality parameters: physical parameters such as current velocity, temperature, and clarity; chemical parameters like pH, salinity, and dissolved oxygen; and biological parameters from water samples. Secondary data were sourced from open access platforms, including satellite imagery. The field survey yielded data on physical and chemical parameters and water samples. These data were then subject to a weighting process to ascertain the suitability of the locations based on the physical and chemical parameters. The outcomes of this weighting process, combined with the biological parameter analysis, were descriptively compared across the two data sets.

Research Phases

The research process encompasses several phases, including preparatory work, station point selection, data gathering, suitability evaluation, and the assembly of research outcomes.

Data Analysis

The analysis utilized existing survey data, comprising physical and chemical parameters, which were subjected to a weighting methodology to ascertain the suitability scores for the locations. In parallel, biological parameters underwent analysis to categorize plankton species, with their abundance determined by the formula (Rosada dan Supardi 2021): N = n $x \frac{1}{Vd}$ x $\frac{Vt}{Vs}$, Additionally, the Simpson diversity index was calculated using the formula: I= 1- D, where D = Σ $(\frac{ni}{N})^2$. Utilizing the Simpson diversity index, water pollution levels are segmented into three classifications (Odum 1971), detailed in Table 1 below:

Table 1. Simpson Diversity Index and Associated Water Pollution Levels

Simpson Diversitas Indeks	Water Pollution Level
>0,8	Light Pollution
0,6-0,8	Moderate Pollution
<0,6	Severe Pollution

The data on physical and chemical parameters were instrumental in evaluating the location's suitability through the application of a location suitability matrix. Presented below is the matrix table for area potential criteria:

Table 2. Criteria for Potential Area Suitability

No	Criteria	Potential Suitability Level			Value range	Weight	Reference
		SS	S	TS			
1	*Disolved oxygen* (mg/L)	>5	>4,1 -5,0	< 4,0	SS : 5 S : 3 TS : 1	4	(Damis et al. 2015),(Dirjen Perikanan Budidaya 2020) ,(Booth dan Kittaka 2008).
2	Depth (m)	10-25	6-10	<6 or >25	SS : 5 S : 3 TS : 1	3	(Mustafa 2013), (Dirjen Perikanan Budidaya 2020), (Damis *et al*. 2015).
3	Current speed (cm/s)	19-25	25-50	>50	SS : 5 S : 3 TS : 1	2	(Supriyadi 2018),(Dirjen Perikanan Budidaya 2020), (Damis et al. 2015).
4	Water Clarity (m)	>3	2-3	<2	SS : 5 S : 3 TS : 1	2	(Dirjen Perikanan Budidaya, 2020), (Supriyadi 2018).
5	Temperature (°C)	26-32	< 26	>32 or <26	SS : 5 S : 3 TS : 1	1	(Dirjen Perikanan Budidaya, 2020), (Damis *et al.* 2015).
6	Salinity (ppt)	28-35	20-27	< 20 or > 36	SS : 5 S : 3 TS : 1	2	(Dirjen Perikanan Budidaya, 2020), (Damis *et al*. 2015).
7	pH	7,1 - 8,5	6,5 – 7,1	< 6,5 or >8,5	SS : 5 S : 3 TS : 1	1	(Dirjen Perikanan Budidaya 2020), (Damis *et al*. 2015).

Note: SS: Highly Suitable, S: Suitable, TS: Not Suitable.

Drawing on the data presented in the table, the suitability score for aquatic locales as potential sites for lobster aquaculture can be gauged. Once the parameter values at each station are established, the subsequent step entails evaluating whether the location qualifies as a viable site for aquaculture. This evaluation involves a weighting process for each site, calculated as follows (Noor 2009):

$$\mathrm{IK} = \sum_{i=1}^{n}\left(\frac{\mathrm{Ni}}{\mathrm{Nmax}}\right) \mathrm{x}\ 100\%$$

Prior to assigning scores, it is essential to establish class intervals to facilitate the evaluation at sampling sites. As per (Ariyati *et al*. 2007), the class interval is determined by the equation:

$$\text{Class interval} = \frac{Nmaks - Nmin}{number\ of\ categories}$$

Applying these formulas, the class range was set at 20, with class interval extremes being 75 for the highest and 15 for the lowest, across three distinct categories. These computations culminated in the assessment of each location's suitability for the cultivation of sand lobsters in Vietnamese cages, which is displayed in the subsequent table:

Table 3. Assessment of Land Suitability for Cultivation

No	Score (%)	Inference
1	80-100	Extremely suitable for cultivation as there are no inhibitive factors.

Source: (Supriyadi 2018)

The analytical findings from the physical, chemical, and biological parameter assessments are then comparatively described for both aquatic sites.

RESULTS AND DISCUSSION

Water Depth

Depth is a pivotal factor in the selection of aquaculture cage sites, as it affects parameters such as temperature, light penetration, wave action, water clarity, current strength, and hydrostatic pressure (Umardani 2022). Data collection utilized a weight-line device to ensure precise vertical measurements at one-meter intervals. The collected depth data are compiled in Table 4 below:

Table 4 Water Depth

Locations	Water depth
Palabuanratu Bay	23 meter
East Pananjung Bay	10 meter

The suitability matrix analysis of the recorded depth data demonstrates that both surveyed locations are classified within the Highly Suitable (SS) category for water depth.

Current Velocity

The velocity of water currents is a key consideration in the placement of floating net cages, especially when employing the Vietnamese cage system. Vigorous currents have the potential to compromise cage integrity and sever anchoring lines. Current velocity was measured using a current meter at each site, with findings detailed in Table 5 below:

Table 5. Current Velocity

Locations	Current velocity
Palabuanratu Bay	25,1 cm/s
East Pananjung Bay	19,5 cm/s

Based on the recorded data, Palabuhanratu Bay's current velocity fits within the Suitable (S) category, whereas East Pananjung Bay attains a classification of Highly Suitable (SS) for this parameter

Dissolved Oxygen

The concentration of dissolved oxygen in the water is indicative of its ability to support aquatic life. DO levels were gauged using a DO meter at each prospective site. The results of these measurements are tabulated in Table 6 Below:

Tabel 6. Dissolved Oxygen

Locations	Depth		
	3 meter	5 meter	7 meter
Palabuanratu Bay	6,2 mg/L	6,6 mg/L	7 mg/L
East Pananjung Bay	7,8 mg/L	7,3 mg/L	7,9 mg/L

The locations, based on the data, are deemed Highly Suitable (SS) for aquaculture, with dissolved oxygen concentrations exceeding 5 mg/L (Booth dan Kittaka 2008). Graphical representation of the DO measurements at each site is provided in Figure 2, in the form of a bar chart.

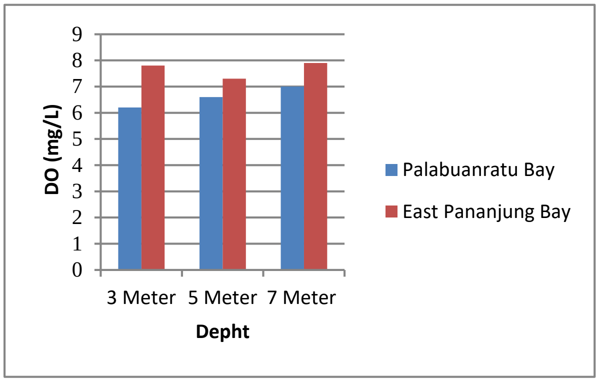

Figure 2. Dissolved Oxygen

Water Clarity

Clarity is subject to various influences, including meteorological conditions, the timing of measurements, plankton concentrations, and the presence of both suspended and dissolved particulates. Notably, water clarity plays a role in the photosynthetic activity of aquatic organisms, subsequently affecting levels of dissolved oxygen (Junaidi *et al*. 2018). Clarity was assessed using a Secchi disk, and the corresponding data are documented in Table 7 below:

Table 7. Water Clarity

Locations	Water Clarity
Palabuanratu Bay	1,65 meter
East Pananjung Bay	3,1 meter

The recorded clarity values demonstrate that Palabuhanratu Bay is categorized as Not Suitable (TS), while East Pananjung Bay is deemed Highly Suitable (SS) in terms of water clarity.

Water Temperature

Among the physical parameters monitored, temperature is a critical measure. Influenced by meteorological factors, solar positioning, geographic location, seasonal variations, atmospheric conditions, and water depth (Umardani 2022), temperature data are crucial for aquaculture viability. The data relating to temperature parameters are consolidated in Table 8:

Table 8. Water Temperature

Locations	Depth		
	3 meter	5 meter	7 meter
Palabuanratu Bay	29,4^{o}celcius	28^{o}celcius	28,1^{o}celcius
East Pananjung Bay	30,1^{o}celcius	29,5^{o}celcius	29,1^{o}celcius

The temperature readings suggest that Palabuhanratu Bay, at depths of 3, 5, and 7 meters, consistently meets the Highly Suitable (SS) criteria. Similarly, East Pananjung Bay, at the same respective depths, also qualifies as Highly Suitable (SS). The temperature data are further illustrated in the bar chart shown in Figure 3.

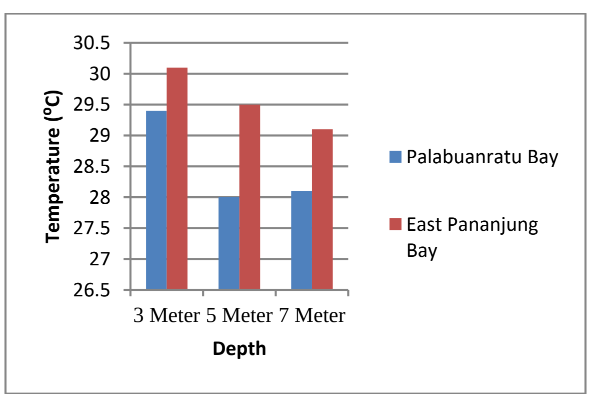

Figure 2. Water Temperature

Salinity

Salinity is a determining factor in assessing a location's potential for fostering lobster growth (Hartami 2008). Salinity levels were measured with a refractometer, with sample collections at 3-, 5-, and 7-meters depths. The compiled data, reflecting measurements across various depths at each location, are outlined in the subsequent Table 9:

Table 9. Salinity

Locations	Depth		
	3 meter	5 meter	7 meter
Palabuanratu Bay	32 ppt	32 ppt	33 ppt
East Pananjung Bay	34 ppt	32 ppt	32 ppt

The data from the salinity parameter table indicate that Palabuhanratu Bay, at depths of 3, 5, and 7 meters, is categorized as Highly Suitable (SS). The same high suitability classification applies to East Pananjung Bay at equivalent depths. A visual representation of these findings is provided in the bar chart in Figure 4.

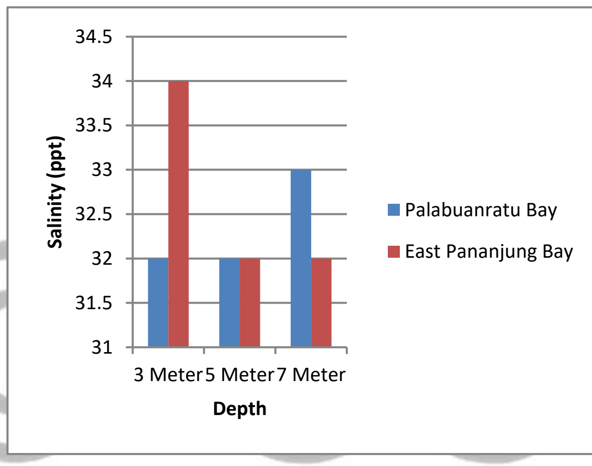

Figure 3. Salinity

pH Levels

The pH level is a vital metric that affects the viability of aquatic flora and fauna, hence serving as an essential indicator of water quality. pH measurements were taken using a pH meter, with samples collected from the depths of 3, 5, and 7 meters. The outcomes of these measurements are compiled in Table 10:

Table 10. pH Levels

Locations	Depth		
	3 meter	5 meter	7 meter
Palabuanratu Bay	7,83	7,82	7,87
East Pananjung Bay	7,95	7,83	7,90

The pH values suggest that both Palabuhanratu Bay and East Pananjung Bay are deemed Highly Suitable (SS) at the measured depths. The associated bar chart is depicted in Figure 5:

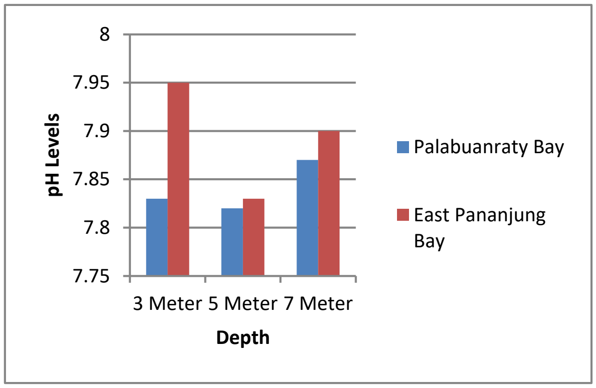

Figure 4. pH Levels

Planktonic Analysis

Analyzing plankton populations aids in evaluating the fecundity of aquatic environments. From a concentrated 50 ml sample reduced to 1 ml, with one count, the conversion is as follows: $\frac{1}{10}\ x\ \frac{1}{1} = 0{,}1\ liter$, which translates to 100 m^3 when converted to cubic meters.

a. Plankton Identification

The observations from the plankton analysis are detailed in Table 11:

Table 11. Plankton Identification

No	Name of species	Number of Plankton	
		Palabuanratu Bay	East Pananjung Bay
	Phytoplankton		
1	*Chaetoceros sp*	300	100
2	*Coscinodiscus sp*	200	700
3	*Thalassiosira sp*	300	200
4	*Ceratium furka*	1.900	-
5	*Peridinium*	1.400	-
6	*Cimacosphenia sp*	200	-
7	*Dinophysis homunculus sp*	4.500	10.700
8	*Ceratium*	1.100	1.700
9	*Leucosolenia sp*	700	-
10	*Ceratium tripos*	900	-
11	*Ceratium fusus*	200	-
12	*Pleurosigma sp*	100	100
13	*Striatella*	100	400
14	*Ethmodiscus*	900	400
15	*Rhabdonema sp*	100	-
16	*Synedra sp*	100	100
17	*Prorocentrum sp*	100	-
18	*Phormidium*	12.700	105.000
19	*Rhizosolenia sp*	100	100
20	*Biddulphia*	600	100
21	*Hemidiscus*	-	100
	Totally phytoplankton	26.500 ind/m^3	119.700 ind/m^3
	Zooplankton		
1	*Calanus spp*	5.500	1.400
2	*Limacine sp*	300	500
3	*Euterpina sp*	300	1.900
4	*Favela sp*	300	-
5	*Pinctada spp*	800	1.000
6	*Cypridina sp*	100	-

Totally zooplankton	7.300 ind/m^3	4.800 ind/m^3
Totally plankton	33.800 ind/m^3	124.500 ind/m^3

b. Simpson Diversity Index

The diversity index was calculated using the Simpson formula, based on the data from Table 10. The Simpson diversity index results for the locations are as follows:

- Palabuhanratu Bay's total plankton diversity index is 0.805, suggesting low pollution levels.
- East Pananjung Bay's total plankton diversity index is 0.280, indicative of significant pollution levels.

These assessments are derived from the Simpson index values relating to plankton diversity, where a high index value correlates with substantial plankton abundance, potentially due to bloom events, which may result from excess feed in the water.

Assessment of Location Suitability

Investigative results reveal that the water conditions at both Palabuhanratu Bay and East Pananjung Bay are categorized as Highly Suitable (SS). The detailed values for each site are tabulated in Table 12:

Table 12. Location Suitability

Depth	DO (mg/L)	Water Depth (m)	Current Speed (cm/s)	Clarity (m)	Tem-pera-ture (°C)	Salinity (ppt)	pH	Score (%)	Basic Substrate
Palabuanratu Bay									
3 meter	6,2	23	25,1	1,65	29,4	32	7,83	84%	Muddy sand
5 meter	6,6	23	25,1	1,65	28	32	7,82	84%	Muddy sand
7 meter	7	23	25,1	1,65	28,1	32	7,87	84%	Muddy sand
East Pananjung Bay									
3 meter	7,7	10	19,5	3,1	29,3	34	7,95	92%	Muddy sand
5 meter	7,3	10	19,5	3,1	29,2	32	7,83	92%	Muddy sand
7 meter	7,9	10	19,5	3,1	29	29	7,9	92%	Muddy sand

The compendium of data underscores that both aquatic environments are deemed Highly Suitable, with suitability percentages ranging from 80% to 100%.

Comparative Analysis of Locations

Comparative analysis was undertaken to determine the most favorable site for lobster aquaculture within the framework of the Vietnamese cage system (KJA) between Palabuhanratu Bay and East Pananjung Bay. This process involved a detailed examination of the similarities and discrepancies between the two sites to identify the superior location.

Shared characteristics of the two locations include concurrent sampling and measurement times, conducted during daylight hours in the second transitional season; both areas are recognized as lobster seed production zones in the West Java region; the variation in parameter values at different depths is minimal; and both sites share proximity to the Indian Ocean.

The discernible differences lie in the suitability percentages, which are pivotal in selecting the optimal site for the Vietnamese cage system lobster aquaculture. Comparative findings favor East Pananjung Bay over Palabuhanratu Bay in terms of suitability. Furthermore, aquaculture operations necessitate substantial transportation facilities. East Pananjung Bay boasts better accessibility than Palabuhanratu Bay, as evidenced by the swift progression of road infrastructure in the Pangandaran Regency. Geographically, Palabuhanratu Bay is characterized by steep terrain. Regarding safety and security, East Pananjung Bay is superior to Palabuhanratu Bay, given the presence of a fishery station and a marine police office in close proximity to the aquaculture zones. From a marketing standpoint, East Pananjung Bay's status as a tourist hotspot offers a strategic advantage, potentially facilitating a more streamline and effective marketing process for lobsters compared to the more remote Palabuhanratu Bay.

Conclusion

The assessment of physical and chemical parameters, alongside the computed location suitability values, confirms that both Palabuhanratu Bay and East Pananjung Bay are categorized as Highly Suitable (SS) for aquaculture at depths of 3, 5, and 7 meters. The suitability rates for East Pananjung Bay are notably higher, with a value of 92%, in comparison to Palabuhanratu Bay's 84%. Biological analyses point to a lower pollution level in Palabuhanratu Bay, as reflected by a Simpson index value of 0.805, whereas East Pananjung Bay exhibits a higher pollution level, with a Simpson index value of 0.280. These findings correlate with the Simpson index for plankton diversity, suggesting that increased pollution is associated with elevated plankton abundance, likely due to plankton bloom events potentially triggered by excess feed. Conclusively, the comparative descriptive analysis underscores that East Pananjung Bay is highly suitable for aquaculture, given its superior location suitability values, logistical advantages, marketing efficiency, and enhanced security measures.

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