Analysis of the Performance of Cargo Clearance Formalities Based on Fuzzy VIKOR Clustering Model: A Case of Dar es Salaam Seaport

Erick P. Massami* • Malima M. Manyasi

Dar es Salaam Maritime Institute.

Author Email: erick.massami@dmi.ac.tz.

Abstract. The ability of a seaport to attract traffic in a highly competitive environment can be negatively affected by its inefficiency and ineffectiveness of cargo clearance formalities. This study analyses the performance of cargo clearance processes at Dar es Salaam Seaport. A questionnaire survey was conducted on a random and stratified sampling of key cargo clearance service providers in Dar es Salaam Port. The data is analysed by Fuzzy VIKOR Clustering Model (FVCM) which is a combination of Fuzzy Clustering Model (FCM) and Fuzzy VIKOR Model (FVM). The results of the analysis reveal that the Customs Authority, Freight Clearing & Forwarding Companies, and Other Government Departments as the most effective agencies in business process management in the port. Moreover, Shipping Agents are the least effective agency in business process management in the port.

Keywords: Seaport, Cargo Clearance, Fuzzy Clustering Model, Fuzzy VIKOR Model, Analysis.

INTRODUCTION

The ability of a seaport to attract traffic in a highly competitive environment can be negatively affected by its inefficiency and ineffectiveness of cargo clearance formalities. Seaports form a vital link to the overall trading chain, and consequently, the level of cargo clearance speed determines to a large extent a country's competitiveness in international trade (Panteial, 2014). Quick cargo movement attracts more cargo; reduces logistics costs and cost of doing business; improve country competitiveness in the international market and attracts global investments (Makiri, 2013). However, cargo clearance in Port is a complex Business to Business (B2B) process consisting of a large number of internal and external port community stakeholders, which are public, Government institutions and private firms. These stakeholders have conflicting interests whereby their participation in service provision are benchmarked by specific requirements or targets which in most cases are directly related to speed movement of cargo within the port (David, 2015).

The current global inter-port competition drives Port Managers to consider service quality improvement as an inevitable strategic factor for their companies to retain and/or attract more customers. For instance, Dar es Salaam Port handles about 95 percent of the Tanzania international trade and serves the landlocked countries of Malawi, Zambia, Democratic Republic of Congo, Burundi, Rwanda, and Uganda (Tanzania Ports Authority, 2020). Nonetheless, the inefficiency of cargo clearance service at the Dar es Salaam Port has been a prominent challenge and pointed by many studies. The Port users experience cargo clearance delays, payments of demurrages and irrational storage charges, high dwell time, high capital tied up. These inefficiencies created financial losses for shippers, users, and shipping companies (World Bank, 2013).More specifically, the Tanzania economy was estimated losing USD 1.8 Billion annually due to inefficient cargo clearance services at the Dar es Salaam Port (World Bank, 2013). This situation is fuelled by poor coordination of port agencies coupled with

non-transparency and complexity of administrative procedures which undermines Tanzania's and the region's trade potential (Tanzania Ports Authority, 2020). Specifically, delays in clearance of cargo from the Port have become a significant barrier to trade in Tanzania and the region as a whole (Tanzania Ports Authority, 2020). Taking into account the high logistics costs (economic loss) resulting from inadequate service quality at the Dar es Salaam Port, it is very crucial to investigate the cargo clearance multi-processes among the parties of the Port Community i.e. Business Process Management (BPM) of the agencies involved in the cargo clearance chain and propose the way forward.

Cargo clearance service quality is difficult to define and measure because of the unique characteristics of service namely, its intangibility, inseparability, heterogeneity, perishability, and ownership (Apostolos *et al.*, 2013). Specifically, the complex nature of B2B multi-process services and the mixed diverse service setting are difficult to measure (Ines *et al.*, 2011). Fuzzy Evaluation Models play an important role in appraising service quality when a small sample is considered.

The remainder of this study is structured as follows: Section 2 provides a review of relevant literature; Section 3 presents an overview of fuzzy sets and fuzzy numbers; Section 4 provides Fuzzy VIKOR Clustering Model; Section 5 presents the application of the Fuzzy VIKOR Clustering Model to assess the performance of service providers involved in the cargo clearance formalities at Dar es Salaam Port; and Section 5 provides the conclusions.

Review of Relevant Literature

There is a limited conceptual and empirical literature on the analysis of service quality in B2B multi-process in the Port environment. Vaghi and Lucietti (2016) analyzed costs and benefits of speeding-up reporting formalities in maritime transport at the Port of Venice and Levante in Italy as a result of the EU directive. Chen (2011) applies the Fuzzy Analytic Hierarchy Process (AHP) to explore the digital capital measures of automated cargo clearance business website in Taiwan. Martincus *et al.*, (2015) estimate the effects of custom-related delays on firms' exports using a unique dataset that consists of the universe of Uruguay's export transactions over the period 2002-2011. Pourakbar and Zuidwijk (2018) developed models that allow customs to optimize its inspection process to target high-risk containers without hindering the flow of safe containers with extra delays at Ports. Elliott and Bonsignori (2019) assess the role played by customs processes focused on goods for immediate release in facilitating trade flows, and how international express delivery by air acts as a channel to transmit this effect. Pak *et al.* (2015) propose a Fuzzy TOPSIS Approach to evaluate intangible resources affecting Port service quality in the Asia-Pacific region.

To-date a comprehensive model has not been developed for the analysis of service quality of multi-process cargo clearance with complex interrelationship between agencies such as Terminal and ICD Operators, Customs Authority, Shipping Agents, Freight Clearing and Forwarding Companies, and Other Government Departments (OGDs). Thus, we develop a Fuzzy VIKOR Clustering Model (FVCM) to investigate the Multi-Criteria Decision Making (MCDM) problem of cargo clearance formalities at Dar es Salaam Port. The Hybrid Model which is a combination of Fuzzy VIKOR Model and Fuzzy Clustering Model is suitable for ranking, selecting and classifying alternatives i.e. agencies in a fuzzy environment. The Fuzzy VIKOR Model ranks and selects alternatives whereas the Fuzzy Clustering Model determines the interrelationship between alternatives. Researchers and Practitioners apply extensively Fuzzy Clustering Model and Fuzzy VIKOR Model for solving MCDM problems in fuzzy environment.

Chang (2014) proposes a Fuzzy VIKOR method for a case study of the hospital service evaluation in Taiwan. Alguliyev *et al.* (2015) propose a Modified Fuzzy VIKOR Method for personnel selection in human resource management. Vahabzadeh *et al.* (2015) analyses the impacts of Reverse Logistics (RL) activities on the environment using Fuzzy VIKOR method. Opricovic (2011) applies Fuzzy VIKOR to water resources planning. Liu *et al.* (2012) apply extended VIKOR method for risk evaluation in failure mode. Rostamzadeh *et al.* (2015) apply fuzzy VIKOR to evaluate green supply chain management practices. Wu *et al.* (2016) apply a multi-criteria group decision making (MCGDM) technique based on fuzzy VIKOR method to solve a Computer Numerical Control (CNC) machine tool selection problem. Zhiliang *et al.* (2017) propose an approach for multi-criteria group decision making (MCGDM) with dual hesitant fuzzy information. Chen (2018) develops novel VIKOR-based methods for multiple criteria decision analysis involving Pythagorean fuzzy information. Gul *et al.* (2019) address job-related hazards and associated risks in the mining industry based on Pythagorean fuzzy VIKOR approach. Liang *et al.* (2019) apply Pythagorean fuzzy VIKOR approaches for evaluating internet banking website quality of Ghanaian banking industry. Kim and Chung (2013) assess the vulnerability of the water supply to climate change and variability in the South Korean provinces using a fuzzy VIKOR approach.

Tóth and Vad (2018) propose a fuzzy clustering method for periodic data, applied for processing turbomachinery beamforming maps. D'Urso and Leski (In Press) propose a fuzzy clustering method for imprecise data based on robust loss functions and ordered weighted averaging. Guillon *et al.* (2019) propose a fuzzy partitioning subspace clustering algorithm that minimizes a variant of the FCM cost function with a weighted Euclidean distance and a non-differentiable penalty term. Zarinbal *et al.* (2015) propose a novel collaborative fuzzy clustering method to calculate the interaction coefficient

between data sites. Yiming *et al.* (2019) propose a new fuzzy clustering algorithm driven by data and knowledge named Density Viewpoint-Induced Possibilistic Fuzzy C-Means (DVPFCM). Hatori and Sato-Ilic (2014) present a fuzzy clustering method that enables the researchers to obtain a clear classification for the complex data. Choi and Kim (2017) propose a fuzzy clustering method to investigate the operating behaviour characteristics of a wind power system. Wu *et al.* (In Press) propose a novel strategy to fuse k-means and fuzzy c-means objective functions based on Modified fuzzy clustering. Trabelsi and Frigui (2019) apply robust fuzzy clustering on remote sensing data to predict the yearly average yield of a crop and to drug activity prediction. Giordani and Ramos-Guajardo (2016) propose a fuzzy clustering method for random fuzzy sets. Li *et al.* (2016) present a multi-objective fuzzy clustering method for change detection in Synthetic Aperture Radar (SAR) images.

This study applies the Fuzzy VIKOR Clustering Model to assess the performance of the service providers concerning cargo clearance processes at Dar es Salaam Port. The operations with Fuzzy Sets and Fuzzy Numbers are presented in the next section.

Overview of Fuzzy Sets and Fuzzy Numbers

Fuzzy Set Theory (FST) deals with problems with vagueness and thus can use imprecise data for decision making.

Definition 1. Suppose $F = \{\delta_1, \ldots \delta_T\}$ be the universe of discourse. A fuzzy set S of F is a set of ordered pairs $\{\delta_t, \delta_S(\delta_t)\}$, $t \in \{1 \ldots T\}$, where $\delta_t : S \to (0,1)$ is the membership function of S and $\delta_S(\delta_t)$ stands for the membership degree of δ_t in S.

A fuzzy number N can take any value between 0 and 1 i.e. $N \in (0,1)$. Many Researchers and Practitioners employ Triangular Fuzzy Numbers (TFNs) for fuzzy analysis. More specifically, fuzzy models that use TFNs prove to be effective for solving decision-making problems where the available information is subjective and vague (Haleh and Hamidi, 2011). Consequently, TFNs is adopted in this study.

Definition 2. A TFN S is defined as $S = (s^l, s^d, s^u)$, $s^l \leq s^d \leq s^u$ where s^l is the smallest possible value, s^d is the most promising value, and s^u is the largest possible value. Each TFN has linear representation as defined by equation (1).

$$\delta_S(x) = \begin{cases} \frac{x - s^l}{s^d - s^l}, & s^l \leq x \leq s^d \\ \frac{s^u - x}{s^u - s^d}, & s^d \leq x \leq s^u \\ 0, & Elsewhere \end{cases} \quad (1)$$

Operations with TFNs

are two triangular fuzzy numbers then the fuzzy arithmetic operations are as follows.

Addition:
$$S_1 + S_2 = (s_1{}^l + s_2{}^l, s_1{}^d + s_2{}^d, s_1{}^u + s_2{}^u) \quad (2)$$

Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then $S_1 + S_2 = (2+3, 5+4, 7+6) = (5,9,13)$.

Subtraction:
$$S_1 - S_2 = (s_1{}^l - s_2{}^u, s_1{}^d - s_2{}^d, s_1{}^u - s_2{}^l) \quad (3)$$
Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then $S_1 - S_2 = (2 - 6, 5 - 4, 7 - 3) = (-4, 1, 4)$.

Scalar Multiplication:
$$kS = \begin{cases} (ks^l, ks^d, ks^u), & k \geq 0 \\ (ks^u, ks^d, ks^l), & k < 0 \end{cases},$$
$k \in \mathbb{R} \quad (4)$
Suppose $S = (-3, 4, 9)$ and $k = -3$ then $kS = -3(-3, 4, 9) = (-27, -12, \ 9)$.

Multiplication of Two FNs:
$$S_1 \times S_2 = (min\{s_1{}^l \times s_2{}^l, s_1{}^l \times s_2{}^u, s_1{}^u \times s_2{}^l, s_1{}^u \times s_2{}^u\}, s_1{}^d \times s_2{}^d, max\{s_1{}^l \times s_2{}^l, s_1{}^l \times s_2{}^u, s_1{}^u \times s_2{}^l, s_1{}^u \times s_2{}^u\}) \quad (5)$$
Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then
$S_1 \times S_2 = (min\{2 \times 3, 2 \times 6, 7 \times 3, 7 \times 6\}, 5 \times 4, max\{2 \times 3, 2 \times 6, 7 \times 3, 7 \times 6\})$
$= (6, 20, 42)$.

Division:
$$S_1 \div S_2 = (min\{s_1{}^l \div s_2{}^l, s_1{}^l \div s_2{}^u, s_1{}^u \div s_2{}^l, s_1{}^u \div s_2{}^u\}, s_1{}^d \div s_2{}^d, max\{s_1{}^l \div s_2{}^l, s_1{}^l \div s_2{}^u, s_1{}^u \div s_2{}^l, s_1{}^u \div s_2{}^u\})$$
Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then
$S_1 \div S_2 = \left(min\left\{\frac{2}{3}, \frac{2}{6}, \frac{7}{3}, \frac{7}{6}\right\}, \frac{5}{4}, max\left\{\frac{2}{3}, \frac{2}{6}, \frac{7}{3}, \frac{7}{6}\right\}\right) = \left(\frac{1}{3}, \frac{5}{4}, \frac{7}{3}\right)$.

Max and Min:
$$max(S_1, S_2) = \left(max(s_1{}^l, s_2{}^l), max(s_1{}^d, s_2{}^d), max(s_1{}^u, s_2{}^u)\right) \quad (7)$$
Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then
$max(S_1, S_2) = \left(max(2,3), max(5,4), max(7,6)\right) = (3,5,7)$.
$$min(S_1, S_2) = \left(min(s_1{}^l, s_2{}^l), min(s_1{}^d, s_2{}^d), min(s_1{}^u, s_2{}^u)\right) \quad (8)$$
Suppose $S_1 = (2,5,7)$ and $S_2 = (3,4,6)$ then
$min(S_1, S_2) = \left(min(2,3), min(5,4), min(7,6)\right) = (2,4,6)$.

Distance Between Two TFNs:
The distance between S_1 and S_2 is denoted as

Table 1: Fuzzy Evaluation Scale

Linguistic Score	Very Low	Low	Moderate	High	Very High
TFN	(0.0,0.1,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.7,0.9,1.0)

$d(S_1, S_2)$ and given by equation (9).

$$d(S_1, S_2) = \sqrt{\frac{1}{3} \sum_{j \in \{l,d,u\}} (s_1^j - s_2^j)^2} \tag{9}$$

Suppose $S_1 = (-1, 5, 10)$ and $S_2 = (3, 8, 14)$ then

$$d(S_1, S_2) = \sqrt{\frac{1}{3}[(-1-3)^2 + (5-8)^2 + (10-14)^2]} = \sqrt{\frac{41}{3}}$$

Inverse of TFN:

Suppose $S = (s^l, s^d, s^u)$ is TFN then its inverse is denoted as S^{-1} and given by equation (10).

$$S^{-1} = \left(\frac{1}{s^u}, \frac{1}{s^d}, \frac{1}{s^l}\right) \tag{10}$$

Suppose $S = (2, 5, 7)$ then $S^{-1} = \left(\frac{1}{7}, \frac{1}{5}, \frac{1}{2}\right)$.

Fuzzy VIKOR Clustering Model

We develop a fuzzy VIKOR Clustering model (FVCM) composed of two stages:

Stage 4.1: Fuzzy VIKOR Evaluation Model (FVEM)

The FVEM is developed for optimal ranking of the alternatives in a fuzzy environment and consists of the following steps.

    Step 4.1.1*: Identify Evaluation Criteria*. Expert opinions and the literature review are used to identify the evaluation criteria.

    Step 4.1.2*: Establish a Group of Decision-Makers*. Let $A_m, m \in \{1,2,\dots M\}$ be a finite set of M alternatives which are to be evaluated by a group of K decision-makers $DM_k, k \in \{1,2,\dots K\}$ for a set of N evaluation criteria $C_n, n \in \{1,2,\dots N\}$.

    Step 4.1.3*: Establish the Evaluation Scale*. The appropriate fuzzy evaluation scale in terms of TFNs is established as shown in table 1.

    Step 4.1.4*: Construct the Matrix for Performance Rating*. A typical performance rating matrix is expressed in matrix form as $X_k = [x_{mnk}]$, where x_{mnk} is the fuzzy performance rating of alternative A_m with respect to criterion C_n evaluated by *kth* Decision-maker DM_k. $x_{mnk} = (x_{mnk}^l, x_{mnk}^d, x_{mnk}^u)$ is a linguistic variable denoted by TFNs.

Step 4.1.5*: Construct the Matrix for Aggregate Fuzzy Ratings for the Alternatives*. The aggregated fuzzy performance rating matrix is given by $X = [x_{mn}]$. Where $x_{mn} = (x_{mn}^l, x_{mn}^d, x_{mn}^u)$ of each alternative is computed as follows:

$$x_{mn}^l = \frac{1}{K} \sum_{k=1}^K x_{mnk}^l,$$
$$\forall m \in \{1,2,\dots M\}, \forall n \in \{1,2,\dots N\} \tag{11a}$$

$$x_{mn}^d = \frac{1}{K} \sum_{k=1}^K x_{mnk}^d,$$
$$\forall m \in \{1,2,\dots M\}, \forall n \in \{1,2,\dots N\} \tag{11b}$$

$$x_{mn}^u = \frac{1}{K} \sum_{k=1}^K x_{mnk}^u,$$
$$\forall m \in \{1,2,\dots M\}, \forall n \in \{1,2,\dots N\} \tag{11c}$$

Step 4.1.6*: Determine the Fuzzy Weight of the Criteria*. The fuzzy weight for each criterion will be determined based on its importance. We use equation (12a) to give the fuzzy weight of criterion C_n with respect to alternative A_m.

$$w_{mn} = (w_{mn}^l, w_{mn}^d, w_{mn}^u),$$
$$m \in \{1,2,\dots M\}, n \in \{1,2,\dots N\} \tag{12a}$$

We then determine the aggregated fuzzy weights of criterion C_n for all alternatives $A_m, m \in \{1,2,\dots M\}$ by using equation (12b).

$$w_n = \left(\frac{1}{M} \sum_{m=1}^M w_{mn}^l, \frac{1}{M} \sum_{m=1}^M w_{mn}^d, \frac{1}{M} \sum_{m=1}^M w_{mn}^u\right) \tag{12b}$$

Step 4.1.7*: Determine the Fuzzy Best Value (x_n^b) and the Fuzzy Worst Value (x_n^w) of All Criteria*. The fuzzy best value and the fuzzy worst value are determined respectively as

$$x_n^b = \max_{m \in \{1,2,\dots M\}} \{x_{mn}\}, \quad n \in \{1,2,\dots N\} \tag{13a}$$

$$x_n^w = \min_{m \in \{1,2,\dots M\}} \{x_{mn}\}, \quad n \in \{1,2,\dots N\} \tag{13b}$$

Step 4.1.8: *Determine the Normalized Fuzzy Decision Matrix*. The normalized fuzzy decision matrix gives each criterion a value between 0 and 1. We adopt the linear normalization method developed by Opricovic and Tzeng (2004) as given by equations (14a) and (14b).

$$S_m = \sum_{n=1}^{N} w_n \left(\frac{x_n^{\ b} - x_{mn}}{x_n^{\ b} - x_n^{\ w}} \right) \tag{14a}$$

$$R_m = \max_{n \in \{1,2,\dots N\}} \left[w_n \left(\frac{x_n^{\ b} - x_{mn}}{x_n^{\ b} - x_n^{\ w}} \right) \right] \tag{14b}$$

Step 4.1.9: *Determine the VIKOR Index* (Q_m) *For Each Alternative*. The VIKOR index for the alternative is given by equation (15a).

$$Q_m = \alpha \left(\frac{S_m - S^-}{S^+ - S^-} \right) + (1 - \alpha) \left(\frac{R_m - R^-}{R^+ - R^-} \right) \tag{15a}$$

Where

$$S^+ = \max_m \{S_m\}, \qquad m \in \{1,2,\dots M\} \tag{15b}$$

$$S^- = \min_m \{S_m\}, \qquad m \in \{1,2,\dots M\} \tag{15c}$$

$$R^+ = \max_m \{R_m\}, \qquad m \in \{1,2,\dots M\} \tag{15d}$$

$$R^- = \min_m \{R_m\}, \qquad m \in \{1,2,\dots M\} \tag{15e}$$

α is the weight for the strategy of the majority of alternatives i.e. maximum group utility and is mostly taken as $\alpha = 0.5$ by most of the Researchers. We also adopt $\alpha = 0.5$ in this study. Consequently, equation (15a) reduces to equation (15f).

$$Q_m = \frac{1}{2} \left[\left(\frac{S_m - S^-}{S^+ - S^-} \right) + \left(\frac{R_m - R^-}{R^+ - R^-} \right) \right] \tag{15f}$$

Step 4.1.10: *Defuzzify* S_m, R_m *and* Q_m *For Each Alternative*. The fuzzy values are defuzzified by using the Centre of Area (CoA) method i.e. taking the average of the normalized triangular fuzzy numbers as given by equation (16).

$$c_{mn} = \frac{1}{3} \sum_{\forall k} s^k, \qquad k \in \{l, d, u\} \tag{16}$$

Step 4.1.11: *Sort the Values of* S_m, R_m *and* Q_m *in Ascending Order For Each Alternative*. Rank the alternatives by sorting the values of S_m, R_m and Q_m from the smallest value to the largest value. The results are the three ranking lists $\{A\}_S$, $\{A\}_R$ and

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$\{A\}_Q$ according to S_m, R_m and Q_m respectively. A_b is the best alternative provided equations (17a) and (17b) hold.

$$Q_m - Q_b \geq \frac{1}{M-1}, \quad \forall m \in \{1,2,\dots M\} \cap \{b\}' \tag{17a}$$

and

$$S_b > S_m \quad or \quad R_b > R_m, \quad \forall m \in \{1,2,\dots M\} \cap \{b\}' \tag{17b}$$

Step 4.1.12: *Determine a Compromise Solution*. When one of the two conditions i.e. equations (17a) and (17b) is not satisfied, a set of compromise solution is proposed as follows:

Case 1:

A_b is the best alternative provided equations (18a) and (18b) hold.

$$Q_m - Q_b < \frac{1}{M-1}, \quad \forall m \in \{1,2,\dots M\} \cap \{b\}' \tag{18a}$$

and

$$S_b < S_m \quad or \quad R_b < R_m, \quad \forall m \in \{1,2,\dots M\} \cap \{b\}' \tag{18b}$$

Case 2:

If the conditions given by equations (18a) and (18b) don't hold, the two alternatives A_b and $A_m, m \neq b$ can be described as the best alternatives.

Stage 4.2: Fuzzy Clustering Model (FCM)

The FCM is developed to measure the interrelationship between alternatives in a fuzzy environment and consists of the following steps:

Step 4.2.1: *Establish the Variable (i.e. Factor)*. Complexities are very common in influential factors. They influence each other and may occur simultaneously. During analysis, we should treat them systematically. So the study on the complexities of influential factors is very crucial for the improvement of cargo clearance processes. Which factors are positively correlated and how much is the degree of correlation? Fuzzy clustering model is applied to tackle this problem using the data obtained from the survey.

Step 4.2.2: *Establish the Table for Similarity of Variables (i.e. Factors)*. We use Related Coefficient to measure the similarity of qualitative variables i.e.

Table 2: Similarity of Qualitative Variables P and R

	R_1	R_2	...	R_T	$\sum_{\forall j} u_{ij}$
P_1	u_{11}	u_{12}	...	u_{1T}	u_1
P_2	u_{21}	u_{22}	...	u_{2T}	u_2
...	...	...	...	...	...
P_T	u_{T1}	u_{T2}	...	u_{TT}	u_T
$\sum_{\forall i} u_{ij}$	$u_{.1}$	$u_{.2}$	...	$u_{.T}$	u

Service providers. This coefficient describes the linear relationship and/or non-linear relationship of variables. Suppose P is a qualitative variable with possible states in total: $P_1, P_2, ... P_t$; R has the states: $R_1, R_2, ... R_t$.
We can use the following table 2 to describe variable P and R .

Where $u_{ij} = \bar{x}_{it} + \bar{x}_{jt}$, $\bar{x}_{it}$ is the mean fuzzy score of all assessors' scores for alternative (i.e. service provider) $i \in (1,2, ..., M)$ when assessing a pillar of business process $P_t, t \in (1,2, ..., T)$ and $\bar{x}_{jt}$ is the mean fuzzy score of all assessors' scores for alternative (i.e. service provider) $j \in (1,2, ..., M)$ when assessing a pillar of business process $R_t, t \in (1,2, ..., T)$

Let γ be the coefficient that can measure the degree of relationship between variable P and R as given by equations (19a), (19b) and (19c).

$$\gamma = \frac{C-D}{C+D} \tag{19a}$$

$$C = \sum_{i<k} \sum_{j<l} u_{ij} u_{kl} \tag{19b}$$

$$D = \sum_{i<k} \sum_{j>l} u_{ij} u_{kl} \tag{19c}$$

Here $-1 \leq \gamma \leq 1$ and γ is symmetrical to P and R .
As in this study we treat the influential factor as a qualitative variable, the *related coefficient* (γ) is suitable for measuring arbitrarily the similarity of two factors. The larger of the value γ , the higher the correlation of the two factors and the more increase of the possibility of complexities.

Nonetheless, γ is a statistical measure, we need the fuzzy value that is membership μ . We define $\mu = 0$ when $-1 \leq \gamma \leq 0$; it means variable P and R are negatively correlated and the two factors don't influence each other. On the other hand, when $0 < \gamma \leq 1$, we have $\mu = \gamma$.

Step 4.2.3*: Defuzzification of Values for Related Coefficients*. We convert fuzzy values for the related coefficients into crisp numbers (i.e. real numbers). This procedure is carried out in order to locate the best non-fuzzy performance (BNP) value of the *related coefficients*. Numerous defuzzification methods have been presented in the literature. Nonetheless, this study adopts the centre-of-area approach due to its simplicity and does not require analyst's personal judgement (Massami and Myamba, 2016). Using this technique, the best non-fuzzy performance value of the related coefficient γ (BNP_γ) is given by equation (20).

$$BNP_\gamma = \frac{[(U_\gamma - L_\gamma) + (M_\gamma - L_\gamma)]}{3} + L_\gamma , \forall \gamma \tag{20}$$

Application of the Fuzzy VIKOR Clustering Model to Assess the Performance of Service Providers Involved in the Cargo Clearance Formalities at Dar es Salaam Port

Literature review and opinions of Port logistics professionals reveal that several business entities and

institutions are involved in the cargo clearance formalities at Sea Ports. The prominent service providers are Terminal and ICD Operators, Customs Authority, Shipping Agents, Freight Clearing and Forwarding Companies, and Other Government Departments. We briefly describe the role of each of these Service providers in the cargo clearance formalities at Sea Port.

Terminal and ICD Operators (A₁): Are firms that are responsible for moving cargo through a Port terminal i.e. creating terminal throughput. The terminal operator may be a Ports Authority that operates a government-owned Port or a private firm that contracts with the Ports Authority to carry out the daily operations of the government owned Port. Specifically, a Terminal operator handles consignments at Port, Stores consignments whenever possible at Port i.e. keeps consignments waiting for shipment at the Port of loading, clearance in Port or delivery at the Port of discharge, and confirms all agencies' release orders and issue a Gate Pass.

Customs Authority (A₂): The government agency responsible for the provision of procedures intended to provide definite, predictable methods by which the goods can enter and/or leave the country and get cleared on payment of applicable duties subject to fulfilling the Customs law of the country. Cargo exported from a country or imported into another country must be subjected to Customs control. Shipping documents should be processed through the Customs Authority, and physical-checks of the goods are sometimes conducted to assess the conformity of the cargo as described on the supplied documents. Customs also keep statistics by destination/origin and on the types, quantities and values of goods on the export market/local market.

Shipping Agents (A₃): Are shipping company's representatives working in shipping company's name and for its account. More specifically, shipping agents process and file Manifest with Customs and Ports Authority, issue delivery orders to the consignee, prepare and submit a discharge list to the Terminal operators, and prepare a shipping order for the shipper.

Freight Clearing and Forwarding Companies (A₄): Are experts in international trade who act on behalf of Importers and/or Exporters in international trade formalities. They carry out the necessary arrangements for the shipment of the goods. They monitor shipping from the moment goods become available from the exporter until goods are delivered to the importer. They register consignments with carriers, call them forward for delivery to the wharf and berth of the carrying vessel, prepare [Bill of Lading] B/L, lodge and retrieve from the carriers' agents, pay for the freight and related expenses, prepare or obtain any other document that may be required, and finally, distribute documentation in accordance with instructions from their principals (UNDP, 2008).

Specifically, they prepare all necessary documentation (Bill of Lading, Commercial Invoice, Assessed Pre-Arrival Declaration, Packing List, Certificate of Origin etc.) and send copies to all parties involved in the cargo clearance processes.

Other Government Departments (A₅): There are other Government Agencies and institutions involved in the facilitation of cargo clearance operations at Dar es Salaam Port.

- Ministry of Agriculture, Food Security and Co-operatives: Issues Veterinary health certificate, Export permit for animal feed, Import release permit for plant and plant products, Import release permit for list of registered pesticides.
- The Government Chemist Laboratory Agency (GCLA): The GCLA as a regulator of Industrial and Consumer Chemicals issues Import release permit, Transport permit, and Export permit.
- The Tanzania Medicines and Medical Devices Authority (TMDA): The TMDA is a government agency responsible for controlling the quality, safety and effectiveness of medicines, diagnostics and medical devices. It issues Import permit, Export permit, Import release permit, Health certificate i.e. Fumigation certificate.
- Ministry of Livestock and Fisheries Development (MoLFD): The MoLFD has the mandate of overall management and sustainable development of Livestock and Fisheries resources. It issues an Export permit, Pre-import permit for live animals and animal products, Import release permit for live animals and animal products, Veterinary health certificate for cattle, sheep and goat, meat and meat product, hides and animal skins.
- The Ministry of Natural Resources and Tourism (MNRT): The MNRT is mandated to protect, manage natural and cultural resources and develop tourism. It issues Import permit, Export permit, Timber grading certificate, Inspection certificate, Phytosanitary certificate, and Certificate of origin.
- Tanzania Bureau of Standards (TBS): According to the Standards Act No. 2 of 2009, TBS is mandated to undertake measures for quality control of products of all descriptions and promote standardization in industry and commerce. The TBS issues Batch Certificate B i.e. Conditional import release permit, Regular importer letter, Batch Certificate A i.e. Import release permit.
- Tanzania Atomic Energy Commission (TAEC): The TAEC was established by the Atomic Energy Act No. 7 of 2003 to provide regulatory service in the use of nuclear technology in the country. It issues Radioactivity analysis certificate for Pre-import permit, Import release permit, Export

Table 3: Aggregated fuzzy decision matrix regarding the use of modern technology

A_m	C_1	C_2	C_3	C_4	C_5
A_1	(0.000,0.010,0.030)	(0.035,0.105,0.175)	(0.015,0.025,0.035)	(0.175,0.245,0.315)	(0.105,0.135,0.150)
A_2	(0.000,0.005,0.015)	(0.020,0.060,0.100)	(0.090,0.150,0.210)	(0.175,0.245,0.315)	(0.070,0.090,0.100)
A_3	(0.000,0.005,0.015)	(0.015,0.045,0.075)	(0.150,0.250,0.350)	(0.125,0.175,0.225)	(0.035,0.045,0.050)
A_4	(0.000,0.010,0.030)	(0.005,0.015,0.025)	(0.120,0.200,0.280)	(0.125,0.175,0.225)	(0.140,0.180,0.200)
A_5	(0.000,0.015,0.045)	(0.010,0.030,0.050)	(0.075,0.125,0.175)	(0.125,0.175,0.225)	(0.175,0.225,0.250)

Table 4: Fuzzy weight, fuzzy best value and fuzzy worst value of the criteria with regard to the use of modern technology

	C_1	C_2	C_3	C_4	C_5
w_n	(0.000,0.009,0.027)	(0.017,0.051,0.085)	(0.090,0.150,0.210)	(0.145,0.203,0.261)	(0.105,0.135,0.150)
x_n^b	(0.000,0.015,0.045)	(0.035,0.105,0.175)	(0.150,0.250,0.350)	(0.175,0.245,0.315)	(0.175,0.225,0.250)
x_n^w	(0.000,0.005,0.015)	(0.005,0.015,0.025)	(0.015,0.025,0.035)	(0.125,0.175,0.225)	(0.035,0.045,0.050)

Table 5: Utility measure, regret measure, VIKOR index and corresponding ranks with regard to the use of modern technology

A_m	S_m	R_m	Q_m	RK_{S_m}	RK_{R_m}	RK_{Q_m}
A_1	0.341	0.457	0.064	2	1	2
A_2	0.511	0.485	−0.078	5	2	1
A_3	0.312	0.541	0.281	1	4	5
A_4	0.433	0.550	0.207	3	5	3
A_5	0.443	0.520	0.221	4	3	4

release permit, and Transport license with regard to the physical distribution of the nuclear materials.

Any inefficient operation by one of these entities leads to the inefficiency of the overall cargo clearance formalities at a Sea Port. Thus, the improvement of the cargo clearance formalities at Dar es Salaam Port necessitates the assessment of the performance of each of these service providers.
This Study uses data from twenty (20) respondents who were supplied with a survey questionnaire. The team comprises service providers involved in the cargo clearance processes at Dar es Salaam Port. A respondent assesses each alternative concerning a given criterion to give values used to construct the Matrix for Performance Ratings.

Assessment of the Performance of Service Providers on the Use of Modern Technology in Cargo Clearance Operations at Dar es Salaam Port

We use the matrix for performance rating regarding the

use of modern technology as given in step 4.1.4 and equations (11a), (11b), and (11c) to form the matrix for aggregate fuzzy ratings for the service providers as represented in table 3.
Where C_k, $k \in \{1,2,\dots 5\}$ stands for respectively Very low, Low, Moderate, High and Very high.
We apply step 4.1.6 and step 4.1.7 to give fuzzy weight of the criteria (w_n), fuzzy best value (x_n^b), and fuzzy worst value (x_n^w) as shown in table 4.
We apply step 4.1.8, step 4.1.9, step 4.1.10 and step 4.1.11 to get defuzzified utility measure (S_m), regret measure (R_m), and VIKOR index (Q_m) for alternative A_m as shown in table 5. The same table shows the ranking of alternative A_m with respect to utility measure, regret measure and VIKOR index.
Using table 5 and step 4.1.12 where M=5, we deduce the set of the Port service providers in decreasing order of performance for modern technology as P_MT={A₂ and A₃; A₁; A₄; A₅} i.e. P_MT={Customs Authority and Shipping Agents; Terminal and ICD Operators; Freight Clearing and Forwarding Companies; Other Government Departments}. Thus, $A_2, A_3 > A_1 > A_4 > A_5$ implies that Customs Authority

Table 6: Aggregated fuzzy decision matrix regarding the use of competent and qualified staff

A_m	C_1	C_2	C_3	C_4	C_5
A_1	(0.000,0.010,0.030)	(0.020,0.060,0.100)	(0.060,0.100,0.140)	(0.175,0.245,0.315)	(0.105,0.135,0.150)
A_2	(0.000,0.005,0.015)	(0.025,0.075,0.125)	(0.090,0.150,0.210)	(0.150,0.210,0.270)	(0.070,0.090,0.100)
A_3	(0.000,0.015,0.045)	(0.015,0.045,0.075)	(0.060,0.100,0.140)	(0.225,0.315,0.405)	(0.035,0.045,0.050)
A_4	(0.000,0.015,0.045)	(0.010,0.030,0.050)	(0.075,0.125,0.175)	(0.200,0.280,0.360)	(0.070,0.090,0.100)
A_5	(0.000,0.015,0.045)	(0.005,0.015,0.025)	(0.135,0.225,0.315)	(0.100,0.140,0.180)	(0.105,0.135,0.150)

Table 7: Fuzzy weight, fuzzy best value and fuzzy worst value of the criteria with regard to the use of competent and qualified staff

	C_1	C_2	C_3	C_4	C_5
w_n	(0.000,0.012,0.036)	(0.015,0.045,0.075)	(0.084,0.140,0.196)	(0.170,0.238,0.306)	(0.077,0.099,0.110)
$x_n{}^b$	(0.000,0.015,0.045)	(0.025,0.075,0.125)	(0.135,0.225,0.315)	(0.225,0.315,0.405)	(0.105,0.135,0.150)
$x_n{}^w$	(0.000,0.005,0.015)	(0.005,0.015,0.025)	(0.060,0.100,0.140)	(0.100,0.140,0.180)	(0.035,0.045,0.050)

Table 8: Utility measure, regret measure, VIKOR index and corresponding ranks with regard to the use of Competent and qualified staff

A_m	S_m	R_m	Q_m	RK_{S_m}	RK_{R_m}	RK_{Q_m}
A_1	−2.871	0.552	0.007	2	2	4
A_2	−1.357	1.029	−0.135	4	4	2
A_3	−3.078	0.467	0.092	1	1	5
A_4	−2.300	0.561	−0.099	3	3	3
A_5	0.819	2.440	−0.733	5	5	1

and Shipping Agents are the best service providers concerning cargo clearance formalities whereas Other Government Departments are the least performing service providers.

Assessment of the Performance of Service Providers on the Use of Competent and Qualified Staff in Cargo Clearance Operations at Dar es Salaam Port

We use the matrix for performance rating regarding the use of competent and qualified staff as given in step 4.1.4 and equations (11a), (11b), and (11c) to form the matrix for aggregate fuzzy ratings for the service providers as represented in table 6.
Where C_k, $k \in \{1,2,\dots 5\}$ stands for respectively Very low, Low, Moderate, High and Very high.
We apply step 4.1.6 and step 4.1.7 to give fuzzy weight (w_n), fuzzy best value $(x_n{}^b)$, and fuzzy worst value $(x_n{}^w)$ of the criteria as shown in table 7.
We apply step 4.1.8, step 4.1.9, step 4.1.10 and step 4.1.11 to get defuzzified utility measure (S_m), regret measure (R_m), and VIKOR index (Q_m) for alternative

A_m as shown in table 8. The same table shows the ranking of alternative A_m with respect to utility measure, regret measure and VIKOR index.
Using table 8 and step 4.1.12 where M=5, we deduce the set of the Port service providers in decreasing order of performance with respect to competent and qualified staff as P_{CCS}={A5; A1, A2, A3; A4} i.e. P_{CCS}={Other Government Departments; Terminal & ICD Operators, Customs Authority, Shipping Agents; Freight Clearing & Forwarding Companies}. Thus, $A_5 > A_1, A_2, A_3 > A_4$ which means Other Government Departments are the best user of competent and qualified staff with regard to cargo clearance formalities. On the other hand, Freight Clearing & Forwarding Companies are the least user of competent and qualified staff with regard to cargo clearance formalities.

Assessment of the Performance of Service Providers on the Use of Effective Business Processes in Cargo Clearance Operations at Dar es Salaam Port

We use the matrix for performance rating regarding the

Table 9: Aggregated fuzzy decision matrix regarding the use of effective business processes

A_m	C_1	C_2	C_3	C_4	C_5
A_1	(0.000,0.010,0.030)	(0.015,0.045,0.075)	(0.090,0.150,0.210)	(0.150,0.210,0.270)	(0.105,0.135,0.150)
A_2	(0.000,0.020,0.060)	(0.005,0.015,0.025)	(0.105,0.175,0.245)	(0.175,0.245,0.315)	(0.035,0.045,0.050)
A_3	(0.000,0.010,0.030)	(0.015,0.045,0.075)	(0.090,0.150,0.210)	(0.225,0.315,0.405)	(0.000,0.000,0.000)
A_4	(0.000,0.010,0.030)	(0.005,0.015,0.025)	(0.135,0.225,0.315)	(0.175,0.245,0.315)	(0.035,0.045,0.050)
A_5	(0.000,0.010,0.030)	(0.005,0.015,0.025)	(0.075,0.125,0.175)	(0.200,0.280,0.360)	(0.140,0.180,0.200)

Table 10: Fuzzy weight, fuzzy best value and fuzzy worst value of the criteria concerning the effective use of business processes

	C_1	C_2	C_3	C_4	C_5
w_n	(0.000,0.012,0.036)	(0.009,0.027,0.045)	(0.099,0.165,0.231)	(0.185,0.259,0.333)	(0.063,0.081,0.090)
x_n^b	(0.000,0.020,0.060)	(0.015,0.045,0.075)	(0.135,0.225,0.315)	(0.225,0.315,0.405)	(0.140,0.180,0.200)
x_n^w	(0.000,0.010,0.030)	(0.005,0.015,0.025)	(0.075,0.125,0.175)	(0.150,0.210,0.270)	(0.000,0.000,0.000)

Table 11: Utility measure, regret measure, VIKOR index and corresponding ranks with regard to the effective use of business processes

A_m	S_m	R_m	Q_m	RK_{S_m}	RK_{R_m}	RK_{Q_m}
A_1	−0.662	0.229	0.319	1	1	5
A_2	−0.469	0.289	0.012	3	2	4
A_3	−0.171	0.500	−0.489	5	5	1
A_4	−0.312	0.414	−0.230	4	4	2
A_5	−0.563	0.375	−0.147	2	3	3

use of effective business processes as given in step 4.1.4 and equations (11a), (11b), and (11c) to form the matrix for aggregate fuzzy ratings for the service providers as represented in table 9.

Where C_k, $k \in \{1,2,\ldots 5\}$ stands for respectively Very low, Low, Moderate, High and Very high. We apply step 4.1.6 and step 4.1.7 to give fuzzy weight (w_n), fuzzy best value (x_n^b), and fuzzy worst value (x_n^w) of the criteria as shown in table 10.

We apply step 4.1.8, step 4.1.9, step 4.1.10 and step 4.1.11 to get defuzzified utility measure (S_m), regret measure (R_m), and VIKOR index (Q_m) for alternative A_m as shown in table 11. The same table shows the ranking of alternative A_m with respect to utility measure, regret measure and VIKOR index.

Using table 11 and step 4.1.12 where M=5, we deduce the set of the Port service providers in decreasing order of performance with respect to effective business processes as $P_{EBP}=\{A_3; A_1, A_2, A_4; A_5\}$ i.e. $P_{EBP}=\{$Shipping Agents; Terminal & ICD Operators, Customs Authority, Freight Clearing & Forwarding Companies; Other Government Departments$\}$. Thus, $A_3 > A_1, A_2, A_4 > A_5$ implies that Shipping Agents are the best service providers on effective business processes with regard to cargo clearance formalities followed by Terminal & ICD operators, Customs Authority, and Freight Clearing & Forwarding Companies. On the other hand, Other Government Departments are the least performing service providers with regard to effective business processes.

Overall Assessment of the Performance of Service Providers on the Use of Pillars of Business Process Management (BPM) in Cargo Clearance Operations at Dar es Salaam Port

For the BPM, the overall fuzzy assessment score for alternative *m* with regard to a particular pillar of BPM is the average score of all assessors' fuzzy scores for the

Table 12: Aggregated fuzzy decision matrix regarding the use of pillars of business process management

Service Provider (A_m)	Modern Technology (MT)	Competent and Qualified Staff (CQS)	Effective Business Processes (EBP)
A_1	(0.330,0.520,0.705)	(0.360,0.550,0.735)	(0.360,0.550,0.735)
A_2	(0.355,0.550,0.740)	(0.335,0.530,0.720)	(0.320,0.500,0.695)
A_3	(0.325,0.520,0.715)	(0.335,0.520,0.715)	(0.310,0.500,0.700)
A_4	(0.390,0.580,0.760)	(0.355,0.540,0.730)	(0.350,0.540,0.735)
A_5	(0.385,0.570,0.745)	(0.310,0.490,0.680)	(0.420,0.610,0.790)

Table 13: Fuzzy weight, fuzzy best value and fuzzy worst value of the criteria with regard to the use of business process management

	$MT(C_1)$	$CQS(C_2)$	$EBP(C_3)$
w_n	(0.357,0.548,0.733)	(0.339,0.526,0.716)	(0.352,0.540,0.731)
$x_n{}^b$	(0.390,0.580,0.760)	(0.360,0.550,0.735)	(0.420,0.610,0.790)
$x_n{}^w$	(0.325,0.520,0.705)	(0.310,0.490,0.680)	(0.310,0.500,0.695)

Table 14: Utility measure, regret measure, VIKOR index and corresponding ranks with regard to the use of business process management

A_m	S_m	R_m	Q_m	RK_{S_m}	RK_{R_m}	RK_{Q_m}
A_1	0.089	0.183	0.221	3	4	3
A_2	0.084	0.153	0.254	2	3	4
A_3	0.154	0.149	0.333	5	2	5
A_4	0.025	0.118	−0.029	1	1	1
A_5	0.112	0.212	0.141	4	5	2

alternative m as given by equation (21).

$$Mean\ Fuzzy\ Score = \frac{1}{K}\sum_{k=1}^{K} V_{mk}, \qquad m \in \{1,2,\dots M\} \qquad (21)$$

V_{mk} is the fuzzy score assessed by assessor k for alternative m and K is the total number of assessors.

We use the matrix for performance rating regarding the use of pillars of business process management as given in step 4.1.4 and equations (11a), (11b), (11c) and (21) to form the matrix for aggregate fuzzy ratings for the service providers as represented in Table 12.

We apply step 4.1.6 and step 4.1.7 to give fuzzy weight (w_n), fuzzy best value $(x_n{}^b)$, and fuzzy worst value $(x_n{}^w)$ of the criteria as shown in table 13.

We apply step 4.1.8, step 4.1.9, step 4.1.10 and step 4.1.11 to get defuzzified utility measure (S_m), regret measure (R_m), and VIKOR index (Q_m) for alternative A_m as shown in table 14. The same table shows the ranking of alternative A_m with respect to utility measure, regret measure and VIKOR index.

Using table 14 and step 4.1.12 where M=5, we deduce the set of the Port service providers in decreasing order of performance with respect to business process management as P_{MT}={A$_2$, A$_4$, A$_5$; A$_1$; A$_3$} i.e. P_{MT}={Customs Authority, Freight Clearing & Forwarding Companies, Other Government Departments; Terminal & ICD operators; Shipping Agents}. Thus, $A_2, A_4, A_5 > A_1 > A_3$ which means Customs Authority, Freight Clearing & Forwarding Companies and Other Government Departments are the best service providers on overall business process management with regard to cargo clearance formalities. On the other hand, Shipping Agents are the least performing service providers when considering the business process management of the Port community.

Table 15: Similarity between Terminal & ICD operators and Customs authority

	MT_2	CQS_2	EBP_2	$\sum_{\forall j} u_{ij}$
MT_1	(0.685,1.070,1.445)	(0.665,1.050,1.425)	(0.650,1.020,1.400)	(2.000,3.140,4.270)
CQS_1	(0.715,1.100,1.475)	(0.695,1.080,1.455)	(0.680,1.050,1.430)	(2.090,3.230,4.360)
EBP_1	(0.715,1.100,1.475)	(0.695,1.080,1.455)	(0.680,1.050,1.430)	(2.090,3.230,4.360)
$\sum_{\forall i} u_{ij}$	(2.115,3.270,4.395)	(2.055,3.210,4.335)	(2.010,3.120,4.260)	

Table 16: Similarity between Terminal & ICD operators and Shipping agents

	MT_3	CQS_3	EBP_3	$\sum_{\forall j} u_{ij}$
MT_1	(0.655,1.040,1.420)	(0.665,1.040,1.420)	(0.640,1.020,1.405)	(1.960,3.100,4.245)
CQS_1	(0.685,1.070,1.450)	(0.695,1.070,1.450)	(0.670,1.050,1.435)	(2.050,3.190,4.335)
EBP_1	(0.685,1.070,1.450)	(0.695,1.070,1.450)	(0.670,1.050,1.435)	(2.050,3.190,4.335)
$\sum_{\forall i} u_{ij}$	(2.025,3.180,4.320)	(2.055,3.180,4.320)	(1.980,3.120,4.275)	

The Similarity Between Service Providers in Cargo Clearance Operations at Dar es Salaam Port

Each service provider A_m, $m \in \{1,2,\dots 5\}$ is assessed with respect to three pillars of business processes i.e. $\{MT_m, CQS_m, EBP_m\}$, $m \in \{1,2,\dots 5\}$, so a table of 3×3 is used to describe the relationship of any two service providers. MT_m is a pillar of BPM termed as *modern technology* and is considered when assessing the service provider A_m; CQS_m is a pillar of BPM termed as *competent and qualified staff* and is considered when assessing the service provider A_m; EBP_m is a pillar of BPM termed as *effective business process* and is considered when assessing the service provider A_m.

The Similarity between Terminal and ICD Operators (A₁) and Customs Authority (A₂)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A₁ and A₂ as shown in table 15. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.704, 0.000, 1.705)$ and $BNP_\gamma = 0.000$ respectively. This implies that Terminal and ICD operations are carried independently of Customs formalities. Thus, each of these cargo supply chain members has the obligation of enhancing its operation which in turns contributes to the optimal cargo clearance formalities at the Port.

The Similarity between Terminal & ICD Operators (A₁) and Shipping Agents (A₃)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A₁ and A₃ as shown in table 16.

Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.746, 0.000, 1.747)$ and $BNP_\gamma = 0.000$ respectively. The zero correlation reveals the

Table 17: Similarity between Terminal & ICD operators and Freight clearing & forwarding companies

	MT_4	CQS_4	EBP_4	$\sum_{\forall j} u_{ij}$
MT_1	(0.720,1.100,1.465)	(0.685,1.060,1.435)	(0.680,1.060,1.440)	(2.085,3.220,4.340)
CQS_1	(0.750,1.130,1.495)	(0.715,1.090,1.465)	(0.710,1.090,1.470)	(2.175,3.310,4.430)
EBP_1	(0.750,1.130,1.495)	(0.715,1.090,1.465)	(0.710,1.090,1.470)	(2.175,3.310,4.430)
$\sum_{\forall i} u_{ij}$	(2.220,3.360,4.455)	(2.115,3.240,4.365)	(2.100,3.240,4.380)	

Table 18: Similarity between Terminal & ICD operators and other government departments

	MT_5	CQS_5	EBP_5	$\sum_{\forall j} u_{ij}$
MT_1	(0.715,1.090,1.450)	(0.640,1.010,1.385)	(0.750,1.130,1.495)	(2.105,3.230,4.330)
CQS_1	(0.745,1.120,1.480)	(0.670,1.040,1.415)	(0.780,1.160,1.525)	(2.195,3.320,4.420)
EBP_1	(0.745,1.120,1.480)	(0.670,1.040,1.415)	(0.780,1.160,1.525)	(2.195,3.320,4.420)
$\sum_{\forall i} u_{ij}$	(2.205,3.330,4.410)	(1.980,3.090,4.215)	(2.310,3.450,4.545)	

independence of operations between Shipping Agents and Terminal & ICD Operators in the cargo clearance formalities. This calls for the Shipping Agents and Terminal & ICD Operators to integrate their operations in order to improve the Tanzanian maritime supply chains.

The Similarity between Terminal & ICD Operators (A_1) and Freight Clearing & Forwarding Companies (A_4)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A_1 and A_4 as shown in table 17. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.603, 0.000, 1.603)$ and $BNP_\gamma = 0.000$ respectively. These values reveal disintegration of operations between Terminal & ICD Operators and Freight Clearing and Forwarding Companies. Thus, the findings necessitate the need of coordination in the

operations of all members of the Port Community at Dar es Salaam Sea Port.

The Similarity between Terminal & ICD Operators (A_1) and Other Government Departments (A_5)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Method (FCM), we determine the interrelationship between A_1 and A_5 as shown in table 18. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.603, 0.000, 1.603)$ and $BNP_\gamma = 0.000$ respectively. The zero correlation between variables, Terminal & ICD Operators and OGDs indicates the existence of the non-harmonious operations between Terminal & ICD facilities and OGDs. These stakeholders are called to take actions that would improve the effectiveness and efficiency in operations of cargo clearance formalities.

Table 19: Similarity between Customs authority and Shipping agents

	MT_3	CQS_3	EBP_3	$\sum_{\forall j} u_{ij}$
MT_2	(0.680,1.070,1.455)	(0.690,1.070,1.455)	(0.665,1.050,1.440)	(2.035,3.190,4.350)
CQS_2	(0.660,1.050,1.435)	(0.670,1.050,1.435)	(0.645,1.030,1.420)	(1.975,3.130,4.290)
EBP_2	(0.645,1.020,1.410)	(0.655,1.020,1.410)	(0.630,1.000,1.395)	(1.930,3.040,4.215)
$\sum_{\forall i} u_{ij}$	(1.985,3.140,4.300)	(2.015,3.140,4.300)	(1.940,3.080,4.255)	

Table 20: Similarity between the Customs authority and Freight clearing & forwarding companies

	MT_4	CQS_4	EBP_4	$\sum_{\forall j} u_{ij}$
MT_2	(0.745,1.130,1.500)	(0.710,1.090,1.470)	(0.705,1.090,1.475)	(2.160,3.310,4.445)
CQS_2	(0.725,1.110,1.480)	(0.690,1.070,1.450)	(0.685,1.070,1.455)	(2.100,3.250,4.385)
EBP_2	(0.710,1.080,1.455)	(0.675,1.040,1.425)	(0.670,1.040,1.430)	(2.055,3.160,4.310)
$\sum_{\forall i} u_{ij}$	(2.180,3.320,4.435)	(2.075,3.200,4.345)	(2.060,3.200,4.360)	

The Similarity between Customs Authority (A$_2$) and Shipping Agents (A$_3$)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A_2 and A_3 as shown in table 19. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.830, 0.000, 1.830)$ and $BNP_\gamma = 0.000$ respectively. The stakeholders have the opinion that the operations of Customs Authority and Shipping Agents are disintegrated. Thus, each of these cargo supply chain members has the duty of enhancing its operation which in turns contributes to the optimal cargo clearance formalities at the Dar es Salaam Port.

The Similarity between Customs Authority (A$_2$) and Freight Clearing & Forwarding Companies (A$_4$)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A_2 and A_4 as shown in table 20. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.677, 0.000, 1.676)$ and $BNP_\gamma = 0.000$ respectively. The zero correlation depicts the non-coordination of operations between Customs Authority and Freight Clearing and Forwarding Companies. Thus, each of these cargo supply chain members has the obligation of enhancing its operation which in turns contributes to the optimal cargo clearance formalities at the Port.

The Similarity between Customs Authority (A$_2$) and Other Government Departments (A$_5$)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A_2 and A_5 as shown in table 21. Applying equations (19a), (19b), (19c) and (20) we get

Table 21: Similarity between Customs authority and other government departments

	MT_5	CQS_5	EBP_5	$\sum_{\forall j} u_{ij}$
MT_2	(0.740,1.120,1.485)	(0.665,1.040,1.420)	(0.775,1.160,1.530)	(2.180,3.320,4.435)
CQS_2	(0.720,1.100,1.465)	(0.645,1.020,1.400)	(0.755,1.140,1.510)	(2.120,3.260,4.375)
EBP_2	(0.705,1.070,1.440)	(0.630,0.990,1.375)	(0.740,1.110,1.485)	(2.075,3.170,4.300)
$\sum_{\forall i} u_{ij}$	(2.165,3.290,4.390)	(1.940,3.050,4.195)	(2.270,3.410,4.525)	

Table 22: Similarity between Shipping agents and Freight clearing & forwarding companies

	MT_4	CQS_4	EBP_4	$\sum_{\forall j} u_{ij}$
MT_3	(0.715,1.100,1.475)	(0.680,1.060,1.445)	(0.675,1.060,1.450)	(2.070,3.220,4.370)
CQS_3	(0.725,1.100,1.475)	(0.690,1.060,1.445)	(0.685,1.060,1.450)	(2.100,3.220,4.370)
EBP_3	(0.700,1.080,1.460)	(0.665,1.040,1.430)	(0.660,1.040,1.435)	(2.025,3.160,4.325)
$\sum_{\forall i} u_{ij}$	(2.140,3.280,4.410)	(2.035,3.160,4.320)	(2.020,3.160,4.335)	

the related coefficients in fuzzy and crisp terms as $\gamma = (-1.676, 0.000, 1.677)$ and $BNP_\gamma = 0.000$ respectively. These values reveal that the operations of Customs authority and other government departments are not integrated. This calls for these cargo supply chain members to render more effective and efficient business operations which in turn contributes to the optimal cargo clearance formalities at the Dar es Salaam Port.

The Similarity between Shipping Agents (A₃) and Freight Clearing & Forwarding Companies (A₄)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A₃ and A₄ as shown in table 22. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.717, 0.000, 1.716)$ and $BNP_\gamma = 0.000$ respectively. These findings show that the operations of Shipping Agents and Freight Clearing and Forwarding Companies

are not connected which in turn leads to the inefficiency of cargo clearance operations at Dar es Salaam Port. Thus, Shipping Agents and Freight Clearing and Forwarding Companies are called to improve the management of their business processes.

The Similarity between Shipping Agents (A₃) and Other Government Departments (A₅)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A₃ and A₅ as shown in table 23. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.719, 0.000, 1.720)$ and $BNP_\gamma = 0.000$ respectively. These values reveal the limitation in the coordination of operations between Shipping Agents and OGDs. Thus, each of these cargo supply chain members has the obligation of enhancing its operation which in turns contributes to the optimal cargo clearance

Table 23: Similarity between Shipping agents and other government departments

	MT_5	CQS_5	EBP_5	$\sum_{\forall j} u_{ij}$
MT_3	(0.710,1.090,1.460)	(0.635,1.010,1.395)	(0.745,1.130,1.505)	(2.090,3.230,4.360)
CQS_3	(0.720,1.090,1.460)	(0.645,1.010,1.395)	(0.755,1.130,1.505)	(2.120,3.230,4.360)
EBP_3	(0.695,1.070,1.445)	(0.620,0.990,1.380)	(0.730,1.110,1.490)	(2.045,3.170,4.315)
$\sum_{\forall i} u_{ij}$	(2.125,3.250,4.365)	(1.900,3.010,4.170)	(2.230,3.370,4.500)	

Table 24: Similarity between Freight clearing & forwarding companies and other government departments

	MT_5	CQS_5	EBP_5	$\sum_{\forall j} u_{ij}$
MT_4	(0.775,1.150,1.505)	(0.700,1.070,1.440)	(0.810,1.190,1.550)	(2.285,3.410,4.495)
CQS_4	(0.740,1.110,1.475)	(0.665,1.030,1.410)	(0.775,1.150,1.520)	(2.180,3.290,4.405)
EBP_4	(0.735,1.110,1.480)	(0.660,1.030,1.415)	(0.770,1.150,1.525)	(2.165,3.290,4.420)
$\sum_{\forall i} u_{ij}$	(2.250,3.370,4.460)	(2.025,3.130,4.265)	(2.355,3.490,4.595)	

formalities at the Dar es Salaam Port.

formalities.

The Similarity between Freight Clearing & Forwarding Companies (A₄) and Other Government Departments (A₅)

Using the values of table 12 and step 4.2.2 of Fuzzy Clustering Model (FCM), we determine the interrelationship between A_4 and A_5 as shown in table 24. Applying equations (19a), (19b), (19c) and (20) we get the related coefficients in fuzzy and crisp terms as $\gamma = (-1.577,0.000,1.577)$ and $BNP_\gamma = 0.000$ respectively. The zero correlation between the operations of Freight Clearing and Forwarding Companies and Other government departments is an indication of the absence of integration of operations on cargo clearance formalities. Thus, each of these cargo supply chain members has the obligation of enhancing its operation which in turns contributes to the optimal cargo clearance

Proposed Measures to Enhance the Efficiency and Quality of Cargo Clearance Services at Dar es Salaam Port

Efficiency in cargo clearance operations is a major commercial instrument used to attract cargo and generate revenues for a Seaport. Besides, Raballand *et al.* (2012) demonstrate that reducing dwell time from a week to four days more than doubles the capacity of the container terminal without any investments in physical extensions. If the dwell time is not reduced, local tax payers will continue to pay twice i.e. pay more than necessary as Port facilities and infrastructure are capital intensive public investments and inefficiencies and rents in the Port are fully reflected in the landed cost of goods and services borne by consumers. More specifically, without rapid import and/or export processes, the

sustainable industrialized economy in Tanzania is impossible, as delays and unpredictability of cargo clearance will increase inventories and prevent integration in the global supply networks. Therefore, all members of the Dar es Salaam Port Community are called to take corrective actions which in turn would increase the speed of cargo clearance operations. This could be easily achieved by implementing the following measures.

a) **Introduction of an integrated Port Management Information System (PMIS)**. The PMIS i.e. Online National Single Window System is a Platform that allows the smart exchange of information between Public and Private Port service providers and customs administrations of trade partners, by creating efficient processes, reducing procedure time and minimizing the use of paper documents. Also, the PMIS reduce the opportunity for corrupt practices among Port service providers and integrate compliance with national and EAC Directives. The PMIS should be used to process all customs documentation including documents pertaining to other government certificates such as Sanitary and Phytosanitary Standards. The PMIS allows the agencies to access only that information which they have the authority to see i.e. Agencies can access only that information about their transactions. It should be noted that building one system is less costly than agencies developing and maintaining their own systems that require agencies to interface with this variety of systems.

b) **Ensure effective Business Process Management (BPM)**. The BPM has attracted many business Managers because of its proven ability to deliver improvements in firm performance, regulatory compliance and service quality. BPM is about managing entire chains of events, activities and decisions that ultimately add value to the organization and its customers Dumas *et al.* (2013). All the parties involved in the cargo clearance processes should ensure effective BPM for timely clearance and delivery of goods and services. In particular, the agency requires sufficient competent and qualified staff supported by effective business processes and, modern and advanced technology for optimal cargo clearance operations.

More specifically, we believe that optimal cargo clearance operations can be achieved provided all interested parties adhere to the following policy recommendations.

- **Fulfillment of the objective of providing One-Stop Services**. All stakeholders involved in the customs clearance process should have offices at the One-Stop Centre (OSC) established by the Tanzania Ports Authority (TPA) to facilitate the processing of cargo clearance and documentation.

- **Improvement of revamped Green channel customs clearance scheme**. The World Customs Organization (WCO) Revised Kyoto Convention is recognized as an international standard, and used as a benchmark, for the global customs community. It provides among other directives for the use of Risk Management System (RMS) for selective screening of high risk cargo while expediting clearance of low risk cargo. The effective implementation of the RMS would replace the system of checking samples out of each consignment by checking a few sample consignments i.e. allowing the bulk of consignments (say 90%) to move out without physical verification.

- **Introduction of fast track clearance of imported cargo**. Faster delivery of cargo from Ports should be provided for accredited importers. There should be a separate area in the Port premises clearly earmarked for immediate delivery of cargo to specified accredited importers. Such an arrangement would enable accredited importers to move out their containers without going through a Container Freight Station (CFS).

- **Simplified import general manifest filing and amendment procedure**. Timely filing of Import General Manifest (IGM) at the first stage is essential to enable the importers to file customs clearance document (Bill of Entry) for clearance of goods.

- **Simplified customs procedure for transshipment permission between gateway port and hinterland ports – ICD/CFS**. A simplified sub-manifest transshipment procedure in an automated format should be adopted in cases where the Port of discharge is indicated as hinterland ICD/CFS.

- **Message exchange on EDI environment among Port community members.** There should be an exchange of message on the EDI environment among Port community members.

- **E-payment of Customs duty and taxes**. The payment for all taxes and customs duties should be through e-banking system.

- **Disposal of uncleared/unclaimed goods.** There should be an e-auction at all customs stations for a simple, transparent and expeditious procedure in the disposal of goods. The introduction of online-auction would discourage cargo owners or importers who are often unable or unwilling to pay very high duty on their high-value goods and deliberately delay formal procedures to take advantage of Customs auction practices.

- **Awareness of the public community on the role of efficient cargo clearance to the National economy.** Tanzania Ports Authority (TPA) and Tanzania Shipping Agencies Corporation (TASAC) should sensitize the local population and trading communities on the importance of a splendid Port clearance performance and the proper calculation of total logistics costs.
- **Devise performance indicators.** The Port community should agree to develop performance indicators to be used by all members involved in the cargo clearance operations, with a benchmark pegged to the most efficient shippers in the Port.
- **Introduction of the Port Terminal Operation Contract (PTOC).** The PTOC establishes service-level agreements between Port Authority and its customers, regarding expected levels of performance. The customer commits to clearing cargo from the Port within agreed time limits.

These measures in conjunction with other initiatives relating to the development of Port infrastructure and Port connectivity are expected to enable Dar es Salaam Port to attain world-class standards. More specifically, Effective implementation of the recommendations of this study would improve the cargo clearance operations at the Dar es Salaam Port and enhance the contribution of the maritime sector to the national economy and/or economies of the neighbouring landlocked countries.

CONCLUSIONS

The efficiency of cargo clearance operations is a strategic key performance indicator for a Sea Port. The high quality of cargo clearance service for the Port reveals the reduction of cargo dwell time and associated costs. Improving cargo clearance processes is necessary for Ports to remain competitive in the international trade. This study applies the Fuzzy VIKOR Clustering Model (FVCM) to assess the performance of the service providers (i.e. agencies) involved in the cargo clearance processes at Dar es Salaam Port. The Fuzzy VIKOR Model appraises the business processes of the agencies whereas the Fuzzy Clustering Model determines the level of interactive influence between the agencies. The findings show in descending order the ranking of agencies in terms of the performance of Business Process Management (BPM) as Customs Authority, Freight Clearing and Forwarding Companies, Other Government Departments (OGDs), Terminal and ICD Operators, and Shipping Agents. These findings also reveal that Dar es Salaam Port can have a competitive advantage over its competitors in the port sector provided there is a more collaborative multi-stakeholder approach. Firstly, there should be a Port Management Information System (PMIS) with harmonized procedures in which all agencies

involved in the cargo clearance operations are electronically connected. Secondly, each Party in the cargo clearance chain should optimize its Business processes. We expect that the effective implementation of the recommendations of this study would improve the cargo clearance operations at the Dar es Salaam Port and hence enhance the contribution of the maritime sector to the national economy and/or economies of the neighboring landlocked countries. The future direction of this study could be the application of Multi-Attribute Decision-Making model to evaluate the performance of service providers that constitute OGDs with respect to BPM in the cargo clearance formalities at Dar es Salaam Port.

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