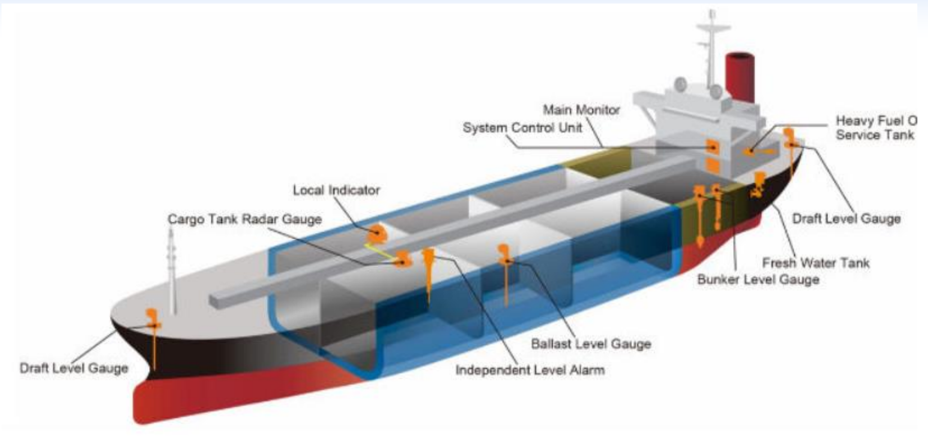

Qualitative and quantitative criteria evaluation using fuzzy AHP: application to the problem of ship bunkering

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Abstract:

Criteria used to make a decision could have numeric values or could have a verbal form used to express proprieties that are opinions or descriptive evaluations. By using the fuzzy AHP, it is possible to compare all this criteria while still maintaining the proper consistency of the AHP method.

Defining an optimal ship bunkering policy is based on a multitude of quantitative and qualitative criteria connected to tank capacity, quantity of cargo on board, fuel price, port facilities, weather conditions, etc. The proper ranking of criteria is vital in order to allow the crew on board to make a decision that adequately weighs the various aspects.

The aim of the paper (which is based on a literature review) is to detect the proper criteria to choose an optimal bunkering and make a proper AHP criteria evaluation. For this purpose, experts from the sector will be involved in the analysis and fuzzy logic computation properties to be used to obtain highly reliable assessments with a high membership degree that could be combined in a multicriteria goal function.

Results:

Evaluation of the criteria, that are qualitative and qualitative, with the Fuzzy AHP method, that helps the experts to define a better evaluation.

Results (and evaluation) have a high membership degree and are more reliable.

Criteria (qualitative and quantitative)	Final crisp weights obtained with the Signed Distance DM
Bunker price	0.10
Port tariffs	0.08
Bunker quality	0.08
Port time	0.01
Supply waiting time	0.05
Port congestion condition	0.03
Efficiency of bunker supply	0.02
Safety of bunkering	0.11
Environmental restrictions effects	0.04
Bunkering risk management	0.05
Experienced human resources	0.03
Information sharing among stakeholders	0.03
Port bunkering supply regulations	0.04
Port weather conditions	0.09
Cargo/Containers on board or to be loaded	0.13
Volume of containers	0.02
Geographical advantage	0.02
Port bunker fuel capacity	0.01
Port bunker suppliers	0.02
Small order bunkering service	0.03
Available bunkering barge	0.02
Bunkering service at night	0.01
CR=0.03	

Literature review:

Field of investigation	Reference	Shipping network design	Methods of investigation
Optimal bunkering model that minimises costs/consumptions - Based only on fuel costs and tank capacity	(Zhen et al., 2017)	Linear shipping	Dynamic programming
	(Aydin et al., 2017)	Linear shipping	Optimisation model
	(Zhen et al., 2016)	Hub and spoke	Scheduling model
	(Wang and Meng, 2015)	Linear shipping	Discrete optimisation model
	(Sheng et al., 2015)	Linear shipping	Optimisation model
	(Pedrielli et al., 2015)	Linear shipping	Optimisation model
	(Meng et al., 2015)	Tramp ship routing	Branch-and-price approach
	(Ghosh et al., 2015)	Linear shipping	Decision model
	(Yanyan and Jianfeng, 2014)	Linear shipping	Optimisation model
	(Vilhelmsen et al., 2014)	Linear shipping	Optimal bunkering model
	(Sheng et al., 2014)	Linear shipping	Dynamic programming
	(Plum et al., 2014)	Linear shipping	Optimisation model
	(Kim, 2014)	Linear shipping	Lagrangian heuristic model
	(Wang et al., 2013)		Review article
	(Yao et al., 2012)	Linear shipping	Fuel management model
	(Kim et al., 2012)	Linear shipping	Epsilon-optimal algorithm
Optimal bunkering port definition – Based on a MCDM approach	(Wang et al., 2014)	Linear shipping	Fuzzy-Delphi and TOPSIS approach
	(Acosta et al., 2011)		Exploratory analysis by questionnaire

Methods:

Factors used in Linear shipping:

Factors are obtained from the literature review and are sorted according to the order of importance proposed by the literature review.

KEY FACTORS	IMPORTANT FACTORS	LESS IMPORTANT FACTORS
Bunker price **Bunker quality** **Port time** **Safety of bunkering** **Volume of containers** **Efficiency of bunker supply** **Geographical advantage** **Port bunker fuel capacity** **Port tariffs**	Supply waiting time Environmental restrictions effects Information sharing among stakeholders Port weather conditions Port bunker suppliers Port bunkering supply regulations	Experienced human resources Port congestion condition Bunkering service at night Small order bunkering service Bunkering risk management Available bunkering barge

Additional performances factor used in Hub and Spoke shipping model: **Cargo/Containers on board or to be loaded**

Fuzzy AHP evaluation of criteria

Verbal comparison scale		Equality of importance	Very weak importance	Weak importance	Quite importance	Fairly importance	Very important	Strong importance	Very strong importance	Maximum head	
Crisp comparison scale	C_i	1	2	3	4	5	6	7	8	9	C_j
Fuzzy comparison scale		$(1,1,1)$	$(1,2,3)$	$(2,3,4)$	$(3,4,5)$	$(4,5,6)$	$(5,6,7)$	$(6,7,8)$	$(7,8,9)$	$(9,9,9)$	

Fuzzy weights are triangular fuzzy numbers

$$\tilde{w}_i = \left(\prod_{j=1}^{n} \tilde{a}_{ij}\right)^{\frac{1}{n}} \cdot \sum_{k=1}^{n}\left(\prod_{j=1}^{n} \tilde{a}_{kj}\right)^{-\frac{1}{n}} = (w_i^l, w_i^m, w_i^u),$$

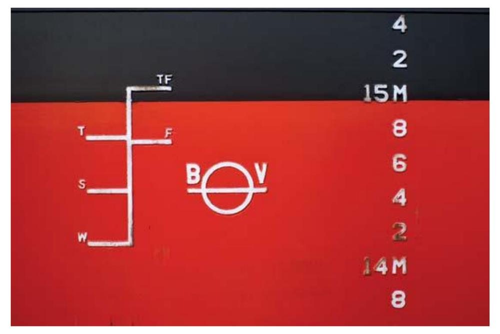
$i = 1, \dots, n$

with the following membership functions:

$$\mu_{\tilde{w}_i}(x) = \begin{cases} \frac{x-w_i^l}{w_i^m-w_i^l} & l < x \le m \\ \frac{w_i^u-x}{w_i^u-w_i^m} & m < x \le u \\ 0 & otherwise \end{cases}$$

Conclusions

- On the base of a literature review are detected qualitative and quantitative criteria used to define an optimal bunkering policy. Criteria are weighted with the Fuzzy AHP method.
- Criteria could be linear combined in a MCDM goal function that could be fuzzy or crisp.
- The obtained results provide the crew a flexible assessment tool with respect to the nature of the data, but at the same time with a high degree of accuracy.



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Key words:

Key words: qualitative criteria, quantitative criteria, fuzzy logic, AHP, ship bunkering