The fuzzy-pair wise comparison matrix of the relative importance of performances is presented (according to Step 1 of the proposed Algorithm):

$$\begin{bmatrix} (1,1,1),(1,1,1),(1,1,1),(1,1,1) & M,H,(1,1,1),L & 1/L,1/VL,1/L,(1,1,1) \\ 1/M,1/H,(1,1,1),1/L & (1,1,1),(1,1,1),(1,1,1),(1,1,1) & 1/M,1/H,(1,1,1),1/VL \\ L,(1,1,1),L,(1,1,1) & M,H,(1,1,1),VL & (1,1,1),(1,1,1),(1,1,1),(1,1,1) \end{bmatrix}_{3x3}$$

Application of FOWA is illustrated by the following example. The aggregated relative importance of quality performance (k=1) over environmental protection performance (k=2) can be calculated as:

$$\tilde{W}_{12} = 0.4\cdot(2,3,4) + 0.3\cdot(3,4,5) + 0.2\cdot(1,1,1) + 0.1\cdot(1,2,3) = (2,2.8,3.6)$$

The fuzzy pair-wise comparison matrix of the aggregated relative importance of performances is:

$$\begin{bmatrix} (1,1,1) & (2,2.8,3.6) & (0.45,0.7,1) \\ (0.28,0.36,0.5) & (1,1,1) & (0.41,0.51,0.58) \\ (1,1.43,2.22) & (1.72,1.96,2.44) & (1,1,1) \end{bmatrix}_{3x3}$$

, C.I.=0.048

The procedure for calculating quality weight is presented as follows (Step 2 of the proposed Algorithm):

$$\alpha_1 = \left[\prod_{k=1}^{3} 1\cdot 2\cdot 0.35\right]^{1/3} = 0.89,\quad \beta_1 = \left[\prod_{k=1}^{3} 1\cdot 2.8\cdot 0.7\right]^{1/3} = 1.25,\ \text{ and }\ \chi_1 = \left[\prod_{k=1}^{3} 1\cdot 3.6\cdot 1\right]^{1/3} = 1.53$$

and

$$\alpha = \sum_{k=1}^{K} \alpha_k = 2.65,\ \beta = \sum_{k=1}^{K} \beta_k = 3.22,\ \text{and}\ \chi = \sum_{k=1}^{K} \chi_k, = 3.95$$

Then the weight of quality performance (k=1) is calculated in compliance with Eq. (2) and Eq. (3):

$$\tilde{w}_1 = \left(0.89\cdot 3.95^{-1}, 1.25\cdot 3.22^{-1}, 1.53\cdot 2.65^{-1}\right) = (0.24, 0.39, 0.58)$$

Similarily, weights of the rest of the performances are calculated:

$$\tilde{w}_2 = (0.12, 0.17, 0.25),\ \text{and}\ \tilde{w}_3 = (0.30, 0.44, 0.66).$$

The fuzzy pair wise comparison matrix of the KPIs under quality performance is:

$$\begin{bmatrix} (1,1,1) & (0.78,0.95,1) & (1.25,2,2.70) & (0.85,1,1) \\ (1,1.05,1.28) & (1,1,1) & (1.4,2.10,2.90) & (0.5,1,1) \\ (0.37,050,0.80) & (0.34,0.48,0.71) & (1,1,1) & (0.34,0.55,0.87) \\ (1,1,1.18) & (1,1,2) & (1.15,1.82,2.94) & (1,1,1) \end{bmatrix}_{4x4}$$

, C.I.=0.1

By using the procedure developed in (Wu et al., 2004), the weights of sub criteria under quality performance are:

$\tilde{v}_1^1 = (0.19, 0.28, 0.38)$, $\tilde{v}_2^1 = (0.19, 0.29, 0.41)$, $\tilde{v}_3^1 = (0.09, 0.14, 0.25)$, and $\tilde{v}_4^1 = (0.21, 0.28, 0.41)$.

The fuzzy pair wise comparison matrix of the KPIs under environmental protection performance is:

$$\begin{bmatrix} (1,1,1) & (0.22,0.25,0.40) & (0.31,0.48,0.80) & (1,1,1.30) \\ (2.50,3.57,4.55) & (1,1,1) & (1.40,2.10,2.90) & (0.50,1,1) \\ (1.25,2.08,3.23) & (0.34,0.48,0.71) & (1,1,1) & (0.34,0.55,0.85) \\ (0.87,1,1) & (1,1,2) & (1.18,1.82,2.94) & (1,1,1) \end{bmatrix}_{4x4}$$, C.I.=0.91

The weights of KPIs under environmental protection performance are:

$\tilde{v}_1^2 = (0.09, 0.14, 0.25)$, $\tilde{v}_2^2 = (0.21, 0.39, 0.59)$, $\tilde{v}_3^2 = (0.11, 0.20, 0.36)$, and $\tilde{v}_4^2 = (0.18, 0.27, 0.48)$

The fuzzy pair wise comparison matrix of the KPIs under safety criterion is:

$$\begin{bmatrix} (1,1,1) & (0.67,0.90,1) & (2.30,3.30,4.30) & (3.50,4.50,5) \\ (1,1.11,1.49) & (1,1,1) & (2.30,3.30,4.30) & (3.80,4.80,4.90) \\ (0.23,0.3,0.43) & (0.23,0.3,0.43) & (1,1,1) & (1.50,2.50,3.50) \\ (0.20,0.22,0.29) & (0.20,0.21,0.26) & (0.29,040,0.67) & (1,1,1) \end{bmatrix}_{4x4}$$, C.I.=0.016

The weights of KPIs under safety performance are:

$\tilde{v}_1^3 = (0.26, 0.38, 0.52)$, $\tilde{v}_2^3 = (0.29, 0.41, 0.58)$, $\tilde{v}_3^3 = (0.09, 0.14, 0.22)$, and $\tilde{v}_4^2 = (0.06, 0.07, 0.11)$.

Similarly, the fuzzy pair-wise comparison matrices of the business processes' preference are presented.

<u>*Quality performance*</u>

(Q1) Quality of the seaport services

$$\begin{bmatrix} (1,1,1) & L & L & H & 1/M \\ 1/L & (1,1,1) & M & M & 1/L \\ 1/L & 1/M & (1,1,1) & 1/L & 1/VH \\ 1/H & 1/M & L & (1,1,1) & 1/VH \\ M & L & VH & VH & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.058

$\tilde{p}_{11}^1 = (0.12, 0.22, 0.41)$ $\tilde{p}_{21}^1 = (0.11, 0.19, 0.38)$, $\tilde{p}_{31}^1 = (0.05, 0.07, 0.14)$, $\tilde{p}_{41}^1 = (0.05, 0.08, 0.14)$ and $\tilde{p}_{51}^1 = (0.25, 0.43, 0.68)$.

(Q2) Average number of customers

$$\begin{bmatrix} (1,1,1) & VH & H & M & H \\ 1/VH & (1,1,1) & VL & VL & 1/H \\ 1/H & 1/VL & (1,1,1) & 1/H & 1/VH \\ 1/M & 1/VL & H & (1,1,1) & 1/L \\ 1/H & H & VH & L & (1,1,1) \end{bmatrix}_{5x5}, \text{ C.I.}=0.085$$

$\tilde{p}_{12}^{1}=(0.28,0.43,0.62)$, $\tilde{p}_{22}^{1}=(0.14,0.19,0.29)$, $\tilde{p}_{32}^{1}=(0.04,0.06,0.09)$, $\tilde{p}_{42}^{1}=(0.07,0.10,0.16)$ and $\tilde{p}_{52}^{1}=(0.14,0.23,0.34)$

(Q3) Average number of vessels in the queue

$$\begin{bmatrix} (1,1,1) & VH & H & L & M \\ 1/VH & (1,1,1) & L & L & VL \\ 1/H & 1/L & (1,1,1) & L & VL \\ 1/L & 1/L & 1/L & (1,1,1) & 1/M \\ 1/M & 1/VL & 1/VL & M & (1,1,1) \end{bmatrix}_{5x5}, \text{ C.I.}=0.093$$

$\tilde{p}_{13}^{1}=(0.25,0.44,0.72)$, $\tilde{p}_{23}^{1}=(0.1,0.17,0.3)$, $\tilde{p}_{33}^{1}=(0.08,0.13,0.26)$, $\tilde{p}_{43}^{1}=(0.06,0.09,0.2)$ and $\tilde{p}_{53}^{1}=(0.12,0.17,0.27)$.

(Q4) Pilotage operation of the vessel

$$\begin{bmatrix} (1,1,1) & L & L & VL & 1/M \\ 1/L & (1,1,1) & M & L & 1/M \\ 1/L & 1/M & (1,1,1) & M & 1/H \\ 1/VL & 1/L & 1/M & (1,1,1) & 1/VH \\ M & M & H & VH & (1,1,1) \end{bmatrix}_{5x5}, \text{ C.I.}=0.1$$

$\tilde{p}_{14}^{1}=(0.15,0.29,0.58)$, $\tilde{p}_{24}^{1}=(0.14,0.28,0.54)$, $\tilde{p}_{34}^{1}=(0.09,0.21,0.34)$, $\tilde{p}_{44}^{1}=(0.06,0.1,0.14)$ and $\tilde{p}_{54}^{1}=(0.07,0.13,0.26)$

Environmental protection

(E1) Quality of air

$$\begin{bmatrix} (1,1,1) & 1/L & 1/L & M & VL \\ L & (1,1,1) & VL & M & VL \\ L & 1/VL & (1,1,1) & L & VL \\ 1/M & 1/M & 1/L & (1,1,1) & L \\ 1/VL & 1/VL & 1/VL & 1/L & (1,1,1) \end{bmatrix}_{5x5}, \text{ C.I.}=0.1$$

$\tilde{p}_{11}^{2}=(0.11,0.18,0.32)$, $\tilde{p}_{21}^{2}=(0.17,0.27,0.40)$, $\tilde{p}_{31}^{2}=(0.15,0.25,0.44)$, $\tilde{p}_{41}^{2}=(0.07,0.12,0.23)$ and $\tilde{p}_{51}^{2}=(0.10,0.17,0.25)$.

(E2) Water quality and (E3) Noise

$$\begin{bmatrix} (1,1,1) & 1/M & 1/M & H & VL \\ M & (1,1,1) & VL & H & H \\ M & 1/VL & (1,1,1) & H & H \\ 1/H & 1/H & 1/H & (1,1,1) & L \\ 1/VL & 1/H & 1/L & 1/L & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.77

$\tilde{p}^{2}_{12} = \tilde{p}^{2}_{13} = (0.09, 0.13, 0.24)$, $\tilde{p}^{2}_{22} = \tilde{p}^{2}_{23} = (0.22, 0.34, 0.59)$, $\tilde{p}^{2}_{32} = \tilde{p}^{2}_{33} = (0.19, 0.34, 0.51)$, $\tilde{p}^{2}_{42} = \tilde{p}^{2}_{43} = (0.05, 0.08, 0.14)$ and $\tilde{p}^{2}_{52} = \tilde{p}^{2}_{53} = (0.06, 0.11, 0.18)$.

(E4) Hazardous substances

$$\begin{bmatrix} (1,1,1) & 1/VL & 1/VL & VH & M \\ VL & (1,1,1) & VL & H & M \\ VL & 1/VL & (1,1,1) & VH & L \\ 1/VH & 1/H & 1/VH & (1,1,1) & 1/M \\ 1/M & 1/M & 1/L & M & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.016

$\tilde{p}^{2}_{14} = (0.15, 0.26, 0.4)$, $\tilde{p}^{2}_{24} = (0.18, 0.33, 0.53)$, $\tilde{p}^{2}_{34} = (0.14, 0.23, 0.43)$, $\tilde{p}^{2}_{44} = (0.05, 0.07, 0.12)$ and $\tilde{p}^{2}_{54} = (0.07, 0.11, 0.22)$.

Seaport safety

(S1) Vessel safety

$$\begin{bmatrix} (1,1,1) & VL & 1/VL & VL & VL \\ 1/VL & (1,1,1) & L & M & L \\ VL & 1/L & (1,1,1) & L & VL \\ 1/VL & 1/M & 1/L & 1/VL & 1/L \\ 1/VL & 1/L & VL & L & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.03

$\tilde{p}^{3}_{11} = (0.12, 0.19, 0.35)$, $\tilde{p}^{3}_{21} = (0.14, 0.31, 0.54)$, $\tilde{p}^{3}_{31} = (0.11, 0.19, 0.43)$, $\tilde{p}^{3}_{41} = (0.06, 0.12, 0.23)$ and $\tilde{p}^{3}_{51} = (0.09, 0.19, 0.38)$.

(S2) Traffic volume

$$\begin{bmatrix} (1,1,1) & VL & (1,1,1) & VL & VL \\ 1/VL & (1,1,1) & M & H & M \\ (1,1,1) & 1/M & (1,1,1) & M & L \\ 1/VL & 1/H & 1/M & (1,1,1) & 1/VL \\ 1/VL & 1/M & 1/L & VL & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.069

$\tilde{p}_{12}^{3} = (0.14, 0.18, 0.36)$, $\tilde{p}_{22}^{3} = (0.2, 0.37, 0.56)$, $\tilde{p}_{32}^{3} = (0.12, 0.21, 0.35)$, $\tilde{p}_{42}^{3} = (0.06, 0.11, 0.16)$ and $\tilde{p}_{52}^{3} = (0.08, 0.13, 0.24)$.

(S3) Weather sea condition and channel condition

$$\begin{bmatrix} (1,1,1) & VL & 1/L & 1/L & 1/VH \\ 1/VL & (1,1,1) & VL & L & 1/H \\ L & 1/VL & (1,1,1) & 1/M & 1/H \\ L & 1/L & M & (1,1,1) & 1/M \\ VH & H & H & M & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.084

$\tilde{p}_{13}^{3} = (0.06, 0.09, 0.16)$, $\tilde{p}_{23}^{3} = (0.09, 0.14, 0.24)$, $\tilde{p}_{33}^{3} = (0.06, 0.11, 0.18)$, $\tilde{p}_{43}^{3} = (0.09, 0.16, 0.30)$ and $\tilde{p}_{53}^{3} = (0.31, 0.49, 0.74)$.

(S4) Other safety factors

$$\begin{bmatrix} (1,1,1) & VL & 1/L & 1/VL & 1/VH \\ 1/VL & (1,1,1) & L & 1/M & 1/H \\ L & 1/L & (1,1,1) & 1/M & 1/M \\ VL & M & M & (1,1,1) & 1/L \\ VH & H & M & L & (1,1,1) \end{bmatrix}_{5x5}$$, C.I.=0.088

$\tilde{p}_{14}^{3} = (0.07, 0.12, 0.19)$, $\tilde{p}_{24}^{3} = (0.06, 0.12, 0.20)$, $\tilde{p}_{34}^{3} = (0.06, 0.11, 0.25)$, $\tilde{p}_{44}^{3} = (0.13, 0.23, 0.45)$ and $\tilde{p}_{54}^{3} = (0.24, 0.44, 0.71)$.