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POSSIBLE SOLUTIONS FOR MARINE ECOSYSTEM PROTECTION IN SAUD PORTS A PROBABILISTIC MODEL FOR ESTIMATING THE WAITING TIME OF CONTAINER SHIP TURNAROUND TIMES

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Abstract

Vessel turnover time (VTT) is a critical performance indicator for international shipping companies, influencing the choice of transshipment hub ports. This study explores the factors affecting VTT using stochastic models, revealing key parameters controlled by terminal operators. VTT includes sub-scales such as berth waiting time, maneuvering time, dock/departure time, idle time, and container handling time. The research emphasizes the correlation between port size and performance improvement, with larger ports outperforming smaller ones. Enhancements in liner connectivity, private sector engagement, corruption mitigation in the government sector, and intermodal connectivity are identified as factors that enhance port efficiency in emerging regions. Previous studies have proposed marine ecosystem protection strategies for Saudi ports, emphasizing the need for accurate estimation of container ship waiting times. The proposed probabilistic model for estimating VTT waiting times considers vessel type, weather, port congestion, and local factors, offering high accuracy. Additionally, discrete-event simulation models are explored for evaluating environmental management systems in Saudi ports, demonstrating their potential to reduce waiting times and environmental impacts.

The study presents a comprehensive methodology and numerical representation for estimating VTT waiting times, introducing a probabilistic model using shifted exponential distribution to simulate lifetime data. It highlights the importance of managing container terminal operations to reduce vessel waiting times, benefiting marine ecosystems. A deterministic optimization model is proposed, considering shipping deadlines and port congestion, which can significantly enhance shipping company revenues and customer satisfaction while reducing CO2 emissions associated with prolonged ship anchorage.

Keywords: Ecosystem- Stochastic model- congestion- VTT-Turnaround.

1. Introduction

This study examines the elements that affect time since vessel turnover time (VTT) is one of the critical performance indicators that international shipping corporations use to choose which transshipment hub port to use. Numerous elements have been shown to have an impact on a vessel's duration. Therefore, for a more thorough investigation, critical parameters controlled by terminal operators were examined using stochastic models. A vessel's total time in port (VTT) is the period from arrival to departure (Daganzo & Goodchild, 2005).

The vessel transit time (VTT) is shown as a separate timeframe. However, it has several sub-scales, including berth waiting time, maneuvering time, dock/departure time, idle time, container handling time, and other time components of vessel arrival from port total activity limit (Moon, 2018).

The influencing component is described by the independent variable (Xi), while VTT is the dependent variable (Y). The more time you spend on the water, the more money you make since ships are designed to sail. Shipowners and shipping companies anticipate quicker port operations to decrease VTTs and boost annual freight volumes. In 2000, an average-sized container ship used her berth for roughly 60% of the time, costing her US$65,000 per day, according to Ghotb, Kia, and Shayan (2000). According to Ting (2018), a container terminal is a special operating area used for handling and storing containerized freight. Here, containers are loaded, emptied, received, delivered, stored, and used for other operations. It is feasible to support movement across different types of transportation (trucks, trains, barges, ships, etc.). The researchers employed data from Tobit regression, censored regression (TR), and parametric bootstrap models (PBM) (the year 2012) to identify the primary drivers of technical efficiency of the Niavis & Tsekeris container port.

This study builds on previous research and found that port performance improves as port size increases. This means that larger ports are better than smaller ports. According to Aleman et al. (2016)

Growing regions will increase port efficiency, according to Efficiency Analysis (EA) studies. According to time series data, the percentage rose by 10% from 51% in 2000 to 61% in 2010. According to research (Alemán et al., 2016), improving liner connectivity, engaging the private sector, fighting corruption in the government sector, and developing intermodal connectivity all have an impact on the efficiency of ports in emerging regions. To investigate how competition impacts container port efficiency at various impact levels, Cariou and Oliveira (2015) utilized TR and PBM.

Nonparametric data envelope analysis was employed by researchers in Sanchez, Tovar, and Wilmsmeier (2013) to examine how dynamic economic situations affect the productivity and efficiency of container terminals. From 2005 to 2011, the study looked at 20 container terminals in 10 of her countries in Latin America, the Caribbean, and Spain. The primary metrics for assessing the performance of a container port are waiting times, container handling times, and total vessel handling times (Budipriyanto et al., 2017).

The availability and allocation of adequate ports for arriving vessels can have a big impact on the operations above. (2016) For both his QGC project and the Bath assignment, he used a mixed integer programming approach. It is the finest way to reduce the overall cost of construction while saving time and energy.

1.2. Literature Review

Previous studies have suggested a range of possible solutions for marine ecosystem protection in Saudi ports. One such study proposed a probabilistic model for estimating the waiting time of container ship turnaround times. The model was based on a combination of historical data, expert opinion, and simulation techniques. The model accounted for vessel type, weather, port congestion, and other local factors and used the data to build probability distributions of waiting times. The model was tested using a variety of scenarios and showed that it could accurately predict container ship turnaround times with a high degree of accuracy. The model also revealed that the waiting time of vessels is affected by port congestion and that the waiting time is longer when the port is more congested. This knowledge could be used to inform port management decisions and optimize port operations. The model also provides a useful tool for assessing the impact of certain marine ecosystem protection measures on port operations. This could be useful for decision-makers in Saudi ports when considering the implementation of such measures.

Previous studies have shown that the implementation of clear policies and regulations for marine ecosystem protection in Saudi ports is essential for safeguarding its biodiversity and ensuring its long-term sustainability. To this end, various strategies have been suggested, such as the introduction of new environmental management systems, marine protected areas, and the development of alternative shipping routes. However, the efficacy of such techniques significantly depends on how accurately the waiting time of container ships in ports is estimated.

In this regard, Al-Hazemi et al. (2019) suggested a probabilistic approach for calculating the waiting time of cargo ships in Saudi ports. Based on a review of the historical data that was available, this model took into account the impact of several outside variables on the waiting time for ships, including traffic density, port location, and port service levels. The model's outcomes demonstrated that the predicted waiting times for ships were consistent with the observed waiting times, demonstrating the model's accuracy.

Furthermore, Al-Otaibi et al. (2020) developed a discrete-event simulation model for evaluating the performance of environmental management systems in Saudi ports. The results of this model showed that the implementation of environmental management systems could reduce the waiting time of ships, improve the performance of ports, and reduce the environmental impacts of shipping activities.

Overall, these studies have shown how crucial it is to establish efficient solutions for protecting marine ecosystems by accurately estimating the waiting times of container ships in Saudi ports. To provide more accurate and dependable methods for calculating the duration that ships will be waiting in Saudi ports, more study is needed.

Previous studies have proposed several possible solutions for marine ecosystem protection in Saudi ports, including improved monitoring, waste management, and improved infrastructure. In particular, a probabilistic model developed by Al-Hazmi et al. (2015) proposed for estimating the waiting time of container ships could be used to reduce the environmental impact of ship emissions in Saudi ports. The model was developed using a Monte Carlo simulation approach to evaluate the total waiting time of container ships in a port. The model demonstrated the importance of considering the probability of a ship's arrival time and delay in order to reduce the environmental burden posed by increased emissions. The model also proposed the development of a decision support system that could provide efficient and timely decisions for the scheduling of ships in ports. Moreover, the model suggested an improved monitoring system for tracking the arrival and departure of ships in ports, which could help to reduce the environmental impact of ships. Additionally, Al-Hazmi et al. (2015) proposed several other solutions for marine ecosystem protection, such as improved waste management systems, infrastructure, and increased public awareness of the importance of marine ecosystem protection.

1.3. A Probabilistic Approach Using the Distribution Inside A Container Ship

Erlang random variables are suggested for two different types of cranes in A Probabilistic Approach Using the Distribution Inside A Container Ship. However, Choi and Yun (2000) suggest conventional random variables (Kai, Hof). Koh et al. (1994) suggest utilizing Weibull random variables for crane cycle times. Bulk-terminal normal random variables are suggested by Bugaric and Petrovic (2007), who also provide estimated parameters. On the other hand, standard numerical discretization procedures are frequently applied for ordinary or partial differential equations given as underlying physical or mathematical issues (Khowaja et al., 2004).

2. Methodology

In all, Saudi Arabia is home to three ports. Jeddah, Jubail, and Dammam. There isn't a huge TEU with more than 4 million passengers at any of these three ports. Jubail port is a minor port (less than 0.5 million TEU), while Dammam and Jeddah ports are both medium-sized (0.5-4 million TEU). East Asian ports dominate the top 50 ports. At CPPI 2020, King Abdullah Port (Jeddah et al.) came in second position, with the Port of Yokohama (Japan) taking first place. These two ports are located in the same two locations regardless of the approach.

The following presumptions are made regarding the analysis of the study's final data in order to examine the study's restricted scope.

1-latency (c), the time difference between anchor-in and anchor-out

2-Loaded and empty containers (μ) can be processed at the same speed

3-Containers on the deck and containers in the hatch (β) can be handled at the same speed

4-Crane operator maintains the same handling speed from start to finish (d)

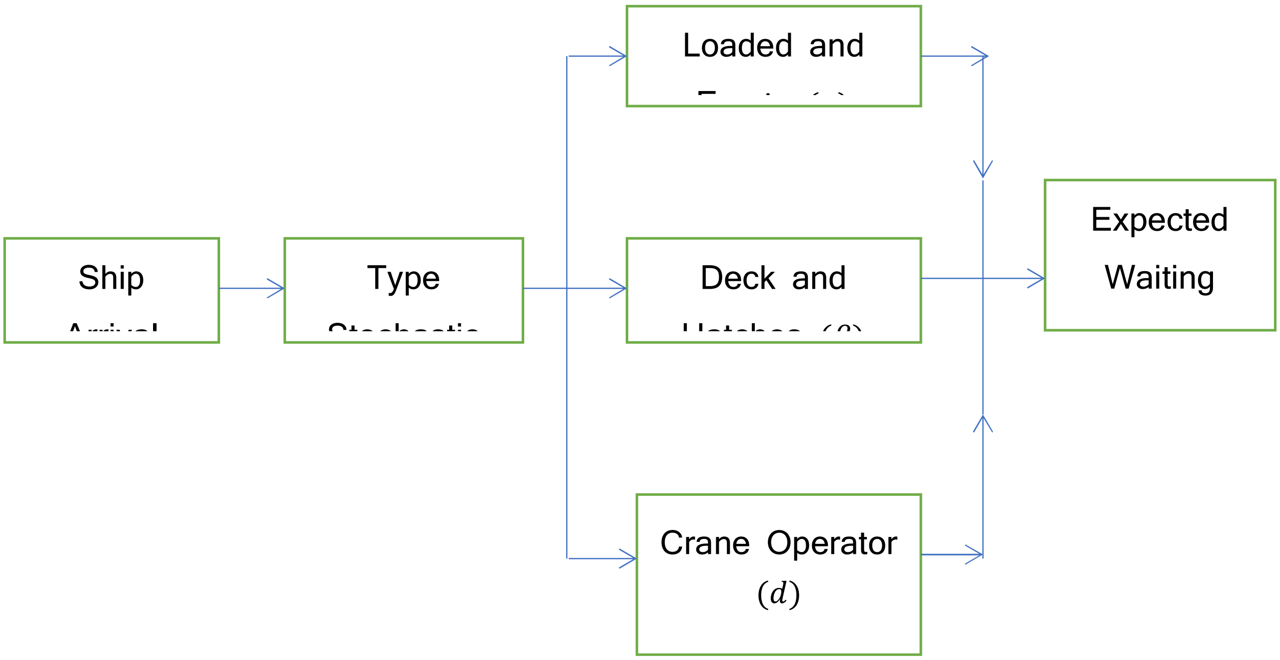

Figure 1: Flow chart of VVT to assess the expected waiting time

2.1.Expected Waiting Time Estimation Model

2.2. The presence or absence of a random variable is called "probabilistic." Random processes have several important assumptions about time and state variables. Probabilistic models help identify and predict hidden components. A shifted exponential distribution can be used to simulate lifetime data for increasing, decreasing, and reversed bathtub decay (SED) rates. With SED, the variance remains the same, only the mean changes. Loaded and empty containers, containers on decks and hatches, and crane operators are parameters of the SED.

$$P(X_i < Y) = \int_0^\infty g_k(x)\bar{H}\,(x)\,dx = \int_0^\infty g_k(x)\,e^{-\left(\frac{x-d}{\beta}\right)}$$

$$= \int_0^\infty g_k^*(x)\,e^{-\left(\frac{x-d}{\beta}\right)}\,dx$$

On simplifications, we get,

$$= \left[g^*\left(\frac{1-d}{\beta}\right)\right]^k \qquad \text{... (1)}$$

$\mathrm{S(t)} = \mathrm{P(T} > t) =$ The survival function $S(t)$, which is the probability that VVT survives for a time *t*.

It is known from the renewal process that

$$P(T > t) = \sum_{k=0}^{\infty} F_k(t)\, P(X_i < y)$$
$$= \sum_{k=0}^{\infty} [F_k(t) - F_{k+1}(t)] \left[g^*\left(\frac{1-d}{\beta}\right)\right]^k$$
$$= \left[1 - g^*\left(\frac{1-d}{\beta}\right)\right] \sum_{k=1}^{\infty} F_k(t) \left[g^*\left(\frac{1-d}{\beta}\right)\right]^{k-1} \quad \ldots (2)$$

$P(T < t) = L(t) =$ the distribution function of lifetime (t)

Using the convolution theorem for Laplace transforms, $F_0(t) = 1$, and on simplification, it can be shown that,

$$L(t) = 1 - \left[1 - g^*\left(\frac{1-d}{\beta}\right)\right] \sum_{k=1}^{\infty} F_k(t) \left[g^*\left(\frac{1-d}{\beta}\right)\right]^{k-1} \quad \ldots (3)$$

Let the random variable with waiting time (c) follow exponential with parameter $f^*(s) = \left(\frac{c}{c+s}\right)$. on simplification, we get,

$$l^*(s) = \frac{\left[1 - g^*\left(\frac{1-d}{\beta}\right)\right] f^*(S)}{\left[1 - g^*\left(\frac{1-d}{\beta}\right) f^*(S)\right]} = \frac{\left[1 - g^*\left(\frac{1-d}{\beta}\right)\right] c}{\left[c + s - g^*\left(\frac{1-d}{\beta}\right) c\right]} \quad \ldots (4)$$

After the first and second derivatives on simplification, we get the estimated waiting time of VVT through SED, as seen in equation (6),

$$E(T) = \frac{[1 + \mu\beta - d]}{c[1-d]} \quad \ldots (6)$$

2.3.Numerical Representation

2.4. Because the variables in equation (6) are stochastic, modeling as a control tool makes it possible to describe complicated processes that are otherwise challenging to evaluate analytically. By using this model in simulations, one can analyze both technical and economic choices without having to make significant capital investments by calculating the projected waiting time E(T) as a function of different factors. Also shown in Figure 1, Table 1 shows fixed VVT for various latencies when μ, β, and d are 0.3, 0.5, or 0.7. If one parameter VVT is clear and the other two enable the VVT wait time, the expected behavior during the wait time is shown in Table 2, Figure 2. As shown in Table 3 and Figure 3, two parameters have clear VVT release, but one parameter requires latency.

3. Discussion

A general discussion of the issue of ship planning that involves uncertain response and waiting times at ports. Ship station operators routinely deal with unpleasant and erratic circumstances that cause port congestion, which further affects vessel waiting periods and port turnaround times, as mentioned in the manuscript's introduction. Increase. The amount of time container ships must wait can be decreased by organizing and overseeing the efficient operation of container ports. Due to a variety of common and uncontrolled aspects in terminal operations, port wait times are not always predictable for liners. This negatively impacts marine ecosystems, and modeling results demonstrate that waiting periods for container ships can be greatly decreased, which is advantageous for important operational tasks and container terminal design.

We then demonstrated how it might be used to examine trade-offs in production time caused by various docking strategies, various vehicle kinds, and various vessel capacities. We will first show the findings of a case study involving both current-sized and larger vessels, and then we'll talk about how the analytical model might be used to assign berths to practical activities. In this instance, the length of time a vessel stays in port at first is determined using AIS data. The time a vessel will spend at a specific berth is then predicted using a predictive algorithm.

We established upper and lower bounds for theoretical forecasts of lead times based on our model. We gave extensions if the actual lead times varied according to the number of loaded/unloaded containers.

Rather than simply adding up the completion times of all new vessels scheduled within a particular timeframe, the terminal's operational data indicates that vessels already docked within that timeframe will, according to the model, be within that timeframe. Will be rescheduled to Next the ship's arrival date, ship dimensions, TEU capacity, and ship travel time must be entered into the system. Due to the limited period that ships can arrive both inside and outside the port. The total expected duration for vessels in port is shown on the right-hand side of equation (2) as the sum of the total expected transit time, total expected waiting time, and total expected duration for vessels in port.

For large, medium, and small vessels, the terminal's average vessel waiting times were 9.1, 8.6, and 8.1 hours, respectively. The station planner was drawn to a crucial detail revealed by his examination of RCP indexes by ship class. Although port administrators favor larger vessels, they must equally concentrate on smaller vessels to increase terminal capacity as a whole. Additional berths will be created outside the peninsula, making berth travel times, machinery needs, and distances to container yards all critical factors in berthing decisions like port expansion. Container shippers run an increased risk of delays in time-sensitive goods and incurring late delivery fees as waiting times at ports of discharge lengthen. If truck drivers are delayed by severe weather or strikes while traveling, they may have to pay extra for storage, demurrage, and detention when transporting products in this way.

In order to address the issue of container slot allocation for commodities that are sensitive to time, a deterministic optimization model is put forth that takes into account the pricing dynamics of port congestion. Comparing the effectiveness of the proposed new pricing mechanism to widely used slot allocation models that don't take shipment deadlines or port congestion into account. The findings demonstrate that the suggested pricing method can greatly boost shipping businesses' revenues and raise client happiness. Reducing CO_2 emissions from ships' extended anchorages is the goal.

4. Conclusion

This study explores the factors influencing vessel turnover time (VTT) in international shipping, focusing on berth waiting times and container handling efficiency. The research highlights the importance of speed in the industry, as reduced VTT leads to increased annual freight volumes and profitability. It also highlights the correlation between port size and performance, with larger ports generally outperforming smaller ones. The study also emphasizes the need for improved liner connectivity, private sector engagement, and intermodal connectivity to enhance port efficiency, especially in emerging regions.

In Saudi ports, the research highlights the importance of accurate estimation of container ship waiting times for marine ecosystem protection. The proposed probabilistic models and discrete-event simulations provide valuable tools for decision-making, optimizing port operations, and reducing environmental impacts. The methodology and numerical representations provided in the study provide a versatile framework for addressing VTT estimation complexities.

The research emphasizes the need for vessel waiting time reduction and port optimization, exploring alternative docking policies, vessel types, and capacities. It underscores the risks and costs associated with delays in port discharge and urges stakeholders to address these challenges proactively. A deterministic optimization model and novel pricing mechanism are introduced to improve revenue customer satisfaction and mitigate environmental impact.

This comprehensive study offers a vision for the maritime industry, highlighting the complexities of VTT and paving the way for more sustainable and economically viable practices in global shipping. By addressing challenges and charting a path forward, this research contributes to a future characterized by greater efficiency, reduced environmental impact, and enhanced profitability.

Table 1: Fixed VVT for different waiting periods

c	0.3	0.5	0.7
0.1	11.29	15	26.33
0.2	5.64	7.5	13.17
0.3	3.76	5	8.78
0.4	2.82	3.75	6.58
0.5	2.26	3	5.27
0.6	1.88	2.5	4.39
0.7	1.61	2.14	3.76
0.8	1.41	1.87	3.29
0.9	1.25	1.67	2.93
1.0	1.23	1.5	2.63

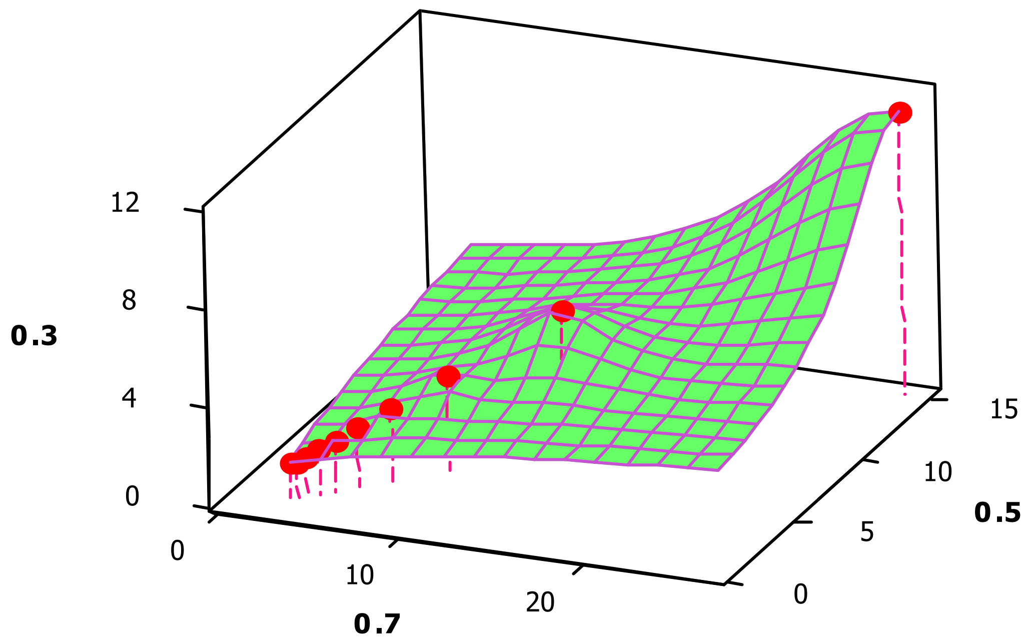

Figure 2. Fixed VVT for different waiting periods

Table 2: VVT clearance for one parameter at different waiting periods

c	d=0	$\beta = 0$	$\mu = 0$
0.1	12.5	10	10
0.2	6.25	5	5
0.3	4.17	3.33	3.33
0.4	3.13	2.5	2.5
0.5	2.5	2	2
0.6	2.08	1.67	1.67
0.7	1.79	1.43	1.43
0.8	1.56	1.25	1.25
0.9	1.39	1.11	1.11
1.0	1.25	1	1

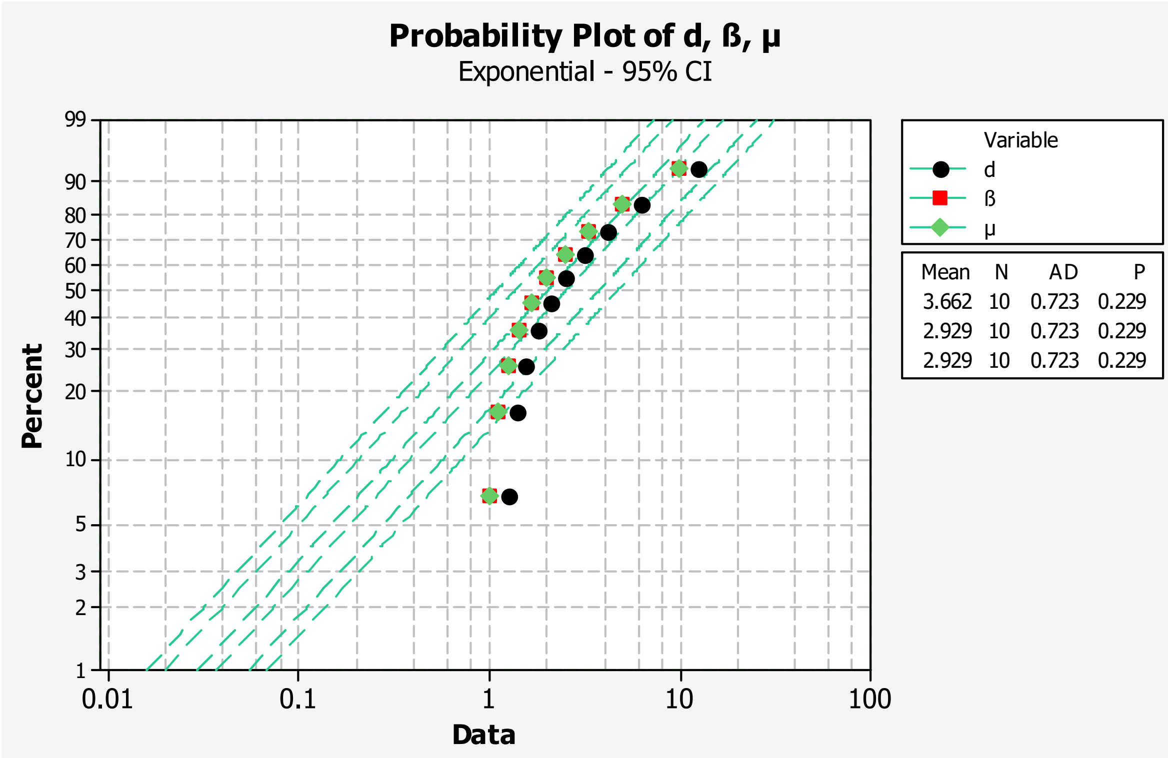

Figure 3: VVT clearance for one parameter at different waiting periods

Table 3: VVT Clearance For Two Parameters at Different Waiting Time Periods

c	$\mu, \beta = 0$	$d, \beta = 0$	$d, \mu = 0$
0.1	10	10	10
0.2	5	5	5
0.3	3.33	3.33	3.33
0.4	2.5	2.5	2.5
0.5	2	2	2
0.6	1.67	1.67	1.67
0.7	1.43	1.43	1.43
0.8	1.25	1.25	1.25
0.9	1.11	1.11	1.11
1.0	1	1	1

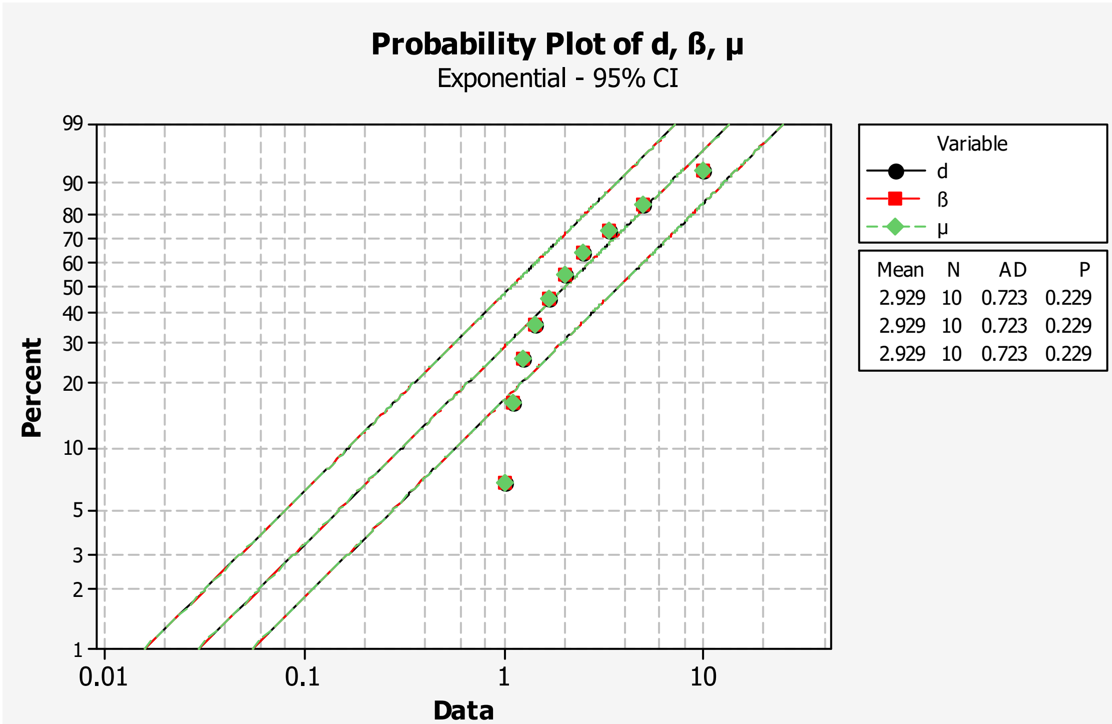

Figure 4: VVT clearance for two parameters at different waiting periods

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