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A Fuzzy MARCOS approach for supplier selection in Ytterbium supply for quantum computing

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Abstract
Selecting the optimal supplier of Ytterbium from a set of alternative suppliers provides an avenue for quality Ytterbium in quantum computing production and it also reduces some bottlenecks in the supply chain network. In this article, a fuzzy MARCOS model was adopted for decision making on selection of optimal supplier from a set of alternative suppliers. Eight decision criteria were applied and these eight criteria were categorized into several sub criteria. The weights of the sub criteria were determined from fuzzy synthetic extent of fuzzified pairwise comparison matrices. The weights of the decision criteria were determined from the weights of the sub criteria. Preliminary decision matrices were developed to represents the availability of the sub criteria in four suppliers of Ytterbium. The aggregates from the preliminary decision matrices were harnessed to obtain the elements of the initial fuzzified decision matrix where the ideal and anti-ideal supplier membership functions were obtained. The utility matrix, utility degree, new utility matrix number and utility functions were obtained in order to obtain ranking for the suppliers. The supplier with the highest score from the decision process had a score of 1.44, while the other three suppliers had scores of 1.32, 1.20 and 1.14 in descending order. The proximity in the final values of the suppliers indicates that the MARCOS model did not just apportion values in the decision process but rather provided a decision value that depends on the weights of the criteria and the performance of the suppliers considering all the sub features. This implies that once the weights of the criteria are changed the final decision will also changes. In essence, the findings from this article shows that the fuzzy MARCOS model is suitable for decision making on the selection of optimal supplier of Ytterbium from a set of alternative suppliers.
Key words: Fuzzy MARCOS; Supplier Selection, Ytterbium; Multicriteria decision making

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I. Introduction

The introduction of quantum computing has led to the discovery and development of elements that can be used for the computing technology. Ytterbium is an important component used in quantum computing because of its low error rates, scalability, robustness and fast gate operations. Ytterbium plays an important role in the development of ion trap quantum computers. The Ytterbium ions are trapped and manipulated using electromagnetic fields and in optical lattices for quantum simulation. Other benefits of Ytterbium in quantum computing are the fact that ytterbium-based quantum gates enable universal quantum computation and its doped materials enhance superconducting qubit performance. There are some properties of ytterbium that makes it suitable for quantum computing technology. These properties include stable ions, low magnetic moment, narrow spectral lines, long coherence times and availability and natural abundance. The stable ions provide stable energy levels while the low magnetic moment reduces magnetic noise and improves the quantum gate fidelity. The advantages of the narrow spectral lines and long coherence times is the provision of precise control over quantum transitions and the ability of the ions to sustain the quantum states for a lengthy period. Further, several applications of Ytterbium in quantum computing includes; processors, metrology, simulations, error correction and communication. In the quantum simulation, the Ytterbium based systems enables secure quantum key distribution and mimic complex quantum phenomena and its ions serves as qubits for computation in the quantum processing. The ytterbium ions also serve as enhancement for sensing and precision measurement and they also facilitate fault tolerant quantum computing (wael, *et. al*., 2019)

Considering the importance of Ytterbium in the quantum computing technology, there is a need to evaluate several suppliers that supplies the element for quantum computing technology. This is crucial for

ensuring quality, reliability, cost effectiveness and timeliness of deliverables. The key players in supply selection process includes reliability, cost structure, delivery and lead times, technical capability and expertise, financial stability and creditworthiness, and customer service and support. Sometimes, factors such as reputation and references, flexibility and adaptability, environmental and social responsibility, and regulatory compliance and certifications comes into play considering the importance and the applications of the goods to be supplied particularly during manufacturing or human consumption. The supplier selection process is an important aspect of manufacturing that must not be downplayed because it goes a long way in affecting the final product or output in the manufacturing system. The selection process is usually initiated by definition of requirements and specifications which is then followed by researching and identification of potential suppliers. The next important step is the evaluation of the suppliers which is usually followed by site visits and audits if the need be. Another important process in the supplier selection is the monitoring and evaluation of supplier performance because this will help in continuous improvement in the selection process.

In order to obtain a quality Ytterbium supply for quantum computing, it is necessary to consider the best supplier selection practices. This will enable effectiveness in terms of supplier selection, inventory management, logistics and transportation, supply chain risk management, sustainability and social responsibility, warehouse location and layout, and supply chain network design. These practices include the development of a clear supplier selection strategy, establishment of a cross-functional selection team, ensuring compliance with regulation and standards, the usage of a data-driven decision-making process, evaluation of suppliers supply chain risk and continuous monitoring of supplier's performances. Also, a prominent method for achieving this practice is the application of Multi-Criteria Decision-making Models (MCDM). The application of MCDM will ensure that a holistic and comprehensive approach is given to all the criteria and sub criteria before a decision is made. The application of the MCDM model will ensure a well-structured decision-making process, consideration of multiple perspectives, improved decision quality and enhanced transparency and accountability in the decision process. Further, the application of the MCDM model will ensure that mistakes are avoided. These mistakes include; solely focusing on price, overlooking quality, non-evaluation of supplier's risk, disregarding long term implications, inefficient monitoring and evaluation of supplier's performance, and dearth of clear communication and expectations. Also, the application of the MCDM model usually involves the effective utilization of supply chain tools and techniques such as proposals and quotations, supplier scorecards, strength, weakness, opportunities and threats (SWOT) analysis, benchmarking and supplier relationship management software. The benefits of applying the MCDM model in decision making particularly for supplier selection is that it provides a means of evaluating several suppliers based on multiple criteria, it also provides a balanced trade-off between competing criteria and the usage of systematic method to aid the decision-making process (Olabanji and Mpofu, 2020; Olabanji and Mpofu, 2022).

Generally, the MCDM model can be broadly categorized into two models. These two models are the Multi- Attribute Decision Model (MADM) and the Multi-Objective Decision Model (MODM). The MADM model finds application when there are several alternatives considering some set of decision criteria. Some of the tools used in MADM are; Weighted Sum Model (WSM), Analytic Hierarchy Process (AHP), Multi- Attribute Utility Theory (MAUT), Elimination and Choice Expressing Reality (ELECTRE), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Simple Additive Weighting (SAW) and lots more (Olabanji and Mpofu, 2020; Olabanji and Mpofu, 2022). The Measurement Alternatives and Ranking according to COmpromise Solution (MARCOS) model is a MADM tool used to evaluate and prioritize options based on multiple criteria. The model was developed in the year 2020 for a sustainable supplier selection in the health care system (Stevic *et. al*, 2020). After its invention, it has been applied in several fields of decision making such as logistics (Ulutas *et. al*, 2020), conceptual design evaluation (Olabanji, 2024) and infrastructure and Technology assessment (Simic *et. al*, 2020). Considering its application in making decisions for suppliers in the health care system and the response of insurance companies in terms of healthcare services to the COVID-19 pandemic (Ecer and Pamucar, 2021), shows that the model is suitable for considering a large set of alternatives with several decision criteria and sub criteria by providing stable and computational integrity in the decision process (Simić, *et. al*., 2020; Stević, and. Brković, 2020; Torkayesh, *et. al*., 2021).

The MARCOS model is a simple and intuitive MADM tool that is based on the Weighted Sum Model and has the ability to handle conflicting criteria considering its classification of quantitative and qualitative criteria, categorical evaluation scale

and suitability for group decision making. The model involves the definition of the decision problem and criteria, establishment of the evaluation scale (which can be categorical or numerical), assigning weights to the criteria, evaluation of the alternatives using the MARCOS scale, and determination of the Weighted sum and raking of the alternatives based on the weighted sum (Trung, 2021; Trung, and Thinh, 2021). The introduction of Fuzzy Membership function in the MARCOS computation process will assist the decision process in dealing with subjectiveness of the evaluation scale, consideration of uncertainty in the values of the criteria and complex relationship between the criteria. The MARCOS model differs from the ELECTRE model because it does not consider the outranking relations. It is also different compare to the AHP model in terms of simpler evaluation scale. Although, it can be compared to the TOPSIS model but with a weighted sum approach.

II. Methodology

The methodology applied in this article involves the identification of criteria and sub criteria needed for effective supplier selection of Ytterbium and application of the Fuzzy MARCOS model to evaluate four different suppliers (Ayşegül and Adali, 2022; Badi and Pamucar, 2020).

2.1 Identification of Criteria and Sub-Criteria for Optimum Supplier Selection

The criteria and sub criteria applied in this article is summarized in Fig. 1. Eight decision criteria are considered in this study. Each of these criteria are described and categorized by several sub-criteria that contributes to the relative importance of the main criteria in the decision process. This is necessary in order to obtain weights of the criteria and achieve a holistic decision process (Puška, *et. al*., 2020; Puška, *et. al*., 2021; Salimian, *et. al*., 2022; Stević *et. al*., 2020; Taş, *et. al*., 2021).

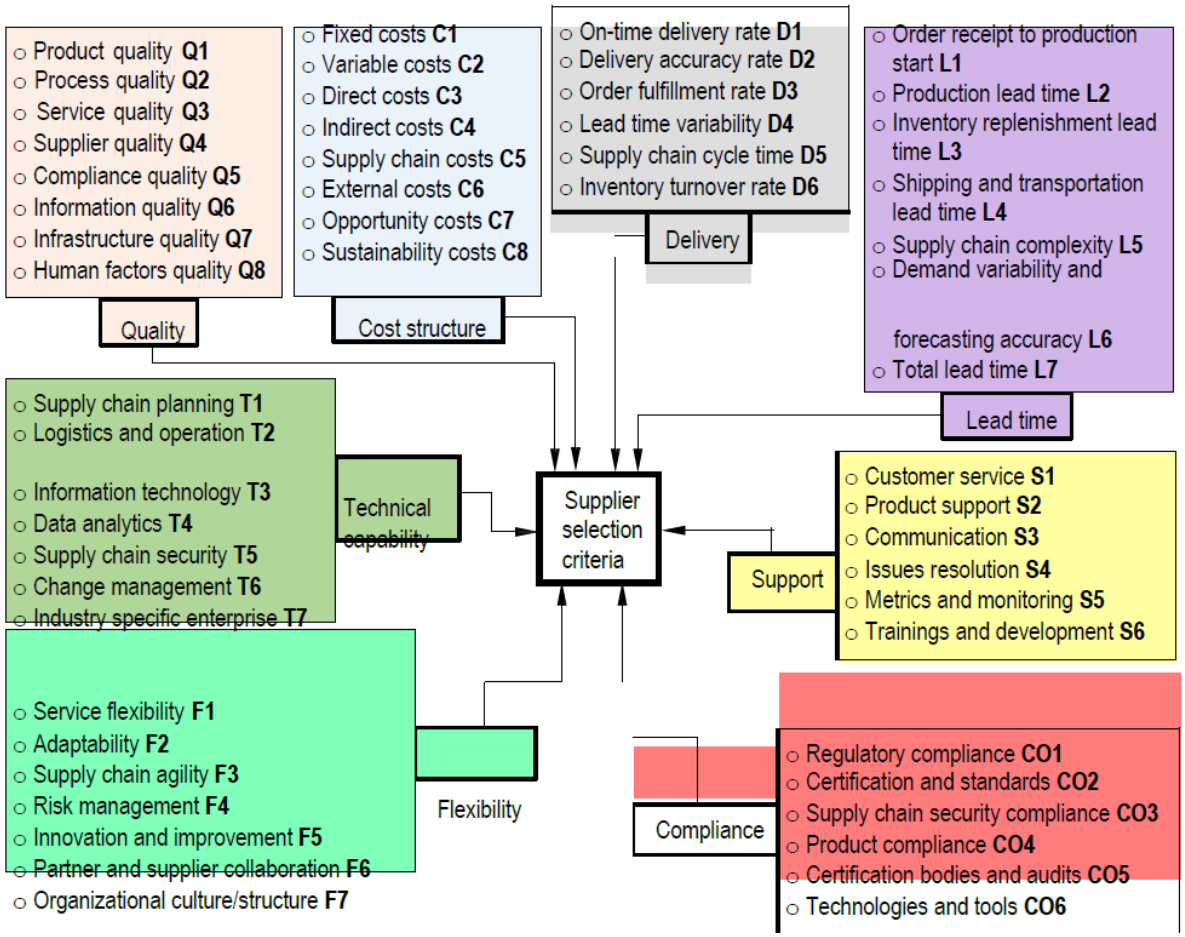

Fig. 1. Decision criteria and sub criteria considered for effective supplier selection

2.2 The Fuzzy MARCOS Decision Process

The framework for the decision process is presented in Fig. 2 (Olabanji, 2024). Considering the fact that the decision criteria and sub criteria are of different characteristics and dimensions, hence it may be difficult to quantify them with a crisp value and

apportioning a single value may introduce ambiguity in the decision process. In view of this, a fuzzy number with the triangular membership function is applied by using a linguistic scale to represent the membership functions for the relative contributions of sub criteria to the main decision criteria and the relative availability of sub criteria in the Ytterbium suppliers as presented in Tables 1 and 2 respectively. The process involved the development of pairwise comparison matrices for each of the sub criteria by obtaining responses from three decision makers. The responses from the decision makers are used to develop the pairwise comparison matrices and the Fuzzy Synthetic Extent (FSE) values are obtained from the pairwise matrices to obtain the weights of the sub criteria. The weight of the decision criteria was obtained from the weights of the sub criteria and the ratings of the suppliers was obtained from the responses of several experts and decision makers with respect to the sub criteria. In order to obtain the initial decision matrix aggregates of the ratings from the sub criteria were obtained alongside the weights of the criteria (Bakır, and Atalık, 2021; Biswas, 2020; Celik, and Gul, 2021; Chakraborty, *et. al*., 2020).

Table 1. Linguistic terms and TFNs for the importance of sub-criteria to main decision criteria

Relative contributions or importance of sub-criteria to main decision criteria	Triangular Fuzzy Numbers and membership function	Inverse of TFN
Equal Importance (**EIP**)	1 1 1	1 1 1
Low Importance (**LIP**)	$1\ \frac{3}{2}\ 2$	$1\ \frac{3}{2}\ 2$
Medium Importance (**MIP**)	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{3}{2}\ 2\ \frac{5}{2}$
High Importance (**HIP**)	$2\ \frac{5}{2}\ 3$	$2\ \frac{5}{2}\ 3$
Very high Importance (**VHP**)	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$

Table 2. Linguistic terms and TFNs for the availability of sub-criteria in the operations of the Ytterbium suppliers

Relative Availability of sub-criteria in the operations of the Ytterbium suppliers	Triangular Fuzzy Numbers and membership function
Extremely Poor Performance (**ELP**)	1 1 1
Very Low Performance (**VLP**)	$1\ \frac{3}{2}\ 2$
Low Performance (**LOP**)	$\frac{3}{2}\ 2\ \frac{5}{2}$
Medium Low Performance (**MLP**)	$2\ \frac{5}{2}\ 3$
Medium Performance (**MEP**)	$\frac{5}{2}\ 3\ \frac{7}{2}$
Medium High Performance (**MHP**)	$3\ \frac{7}{2}\ 4$
High Performance (**HGP**)	$\frac{7}{2}\ 4\ \frac{9}{2}$
Very High Performance (**VHP**)	$4\ \frac{9}{2}\ 5$
Extremely High performance (**EHP**)	$\frac{9}{2}\ 5\ \frac{11}{2}$

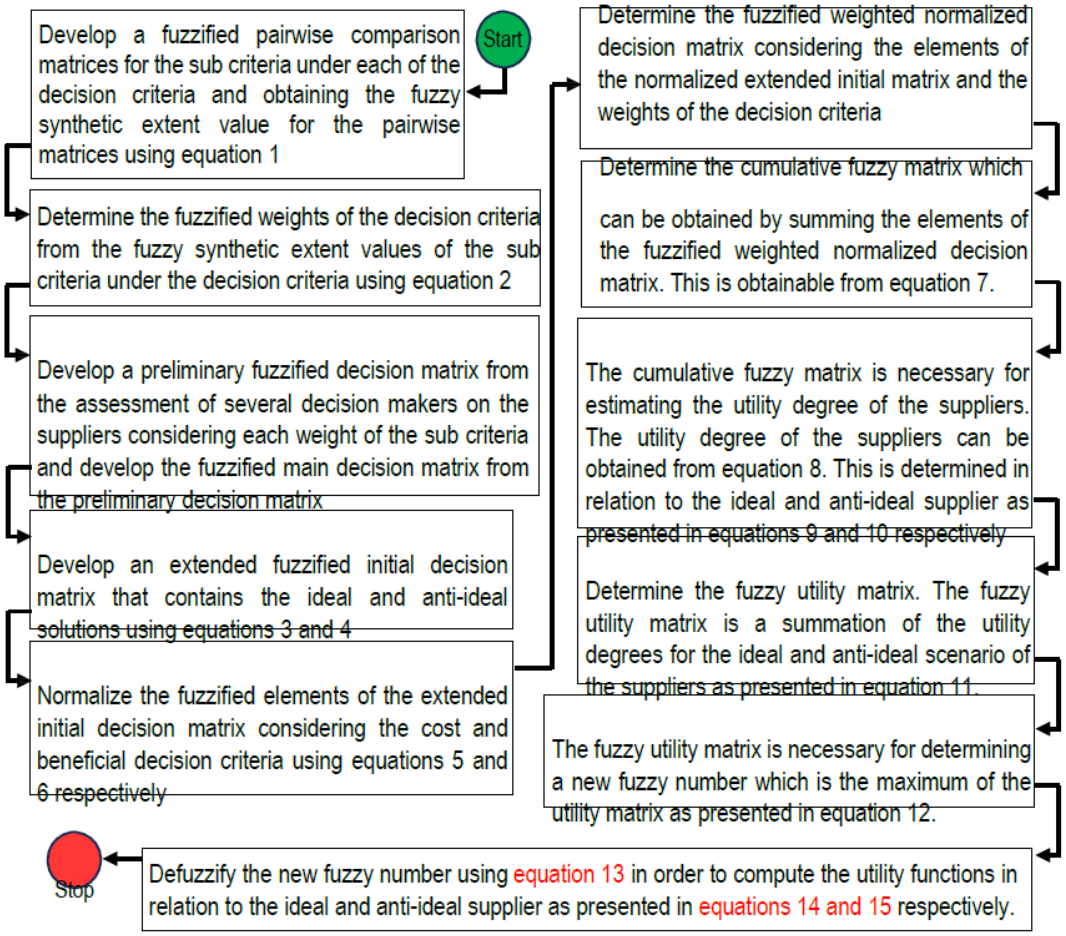

Fig. 2. Framework for the application of fuzzy MARCOS for supplier assessment

$$\tilde{S}_{sc}^{s} = \sum_{j=1}^{v} \tilde{s}_{gi}^{j} \otimes \left[\sum_{i=1}^{u} \sum_{j=1}^{v} \tilde{s}_{gi}^{j} \right]^{-1} \tag{1}$$

In equation 1, $\tilde{s}_{gi}^{j}$ represents the elements of the fuzzified pairwise judgment matrix with u column and v rows while S_{sc}^{s} is the fuzzy synthetic value representing the weights of the sub criteria under each decision criteria.

$$\tilde{S}_{dc}^{s} = \sum_{sc=1}^{sc=n} S_{sc}^{s} = \sum_{j=1}^{v} \sum \tilde{s}_{gi}^{j} \otimes \left[\sum_{i=1}^{u} \sum_{j=1}^{v} \tilde{s}_{gi}^{j} \right]^{-1} \tag{2}$$

In equation 2, $\tilde{S}_{dc}^{s}$ is the fuzzy membership function representing the weight of the decision criteria

$$S^{id} = \begin{cases} Min\left[A\right]_n^m \quad \forall\, m \in B_{dc} \\ \\ Max\left[\tilde{A}\right]_n^m \quad \forall\, m \in C_{dc} \end{cases} \tag{3}$$

$$S^{aid} = \begin{cases} Max\left[A\right]_n^m \quad \forall\, m \in B_{dc} \\ \\ Min\left[\tilde{A}\right]_n^m \quad \forall\, m \in C_{dc} \end{cases} \tag{4}$$

In order to implement the fuzzy MARCOS model, the first step is to create an extended fuzzy matrix containing the ideal S^{id} and anti-ideal S^{aid} suppliers based on the beneficial B_{dc} and cost C_{dc} decision criteria. In equations 3 and 4, $\left[\tilde{A}\right]_n^m$ is the fuzzy number representing the element of the preliminary decision matrix categorized by m number of suppliers and n number of decision criteria. More also, the elements of the extended fuzzified decision matrix can be normalized using equations 5 and 6 for the beneficial B_{dc} and cost C_{dc} decision criteria considering the notations for the lower, modal and upper values of the TFN.

$$\left[\tilde{A}\right]_{wN}^{m} = \left[a \;\; b \;\; c\right]_{wN}^{m} = \frac{\left[A\right]_n^m\Big|^a}{\left[\tilde{A}\right]_w^m\Big|^c} \;\; \frac{\left[A\right]_n^m\Big|^b}{\left[\tilde{A}\right]_w^m\Big|^c} \;\; \frac{\left[A\right]_n^m\Big|^c}{\left[\tilde{A}\right]_w^m\Big|^c} \qquad \forall\, m \in B_{dc} \tag{5}$$

$$\left[\tilde{A}\right]_{wN}^{m} = \left[a \;\; b \;\; c\right]_{wN}^{m} = \frac{\left[\tilde{A}\right]_w^m\Big|^a}{\left[A\right]_n^m\Big|^c} \;\; \frac{\left[\tilde{A}\right]_w^m\Big|^a}{\left[A\right]_n^m\Big|^b} \;\; \frac{\left[\tilde{A}\right]_w^m\Big|^a}{\left[A\right]_n^m\Big|^a} \qquad \forall\, m \in C_{dc} \tag{6}$$

In equations 5 and 6, $\left[\tilde{A}\right]_n^m\Big|^a \;\; \left[\tilde{A}\right]_n^m\Big|^b \;\; \left[\tilde{A}\right]_n^m\Big|^c$ represents the lower, modal and upper values of the elements of the extended fuzzy decision matrix while $\left[A\right]_w^m\Big|^a \;\; \left[A\right]_w^m\Big|^b \;\; \left[A\right]_w^m\Big|^c$ represents the lower, modal and upper values of the elements of the anti-ideal supplier (Do-Trung, 2022; Ecer and Pamucar, 2021; Miškić, *et. al*., 2021). The cumulative fuzzy matrix $(\tilde{C}_I)$ can be obtained by summing the elements of the weighted matrix. This is obtainable from equation 7. The cumulative fuzzy matrix is necessary for estimating the utility degree of the suppliers $\left[U^I\right]_n$. The utility degree of the suppliers is a function of the cumulative matrices of the best and worst design. Hence, the utility degree can be expressed in terms of ideal $\left[\tilde{S}id\right]_n^+$ and anti-ideal $\left[\tilde{S}aid\right]_n^-$ customers as presented in equations 8 and 9 respectively.

$$\tilde{C}_I = \sum_{m=1}^{m=m} \left[\upsilon\right]_n^m \tag{7}$$

$$\lceil U^I \rceil^+_{\lfloor Sid \rfloor_n} = \frac{\tilde{C}_I}{C_I^b} \quad (8)$$

$$\lceil \tilde{U}^I \rceil^-_{\lfloor Said \rfloor_n} = \frac{\tilde{C}_I}{C_I^w} \quad (9)$$

The fuzzy utility matrix is a summation of the utility degrees for the ideal and anti-ideal situation of the suppliers as presented in equation 10. The new fuzzy number $\lfloor \tilde{T} \rfloor_n^{new}$ which is the maximum of the utility matrix as presented in equation 11. This new fuzzy number will be defuzzified using equation 12 in order to compute the utility functions in relation to the ideal $F\lceil U^I \rceil^+_{\lfloor Sid \rfloor_n}$ and anti-ideal $F\lceil U^I \rceil^-_{\lfloor Said \rfloor_n}$ suppliers as presented in equations 13 and 14 respectively.

$$\lfloor \tilde{T} \rfloor_n^{new} = \lceil \tilde{U}_{Sid} \rceil^+_{\lfloor Sid \rfloor_n} \oplus \lceil \tilde{U}_{Said} \rceil^-_{\lfloor Said \rfloor_n} \quad (10)$$

$$\lfloor T \rfloor_n = Max_n \lfloor T \rfloor_n \quad (11)$$

$$M_{crisp} = \frac{a+4b+c}{6} \quad (12)$$

$$F\lfloor U_{Sid} \rfloor_n = \frac{\lceil U_{Sid}^I \rceil_n^+}{\lfloor \tilde{T} \rfloor_n^{new}|_{crisp}} \quad (13)$$

$$F\lfloor U_{Said} \rfloor_n = \frac{\lceil U_{Said}^I \rceil_n^-}{\lfloor \tilde{T} \rfloor_n^{new}|_{crisp}} \quad (14)$$

Defuzzifying the TFNs for the ideal and anti-ideal utility degree scenarios and utility functions can be obtained in order to arrive at a crisp value for the overall utility function of the suppliers as presented in Equation 15.

$$F\lfloor U_s \rfloor_n = \frac{\lceil U_{Sid}^I \rceil_n^+ + \lceil U_{Said}^I \rceil_n^-}{1 + \frac{1 - F\lceil U_{Said}^I \rceil^-}{F\lfloor U_{Sid} \rfloor_n^+} + \frac{1 - F\lfloor U_{Sid}^I \rfloor_n^+}{F\lfloor U_{Said} \rfloor_n^-}}$$

In equation 15, $\lceil U^I \rceil^+_{\lfloor Sid \rfloor_n}$, $\lceil U^I \rceil^-_{\lfloor Said \rfloor_n}$, $F\lceil U^I \rceil^+_{\lfloor Sid \rfloor_n}$ and $F\lceil U^I \rceil^-_{\lfloor Said \rfloor_n}$ represents the crisp values for $\lceil U^I \rceil^+_{\lfloor Sid \rfloor_n}$, $\lceil \tilde{U}^I \rceil^-_{\lfloor Said \rfloor_n}$, $F\lfloor U_{Sid} \rfloor_n^+$ and $F\lfloor U_{Said} \rfloor_n^-$ respectively. The suppliers are ranked according to the values of the overall utility functions such that the supplier with the highest value is the top supplier.

III. Results and Discussions

3.1 Results

The fuzzy MARCOS model was applied to access four suppliers of Ytterbium. In order to achieve this, pairwise comparison matrices were developed for the sub criteria under each of the eight decision criteria considered in the evaluation process. The fuzzified pairwise comparison matrices that represents the relative importance and contributions of the sub criteria to the main decision matrix is obtained for all the decision criteria. Table 3 presents the results of the pairwise comparison for Quality. The pairwise matrices for other decision criteria are presented in Tables A to G in the Appendix. Preliminary decision matrices are obtained for the availability of the sub criteria in the Ytterbium suppliers. The matrix for the performance of the suppliers in terms of the sub criteria for lead time is presented in Table 4, while Tables H to N in the Appendix presents the availability of other sub criteria in other decision criteria. The aggregates from the preliminary decision matrices are harnessed to form the main decision matrix as presented in Table 5. In Table 5, the best and worst suppliers have been determined. In order to ensure that the elements of the membership function in the main decision matrix are defined within the [0, 1] range, the elements are normalized and the result of the weighted normalized decision matrix is presented in Table 6. In Table 6, the weights of the decision criteria are obtained from the aggregates of the weights of the sub criteria from the pairwise matrices. Further, the cumulative TFNs, utility degrees and utility functions considering the ideal and anti-ideal suppliers, and ranking of the Ytterbium suppliers are obtained and presented in Table 7.

Table 3. Fuzzified pairwise comparison matrix for the sub criteria of quality

QUALITY									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	FSE
Q1	1 1 1	$1\ \frac{3}{2}\ 2$	$2\ \frac{5}{2}\ 3$	$1\ \frac{3}{2}\ 2$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{5}{59}\ \frac{11}{80}\ \frac{7}{32}$
Q2	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$2\ \frac{5}{2}\ 3$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{10}{77}\ \frac{14}{73}\ \frac{17}{60}$
Q3	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	1 1 1	$1\ \frac{3}{2}\ 2$	$2\ \frac{5}{2}\ 3$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$1\ \frac{3}{2}\ 2$	$\frac{3}{50}\ \frac{7}{74}\ \frac{5}{34}$
Q4	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{5}{2}\ 3\ \frac{7}{2}$	$1\ \frac{3}{2}\ 2$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{7}{94}\ \frac{5}{43}\ \frac{5}{27}$
Q5	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{4}{47}\ \frac{3}{23}\ \frac{1}{5}$
Q6	$1\ \frac{3}{2}\ 2$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$1\ \frac{3}{2}\ 2$	$\frac{1}{15}\ \frac{14}{73}\ \frac{17}{60}$
Q7	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{5}{72}\ \frac{5}{47}\ \frac{13}{80}$
Q8	$1\ \frac{3}{2}\ 2$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{4}{53}\ \frac{2}{17}\ \frac{15}{79}$
$\frac{20}{31}\ 1\ \frac{5}{3}$									

Table 4. Availability of sub criteria of Lead time in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
L1 $\frac{5}{43}$ $\frac{8}{43}$ $\frac{24}{83}$	MHP	MEP	HGP	HGP	VHP	HGP	MHP	MHP	MLP	HGP	HGP	VHP
L2 $\frac{8}{83}$ $\frac{5}{32}$ $\frac{1}{4}$	HGP	MHP	MHP	MHP	HGP	VHP	HGP	HGP	MHP	HGP	VHP	VHP
L3 $\frac{8}{89}$ $\frac{1}{7}$ $\frac{16}{71}$	MHP	HGP	HGP	VHP	MHP	HGP	MHP	HGP	HGP	VHP	HGP	VHP
L5 $\frac{6}{85}$ $\frac{6}{53}$ $\frac{3}{16}$	MEP	MEP	MLP	HGP	MHP	MEP	MEP	MLP	HGP	HGP	VHP	HGP
L5 $\frac{1}{6}$ $\frac{14}{55}$ $\frac{5}{13}$	HGP	MHP	MHP	MHP	HGP	VHP	HGP	HGP	MHP	HGP	VHP	VHP
L6 $\frac{1}{19}$ $\frac{4}{49}$ $\frac{5}{38}$	MHP	HGP	HGP	VHP	MHP	HGP	MHP	HGP	HGP	VHP	HGP	VHP
L7 $\frac{4}{89}$ $\frac{1}{15}$ $\frac{10}{93}$	VHP	VHP	HGP	HGP	MHP	HGP	HGP	HGP	VHP	MHP	MHP	MEP
Pre-DM	$\frac{2}{7}$ $\frac{13}{25}$ $\frac{67}{72}$			$\frac{11}{35}$ $\frac{47}{83}$ 1			$\frac{2}{7}$ $\frac{47}{90}$ $\frac{14}{15}$			$\frac{29}{86}$ $\frac{50}{83}$ $1\frac{4}{67}$		

Table 5. fuzzified decision matrix containing the best and worst suppliers

Decision Criteria		Worst supplier	S1	S2	S3	S4	Best supplier
Quality	$\frac{20}{31}$ 1 $\frac{5}{3}$	$\frac{11}{65}$ $\frac{25}{71}$ $\frac{9}{14}$	$\frac{14}{79}$ $\frac{29}{79}$ $\frac{2}{3}$	$\frac{3}{13}$ $\frac{28}{61}$ $\frac{17}{21}$	$\frac{15}{58}$ $\frac{47}{33}$ $\frac{10}{11}$	$\frac{11}{65}$ $\frac{25}{71}$ $\frac{9}{14}$	$\frac{15}{58}$ $\frac{47}{33}$ $\frac{10}{11}$
Delivery	$\frac{10}{17}$ 1 $1\frac{58}{83}$	$\frac{8}{35}$ $\frac{35}{74}$ $\frac{19}{20}$	$\frac{8}{35}$ $\frac{35}{74}$ $\frac{19}{20}$	$\frac{24}{79}$ $\frac{3}{5}$ $1\frac{16}{95}$	$\frac{1}{3}$ $\frac{23}{35}$ $1\frac{13}{49}$	$\frac{9}{34}$ $\frac{31}{58}$ $1\frac{3}{53}$	$\frac{1}{3}$ $\frac{23}{35}$ $1\frac{13}{49}$
Support	$\frac{37}{57}$ 1 $1\frac{20}{37}$	$\frac{7}{23}$ $\frac{27}{49}$ $\frac{43}{44}$	$\frac{21}{59}$ $\frac{12}{19}$ $1\frac{1}{10}$	$\frac{7}{23}$ $\frac{16}{29}$ $\frac{46}{47}$	$\frac{7}{23}$ $\frac{27}{49}$ $\frac{43}{44}$	$\frac{19}{59}$ $\frac{25}{43}$ $1\frac{1}{41}$	$\frac{21}{59}$ $\frac{12}{19}$ $1\frac{1}{10}$
Lead time	$\frac{7}{11}$ 1 $1\frac{43}{75}$	$\frac{2}{7}$ $\frac{13}{25}$ $\frac{67}{72}$	$\frac{2}{7}$ $\frac{13}{25}$ $\frac{67}{72}$	$\frac{11}{35}$ $\frac{47}{83}$ 1	$\frac{2}{7}$ $\frac{47}{90}$ $\frac{14}{15}$	$\frac{29}{86}$ $\frac{50}{83}$ $1\frac{4}{67}$	$\frac{29}{86}$ $\frac{50}{83}$ $1\frac{4}{67}$
Compliance	$\frac{58}{83}$ 1 $1\frac{30}{53}$	$\frac{28}{83}$ $\frac{52}{85}$ $1\frac{2}{3}$	$\frac{31}{90}$ $\frac{28}{45}$ $1\frac{7}{67}$	$\frac{28}{83}$ $\frac{52}{85}$ $1\frac{2}{3}$	$\frac{28}{85}$ $\frac{3}{5}$ $1\frac{2}{29}$	$\frac{11}{32}$ $\frac{18}{29}$ $1\frac{6}{59}$	$\frac{31}{90}$ $\frac{28}{45}$ $1\frac{7}{67}$
Flexibility	$\frac{57}{92}$ 1 $1\frac{26}{53}$	$\frac{12}{43}$ $\frac{1}{2}$ $\frac{53}{60}$	$\frac{13}{46}$ $\frac{38}{75}$ $\frac{33}{37}$	$\frac{18}{59}$ $\frac{13}{24}$ $\frac{53}{56}$	$\frac{13}{41}$ $\frac{14}{25}$ $\frac{40}{41}$	$\frac{12}{43}$ $\frac{1}{2}$ $\frac{53}{60}$	$\frac{13}{41}$ $\frac{14}{25}$ $\frac{40}{41}$
Technical Capability	$\frac{31}{48}$ 1 $1\frac{17}{31}$	$\frac{9}{31}$ $\frac{13}{25}$ $\frac{87}{95}$	$\frac{13}{43}$ $\frac{7}{13}$ $\frac{69}{73}$	$\frac{4}{13}$ $\frac{17}{31}$ $\frac{95}{99}$	$\frac{19}{59}$ $\frac{37}{65}$ 1	$\frac{9}{31}$ $\frac{13}{25}$ $\frac{87}{95}$	$\frac{19}{59}$ $\frac{37}{65}$ 1
Cost structure	$\frac{7}{11}$ 1 $\frac{11}{7}$	$\frac{7}{27}$ $\frac{8}{17}$ $\frac{31}{37}$	$\frac{16}{59}$ $\frac{23}{47}$ $\frac{46}{53}$	$\frac{7}{29}$ $\frac{42}{95}$ $\frac{27}{34}$	$\frac{1}{4}$ $\frac{39}{85}$ $\frac{50}{61}$	$\frac{7}{27}$ $\frac{8}{17}$ $\frac{31}{37}$	$\frac{16}{59}$ $\frac{23}{47}$ $\frac{46}{53}$

Table 6. Weighted Normalized decision matrix containing the best and worst suppliers

Decision Criteria		Worst supplier	S1	S2	S3	S4	Best supplier
Quality	$\frac{20}{31}$ 1 $\frac{5}{3}$	$\frac{3}{25}$ $\frac{8}{19}$ $1\frac{2}{11}$	$\frac{1}{8}$ $\frac{40}{91}$ $1\frac{5}{22}$	$\frac{9}{55}$ $\frac{50}{91}$ $1\frac{20}{41}$	$\frac{9}{49}$ $\frac{45}{73}$ $1\frac{2}{3}$	$\frac{3}{25}$ $\frac{8}{19}$ $1\frac{2}{11}$	$\frac{9}{49}$ $\frac{45}{73}$ $1\frac{2}{3}$
Delivery	$\frac{10}{17}$ 1 $1\frac{58}{83}$	$\frac{5}{47}$ $\frac{3}{8}$ $1\frac{27}{98}$	$\frac{5}{47}$ $\frac{3}{8}$ $1\frac{27}{98}$	$\frac{14}{99}$ $\frac{19}{40}$ $1\frac{37}{65}$	$\frac{13}{83}$ $\frac{27}{52}$ $1\frac{7}{10}$	$\frac{9}{73}$ $\frac{30}{71}$ $1\frac{31}{74}$	$\frac{13}{83}$ $\frac{27}{52}$ $1\frac{7}{10}$
Support	$\frac{37}{57}$ 1 $1\frac{20}{37}$	$\frac{7}{39}$ $\frac{1}{2}$ $1\frac{31}{84}$	$\frac{4}{19}$ $\frac{31}{54}$ $1\frac{20}{37}$	$\frac{7}{39}$ $\frac{1}{2}$ $1\frac{36}{97}$	$\frac{7}{39}$ $\frac{1}{2}$ $1\frac{31}{84}$	$\frac{4}{21}$ $\frac{37}{70}$ $1\frac{37}{85}$	$\frac{4}{19}$ $\frac{31}{54}$ $1\frac{20}{37}$
Lead time	$\frac{7}{11}$ 1 $1\frac{43}{75}$	$\frac{17}{99}$ $\frac{47}{99}$ $1\frac{1}{3}$	$\frac{17}{87}$ $\frac{11}{20}$ $1\frac{27}{47}$	$\frac{2}{11}$ $\frac{49}{97}$ $1\frac{28}{65}$	$\frac{15}{77}$ $\frac{23}{42}$ $1\frac{21}{37}$	$\frac{17}{99}$ $\frac{47}{99}$ $1\frac{1}{3}$	$\frac{17}{87}$ $\frac{11}{20}$ $1\frac{27}{47}$
Compliance	$\frac{58}{83}$ 1 $1\frac{30}{53}$	$\frac{4}{21}$ $\frac{51}{94}$ $1\frac{31}{60}$	$\frac{1}{5}$ $\frac{31}{55}$ $1\frac{17}{30}$	$\frac{8}{41}$ $\frac{41}{74}$ $1\frac{13}{24}$	$\frac{4}{21}$ $\frac{51}{94}$ $1\frac{31}{60}$	$\frac{1}{5}$ $\frac{9}{16}$ $1\frac{9}{16}$	$\frac{1}{5}$ $\frac{31}{55}$ $1\frac{17}{30}$
Flexibility	$\frac{57}{92}$ 1 $1\frac{26}{53}$	$\frac{14}{79}$ $\frac{36}{73}$ $1\frac{29}{83}$	$\frac{7}{39}$ $\frac{1}{2}$ $1\frac{33}{91}$	$\frac{6}{31}$ $\frac{8}{15}$ $1\frac{41}{92}$	$\frac{1}{5}$ $\frac{16}{29}$ $1\frac{26}{53}$	$\frac{14}{79}$ $\frac{36}{73}$ $1\frac{29}{83}$	$\frac{1}{5}$ $\frac{16}{29}$ $1\frac{26}{53}$
Technical Capability	$\frac{31}{48}$ 1 $1\frac{17}{31}$	$\frac{3}{16}$ $\frac{13}{25}$ $1\frac{33}{79}$	$\frac{17}{87}$ $\frac{7}{13}$ $1\frac{44}{95}$	$\frac{1}{5}$ $\frac{17}{31}$ $1\frac{17}{35}$	$\frac{5}{24}$ $\frac{37}{65}$ $1\frac{23}{43}$	$\frac{3}{16}$ $\frac{13}{25}$ $1\frac{33}{79}$	$\frac{5}{24}$ $\frac{37}{65}$ $1\frac{23}{43}$
Cost structure	$\frac{7}{11}$ 1 $\frac{11}{7}$	$\frac{11}{62}$ $\frac{46}{93}$ $1\frac{29}{72}$	$\frac{11}{62}$ $\frac{46}{93}$ $1\frac{29}{72}$	$\frac{6}{31}$ $\frac{52}{95}$ $1\frac{27}{47}$	$\frac{3}{16}$ $\frac{48}{91}$ $1\frac{36}{71}$	$\frac{9}{49}$ $\frac{18}{35}$ $1\frac{7}{15}$	$\frac{6}{31}$ $\frac{52}{95}$ $1\frac{27}{47}$

Table 7. Cumulative TFNs, utility degrees, utility functions and ranking of the Ytterbium suppliers

Alternative suppliers	Cumulative fuzzy matrix	Utility degree of suppliers to the anti-ideal scenario	Utility degree of suppliers to the ideal scenario	Fuzzified utility matrix	Utility function of suppliers to the anti-ideal scenario	Utility function of suppliers to the ideal scenario	Overall utility grade	Ranking
BS	$1\frac{17}{31}\ 4\frac{28}{57}\ 12\frac{35}{54}$							
S1	$1\frac{37}{95}\ 4\frac{1}{30}\ 11\frac{19}{46}$	$\frac{5}{39}\ 1\frac{1}{18}\ 8\frac{12}{17}$	$\frac{10}{91}\ \frac{44}{49}\ 7\frac{22}{59}$	$\frac{5}{21}\ 1\frac{41}{43}\ 16\frac{4}{51}$	$\frac{1}{34}\ \frac{8}{33}\ 2$	$\frac{2}{79}\ \frac{20}{97}\ 1\frac{9}{13}$	1.20	3rd
S2	$1\frac{43}{96}\ 4\frac{3}{14}\ 11\frac{29}{32}$	$\frac{2}{15}\ 1\frac{4}{39}\ 9\frac{5}{61}$	$\frac{4}{35}\ \frac{61}{65}\ 7\frac{65}{94}$	$\frac{1}{4}\ 2\frac{4}{97}\ 16\frac{41}{53}$	$\frac{3}{98}\ \frac{20}{79}\ 2\frac{4}{47}$	$\frac{1}{38}\ \frac{14}{65}\ 1\frac{49}{64}$	1.32	2nd
S3	$1\frac{1}{2}\ 4\frac{3}{8}\ 12\frac{29}{82}$	$\frac{9}{65}\ 1\frac{11}{76}\ 9\frac{11}{26}$	$\frac{7}{59}\ \frac{38}{39}\ 7\frac{50}{51}$	$\frac{9}{35}\ 2\frac{5}{42}\ 17\frac{23}{57}$	$\frac{2}{63}\ \frac{5}{19}\ 2\frac{8}{49}$	$\frac{1}{37}\ \frac{17}{76}\ 1\frac{5}{6}$	1.44	1st
S4	$1\frac{6}{17}\ 3\frac{15}{16}\ 11\frac{1}{16}$	$\frac{1}{8}\ 1\frac{1}{33}\ 8\frac{46}{89}$	$\frac{3}{28}\ \frac{64}{73}\ 7\frac{13}{61}$	$\frac{19}{82}\ 1\frac{39}{43}\ 15\frac{27}{37}$	$\frac{1}{35}\ \frac{22}{93}\ 1\frac{64}{67}$	$\frac{1}{41}\ \frac{1}{5}\ 1\frac{61}{93}$	1.14	4th
WS	$1\frac{9}{29}\ 3\frac{60}{73}\ 10\frac{11}{13}$							

3.2 Discussions

Considering the fuzzified weighted normalized decision matrix in Table 6, a clear description of the performance of the suppliers with respect to the decision criteria can be obtained in the form of TFNs. Also, an interesting aspect of the fuzzy MARCOS method is the determination of the best and worst supplier. The identification of best and worst suppliers from the decision matrix creates a means of benchmarking what is expected from an ideal supplier considering all the decision criteria. However, it is not possible to have a supplier that will perform excellently in all the decision criteria and that is why it is an ideal scenario.

Similarly, it is expected that all the suppliers must also overcome the anti-ideal scenario which contains poor performance in all the decision criteria. In essence, the MARCOS method will tend to compare all the suppliers considering the ideal and anti-ideal scenarios. Since it is not possible to have a supplier with excellent performance in all the decision criteria, there will be a compromise in the decision process such that some decision criteria will not be predominantly available in the supplier. It is worthwhile to note that such decision criteria are also important but the decision to prioritize the decision criteria has come to play in order to satisfy the criteria that are necessary for an improved decision process. Also, when there is a need to prioritize some other decision criteria, the alternatives which has the best performance in all these criteria can easily be identified. In essence, MARCOS model classifies the decision criteria into cost and beneficial criteria. The classification of the decision criteria into cost and beneficial criteria will enable the decision-making team to know which of the suppliers that will be cheaper to engage with in terms of cost reduction of the Ytterbium and which of the suppliers to engage with in terms of Ytterbium with beneficial services. Another observation from the results obtained in the MARCOS model is that, none of the suppliers is performing close to the anti-ideal and ideal supplier. Although there TFN membership function have values in between these two ranges which means that all suppliers will tend to move closer to the ideal scenario while moving far from the anti-ideal instance. This implies that any of the suppliers can be improved upon depending on their performance in any of the preferred decision criteria because the weights of the decision criteria are subjected to change depending on the logistics and policy of the decision makers at the instance of purchase. In essence, that supplier "3" is the best in this example based on the data obtained does not imply that it will continue to be the best always. This may be due to improvement in the operations of other suppliers over time which will change their performance in the sub criteria or due to change in the preference of weights of the sub criteria and decision criteria. Considering the utility degrees, fuzzy utility functions and overall utility function, the MARCOS model determined the optimal supplier rather than mere defuzzification and comparison with the best and worst supplier. The MARCOS model was also able to establish the level of performance of the suppliers relative to the expected performance of the best and worst supplier but a judgment on the optimal supplier from the set of alternative suppliers cannot be made because the utility degree which is a function on how each of the supplier performs with respect to the ideal and anti-ideal scenario needs to be determined. Hence, the suppliers were ranked based on their scores in the overall utility function. An

observation of the final values of the overall utility function showed that there is a closeness in the final values of the suppliers. This is an indication that the MARCOS model did not apportion values to the suppliers but rather compared their performances in all the decision criteria and their utility degrees and functions.

IV. Conclusion

Conclusively, the importance of identifying the best supplier from a set of alternative suppliers cannot be overstated because it will go a long way in controlling the price and quality of the final product. Aside from the issues of price and quality the decision-making process to select the optimal supplier also helps to strengthen the supply chain network. Hence more efforts and resources are needed to be put into action in the decision process for identification of optimal supplier for effective logistics process in the production system. This is necessary because it provides more information on the decision criteria associated with the suppliers and the Ytterbium product itself. In essence, considering the importance that is attached to the supplier section process, this article has presented fuzzy MARCOS as a multicriteria decision making model which can be adopted as a tool for carrying out a robust decision process. The uniqueness in the application of the fuzzy MARCOS model in this article is the development of fuzzified pairwise comparison matrices in order to determine the weights of the sub criteria under each of the decision criteria and application of three expert's response in determining the elements of the preliminary decision matrices. The main decision matrix in this method is not a function of the aggregates of the preliminary decision matrices in order to ensure that there are no unambiguous TFNs or bias judgements in the final elements of the decision matrix. The framework for the application of the model to selection of optimal supplier was developed based on its procedure in other areas of application and the model provided an excellent performance by identifying the best supplier considering its overall utility value relative to the ideal and anti-ideal supplier scenario. Further work can also be carried out in the aspect of identifying the more sub criteria that can be used to characterize the decision criteria and also in the aspect of improving the computational process by developing a computer aided system where computations can be made easily for the decision process. this will go a long way in reducing the stress of computation.

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APPENDIX

COST STRUCTURE

	C1	C2	C3	C4	C5	C6	C7	C8	FSE
C1	1 1 1	1 3/2 2	3/2 2 5/2	1 3/2 2	2/7 1/3 2/5	2 5/2 3	2 5/2 3	3/2 2 5/2	4/39 16/97 9/35
C2	1/2 2/3 1	1 1 1	1 3/2 2	1 3/2 2	2/7 1/3 2/5	2 5/2 3	3/2 2 5/2	2 5/2 3	5/54 11/74 7/30
C3	2/5 1/2 2/3	1/2 2/3 1	1 1 1	1 3/2 2	2/5 1/2 2/3	3/2 2 5/2	2 5/2 3	3/2 2 5/2	1/12 7/53 14/67
C4	1/2 2/3 1	1/2 2/3 1	1/2 2/3 1	1 1 1	1/3 2/5 1/2	3/2 2 5/2	1 3/2 2	2/7 1/3 2/5	1/18 6/67 14/95
C5	5/2 3 7/2	5/2 3 7/2	3/2 2 5/2	2 5/2 3	1 1 1	1 3/2 2	2 5/2 3	1 3/2 2	7/52 4/19 9/28
C6	1/3 2/5 1/2	1/3 2/5 1/2	2/5 1/2 2/3	2/5 1/2 2/3	1/2 2/3 1	1 1 1	1 3/2 2	1 3/2 2	1/20 2/25 3/23
C7	1/3 2/5 1/2	2/5 1/2 2/3	1/3 2/5 1/2	1/2 2/3 1	1/3 2/5 1/2	1/2 2/3 1	1 1 1	2/7 1/3 2/5	1/27 2/37 2/23
C8	2/5 1/2 2/3	1/3 2/5 1/2	2/5 1/2 2/3	5/2 3 7/2	1/2 2/3 1	1/2 2/3 1	5/2 3 7/2	1 1 1	3/37 10/83 18/97
				7/11 1 11/7					

DELIVERY														
	D1			D2			D3			D4			D5			D6			FSE		
D1	1	1	1	3/2	2	5/2	2	5/2	3	2	5/2	3	2	5/2	3	3/2	2	5/2	12/67	12/41	21/46
D2	2/5	1/2	2/3	1	1	1	3/2	2	5/2	3/2	2	5/2	3/2	2	5/2	1/2	2/3	1	11/96	1/5	12/37
D3	1/3	2/5	1/2	2/5	1/2	2/3	1	1	1	1/2	2/3	1	1/2	2/3	1	2/5	1/2	2/3	1/17	10/97	16/83
D4	1/3	2/5	1/2	2/5	1/2	2/3	1/2	2/3	1	1	1	1	3/2	2	2/5	1/2	2/3	1/17	10/97	16/83	
D5	1/3	2/5	1/2	2/5	1/2	2/3	1	3/2	2	1/2	2/3	1	1	1	2/5	1/2	2/3	1/17	10/97	16/83	
D6	2/5	1/2	2/3	1/2	2/3	1	3/2	2	5/2	3/2	2	5/2	3/2	2	5/2	1	1	1	2/17	1/5	18/53
10/17 1 1 58/83																					

COMPLIANCE																				
	CO1			CO2			CO3			CO4			CO5			CO6			FSE		
CO1	1	1	1	2	5/2	3	1	3/2	2	1	3/2	2	1	3/2	2	3/2	2	5/2	7/53	17/78	10/29
CO2	1/3	2/5	1/2	1	1	1	1	3/2	2	3/2	2	5/2	5/2	3	7/2	1/2	2/3	1	3/25	17/91	11/38
CO3	1/2	2/3	1	1/2	2/3	1	1	1	1	1	3/2	2	2	5/2	3	1/3	2/5	1/2	3/32	5/34	15/64
CO4	1/2	2/3	1	2/5	1/2	2/3	1/2	2/3	1	1	1	1	3/2	2	5/2	2/5	1/2	2/3	5/66	5/43	13/69
CO5	1/2	2/3	1	2/7	1/3	2/5	1/3	2/5	1/2	2/5	1/2	2/3	1	1	1	2/7	1/3	2/5	4/81	5/71	7/64
CO6	2/5	1/2	2/3	1	3/2	2	2	5/2	3	3/2	2	5/2	5/2	3	7/2				1/6	17/65	2/5
58/83 1 1 30/53																					

SUPPORT																				
	S1			S2			S3			S4			S5			S6			FSE		
S1	1	1	1	3/2	2	5/2	2	5/2	3	1	3/2	2	5/2	3	7/2	1	3/2	2	6/37	13/51	7/18
S2	2/5	1/2	2/3				1	3/2	2	3/2	2	5/2	1	3/2	2	2	5/2	3	1/8	1/5	9/29
S3	1/3	2/5	1/2	1/2	2/3	1	1	1	1	1	3/2	2	3/2	2	5/2	2	5/2	3	4/35	5/28	5/18
S4	1/2	2/3	1	2/5	1/2	2/3	1/2	2/3	1	1	1	1	2	5/2	3	3/2	2	5/2	5/47	13/80	14/55
S5	2/7	1/3	2/5	1/2	2/3	1	2/5	1/2	2/3	1/3	2/5	1/2	1	1	1	5/2	3	7/2	1/11	3/23	11/56
S6	1/2	2/3	1	1/3	2/5	1/2	1/3	2/5	1/2	2/5	1/2	2/3	2/7	1/3	2/5	1	1	1	2/39	3/41	7/62
37/57 1 1 20/37																					

LEAD TIME

	L1	L2	L3	L4	L5	L6	L7	FSE
L1	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$1\ \frac{3}{2}\ 2$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$2\ \frac{5}{2}\ 3$	$2\ \frac{5}{2}\ 3$	$\frac{5}{43}\ \frac{8}{43}\ \frac{24}{83}$
L2	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$1\ \frac{3}{2}\ 2$	$1\ \frac{3}{2}\ 2$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$2\ \frac{5}{2}\ 3$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{8}{83}\ \frac{5}{32}\ \frac{1}{4}$
L3	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$2\ \frac{5}{2}\ 3$	$\frac{8}{89}\ \frac{1}{7}\ \frac{16}{71}$
L4	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$1\ \frac{3}{2}\ 2$	$\frac{6}{85}\ \frac{6}{53}\ \frac{3}{16}$
L5	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$2\ \frac{5}{2}\ 3$	1 1 1	$\frac{3}{2}\ 2\ \frac{5}{2}$	$2\ \frac{5}{2}\ 3$	$\frac{1}{6}\ \frac{14}{55}\ \frac{5}{13}$
L6	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{1}{19}\ \frac{4}{49}\ \frac{5}{38}$
L7	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{4}{89}\ \frac{1}{15}\ \frac{10}{93}$
$\frac{7}{11}\ 1\ 1\frac{43}{75}$								

FLEXIBILITY

	F1	F2	F3	F4	F5	F6	F7	FSE
F1	1 1 1	$2\ \frac{5}{2}\ 3$	$1\ \frac{3}{2}\ 2$	$1\ \frac{3}{2}\ 2$	$1\ \frac{3}{2}\ 2$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{3}{26}\ \frac{7}{37}\ \frac{25}{84}$
F2	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	1 1 1	$1\ \frac{3}{2}\ 2$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{11}\ \frac{13}{92}\ \frac{12}{55}$
F3	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$1\ \frac{3}{2}\ 2$	$2\ \frac{5}{2}\ 3$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$2\ \frac{5}{2}\ 3$	$\frac{3}{32}\ \frac{8}{55}\ \frac{13}{57}$
F4	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{1}{2}\ \frac{2}{3}\ 1$	1 1 1	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{2}{27}\ \frac{3}{2}\ \frac{5}{27}$
F5	$\frac{1}{2}\ \frac{2}{3}\ 1$	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	1 1 1	$\frac{2}{7}\ \frac{1}{3}\ \frac{2}{5}$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{1}{25}\ \frac{2}{35}\ \frac{7}{79}$
F6	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$1\ \frac{3}{2}\ 2$	$2\ \frac{5}{2}\ 3$	$\frac{3}{2}\ 2\ \frac{5}{2}$	$\frac{5}{2}\ 3\ \frac{7}{2}$	1 1 1	$2\ \frac{5}{2}\ 3$	$\frac{9}{74}\ \frac{7}{37}\ \frac{21}{73}$
F7	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$2\ \frac{5}{2}\ 3$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	$\frac{2}{5}\ \frac{1}{2}\ \frac{2}{3}$	$2\ \frac{5}{2}\ 3$	$\frac{1}{3}\ \frac{2}{5}\ \frac{1}{2}$	1 1 1	$\frac{1}{12}\ \frac{7}{57}\ \frac{5}{27}$
$\frac{57}{92}\ 1\ 1\frac{26}{53}$								

TECHNICAL CAPABILITY								
	T1	T2	T3	T4	T5	T6	T7	FSE
T1	1 1 1	$\frac{3}{2}$ 2 $\frac{5}{2}$	2 $\frac{5}{2}$ 3	1 $\frac{3}{2}$ 2	$\frac{5}{2}$ 3 $\frac{7}{2}$	1 $\frac{3}{2}$ 2	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{8}{65}$ $\frac{6}{31}$ $\frac{11}{37}$
T2	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	1 1 1	1 $\frac{3}{2}$ 2	$\frac{3}{2}$ 2 $\frac{5}{2}$	1 $\frac{3}{2}$ 2	2 $\frac{5}{2}$ 3	$\frac{3}{2}$ 2 $\frac{5}{2}$	$\frac{10}{91}$ $\frac{11}{62}$ $\frac{28}{83}$
T3	$\frac{1}{3}$ $\frac{2}{5}$ $\frac{1}{2}$	$\frac{1}{2}$ $\frac{2}{3}$ 1	1 1 1	1 $\frac{3}{2}$ 2	$\frac{3}{2}$ 2 $\frac{5}{2}$	2 $\frac{5}{2}$ 3	$\frac{3}{2}$ 2 $\frac{5}{2}$	$\frac{4}{39}$ $\frac{6}{37}$ $\frac{18}{71}$
T4	$\frac{1}{2}$ $\frac{2}{3}$ 1	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{1}{2}$ $\frac{2}{3}$ 1	1 1 1	2 $\frac{5}{2}$ 3	$\frac{3}{2}$ 2 $\frac{5}{2}$	1 $\frac{3}{2}$ 2	$\frac{1}{11}$ $\frac{1}{7}$ $\frac{12}{53}$
T5	$\frac{2}{7}$ $\frac{1}{3}$ $\frac{2}{5}$	$\frac{1}{2}$ $\frac{2}{3}$ 1	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{1}{3}$ $\frac{2}{5}$ $\frac{1}{2}$	1 1 1	$\frac{5}{2}$ 3 $\frac{7}{2}$	$\frac{1}{3}$ $\frac{2}{5}$ $\frac{1}{2}$	$\frac{4}{57}$ $\frac{6}{59}$ $\frac{2}{13}$
T6	$\frac{1}{2}$ $\frac{2}{3}$ 1	$\frac{1}{3}$ $\frac{2}{5}$ $\frac{1}{2}$	$\frac{1}{3}$ $\frac{2}{5}$ $\frac{1}{2}$	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{2}{7}$ $\frac{1}{3}$ $\frac{2}{5}$	1 1 1	$\frac{5}{2}$ 3 $\frac{7}{2}$	$\frac{4}{57}$ $\frac{6}{59}$ $\frac{2}{13}$
T7	$\frac{3}{2}$ 2 $\frac{5}{2}$	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{2}{5}$ $\frac{1}{2}$ $\frac{2}{3}$	$\frac{1}{2}$ $\frac{2}{3}$ 1	2 $\frac{5}{2}$ 3	$\frac{2}{7}$ $\frac{1}{3}$ $\frac{2}{5}$	1 1 1	$\frac{2}{25}$ $\frac{11}{91}$ $\frac{3}{16}$
				$\frac{31}{48}$ 1 $1\frac{17}{31}$				

Table I. Availability of sub criteria of quality in the Ytterbium suppliers

Sub Criteria	**S1**			**S2**			**S3**			**S4**		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
Q1 $\frac{5}{59}$ $\frac{11}{80}$ $\frac{7}{32}$	MEP	HGP	MHP	HGP	MHP	VHP	VHP	HGP	VHP	MEP	MHP	MHP
Q2 $\frac{10}{77}$ $\frac{14}{73}$ $\frac{17}{60}$	HGP	MEP	MEP	HGP	HGP	VHP	MHP	VHP	EHP	MLP	MHP	MHP
Q3 $\frac{4}{47}$ $\frac{3}{23}$ $\frac{1}{5}$	MLP	MLP	MHP	HGP	HGP	MHP	VHP	VHP	MHP	MEP	MEP	MLP
Q4 $\frac{1}{15}$ $\frac{14}{73}$ $\frac{17}{60}$	MHP	HGP	MLP	VHP	MHP	MHP	VHP	EHP	EHP	MLP	HGP	MEP
Q5 $\frac{3}{50}$ $\frac{7}{74}$ $\frac{5}{34}$	MHP	MLP	MEP	MLP	MLP	MEP	VHP	HGP	VHP	MEP	MLP	MEP
Q6 $\frac{7}{94}$ $\frac{5}{43}$ $\frac{5}{27}$	HGP	MEP	MEP	HGP	HGP	VHP	MHP	VHP	EHP	MLP	MHP	MHP
Q7 $\frac{5}{72}$ $\frac{5}{47}$ $\frac{13}{80}$	MLP	MLP	MHP	HGP	HGP	MHP	VHP	VHP	MHP	MEP	MEP	MLP
Q8 $\frac{4}{53}$ $\frac{2}{17}$ $\frac{15}{79}$	MHP	HGP	MLP	VHP	MHP	MHP	VHP	EHP	EHP	MLP	HGP	MEP
Pre-DM	$\frac{14}{79}$	$\frac{29}{79}$	$\frac{2}{3}$	$\frac{3}{13}$	$\frac{28}{61}$	$\frac{17}{21}$	$\frac{15}{58}$	$\frac{47}{33}$	$\frac{10}{11}$	$\frac{11}{65}$	$\frac{25}{71}$	$\frac{9}{14}$

Table J. Availability of sub criteria of delivery in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
D1 $\frac{12}{67}$ $\frac{12}{41}$ $\frac{21}{46}$	MLP	MEP	VLP	MHP	MLP	MEP	MEP	MEP	MHP	MLP	MLP	MEP
D2 $\frac{11}{96}$ $\frac{1}{5}$ $\frac{12}{37}$	MEP	MHP	MLP	HGP	VHP	MHP	VHP	VHP	MHP	MEP	MEP	MHP
D3 $\frac{1}{17}$ $\frac{10}{97}$ $\frac{16}{83}$	VLP	LOP	MEP	VHP	HGP	VHP	VHP	EHP	VHP	HGP	HGP	MHP
D4 $\frac{1}{17}$ $\frac{10}{97}$ $\frac{16}{83}$	MHP	MEP	HGP	HGP	MHP	MHP	MHP	HGP	HGP	MHP	HGP	MEP
D5 $\frac{1}{17}$ $\frac{10}{97}$ $\frac{16}{83}$	MLP	MHP	HGP	VHP	MHP	MEP	HGP	VHP	VHP	HGP	MLP	MHP
D6 $\frac{2}{17}$ $\frac{1}{5}$ $\frac{18}{53}$	MEP	MLP	HGP	HGP	MHP	MHP	VHP	HGP	VHP	MHP	HGP	MEP
Pre-DM	$\frac{8}{35}$ $\frac{35}{74}$ $\frac{19}{20}$			$\frac{24}{79}$ $\frac{3}{5}$ $1\frac{16}{95}$			$\frac{1}{3}$ $\frac{23}{35}$ $1\frac{13}{49}$			$\frac{9}{34}$ $\frac{31}{58}$ $1\frac{3}{53}$		

Table K. Availability of sub criteria of Support in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
S1 $\frac{6}{37}$ $\frac{13}{51}$ $\frac{7}{18}$	VHP	MHP	VHP	MLP	MLP	MHP	MEP	MEP	MLP	HGP	MHP	MHP
S2 $\frac{1}{8}$ $\frac{1}{5}$ $\frac{9}{29}$	MHP	MHP	HGP	HGP	HGP	VHP	MHP	HGP	VHP	HGP	VHP	VHP
S3 $\frac{4}{35}$ $\frac{5}{28}$ $\frac{5}{18}$	HGP	HGP	MHP	MEP	MLP	MEP	MEP	MLP	MLP	MLP	MEP	LOP
S4 $\frac{5}{47}$ $\frac{13}{80}$ $\frac{14}{55}$	MLP	MEP	MEP	MHP	HGP	MLP	HGP	MHP	MEP	HGP	HGP	MHP
S5 $\frac{1}{11}$ $\frac{3}{23}$ $\frac{11}{56}$	VHP	VHP	HGP	HGP	MHP	HGP	HGP	HGP	VHP	MHP	MHP	MEP
S6 $\frac{2}{39}$ $\frac{3}{41}$ $\frac{7}{62}$	HGP	HGP	MHP	MEP	MLP	MEP	MEP	MLP	MLP	MLP	MEP	LOP
Pre-DM	$\frac{21}{59}$ $\frac{12}{19}$ $1\frac{1}{10}$			$\frac{7}{23}$ $\frac{16}{29}$ $\frac{46}{47}$			$\frac{7}{23}$ $\frac{27}{49}$ $\frac{43}{44}$			$\frac{19}{59}$ $\frac{25}{43}$ $1\frac{1}{41}$		

Table M. Availability of sub criteria of Compliance in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
CO1 $\frac{7}{53}$ $\frac{17}{78}$ $\frac{10}{29}$	MHP	VHP	MHP	MHP	MHP	HGP	MHP	HGP	HGP	MLP	MEP	MHP
CO2 $\frac{3}{25}$ $\frac{17}{91}$ $\frac{11}{38}$	HGP	MHP	VHP	MHP	HGP	HGP	MHP	MEP	MHP	MHP	HGP	MEP
CO3 $\frac{3}{32}$ $\frac{5}{34}$ $\frac{15}{64}$	MHP	MEP	MLP	MEP	MHP	MHP	HGP	HGP	MHP	HGP	HGP	MHP
CO4 $\frac{5}{66}$ $\frac{5}{43}$ $\frac{13}{69}$	HGP	MHP	HGP	MHP	MEP	MLP	MHP	HGP	MEP	HGP	VHP	HGP
CO5 $\frac{4}{81}$ $\frac{5}{71}$ $\frac{7}{64}$	VHP	VHP	HGP	HGP	MHP	HGP	HGP	HGP	VHP	MHP	MHP	MEP
CO6 $\frac{1}{6}$ $\frac{17}{65}$ $\frac{2}{5}$	MEP	HGP	HGP	VHP	HGP	MHP	MHP	MLP	HGP	HGP	VHP	VHP
Pre-DM	$\frac{31}{90}$ $\frac{28}{45}$ $1\frac{7}{67}$			$\frac{28}{83}$ $\frac{52}{85}$ $1\frac{2}{3}$			$\frac{28}{85}$ $\frac{3}{5}$ $1\frac{2}{29}$			$\frac{11}{32}$ $\frac{18}{29}$ $1\frac{6}{59}$		

Table N. Availability of sub criteria of Flexibility in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
F1 $\frac{3}{26}\ \frac{7}{37}\ \frac{25}{84}$	HGP	MHP	MHP	HGP	VHP	MHP	HGP	HGP	VHP	MHP	MHP	HGP
F2 $\frac{1}{11}\ \frac{13}{92}\ \frac{12}{55}$	MHP	MHP	HGP	MHP	HGP	VHP	VHP	HGP	HGP	HGP	MHP	MEP
F3 $\frac{3}{32}\ \frac{8}{55}\ \frac{13}{57}$	MEP	MEP	HGP	MHP	MEP	HGP	HGP	HGP	MHP	MEP	MEP	MHP
F4 $\frac{1}{12}\ \frac{7}{57}\ \frac{5}{27}$	MHP	MHP	HGP	HGP	VHP	HGP	VHP	VHP	HGP	HGP	HGP	MHP
F5 $\frac{2}{27}\ \frac{3}{26}\ \frac{5}{27}$	MEP	MEP	VHP	VHP	HGP	MHP	HGP	HGP	VHP	MHP	MHP	HGP
F6 $\frac{1}{25}\ \frac{2}{35}\ \frac{7}{79}$	HGP	VHP	HGP	HGP	MHP	VHP	VHP	HGP	VHP	HGP	VHP	HGP
F7 $\frac{9}{74}\ \frac{7}{37}\ \frac{21}{73}$	VHP	HGP	MHP	MHP	HGP	VHP	MHP	HGP	HGP	HGP	MHP	MHP
Pre-DM	$\frac{13}{46}\ \frac{38}{75}\ \frac{33}{37}$			$\frac{18}{59}\ \frac{13}{24}\ \frac{53}{56}$			$\frac{13}{41}\ \frac{14}{25}\ \frac{40}{41}$			$\frac{12}{43}\ \frac{1}{2}\ \frac{53}{60}$		

Table O. Availability of sub criteria of Technical Capability in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
T1 $\frac{8}{65}\ \frac{6}{31}\ \frac{11}{37}$	VHP	HGP	HGP	MEP	MHP	MHP	MEP	MEP	MHP	MHP	MEP	HGP
T2 $\frac{10}{91}\ \frac{11}{62}\ \frac{23}{83}$	MHP	HGP	VHP	MEP	MEP	HGP	MHP	MHP	HGP	MHP	MHP	VHP
T3 $\frac{4}{39}\ \frac{6}{37}\ \frac{18}{71}$	HGP	VHP	HGP	MHP	HGP	MHP	MHP	HGP	HGP	HGP	VHP	MHP
T4 $\frac{2}{25}\ \frac{11}{91}\ \frac{2}{16}$	MEP	HGP	MHP	MEP	MHP	MHP	MEP	HGP	MHP	HGP	MHP	HGP
T5 $\frac{1}{11}\ \frac{1}{7}\ \frac{12}{53}$	HGP	HGP	MHP	HGP	HGP	VHP	HGP	HGP	MEP	MHP	MEP	HGP
T6 $\frac{4}{57}\ \frac{6}{59}\ \frac{2}{13}$	MHP	MEP	MHP	MHP	MEP	MEP	HGP	MHP	MHP	HGP	HGP	MHP
T7 $\frac{4}{57}\ \frac{6}{59}\ \frac{2}{13}$	MHP	VHP	VHP	VHP	HGP	HGP	HGP	HGP	VHP	MHP	MHP	VHP
Pre-DM	$\frac{13}{43}\ \frac{7}{13}\ \frac{69}{73}$			$\frac{4}{13}\ \frac{17}{31}\ \frac{95}{99}$			$\frac{19}{59}\ \frac{37}{65}\ 1$			$\frac{9}{31}\ \frac{13}{25}\ \frac{87}{95}$		

Table P. Availability of sub criteria of Cost Structure in the Ytterbium suppliers

Sub Criteria	S1			S2			S3			S4		
	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3	ER1	ER2	ER3
C1 $\frac{4}{39}$ $\frac{16}{97}$ $\frac{9}{35}$	MHP	MEP	HGP	HGP	HGP	VHP	VHP	VHP	MHP	HGP	MHP	MHP
C2 $\frac{5}{54}$ $\frac{11}{74}$ $\frac{7}{30}$	HGP	HGP	MHP	MEP	MHP	HGP	HGP	MHP	MEP	MHP	MHP	MEP
C3 $\frac{1}{12}$ $\frac{7}{53}$ $\frac{14}{67}$	HGP	MHP	MEP	HGP	MHP	HGP	VHP	HGP	HGP	MEP	MHP	MLP
C4 $\frac{1}{27}$ $\frac{2}{37}$ $\frac{2}{23}$	MLP	MEP	HGP	MHP	MEP	MEP	HGP	MEP	MHP	MHP	HGP	HGP
C5 $\frac{1}{18}$ $\frac{6}{67}$ $\frac{14}{95}$	VHP	VHP	HGP	HGP	VHP	HGP	HGP	HGP	VHP	HGP	VHP	HGP
C6 $\frac{7}{52}$ $\frac{4}{19}$ $\frac{9}{28}$	MHP	VHP	VHP	VHP	HGP	HGP	HGP	HGP	VHP	MHP	MHP	VHP
C7 $\frac{1}{20}$ $\frac{2}{25}$ $\frac{3}{23}$	VHP	HGP	HGP	MEP	MHP	MHP	MEP	MEP	MHP	MHP	MEP	HGP
C8 $\frac{3}{37}$ $\frac{10}{83}$ $\frac{18}{97}$	MHP	MHP	HGP	HGP	VHP	HGP	VHP	VHP	HGP	HGP	HGP	MHP
Pre-DM	$\frac{16}{59}$	$\frac{23}{47}$	$\frac{46}{53}$	$\frac{7}{29}$	$\frac{42}{95}$	$\frac{27}{34}$	$\frac{1}{4}$	$\frac{39}{85}$	$\frac{50}{61}$	$\frac{7}{27}$	$\frac{8}{17}$	$\frac{31}{37}$