

# Sustainable Procurement for Port Infrastructure Projects

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**Abstract** There is a growing number of ports with sustainable policies. At the moment most of these policies are focused on clean transport. This study handles ports themselves by implementing sustainable criteria for the procurement of infrastructure projects. The aim is to get a balance between People, Planet and Profit. This means that those sustainable criteria have to be compared with the investment costs. A solution of this problem is given by setting a procurement model based on the so called concordance analysis, in combination with criteria which are based on the 3P theory and Life Cycle Analysis. Furthermore, the position of both client and contractor are taken into account by giving recommendations about contracting forms. As part of the research interviews were done with stakeholders as governments, port authorities and contractors. These interviews formed a basis for the obtained model.

**Keywords** Sustainable port development • Infrastructure projects • Procurement • Life cycle analysis • Value management • Sustainable management • Contract forms • Concordance analysis

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## Introduction

While in other industries sustainable management is of the order of the day, sustainability is still in many ports' infancy. It is not only the legislator which forces ports to sustainable management, but also the society as a whole. More and more economic experts are convinced about the lower costs on the long term as a result of sustainability.

The port of Los Angeles was one of the pioneers of ports on this field by starting in 2006 the San Pedro Bay Ports Clean Air Action Program (CAAP): it was the most ambitious program in the world for cleaner ports. It led to emission reductions of 50–75 % in five years time for DPM, PM<sub>2.5</sub>, PM<sub>10</sub>, NO<sub>x</sub> and SO<sub>x</sub> (see Fig. 1). After this success more and more initiatives followed, like the World Ports Climate Initiative (WPCI) in 2008: a cooperation network of 55 ports in the world originated from the International Association of Ports and Harbors (IAPH) for reduction of CO<sub>2</sub> emissions.

By far, most attention is focused on cleaner transport and shipping. This chapter, a summary of the study of Broesterhuizen [3],<sup>1</sup> handles ports themselves by introducing a procurement model that contains sustainable criteria for the design, realization, use, demolition and recycling of infrastructure projects. Sustainability in procurement is inevitable to make the port's infrastructure more sustainable. Not only the project itself is investigated by setting criteria, but also the relation between client and contractor. The scope of the study concerns ports with transshipment as main function.

The study is divided into four phases: Analysis, Synthesis, Simulation and Evaluation. In the Analysis insight is gained in the current and future situation around sustainable procurement and sustainability in ports. The procurement model is formed in the Synthesis and applied on different projects from the field. One of these projects is described and analyzed in this chapter. The Evaluation gives a feedback to the main research question reading how sustainability criteria can be implemented in the procurement process for port infrastructure.

## Analysis

In this phase different topics are studied about procurement in general, the role of sustainable criteria in the procurement process, the commercial (dis)advantage of sustainable management and the visions and policies around sustainable port development. As a part of this analysis several parties<sup>2</sup> are interviewed about their views and policies.

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<sup>1</sup> Paragraphs 2.1–3.1 were part of the introduction to this study, published in a discussion paper: Broesterhuizen et al. [4].

<sup>2</sup> 2 large contracting companies, 2 port authorities, the government and a NGO.

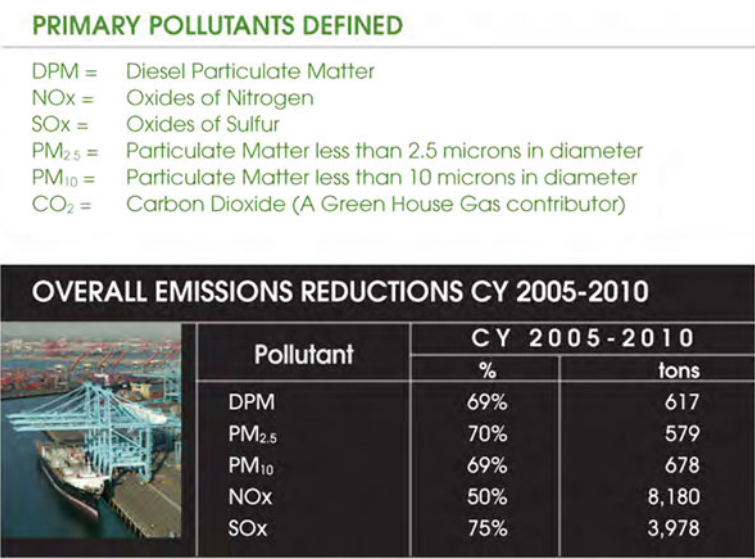


Fig. 1 Emission reductions port of Los Angeles [8]

*Procurement Process*

European ports are bounded to European laws and these ports are obliged to European public procurement above a certain contract sum and many port infrastructure projects sums exceed this value. When it is a matter of public European procurement Port Authorities have the choice for procurement with a selection based on the lowest price or the most economically advantageous tender. The last criterion is a criterion which selects the alternative with the best price-quality ratio. This can be realized by setting criteria for a more sustainable alternative.

One of the goals of this study is to make a project as sustainable as possible. In the procurement phase of a project, it does not depend only from setting sustainable criteria. The choice for a type of contract is very important. Lately innovative contract forms, e.g. D&B and DBFM, are more popular. When using these types of contracts, contracting companies gain more freedom and influence in the design of the project. Therefore, more different kinds of alternatives are possible which helps the sustainability. Besides, these innovative contract forms involve the contractor in the project over a longer period of time. In practice these developments has led to the applying of Life Cycle Analysis (LCA) by contractors leading to a higher value of the project [9]. This is an important property of a sustainable project design: projects should not only be sustainable for a limited period of time, but also during their whole lifetime.

## Economical Effects of Sustainable Management

In most industries (especially industries in consumer markets) sustainable purchasing and procurement is already integrated, more than the port sector. According to the study of Adams [1], many port authorities approach sustainability in a negative way: sustainability is seen as a necessity for reducing external effects (e.g. emissions), instead of the optimization of advantages like retaining and attracting clients while other industries make use of these advantages of sustainable management. According to MIT and the Boston Consulting Group [2] sustainable management has many commercial advantages which lead to a larger return for shareholders (see Fig. 2). Ports should make use of these advantages and sustainable procurement is one of the possibilities to realize this. Using sustainable policies ports will get a better image which lead to a license to operate and a license to grow.

Besides advantages, sustainable and innovative operational management can have disadvantages. Most of these disadvantages are dealing with uncertainties about the future due to the fact that in many cases sustainable investments are long term investments. A second disadvantage is the risks of investing in innovation. Private parties incline to make fewer investments in innovation due to the risk of spillovers of knowledge, investment risks and the differences in benefits between companies and the society in general.

## Analysis of Actors

By making an analysis of the views and policies of the different actors (e.g. governments, port authorities, contractors, etc.) involved in sustainable port development insight is gained in the interests and the importance of the different topics. One of these actors is the Dutch government which set different themes that are important in sustainable port development [7]. These themes include: use of

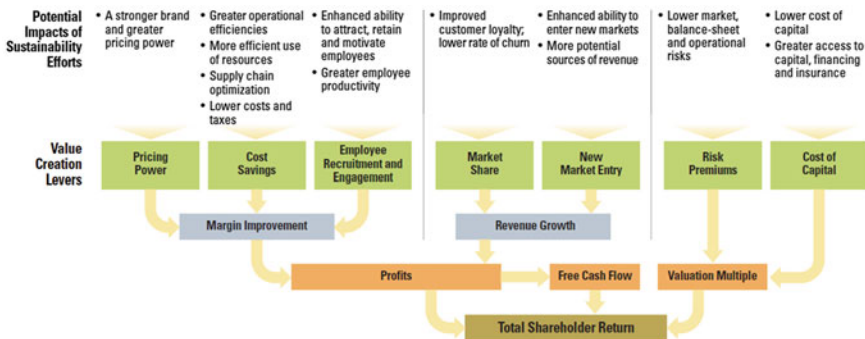


Fig. 2 Advantages of sustainable management [2]

space; mobility of the hinterland; development of nature; air quality; environmental management; energy, CO<sub>2</sub> emissions and waste flows; water quality. Research company CE Delft has set indicators based on these themes to measure the sustainability of the Dutch ports [6], which can be used for setting sustainability criteria. Based on the themes there is made an inventory of the different topics of attention from the actors. The conclusion is that most attention is going to environmental management (e.g. cooperation in knowledge, use of environmental management systems, ISO14001) and energy, CO<sub>2</sub> emissions and waste flows.

## ***Interviews***

As mentioned before, different parties from the procurement process were interviewed. Here, the most important conclusions are picked from the results. Due to the number of respondents, a statistical conclusion cannot be made but the results are very useful to get insight in different views and solutions. There was consensus in opinion about some topics, but there were many topics with disagreement too. This shows that more research has to be done about this subject. Most respondents were of opinion that especially the large companies in the building sector see the (commercial) advantages of sustainable management. Small companies still link sustainability with extra costs. There was agreement too about the proposition that sustainability should come from the contractor instead of the awarding authority. But the companies gave very different answers to the question if contractors are given enough space to make this possible. All respondents were of opinion that owners choose contracting forms which give too little space for innovation. Together with the opinion that sustainability should come from the contractor the conclusion can be made that contractors do not have enough space to realize sustainable projects.

There was disagreement too about the question if there should exist a general procurement model for the whole soil, road and hydraulic building sector instead of a model that is focused on the project itself. As advantage of such a model the ease of application is mentioned. A disadvantage could be the lack of freedom and the fact that every project is different.

It was very noticeable that most respondents didn't mention air quality as an important criterion for sustainability, while air quality is the number 1 topic in the several sustainable initiatives of international ports.

## **Synthesis**

In this phase of the research the criteria of the procurement model are set. After the choice of the criteria an evaluation method is chosen with weight factors for the criteria. These choices are based on requirements as flexibility, adaptability, stability, transparency and user-friendliness.

Criteria

Before setting criteria, the question has to be answered which criteria will contribute to a more sustainable port infrastructure. To be able to answer this question a definition for a sustainable port is needed. In this study there is referred to the definition of the Dutch and Flemish environment organizations [5]: a port with an optimal balance between performance of business economics, utilizing the available capacity, limited use of space, minimal negative influence on the environment and a relation between port and hinterland. This is a very important definition for this study. To reach this 11 criteria are mentioned in the referred report. These criteria combined with the different indicators for sustainable ports set by CE Delft

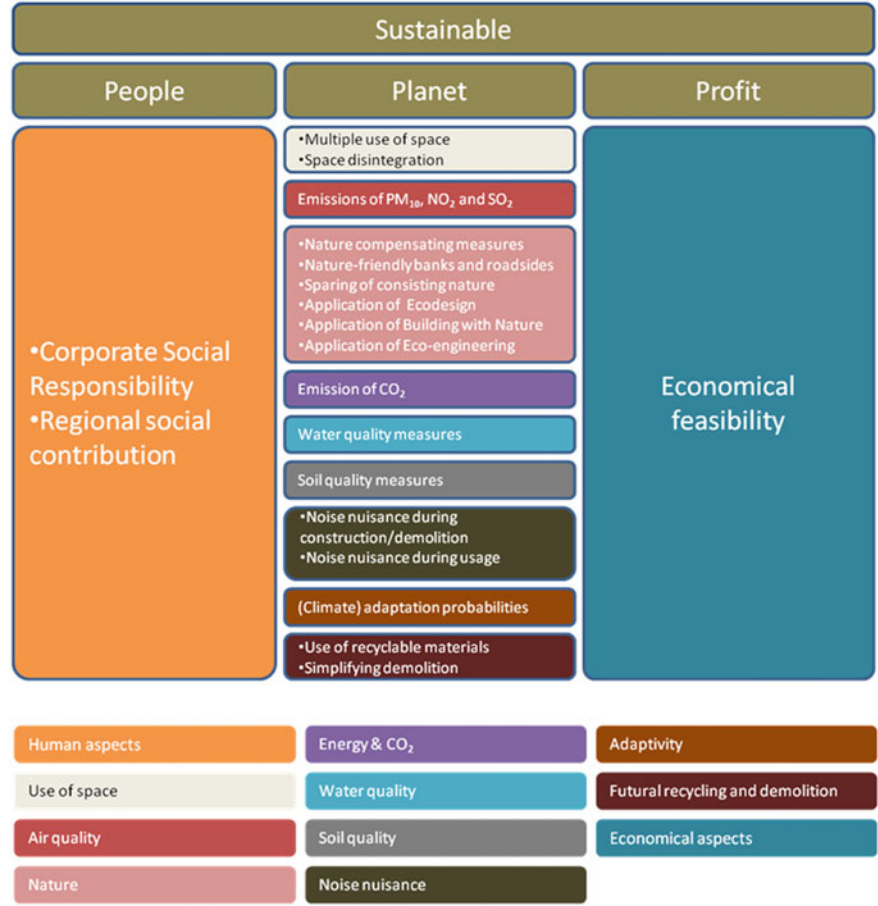


Fig. 3 Criteria framework: the colors of the themes in the lower part correspond with the colors of the different criteria

**Table 1** Selection table for evaluation method: the total score is calculated by the sum of the individual performance scores in which -- is equal to -2 points, - is equal to -1 point, ± is equal to 0 points, + is equal to 1 point and ++ is equal to 2 points

Method	Applicable	Transparent	Flexible	Stable	Effective	User friendly	Total
CBA	—	+	++	+	++	++	7
CEA	—	+	++	+	++	++	7
Score card	++	++	++	—	--	±	3
Weighted summation	++	+	±	±	—	+	3
Permutation method	++	++	—	±	+	—	4
Concordance analysis	++	+	—	±	++	±	5
Saaty method	++	—	±	—	±	+	1
Multidimensional scale method	++	--	--	±	++	--	-2

and the People, Planet, Profit definition of sustainability led to different themes which are important when approaching sustainable port development. Then, the themes are translated to indicators for port infrastructure after analyzing the application of the themes on infrastructure. After setting the indicators for the sustainability of port infrastructure, criteria can be formulated. This has led criteria divided in 3 classes based on Life Cycle Analysis: People, Planet and Profit [3]. People contents the social criteria as corporate social responsibility, Planet consists the criteria for the environment, e.g. emissions and development of nature, and the Profit criterion will be formulated as the financial Net Present Value. A notable criterion is the adaptability of the work and is not included in traditional procurement criteria. This is understood to mean a flexible design which makes the construction works durable against changing circumstances in the future. For ports a very important changing circumstance is the climate change. Examples of a flexible design are floating quay walls and flexible designs for capacity expansions. The framework with the different criteria is shown in Fig. 3. The criteria are set in such a manner that the correlation between the criteria is minimized.

### *Selection of Evaluation Method*

To evaluate alternatives based on these criteria, a suitable evaluation method is needed. Different kinds of evaluation methods are compared in Table 1 to each other based on applicability, transparency, flexibility, stability, effectiveness and user friendliness. These properties are chosen such to get an appropriate model for both the client and contractor and to optimize the sustainability of the project. The most common evaluation methods in civil engineering are compared in which a distinction is made between monetary evaluation methods [cost-benefit analysis (CBA), cost effectiveness analysis (CEA)], the score card method and Multicriteria Evaluation methods (MCE's; weighted summation, permutation method, concordance analysis, multidimensional scale method, Saaty method).

### **Cost-Benefit Analysis and Cost Effectiveness Analysis**

In the CBA all effects are translated to costs using shadow prices. The preferred alternative is the alternative with the best balance. The advantage of this method is the amount of insight gained about the effects and all criteria can be compared to each other. The main disadvantage is that some criteria are difficult to translate in a monetary value.

In the CEA first a goal is set. Then it is analyzed which alternative can fulfill that goal against the lowest costs.

### **Weighted Summation**

The weighted summation is the most common evaluation method in the civil engineering industry. It is based on the principle  $P = W \cdot E$  where  $P$  is the score,  $W$  the weight and  $E$  the effect. After standardization of the effects and multiplication with the weights of the effects score can be calculated. The advantage of this method is that it is very comprehensible. The disadvantage is that the weights are determined independently, allowing the case that the preferring alternative scores high on criteria with large weights while there are more criteria where it scores bad.

### **Concordance Analysis**

The concordance analysis is a method where there the alternatives are first compared in pairs based on weighted scores. After that again a pairwise comparison is made between the alternatives but then without weights to inspect how bad the alternatives score to each other. The preferable alternative is the alternative that gives a good balance between scoring high on weighted criteria and scoring low without weights. The advantage of this method that the compensating effect of the weighted summation is removed.

### **Permutation Method**

This method is based on the order of preference of the alternatives on all effects. Per criterion all orders of alternatives get a score. The order of preference with the best score on the end is the ultimate order of preference. Disadvantage of this method is that if there are a lot of alternatives, many calculations have to be done: when there are alternatives, already  $5! = 120$  different orders of preference have to be evaluated.



### **Saaty-Method/Analytical Hierarchy Process Method**

First the alternatives are compared pairwise on the criteria, making use of the Saaty scale: every time the better alternative get a score of 1 (equal score), 3, 5, 7 or 9 (by far better). This leads to the matrix  $A_J$  for criterion J. The eigenvectors of these matrices form the Option Performance Matrix (OPM). The same is done with the criteria: a score of 1 stands for equal important, 9 for by far more important. This leads to the Relative Value Vector (RVV). Then, the OPM is multiplied with the RVV resulting in the Value For Money Vector (VFM). This vector gives the total scores per alternative. The alternative with the highest score is the preferred alternative.

One of the advantages of this method is that it is giving insight in the importance of effects without the need of setting weights. A disadvantage is the mathematical nature, leading to less transparency.

### **Multidimensional Scaling Method**

This method decreases the number of dimensions of a set of (correlated) criteria. These dimensions are not correlated to each other. Between these dimensions a point is determined in the dimension space. The alternative with the smallest distance to this point is the preferred alternative. This analysis is possible with a complex optimizing process which makes interpretation of results difficult.

### **Score Card Method**

In this method it is indicated with colors how well an alternative scores on a list of criteria. With this method it is not needed to standardize scores or translate effects. Disadvantage is that it is difficult to make a quantitative comparison between alternatives.

The main advantages of monetary evaluation methods are their simplicity in their calculations but it is necessary to translate the different effects of the criteria to shadow prices, which can be dubious. The score card method is very transparent but a clear quantitative calculation is not possible. In contrast, MCE's are able to combine qualitative with quantitative data. Since the applicability of monetary evaluation methods is weak, a choice is made for the concordance method since this is the most practical method. In this method an alternative is evaluated based on weighted criteria how well the alternative scores in comparing with the other alternatives and how many times it scores worse on unweighted criteria. This leads to a balance between criteria which is important since sustainability is all about the balance between People, Planet and Profit.

## Application of the Model

To ease the application of the model for both the contractor and client there is chosen for a model with qualitative criteria to avoid complex calculations and uncertainties. All measures by the contractor described in the tender are scored. In the case that there are no clear quantitative results available, this score is a grade between 1 and 10 during the tender stage, in which 10 is the best and 1 the worst. If there is a negotiation stage a grade between 1 and 3 will be given, since the selection process is progressed and a clearer distinction between the alternatives is needed. The score is based on how SMART<sup>3</sup> a measure is. If a clear quantitative effect is known as the investment costs, the effect can be used as a score.

After the scores are given to the alternatives all scores are standardized to 1 or (in case of negative score as investment costs) to  $-1$ .

The next step is to determine the concordance indices  $K_{ij}$ . A pairwise comparison is done between two alternatives  $i$  and  $j$ . The concordance index  $K_{ij}$  is simply the sum of the weights of the criteria of which alternative  $i$  scores better than alternative  $j$ . In Table 2 an overview is given of weights that can be used in this calculation. These weights are based on the current situation and can be changed by the client under the restriction that the sum of the weights is equal to 1. This step is repeated for all possible combinations resulting in a concordance matrix, see Table 3.

With this concordance matrix the net concordance dominance index can be calculated. For Alternative 1, this index is calculated as the sum of its concordance indices against the other alternatives minus the sum of the concordance indices of the other alternatives against Alternative 1, in general

$$K_i = \sum K_{ij} - \sum K_{ji}$$

This index is a measure for the scores on criteria with a large weight. From now on this index will be mentioned as the concordance. The higher the concordance, the higher the scores on the most important criteria.

After that, the discordance index  $D_{ij}$  is calculated as the absolute difference between the scores of alternatives  $i$  and  $j$  on the criteria for which  $i$  scores worse than  $j$ . This is repeated until the discordance matrix can be filled, see Table 4.

Now a discordance dominance is computed with the formula

$$D_i = \sum D_{ij} - \sum D_{ji}$$

This value will be named as discordance from now on. The higher the discordance, the worse the scores and it is a measure for bad scoring on all criteria.

The final step in the evaluation is to combine the concordance with the discordance. Since both indices have different meanings these indices cannot be summed. First the alternatives will be ranked based on concordance.

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<sup>3</sup> Definition of SMART: Specific, Measurable, Acceptable, Realistic, Time restricted.

**Table 2** Sustainability criteria with their weights

Main criterion	Criterion	Weight
People	Corporate social responsibility	0.11
	Regional social contribution	0.06
Planet	Use of space	0.03
	Emissions of PM <sub>10</sub> , NO <sub>2</sub> , SO <sub>2</sub>	0.03
	Nature	0.06
	Emission of CO <sub>2</sub>	0.06
	Water quality	0.03
	Soil quality	0.03
	Noise nuisance	0.01
	Adaptability	0.05
	Futural recycling and demolition	0.04
Profit	Nett present value	0.50

The sum of the weights is equal to 1 and the weights are based on the general situation for a large European port

**Table 3** Concordance matrix

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Alternative 1	X	K <sub>12</sub>	K <sub>13</sub>	K <sub>14</sub>	K <sub>15</sub>
Alternative 2	K <sub>21</sub>	X	K <sub>23</sub>	K <sub>24</sub>	K <sub>25</sub>
Alternative 3	K <sub>31</sub>	K <sub>32</sub>	X	K <sub>34</sub>	K <sub>35</sub>
Alternative 4	K <sub>41</sub>	K <sub>42</sub>	K <sub>43</sub>	X	K <sub>45</sub>
Alternative 5	K <sub>51</sub>	K <sub>52</sub>	K <sub>53</sub>	K <sub>54</sub>	X

**Table 4** Discordance matrix

	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Alternative 1	X	D <sub>12</sub>	D <sub>13</sub>	D <sub>14</sub>	D <sub>15</sub>
Alternative 2	D <sub>21</sub>	X	D <sub>23</sub>	D <sub>24</sub>	D <sub>25</sub>
Alternative 3	D <sub>31</sub>	D <sub>32</sub>	X	D <sub>34</sub>	D <sub>35</sub>
Alternative 4	D <sub>41</sub>	D <sub>42</sub>	D <sub>43</sub>	X	D <sub>45</sub>
Alternative 5	D <sub>51</sub>	D <sub>52</sub>	D <sub>53</sub>	D <sub>54</sub>	X

The alternative with the highest ranking (that is with the highest concordance) gets 1 point, the second alternative 2 points, etcetera. Then the alternatives are ranked again, but this time based on their discordance. The alternative with the lowest discordance gets 1 point, the second 2 points and so on. Finally the ranking points are summed and the alternative with the lowest amount of points is the preferred alternative.

## Simulation

In this part the developed procurement model is applied to a tender for a certain port infrastructure project. The outcomes will be evaluated and a comparison is made with the traditional method.

### *Example Project: Quay Wall*

The example project consists of the design and realization of a quay wall with future expansion possibilities. The main components of the project are the design and construction of a mooring facility for oil tankers and the foundations for load arms and a rail with a crane.

After selection of 5 contractors the offers are evaluated using the model. In the original case, the offers were evaluated using a weighted summation method in which sustainability got a weighing percentage of 15 %. Within this percentage, sustainability was divided in 4 criteria:

- Avoiding transport during rush hours (33 %)
- Number of transports (17 %)
- Use of clean fuels (17 %)
- Recycling of material (33 %).

Therefore, these criteria are different from the model's criteria. Since the Net Present Values are not known, the investment costs are used as a measure for the economical feasibility. The negative value of the costs can be used directly as a score for this criterion. If the contractor does not take measures a neutral 5 is given as score, since the design does not necessarily leads to a more or less sustainable project. Furthermore, the tender is not yet in the final stage that means that improvements in the offers are possible.

The contractor of Alternative 1 took quite a lot measures within the criterion for the emissions of PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub>. These measures differ in being SMART and there are a much transport movements leading to a considerably low mark (6). There is a limited amount of measures to limit CO<sub>2</sub> emissions and the contractor scores a 6 on this criterion and a low score for the economical feasibility since the investment costs are large.

The second alternative got the second place in the real situation. There was only a small amount of freight transport by trucks, in contrast to a large amount of commuter traffic. Thanks to a no-claims bonus system the measures scored higher on being SMART. This alternative got a high score on the criterion to limit the CO<sub>2</sub> emissions (9). There are a lot of measures to recycle material and the company is certificated with the highest award against CO<sub>2</sub> emission. There is much saving on use of steel and the contractor gave clear insight into the CO<sub>2</sub> emissions. On the profit criterion scores this alternative a second place.

The contracting company of the third alternative is the only contractor which is implementing the guidelines of ISO 26000, leading to a 9 as score on the criterion for Corporate Social Responsibility. Furthermore, it is the only alternative with possibilities for multiple use of space, protection of the soil quality and the application of nature friendly banks and roadsides. There are no clear measures about transport and there is much freight transport with trucks which is not enough compensated by the high score on commuter traffic. This leads to a 5 as score for the criterion against emissions of  $PM_{10}$ ,  $NO_2$  and  $SO_2$ . On the field of limitation of  $CO_2$  emissions the total influence on the life cycle by the measures is small. Alternative 3 scores the third place on investment costs.

Alternative 4 takes initiatives to help the regional society. Some crafts are outsourced to the regional sheltered workshops. Alternative 4 scores an 8 when it comes to regional social contribution. The amount of freight transport by road is small, but the number of commuter transports is not known. The contractor scores bad for measures on clean fuels leading to a 5 for the criterion against emissions of  $PM_{10}$ ,  $NO_2$  and  $SO_2$ . This alternative is the most expensive alternative.

Alternative 5 was chosen by the client. It scored a 7 on Corporate Social Responsibility since the company is certificated on this field. There are a lot of actions against the emissions of  $PM_{10}$ ,  $NO_2$  and  $SO_2$ , rated with a 9. Like Alternative 2, this alternative is certificated with the highest award against  $CO_2$  emission. Furthermore there is much saved on the amount of steel leading to less  $CO_2$  emissions and the alternative is given a 9 for this criterion. Alternative 5 has the lowest investment costs.

The foregoing summarizes the contractors' most important actions described in their offers. The scores for all measures on all criteria are given in Table 5. Based on these scores the model can be filled in. According to the criteria of the model Alternative 5 is the most economically advantageous tender. Alternative 1 and Alternative 4 are sharing the last place as seen in Table 6.

In the real case, the contractor of Alternative 5 got the work and Alternative 2 scored the second place. The difference can be explained by taken other criteria into account, e.g. technical design. This makes it difficult to compare the outcomes, but they lay close together.

In the case of leaving the Profit criterion out, the outcome is different than the real case (that is, the ranking based on the sustainability criterion), see Table 7.

The large differences can be explained again to the differences in criteria. Alternative 3 scores high on criteria as Corporate Social Responsibility, use of space, water quality, soil quality, noise nuisance and adaptability. These are just the criteria which are not included in the real tender. This is more visible when the real outcome is compared to the analysis based on only the Planet criterion. This leads to an analysis with criteria which are more close to the real case, see Table 8.

The ranking of the concordance is almost the same as the ranking in the real case in Table 7. Looking to the concordance only is similar to the weighted summation method used by the client. By adding the discordance Alternative 3 gets a higher ranking, because this alternative has a better balance between more criteria what is important for a sustainable project, inspecting the very negative

**Table 5** Scoring table; the scores on the profit criterion (investment costs) are given as ratios

Main criterion	Criterion	A1	A2	A3	A4	A5
People	Corporate social responsibility	5	5	9	5	7
	Regional social contribution	5	5	5	8	5
Planet	Use of space	5	5	7	5	5
	Emissions of PM <sub>10</sub> , NO <sub>2</sub> , SO <sub>2</sub>	6	6	5	5	9
	Nature	5	5	6	5	5
	Emission of CO <sub>2</sub>	6	9	6	7	9
	Water quality	5	7	8	5	5
	Soil quality	5	5	7	5	5
	Noise nuisance	5	5	9	5	8
	Adaptability	5	5	8	5	5
	Future recycling and demolition	5	7	5	6	6
Profit	Nett present value	−0.23921	−0.170607	−0.1883	−0.24504	−0.15684

**Table 6** Ranking of alternatives

	Concordance	Discordance	Ranking
Alternative 1	−1.75	1.54	4
Alternative 2	1.04	0.33	3
Alternative 3	0.59	−1.80	2
Alternative 4	−2.33	0.82	4
Alternative 5	2.45	−0.89	1

**Table 7** Ranking concordance analysis based on People and Planet criteria

	Concordance	Discordance	Ranking	Ranking real case
Alternative 1	−1.49	1.34	5	4
Alternative 2	0.10	0.40	3	1
Alternative 3	1.16	−1.80	1	2
Alternative 4	−0.67	0.60	4	5
Alternative 5	0.90	−0.54	2	2

**Table 8** Ranking based on only Planet criterion

	Concordance	Discordance	Ranking	Ranking concordance
Alternative 1	−1.40	1.23	5	5
Alternative 2	0.97	0.03	1	1
Alternative 3	0.57	−1.46	1	3
Alternative 4	−0.99	1.06	4	4
Alternative 5	0.85	−0.86	1	2

discordance index. In the real case the client negotiated with the contractors of alternatives 2 and 5. According to this model, Alternative 3 should be given a chance too. This underlines the usefulness of the concordance analysis.

## Evaluation and Conclusion

To incorporate sustainability as criterion in the procurement process it is necessary for the client to choose a contract form that is based on the most economically advantage tender where the winning alternative is the alternative with the best price to quality ratio. Sustainability is then a criterion for the quality. There are different kinds of contracting forms possible, where integrated contracting forms are preferable. The more the contractor is involved in the life cycle of the work, the more sustainable a design will be. Examples of integrated contracting forms are D&C or Design & Build contracting forms and DBFM(O) contracting forms.

Sustainability can be specified in criteria based on the 3P theory with the main criteria People, Planet and Profit. These main criteria can be divided in Corporate Social Responsibility, regional social contribution, multiple use of space, emissions of PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub>, nature, CO<sub>2</sub> emission, water quality, soil quality, noise nuisance, adaptability, future recycling and demolition and Net Present Value. The request of the client has to be as clear as possible in such a way that the contractor knows exactly what the criteria are and how they are measured with which indicators.

The aim is to quantify criteria as much as possible, which is easier for implementing results by both the client as contractor. An analysis of the impact on the total Life Cycle (LCA) from realization to demolition is needed to get insight of the sustainability of the work. Based on these results an assessment can be performed.

The traditional method of weight summation does not take the balance between criteria into account. This balance is necessary for a sustainable project. The studied model gives a solution for this problem by including more criteria and by analyzing both the sustainable performance of the project and the underperformance. This gives more insight in the sustainability of the alternative and a better balance between the criteria. An example is the adaptability of a design which is not taken into account in current models.

The main problem with traditional methods is that scores on criteria with a heavy weight can compensate for scores with a lower weight. In this study there is shown that an alternative with the highest scores on the most weighty criteria is not automatically the preferred alternative.

Another advantage of the concordance analysis is the amount of extra information about the outcomes. When outcomes lay closely together, this information can help to decide which alternative is the most preferable. For example, when the concordance indices are almost equal, but there is a large difference in

discordance, the choice can be made based on these discordance values. To make the method more reliable for determining the most economically advantageous tender other criteria can be added such as the technical design.

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