Characteristics of the EMAT-superformula

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ABSTRACT, The EMAT-superformula is currently being used at the Dutch Tax and Customs Administration to evaluate tender offers. The main benefit of this method is that scoring of the combination of price and quality can be done according to one's own preference instead of relative to other bids. However, the EMAT-superformula has several drawbacks concerning the sensitivity for price uncertainty. Additionally, the complexity of the EMAT-superformula causes this tender evaluation method to be less transparent than simpler methods. In order to eliminate the drawbacks while maintaining the positive aspects, an alternative method is proposed. This method is a variant of the quality-to-price method. A quality to price method subtracts the monetary value of the quality from the price of the bids. This method enables the buying agency to better value quality, while also being minimally influenced by price uncertainty. Additionally the quality-to-price method is simpler, causing this method to be more transparent than the EMAT-superformula.

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1.INTRODUCTION

When evaluating tender offers, a tender bid evaluation method is used to select the best offer in terms of price and quality. A large variety of methods have been proposed. One of these methods is the EMAT-superformula developed by Ir. J.C. Kuiper in cooperation with the Dutch Tax and Customs administration (DTCA). The EMAT-superformula is derived from Gielis (2002), in which a superformula is described and how its graph can transform into a wide range of natural and abstract shapes. With the EMAT-superformula it is possible to select, from an economical perspective, the best offer according to one's own preferences for quality and price. Currently however, the main drawback for this method is the fact that it utilizes a complex formula to select the best offer and therefore may have some drawbacks in communicating with internal customers, purchasing personnel and suppliers.

The concept EMAT will be used throughout this paper. In this paper we use the following definition;

EMAT: 'Abbreviation for Economic Most Advantageous Tender. With EMAT, other criteria next to price can be used to evaluate an offer. The Dutch law doesn't restrict the contracting authority in the amount and kind of sub-award criteria. However these sub-award criteria need to be relevant to the assignment. The sub-award criteria can for example include the effect on the environment, sustainability or the reliability of the supplier.' (PIANOo expertisecentrum aanbesteden, 2016).

The goal of this paper is to analyze the pros and cons of the EMAT-superformula and, with these issues in mind, attempt to propose an alternative method that incorporates the same advantages while eliminates most of the negative aspects. Derived from this goal, the following main research question has been formulated: How can the EMAT-superformula be improved for better communication? In order to find an answer to the main research question, several sub-research-questions have to be answered. These sub-research-questions are:

- What are the characteristics of the EMAT-superformula?
- What are the positive and negative aspects of the EMAT-superformula
- Is there another method that eliminates these negative aspects and maintains the positive aspects?
- What are the results of the adaptation?

Every section in this paper will answer a different sub question. Therefore, first the EMAT-superformula will be described in terms of the procedure and its functional characteristics. After this section the positive and negative aspects will be described, according to the interviews with several stakeholders of the EMAT-superformula. Subsequently, conform these aspects a new method will be proposed.

The practical relevance of this research is to give a clear insight in the implications and benefits of the EMAT-superformula, and develop an alternative tender evaluation method in collaboration with the DTCA that will be improved in terms of its communication to the internal and external customers. These insights could prove useful since a large amount of money is spent on suppliers that have been awarded the tender with such

a method. Therefore the selection of the best method of supplier selection is of great importance for the DTCA.

This paper is of academic relevance since very few papers have been written about the application of the EMAT-superformula in practice. Therefore this paper could be seen as an explorative paper that describes the implications of the EMAT-superformula and may expose possible points of improvement.

2.METHODOLOGY

As previously mentioned, the EMAT-superformula is currently being applied by the DTCA and the research for this paper will be done within this office. This section will go in depth into the methodology used to answer each sub-research question and how, at the end of this paper, a conclusion will be formed.

As mentioned above, in the third section the functional characteristics of the EMAT-superformula and the procedure in which the formula is being applied will be described. The first step in this section is to describe the procedure of using the EMAT-superformula to evaluate tender offers. This is done by looking into the procedure of scoring both price and quality. Other values that have to be determined will also be described in terms of their procedure and contents. Next will be described how all input variables form the final score and how the winning offer is determined. The next step is to show how different input variables influence the result of this evaluation method, and how these variables have influence on the weights of different factors. This is visualized using the graphs made with the spreadsheets provided by the DTCA. The goal of this section is to not only gain better insight into the required input variables of the formula and the procedure in which these input variables are determined, but also what influence these different input variables have on preference of the buying agency that is displayed to the bidders through the EMAT-superformula. This paper will focus on the functional properties of the EMAT-superformula and their economic consequences rather than the mathematical properties the EMAT-superformula has

The information that is required to describe these functional characteristics will be mostly gained from conversations with the advisors procurement economics at the DTCA. Furthermore, the information will also be acquired from an interview with Ir. J.C. Kuiper and the paper of Kuiper (2016) in which the EMAT-superformula is described.

The fourth section will discuss the positive and negative aspects of the EMAT-superformula. These positive and negative aspects are derived from open interviews with the internal stakeholders of the EMAT-superformula at the DTCA. Additionally, any complaints that the DTCA received from bidders concerning the EMAT-superformula will also be used to obtain information. The interviews will be done in an open and organic manner, meaning that no strict structure will be followed during the interviews. These interviews are meant to broaden the perspective that was formed of the EMAT-superformula. During these interviews is asked if they can name a case or more cases in which the EMAT-superformula has been applied and what their experience has been with the EMAT-superformula during that case. The goal of these interviews is to point out a number of aspects of the EMAT-

superformula that the interviewees have experienced as advantageous and disadvantageous. To achieve this goal, five interviews next to the conversations with two advisors procurement of the DTCA will be conducted. The opinions of both the users that have in depth knowledge of the formula and the opinions of the stakeholders that do not have in depth knowledge of the formula are important. Both opinions are important since in order to improve the internal communication of the formula, the EMAT-superformula should be understandable to both types of users.

At the end of section 4, a list of requirements will be made. This list will be made up of summarized versions of the positive effects the new method has to contain and the negative aspects the new method should eliminate that were mentioned in this section.

In the fifth section an alternative tender evaluation method will be proposed. This alternative method should comply to the list of requirements that has been described in the previous section.

This new method will be found by point-by-point evaluation of the list of requirements and a solution will be proposed by using available literature that identifies these problems and proposes possible alternative methods to deal with these problems. The opinions of experts in the tender evaluation field will also be utilized.

In the sixth section the characteristics of the alternative method will be described, and how this new method complies to the list of requirements. This will be done using the literature that has been found about the alternative method and opinions of experts in the public procurement field.

3. FUNCTIONAL CHARACTERISTICS

3.1 The procedure

One of the documents that is released during the publication of a tender is the specifications document. In this document is described (among other information) what the content of the tender is, what the requirements of the tender are and what the wishes of the buying agency are concerning the quality of the product(s). Most importantly, in this document is described how the price and quality of an offer are combined into a score in detail for this particular tender.

3.1.1 Scoring and measurement of quality

In order to score the quality of an offer, the quality as described by the bidder has to be quantified. In case of the EMAT-superformula, the total quality is divided into requirements and wishes. At the DTCA, the determination of the wishes, requirements and the weights is done by a multi-disciplinary team. This team, as the name implies, is formed from advisors, purchasers and specialists from the relevant departments. In case of an IT tender, an IT-architect could for example be included in the team. An advisor would for example be someone that has in-depth knowledge of the evaluation method, in this case the EMAT-superformula. Important to note is that the determination of wishes and requirements is done before the tender is published and the bids have been done. This is to decrease undesirable effects such as favoritism.

The first part of the total quality are the requirements. The requirements, as the term implies, are the aspects of the tender that are obligatory to be fulfilled by the bidder. If a bidder were to be unable to fulfill one of the requirements, it would result in an immediate knockout, meaning the bid is laid aside. Requirements range from legal requirements to requirements about the contents of an offer. For example, a requirement could be that the supplier is required to repair a broken machine within 1 day of notifying.

The rest of the quality consists of the wishes. The wishes are the part of the quality where the bidder can differentiate himself in terms of quality from the other bidders. Every wish has a weight in the form of a maximum amount of points that a bidder can score on that particular wish. For example, a wish could be: "Employees should be able to use the tool within a maximum of 3 days". An example of a scoring system could be, 3 days awards 0 points, 2 days awards 5 points and 1 day will score the total amount of points which is 10. Wishes however, are not always additional services or products that are delivered. Wishes can also be formulated to verify a requirement. A requirement for example can be that the tool is easy to use. 'Easy to use', is a subjective term that, by answering this question with yes, might not mean that the program is actually easy to use for someone that is for example not as skilled with computers. Therefore a wish could be formulated as previously mentioned, in which is verified that the program can be learned by anyone in a maximum of a certain number of days. One could state that this does not imply that by fulfilling this wish, additional quality is delivered. However one could also argue that this additional quality is actually delivered in the form of reliability that the tool is actually easy to use and therefore the requirement is fulfilled.

Weight has been given to the requirements and wishes in the form of a maximum amount of points. On certain wishes and requirements, more points can be scored than with other wishes, the more points can be scored, the higher the weight of the wish or requirement. Additionally, the multi-disciplinary team can decide what part of total quality is fulfilled by the wishes and what part are requirements. Therefore, the buying agency has the choice to apply weight to the requirements and wishes overall. This is a unique aspect of the EMAT-superformula since other methods only take wishes into account when assessing quality.

When scoring bids, the points scored for the wishes will be accumulated and added up to the points scored by meeting the requirements, assuming the requirements are fulfilled. The accumulated amount of points of both the wishes and the requirements is called Q_{bid}. We can state that:

$$Q_{bid} = Q_{requirements} + Q_{wishes}$$

3.1.2 Determination of the reference point

Using the EMAT superformula requires the buying agency to determine a reference-point. This reference-point is defined as the expectation of the buying agency of the price and associated quality and is determined before the tender is made public. The reference-point is made up of P_{ref} and Q_{ref}. P_{ref} is the expected price, and Q_{ref} is the associated amount of quality points. At the DTCA the reference-point is found using

historical data of comparable tenders, a market analysis and/or advise of experts.

With all these values determined, the scoring of quality can be done. The following scoring formula is used to score quality:

$$Qscore = (2 - \frac{Q_{bid}}{Q_{ref}})$$

As can be seen in the formula, the Qscore is determined via a linear formula and can range between 2 and 0. This formula scores the amount of quality points scored by a particular tender offer relative to the Q_{ref}. The lower the score, the better the score is.

3.1.3 Scoring of price

The EMAT-superformula requires the user to transform the price of the bid into a score. The price of an offer is scored using the following formula:

$$Pscore = (\frac{P_{bid}}{P_{ref}})$$

The score of the price of an offer is called P_{bid} and the P_{ref} is the price of the reference-point that was previously determined. The price of an offer is scored relative to the reference price that has been set beforehand. As is the same with Qscore, the lower the score, the better the score is.

3.1.4 Determination of the n-value

The next step is to determine the n-value that will be used in the EMAT-superformula. In order to do this, another point has to be determined. This point is called the maximum-point and requires the buying agency to determine the price it is willing to pay if maximum quality is achieved. This price is called P_{max}, and the quality points associated with this price is called Q_{max}.

The n-value is determined by taking into account the difference in price and quality between the reference point and the maximum-point.

At the DTCA, the n-values are determined using a solver to draw the curve through the reference-point and maximum-point using the EMAT-superformula. Therefore, as will become evident later in this paper, the n-value determines the curvature of the lines that are formed by the EMAT-superformula

3.1.5 The superformula and awarding procedure

The next step is to fill in the EMAT-superformula to combine the Pscore and the Qscore according to the predetermined n-value. In order to do this, the following formula is used:

$$EMAT = \sqrt[n]{0.5(Pscore^n + Qscore^n)}$$

The EMAT-score is determined by combining both scores into a formula that can be graphically displayed with so called EMAT-lines. These EMAT-lines are derived from the buyer's own preference and display the lines in which a certain score is achieved. Figure 1 displays an example of the EMAT-superformula with n =2 with P in euros and Q in points.
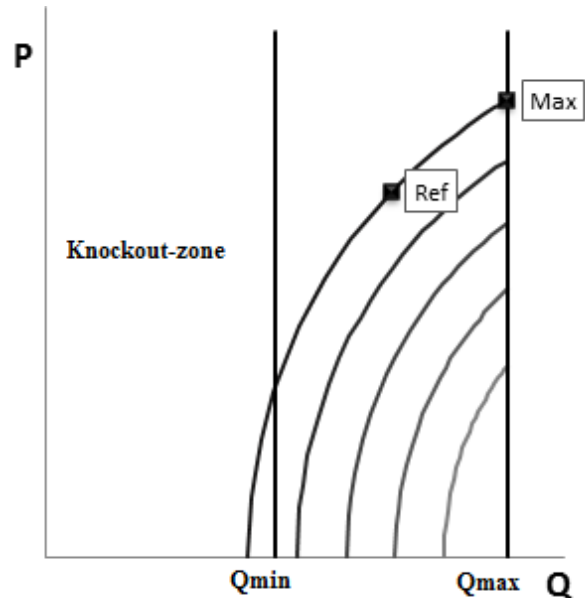

Figure 1. EMAT lines visually displayed with n = 2

As can be seen in figure 1, the reference-point and the maximum-point have been indicated, and a line according to these points with n = 2 has been plotted. The line on which the reference-point and the maximum-point lie is scored EMAT = 1. The lines below EMAT = 1 display EMAT = 0.9; 0.8; 0.7; 0.6 respectively. The lower the EMAT score of a certain bid on the tender, the better that particular supplier scores. Also displayed in the graph are two vertical lines. The left vertical line displays the minimum quality that is scored when only the requirements are fulfilled (Q_{min}). The right vertical line displays the quality if all requirements and wishes are fulfilled (Q_{max}). In practice, the area left of the Q_{min} line is called the "knock-out zone". The bids that score in this zone will not be taken into account since the requirements were not met and therefore quality is insufficient.

After the bids have been scored using the EMAT-superformula they can be added to the graph with the EMAT-lines. In figure 2 a theoretical case is displayed in which supplier A, B, C and D have been evaluated. Their EMAT scores are 0.915, 1.016, 0.884 and 0.922 respectively. Looking at the scores and their place in the graph, supplier C should be awarded this tender since it has the lowest EMAT score.

The procedure of combining price and quality into a single score are visualized in figure 3.
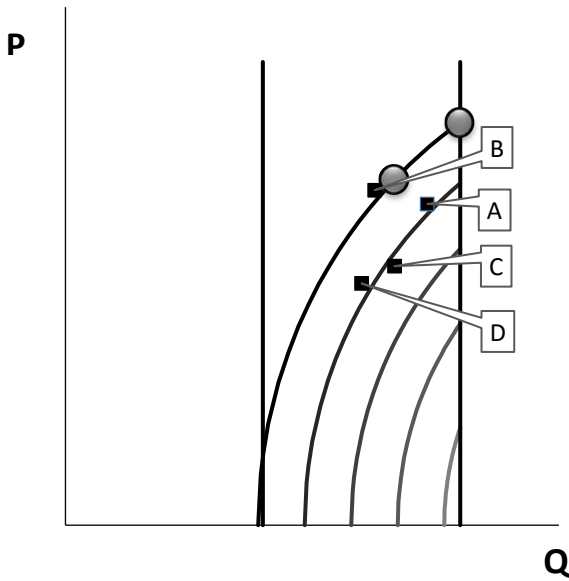
P

Q

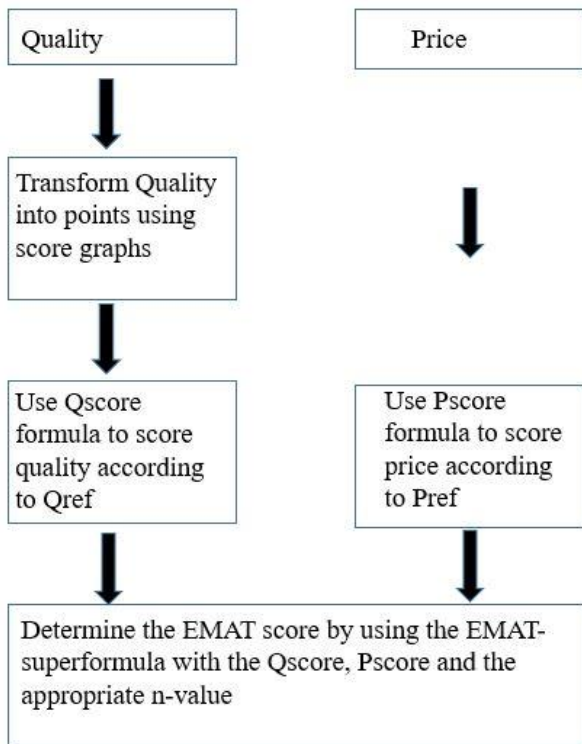**Figure 2. Theoretical case with n=2**

Figure 3. Visualization of quality and price scoring for the EMAT-superformula.

3.2 Functional characteristics

3.2.1 Preference at micro and macro level

We can state that the preference of the buyer can be displayed at two levels during the procedure. The first level is at the micro level, in which the score graphs are determined. At this level different weights can be given to wishes by assigning a certain amount of points to a wish. By assigning different amounts of points to different wishes, different weights can be given to the wishes. For example, if the maximum amount of points a bidder can score on one wish is higher than another, the weight of this wish is greater. Therefore applying weight to the wishes by for example using a multiplier for a wish is redundant, since the weight has already been given to a wish in the form of points.

The second level in which the preference of the buyer can be represented is at the macro level. The preference at the macro level can be displayed in the EMAT-lines using the n-values. The next sub-section will describe in depth how the n-values influence the displayed preference of the buying agency in the EMAT-lines.

3.2.2 Weight of quality at different n-values

As was mentioned in the introduction, the EMAT-superformula is derived from a formula designed to be able to transform into a wide range of abstract shapes. If one would view the total graph that is formed by the EMAT-superformula, one would see that at n=1 the lines continue their linear path, at n=2 the formula forms a perfect circle and with n = 7 an almost square like figure is formed. The EMAT-superformula is able to use these characteristics to form EMAT-lines with different curvatures that resemble one's own preference. The curvature can be adjusted by adjusting the place of the reference-point and the price one is willing to pay for the maximum quality. By changing these variables, the n-value is changed and thus the curvature of the EMAT-lines. As one might recognize, the EMAT lines show similarities with the indifference curves described by the established economic theory that as quality at the macro level increases, one wants to pay increasingly less per additional amount of quality that is added. These properties can be seen in the EMAT-lines. In the case of the EMAT-superformula, the n-value determines the degree of curvature. Therefore the weight of quality at different points along the EMAT-lines are directly influenced by the n-value.

In practice, the n-values range between the two extreme cases displayed in figure 4 and figure 5. In figure 4 can be seen that with a n-value of n=1, the EMAT-lines show a linear pattern. N=1 visualizes the buyers preference in which he is willing to pay the same additional amount for every additional quality point that is added on top of the reference quality. This is also the case on the left side of the reference point. In the case of a larger n-value, which is displayed in figure 5, the EMAT lines become increasingly curved. This extreme curvature at n=7 results in the fact that the reference-point becomes a corner point in the graph, resulting in an almost vertical line beneath the reference-point and an almost horizontal line next to the reference-point. The n value of n=7 results from the preference of the buyer that he is only willing to pay a very small extra amount for the additional quality that is delivered on top of the reference quality. Unlike with n=1, to the left of the reference price shows another preference that may or may not have been the preference of the buyer. If one follows the EMAT-lines (with n greater than 1) from bottom to top, one can see that the slope of the line decreases. This shows that the buyer is willing to pay increasingly less for a certain increase in quality
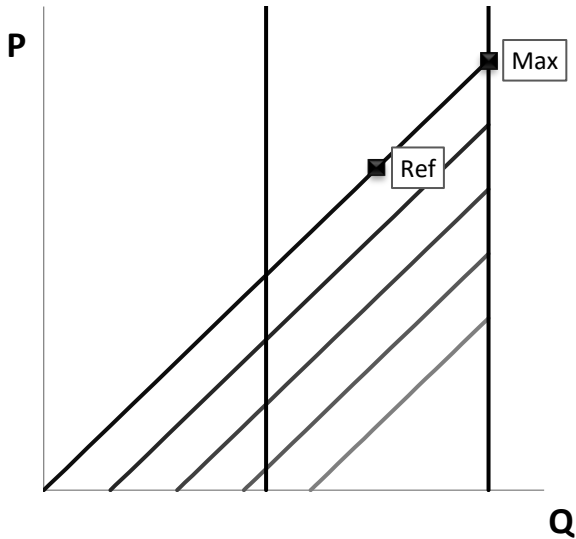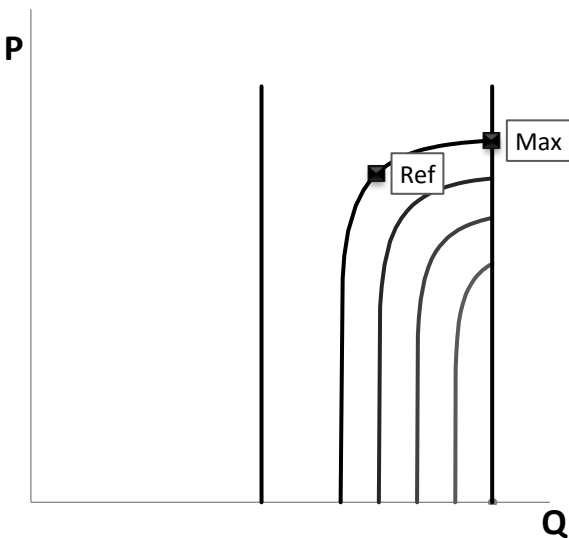
Figure 4. EMAT-lines with n=1

Figure 5. EMAT-lines with n = 7

The average slope left and right of the reference point indicates the degree of importance or weight that has been given to changes in price and quality of the offers. These degrees of importance are displayed in table 2 for n=1, n=2 and n=7

Table 2. Degrees of importance for quality

Side of the reference point	Degree of importance for quality		
	n=1	n=2	n=7
Left	50%	71%	91%
Right	50%	45%	30%

As can be seen in table 2, the n-value that has been determined has a significant influence on the degree of importance of quality at different sides of the reference point. Therefore the placement of the reference point and the maximum point have

significant influence on the degree of importance along the EMAT-line.

4.POSITIVE AND NEGATIVE ASPECTS

As previously mentioned, several internal stakeholders within the DTCA have been interviewed to give their perspective on the EMAT-superformula and its application in practice. It became clear that most people viewed an EMAT tender evaluation method only as a tool in which they want their preference to be reflected and in a clear way a winner to be appointed.

4.1 Positive aspects

During the interviews the interviewees pointed out that the customizability of the EMAT-lines was something most purchasers were positive about. In 30 of the 31 cases the use of the EMAT-superformula when evaluating bids on tenders has resulted in no complaints from bidders. In several cases the procedure of the EMAT-superformula even resulted in positive feedback that has been given to the DTCA by bidders. This positive feedback included that the bidders felt that with this evaluation method they can get a clear view on where they stand on their price and quality combination of their offer. A list of all previous cases in which the EMAT-superformula has been applied together with their n-values is displayed in Appendix A.

The main positive aspect of the EMAT-superformula is the fact that the EMAT-lines are customizable according to one's own preference. And therefore can display curvature. Although crafting these lines may require some training, the EMAT-superformula enables the user to do this. The n-value that is determined using one's own preference determines the curvature of the EMAT-lines, enabling the user to display their preference in a linear or non-linear manner. As was previously mentioned, with a n-value larger than 1, the EMAT-curves are shaped in a way that can be compared to the preference of the buyer described by the established economic theory of the indifference curves or utility curves. Furthermore, the ability to display curvature in the EMAT-lines gives the ability to the user to award tenders to bids that, with a linear method, never would have been selected. These situations are described in the paper of Kuiper (2016).

4.2 Negative aspects

In this section, the complaint the DTCA received from one case and the notes from the open interviews will be used.

4.2.1 Determination of reference-points

The first negative aspect was about the determination of the reference-points. The internal stakeholders liked the idea that one can input their own preference into the EMAT-superformula. However, one drawback of these reference points was that they were sometimes hard to determine because of price uncertainty. As was shown in the previous section, the placement of both the reference point and the maximum point have a significant impact on the curvature of the EMAT-lines. Therefore, if one were to place these points in a less elaborate

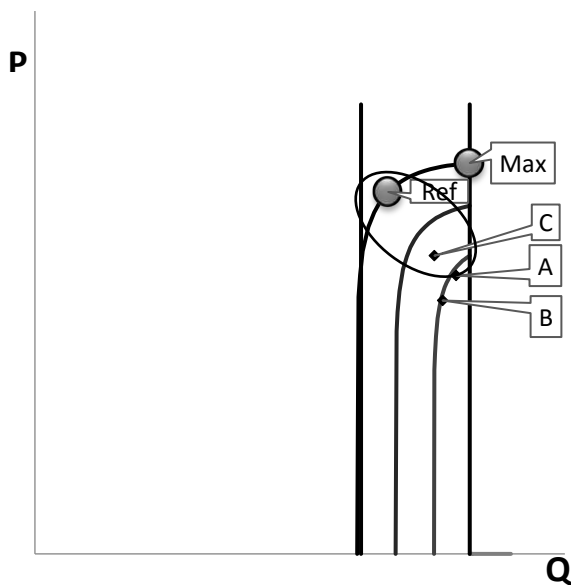way, the curvature of the EMAT lines could show undesirable results. The following case displays this issue.

Figure 6. Previous case of the DTCA

Table 3. Results of the case with the EMAT-superformula

Supplier	Q	P	EMAT score
A	775	€ 3.843.984,40	0.790
B	750	€3.499.809,57	0.796
C	735	€4.119.668,53	0.849

In the graph above, EMAT-lines with n=8.236 and the bids of a previous case are visualized. This case is referred to in Appendix A as "European Tender 13". In figure 6, a circle has been drawn. This circle visualizes the area in which the buying agency expects the bids on the tender to be placed. However, as can be seen in the graph, the cloud of bids is shifted down right of the circle. Outside the circle lies the area in which the EMAT lines may give unwanted results. If the "cloud" of bidders were to be in the area under the circle for example, quality is given an high weight that in most cases is not desirable. As was in the case mentioned above. The 25 quality points difference that can be seen between supplier A and B is caused by one quality aspect. Table 3 shows that the price difference between the bids is significant meaning that the DTCA displayed to be willing to pay a significant amount of additional money for only a relatively small amount of extra quality. Supplier A has been awarded the tender while only having a little extra quality, but with a price that seems too high for that addition of quality. The DTCA was not satisfied with the result since it did not display their preference properly. Next to this, supplier B filed a complaint stating that quality has been given too much weight in their case. The same problem is with the area to the right of the circle, where the EMAT lines are almost horizontal. In this case price is given an extremely high weight, that may give undesirable results. If the cloud of bids were not to fall in the expected zone, the bids would be evaluated with "the wrong" curves, meaning they don't represent the actual preference, but are more or less a result of

wrongful price estimation. In figure 2,4 and 5 can be seen that the area in which the EMAT-lines are almost horizontal or vertical is larger as the n-value increase. Therefore the higher the n-value, the larger the area in the EMAT-line graph in which the EMAT-superformula may give undesired results. This results in the fact that while the n-value is determined by the difference between the maximum-point and reference-point, it actually becomes a degree of uncertainty rather than an indication of personal preference. The higher the n-value the greater should be the certainty of the buying agency to know where the cloud of bidders will form. The EMAT-superformula with a high n-value may work well in case of zero price uncertainty. In practice however, particularly in the IT sector, price uncertainty is something that exists almost constantly.

To summarize, in case of high price uncertainty, a low n-value is recommended. When price certainty becomes greater, a higher n-value is possible.

In Appendix A is visible that over time the n-values for tenders has decreased. This resulted in the fact that over time less risk was taken by the DTCA and therefore the risk for these problems to occur has also decreased.

4.2.3 Locally determined preference

Next to the fact that the reference points may be hard to determine when price uncertainty is high, the overall preference is determined based on local preferences. This is due to the EMAT-line being drawn according to the difference one wants to pay between the maximum-point and the reference-point. This means that one's overall preference is based solely on one's preference of price difference between these points. If one bases one's maximum price on the budget that has been set on a particular tender, the difference between the two reference points may be very small, causing the n-value to be high. This indication of preference at the right side of the reference-point, thus caused the line left of the reference-point to be almost vertical. This local preference determined between the reference point and the maximum point may cause the preference displayed left of the reference point to be undesirable.

In conclusion, when using the EMAT-superformula, the user should be aware of the results for their overall preference when determining the place of the two reference points.

4.2.4 Transparency in quality preference to internal and external customer

Determining the weight of the wishes was another complication indicated by the interviewees. It was unclear, when determining the amount of points that can be scored by fulfilling a certain wish, what the effect was on the overall preference that is communicated to the bidders. For example, as displayed in the case in figure 6, for only one small quality aspect, their EMAT-lines indicated that they were willing to pay a significant amount of additional money for only a small amount of additional quality. When awarding points to certain wishes at the micro level it may be unclear what the effects of the amount of points awarded are since overall quality is also valued at the macro level. This becomes a larger problem the greater the n-value becomes.

The same can be said from the bidders perspective. For the bidder, additional value that has been added by fulfilling wishes may be unclear. This is since these scores are not only scored at the micro level, but also at the macro level in which the points are valued differently overall at different levels of quality. The weight applied to quality at the micro level is not visible in the EMAT-lines, since these only display the preference of the buyer at the macro level. This complexity may therefore result in decreased transparency for the buying agency concerning the effect of the determination of the input variables and decreased transparency for the bidders concerning the effect on the score when adding quality.

Currently, when determining the variables, tools have been developed that give a visual representation of the EMAT-lines according to the input variables. This tool is also available for the bidders. It may help the buying agency and the bidders in determining the effects at the macro level of changes in input variables.

4.3 List of requirements for the proposed supplier evaluation method

As can be concluded from section 4, the EMAT-superformula performs well in most cases. However in cases where price uncertainty is high, a high value imposes risk on good supplier evaluation. These drawbacks can mainly be prevented by the proper placement of the reference points, in a manner that may protect against unwanted results because of price uncertainty. This however requires education, professional expertise and in depth knowledge of the EMAT-superformula, and price certainty. It is therefore interesting to check whether there are simpler methods in which the preferences can be displayed just like the EMAT-superformula does, but without these complications.

Concerning the aspects that the new method should maintain, the new method should maintain the customizability according to one's own preference. This means that along the quality scoring curve, additional quality could be valued according to one's own preference, whether these are indifference curve like characteristics or other preferences. The new method should also make the user aware of the total value of wishes and consciously determine what part of this value is fulfilled by every wish. This should be done in order for the user to get a good view of what the weight of the wishes are relative to each other.

Unlike the EMAT-superformula the new method should be minimally affected by price uncertainty. This means that the effectiveness of the new scoring method should not be depended upon certainty of what the price and quality ratios of the bids will be. Next to this, overall the new supplier evaluation method should be transparent in its use. This means that if a certain amount of weight in the form has been given to the fulfillment of a wish, the effects this has on the overall preference one communicates should be clear. Additionally, the preference should be based on one's overall preference rather than a locally determined preference as is currently the case with the EMAT-superformula.

This gives us the following list of requirements:

- The new method should value quality addition differently at different levels of quality, according to one's own preference
- The displayed preference should be based on one's overall preference, rather than one's local preference
- The new method should be minimally affected by price uncertainty
- When determining the input variables, the effect this displayed preference has on the scoring should be communicated clearly to the buying agency and the bidder.

5. PROPOSED SUPPLIER SELECTION METHOD

5.1 Quality-to-price methods

In order to comply to the list of requirements, a quality-to-price method is proposed. Quality-to-price methods were compared to price-to-quality methods in Bergman & Lundberg (2013). This paper described, among other things, the effect of price uncertainty on both methods.

Quality-to-price methods are methods in which the quality value in excess of the minimum can be subtracted from the price bid i.e. the supplier selection method will be quality adjusted lowest price (Bergman & Lundberg, 2013). This new method would lead to the following EMAT formula:

EMAT (in monetary value) $= P_{bid} - P(Q)$

The following input variables are needed in order to apply this method: the price of the offer (P_{bid}) and the sum of the monetary value of the wishes that have been fulfilled ($P(Q)$).

The supplier with the lowest EMAT score, meaning the lowest price after the evaluation should be awarded the tender.

Awarding on Value (AOV) is also a quality-to-price method and may seem similar to this method. However, one of the most important differences is that AOV values quality exclusively in a linear manner, while the method in this paper does not.

5.1.1 Determining the value of quality

The first step in determining quality is the determination of the monetary value of all the wishes. Subsequently, different score graphs can be made per wish. Per score graph can be determined in which manner is scored. This should be done according to the users personal preference for monetary value addition, per addition of quality within a wish. One should rely on what the wish is worth to the buying agency, instead of estimating what the wish is actually worth. In figure 7 the steps are visualized that are necessary in order to score quality with the quality-to-price method.
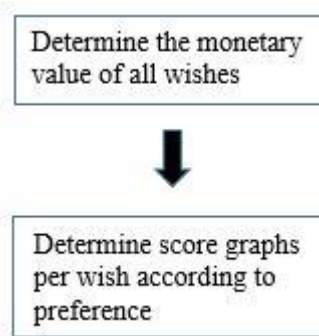
Figure 7. Visualization of the determination of quality

In table 4 and figure 8 is an example displayed of a score graph that values quality addition within a wish. The example displays the value of the amount of service employees that are at place directly available for maintenance.

Table 4. Value of service employees

# service employees	Value
6	€ 725,00
5	€ 675,00
4	€ 600,00
3	€ 500,00
2	€ 320,00
1	€ 160,00
0	€ -
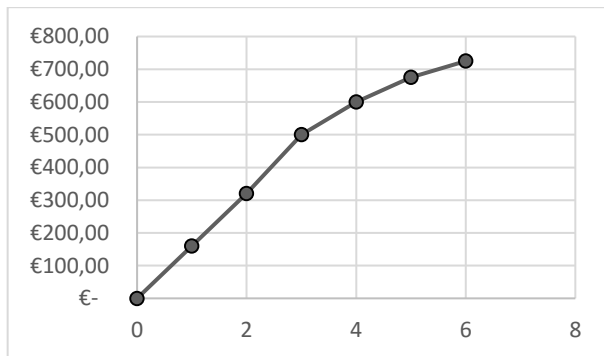
Figure 8. Score graph service employees

As one can see in figure 8 and table 4, every added service employee is valued less, therefore this wish is scored in a non-linear manner.

The bids are scored per wish according to the score graphs. This results in an accumulated monetary value achieved by fulfilling wishes. As was already mentioned above, this monetary value will be subtracted from the price of a bid in order to come to a final score.

Since the requirements are fulfilled by all the suppliers in order to qualify for the tender, subtracting the value of the requirements is redundant.

5.2 Benefits of quality-to-price scoring

5.2.1 Quality scoring

Using quality-to-price scoring has a number of benefits that have been discussed in literature. The benefit of transforming quality into price has been discussed in (Bergman & Lundberg, 2013) and (Dreschler M. , 2008). In (Bergman & Lundberg, 2013) is indicated that quality to price scoring is preferable to price to quality scoring since we are all used to making assessments in monetary terms when making choices between products that differ in terms of quality and that "Quality validation as a scoring rule for supplier selection also has the advantage that ranging of the bids will not depend on irrelevant alternatives (non-competitive bids)". Although one can't classify the EMAT-superformula as a price-to-quality method, since both of the quality and price are transformed into one score. Quality in the EMAT-superformula is transformed into points rather than monetary value. As was already mentioned earlier, this often leads to confusion about the effects that a certain amount of points awarded by fulfilling a certain wish has on the total evaluation. Furthermore, "literature and field experts state that the monetization systems deserves priority, because it is clearer for everyone involved when value is expressed into money." (Dreschler M. , 2008)

If one were to score a wish in terms of what the buying agency is willing to pay for a certain increase in quality, transparency increases and it may be clearer to the internal stakeholders. The buying agency should focus more on what the fulfillment of the wish is actually worth to them, rather than trying to determine the actual value of the wish. In the case that quality scoring is based more on individual willingness to pay for a certain addition of quality, the communication to suppliers may also increase. If the value that is awarded by the buying agency is significantly larger than what the quality addition actually costs, more preference is given to fulfilling that particular quality aspect by the supplier. On the other hand, if the buying agency awards less additional money to a certain wish that what the addition is actually worth, the result may be that that particular addition of quality may not be worth it for both the supplier and the bidder. This is based on the assumption that the supplier has perfect knowledge of prices.

5.2.2 Price scoring

Absolute price scoring implies that the price scoring mechanism does not determine the price score relative to other bids, but rather scores price relative to an absolute point set by the buying agency. The price scoring mechanism of the EMAT-superformula can therefore be classified as absolute. However, this scoring technique is still relative to one's own reference price. As was shown before, this reference price may be hard to determine. In the case of a quality-to-price method, price remains unscored, and therefore utilizes neither an absolute nor a relative price scoring mechanism.

6.RESULTS OF ADAPTATION

6.1 Compliance to the list of requirements

In order to check whether the new method eliminates the negative characteristics while maintaining the positive

characteristics of the EMAT-superformula, the quality-to-price method needs to comply to the list of requirements.

6.1.1 Different value of quality addition on different places along the curve

The first point on the list of requirements was that the new method should be able to display one's preference for quality addition at different levels of quality. If one would follow the EMAT-line with EMAT=1 in a graph with n=2, one will see that every quality addition is valued less as the level of quality increases.

The same can be achieved with a quality-to-price method. This can be done, not by using a complex formula, but by manually assigning different values to different quality additions within the wishes. Therefore in the quality-to-price method instead of valuing quality addition exponentially less as quality increases at macro level, this is achieved at the micro level. The wish displayed in table 6 and figure 8 is used to illustrate this. In order to visualize the effect that this wish has on the score, the amount of service employees on the x-axis is plotted against the score on the y-axis. This is visualized in figure 9.
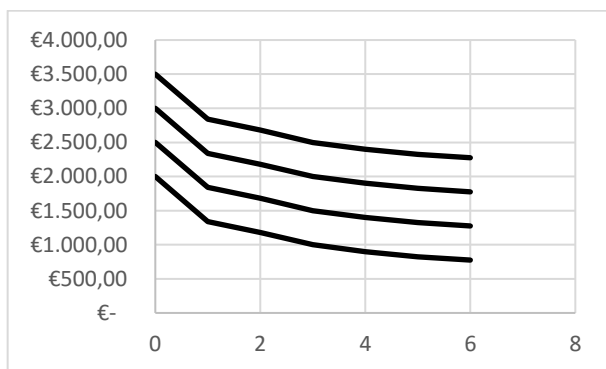

Figure 9. EMAT score per quality addition

In figure 9 one can see different lines that resemble the changes in in the EMAT-scores if quality increases. The different lines resemble the score changes for bids with different prices. The bid prices from top to bottom are 3500, 3000, 2500 and 2000. One can see that for every bid price, the effect of the wish is the same.

In reality, it is difficult to display the scores in one graph. This is due to the fact that a large possible number of wishes may or may not influence the score depending upon whether they are fulfilled or not. In the case of a larger number of wishes, the effects of a wish on the total score can be enhanced or be compensated by another wish. Therefore the macro effect of displaying one's preference at the micro level will be derived from the combined preference in terms of valuating quality addition displayed in all wishes.

6.1.2 Customizability according to one's overall preference

The next point on the list of requirements is that the scoring system should be customizable according to one's own preference. The EMAT-superformula allows the user to show their own preference by being able to input different n-values that determined the impact of quality on the EMAT-score. In 6.1.1 was shown that this preference can also be represented when determining the score graphs at the micro level. With the quality-to-price method, it is possible to adjust the curvature of the graphs. This can be done by adjusting one's preference of value addition when quality increases. Because this value addition is determined for quality addition at every quality level, the displayed preference shows the overall preference of the buying agency instead of only the local preference as was the case with the EMAT-superformula.

Additionally, since the score graphs are plotted according to a table, all kinds of different curves can be used to display one's preference at the micro level. This means that s-curves, linear lines, convex lines and concave lines can all be displayed as preference in a score graph. This could also have been done at the micro level with the EMAT-superformula, but as was already previously mentioned, this would make the preference even less transparent since at the macro level linear or concave preferences are displayed for total quality valuation.

6.1.3 Price uncertainty

As was already mentioned before, quality-to-price methods require no direct price estimation. This is because the price of the bid is taken as initial score and the quality in monetary value is subtracted from this score. The buying agency should base the value of a wish on the value the buying agency is willing to pay for a certain value addition. In this way, the weight of quality relative to price will be determined unconsciously. To illustrate this, imagine the following case. The total value that is given to the fulfillment of wishes is €500. If the price of the bid were to be €700, the weight of the wishes would be higher than at the price level of €1000. The contrary happens if the bid would be €1300, since in this case the weight of the wishes would be lower than at the price level of €1000. Therefore implicitly, the weight of quality is different along different levels of price. This means that when determining the monetary value of the wishes, the weight of quality relative to price is determined indirectly according to one's preference.

6.1.4 Transparency

Figure 10 visualizes the price and quality scoring for the quality-to-price method. Instead of representing the preference of the curvature in the last step of the procedure, the quality-to-price method simplifies this by doing this in the first step alone. When applying the EMAT-superformula, one also has the possibility to visualize this preference in the first step, next to visualizing the macro preference too in the last step. This would only decrease transparency even more for the buying agency, however since the preference would be represented in two steps. Only representing the preference on the micro level with the score graphs is not a replacement for the EMAT-line curvature, since this values quality and price at the macro level. However, by only representing the preference at one step in the

process, the influence of a wish becomes more transparent, while still being able to display the preference of the user. The bidder will also be able to easily see on which quality aspect they lack value in the score graphs. This lack of value will be directly subtracted from the score. Therefore, the process will also become more transparent for the bidder.

The EMAT-superformula with n=1 and the preference displayed in the score graphs can be compared with the quality-to-price method in terms of results. However, the EMAT curve with n=1 does not display the micro preference, since the linear line shows only the macro preference. Therefore, in terms of transparency, this may be confusing to the bidder as well as the buying agency.
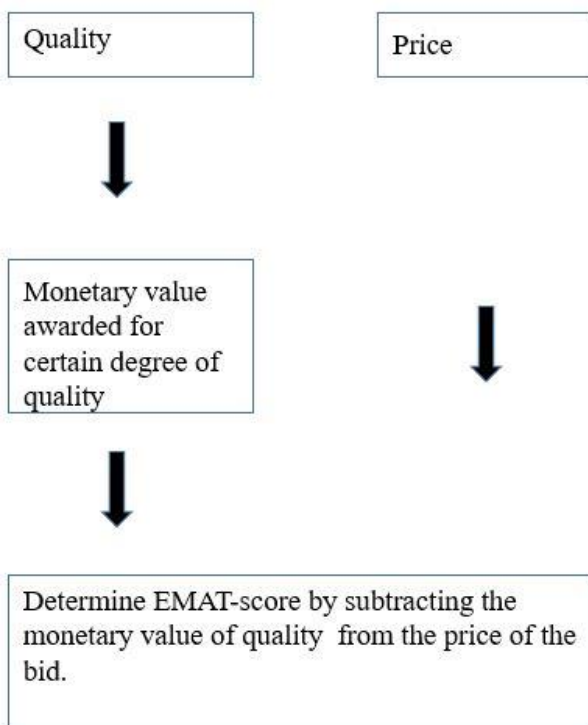
Figure 10. Visualization of the price and quality scoring of the quality-to-price method.

7.CONCLUSION & DISCUSSION

The main research question in this paper was: : How can the EMAT-superformula be improved for better communication? To answer this question several sub-research questions have been answered and described in the previous sections. As a result of these research questions a variant of a quality-to-price method has been proposed. The drawbacks of the EMAT-superformula were mostly caused by its complexity and sensitivity to price uncertainty.

In order to eliminate the negative aspects, the alternative method:

- Utilizes a simpler method, causing the transparency of the new method to be higher.
- Determines the displayed preference based on one's overall preference, rather than only a local preference
- Reduces sensitivity to price uncertainty, since the value of quality is determined according to one's own

willingness to pay for a certain quality addition. Additionally, the new method does not require the user to determine reference points.

In order to maintain the positive aspects, the alternative method:

- Values quality addition differently at different levels of quality according to one's own preference

The new method is less complex and enables the user to display their preference the same way. This results in a method that is easier to communicate to the internal as well as the external customers. One matter of discussion is what the influence is of both displaying one's preference at the micro and macro level. It may be interesting for further research to see whether the additional complexity of displaying preference in macro level too adds to the effectiveness of the evaluation method.

If the DTCA continues to use the EMAT superformula, they should take into account price uncertainty when assigning n-values. Further research could be done concerning the risk of "wrongful" evaluation when assigning certain n-values. Next to this, the DTCA should also translate the point system that is currently being used to a monetary value system. A monetary valuing system has several benefits over a point systems, as have been described in this paper.

The research for this paper was done within the IT purchasing department of the DTCA, therefore only the aspects concerning the application of the EMAT-superformula in an IT environment have been researched and taken into account. In for example the construction market, where price uncertainty may be less common, a method that requires the buyer to estimate a reference price may have better results. One should take into account that there may not be one method that fits all environments, but rather several methods that work better in different environments. Future research could explore which tender evaluation methods fits which environment.

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9.APPENDIX

Appendix A:

Cases Applied/finished with the EMAT-superformula

#	Unit	Year		Name (anonymous)	# parts	N-value
1	ICK		2012	European tender 1	1	3,369
2	ICT		2013	European tender 2	1	3,089
3	ICT		2013	European tender 3	1	3,757
4	ICT		2013	European tender 6	2	1,975
5	ICT		2013	European tender 7	1	2,000
6	FD		2013	European tender 8	1	3,530
7	ICT		2014	European tender 9	1	4,190
8	ICT		2014	European tender 10	1	2,000
9	ICT		2014	European tender 11	1	3,572
10	ICT		2014	European tender 12	1	3,370
11	ICT		2014	European tender 13	1	8,236
12	ICT		2014	European tender 14	1	3,573
13	ICK		2014	European tender 15	1	1,805
14	ICT		2014	European tender 22	1	1,000
15	ICT		2014	European tender 23	1	1,000
16	ICT		2015	European tender 4	1	4,478
17	ICT		2015	European tender 5	1	2,000
18	ICT		2015	European tender 16	1	4,675
19	ICT		2015	European tender 17	1	1,508
20	ICT		2015	European tender 18	1	2,000
21	ICT		2015	European tender 19	1	3,370
22	ICT		2015	Quotation 1	1	1,975
23	ICT		2015	European tender 24	1	1,000
24	ICT		2015	Quotation 2	1	3,311
25	ICT		2015	Quotation 3	1	2,000
26	ICT		2015	Quotation 4	1	3,597
27	ICT		2015	Quotation 5	1	3,597
28	ICT		2016	European tender 20	1	1,000
29	ICT		2016	European tender 21	1	2,000
30	ICT		2016	European tender 25	1	1,000
31	ICT		2016	Quotation 6	1	1,000

N-value of the EMAT-superformula