Appendix C. Cost Estimation of the Bolivar Roads Barrier Using Recent Methods for Cost Estimation

This appendix presents further information with respect to the cost estimate for the proposed storm surge barrier at Bolivar Roads. For these cost estimates the method from Kluijver et al. (2019) has been used. The model is based on the costs of existing barriers around the world, and the dimensions of the various barrier features. It utilizes the following formula:

\[
\text{Cost} = €157,000 \times \text{Navigable Area} + €102,000 \times \text{Auxiliary Area} + €26,000 \times \text{Dam Area}
\]

Auxiliary area refers to the environmental gates; all areas in m²; price levels in 2019 Euros. The exchange rate at this moment is € 1 = $ 1.20 and this value has been assumed here.

The above formula does include planning, engineering and design costs. It produces an expected (50%) cost value. A 90% confidence interval can be defined based upon the dataset analyzed with the following slope intervals: +/- €60,000 on the Navigational area (NA) term coefficient, +/- €54,000 on the Auxiliary flow area (AA) term coefficient and +/- €13,500 on the Dam or static term (DA) term coefficient (Kluijver et al 2019).

As inputs to the formula information on the gates has been derived from the engineering report and Annex 19. For estimating the height of navigational and environmental gates the channel depths plus an additional 10 ft was used. This estimate presented here does not include the earthen levee on Bolivar peninsula, nor visitor building. Table C-1 presents the barrier dimensions. Table C-2 presents the cost estimates based on these barrier dimensions. Table C-3 summarizes some main metrics related to the width of the barrier and its various elements. Table C-4 presents an alternative cost estimate using the unit cost proposed by Mooyaart (2017) which is based on a unit cost of 2.47 MEuro/m per meter gate width.

**Table C-1.** Barrier elements and dimensions

<table>
<thead>
<tr>
<th>Section</th>
<th>amount</th>
<th>width (ft)</th>
<th>width (m)</th>
<th>total width (m)</th>
<th>Avg. height (ft)</th>
<th>Avg. height (m)</th>
<th>total cross section (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combi wall</td>
<td>1</td>
<td>5300</td>
<td>1616</td>
<td>1616</td>
<td>22</td>
<td>6,7</td>
<td>10838</td>
</tr>
<tr>
<td>Environmental gate shallow</td>
<td>16</td>
<td>96</td>
<td>29</td>
<td>468</td>
<td>26,5</td>
<td>8,1</td>
<td>3783</td>
</tr>
<tr>
<td>Environmental gate large 20ft</td>
<td>8</td>
<td>300</td>
<td>91</td>
<td>732</td>
<td>30</td>
<td>9,1</td>
<td>6692</td>
</tr>
<tr>
<td>Environmental gate large 40ft</td>
<td>7</td>
<td>300</td>
<td>91</td>
<td>640</td>
<td>50</td>
<td>15,2</td>
<td>9760</td>
</tr>
<tr>
<td>Navigational gate - large</td>
<td>2</td>
<td>650</td>
<td>198</td>
<td>396</td>
<td>70</td>
<td>21,3</td>
<td>8459</td>
</tr>
<tr>
<td>Navigational gate - small</td>
<td>2</td>
<td>125</td>
<td>38</td>
<td>76</td>
<td>50</td>
<td>15,2</td>
<td>1162</td>
</tr>
</tbody>
</table>
Table C-2. Barrier elements and dimensions and costs according to the model of Kluijver et al (2019)

<table>
<thead>
<tr>
<th>Section</th>
<th>total cross section (m²)</th>
<th>Unit cost (E/m² avg)</th>
<th>Unit cost (low)</th>
<th>Unit cost (high)</th>
<th>Total cost (Euro Avg)</th>
<th>total Cost (ME)</th>
<th>Total cost (M$)</th>
<th>Total cost (ME low)</th>
<th>Total cost (ME high)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combi wall</td>
<td>10838</td>
<td>26000</td>
<td>12500</td>
<td>39500</td>
<td>2,82E+08</td>
<td>282</td>
<td>338</td>
<td>135</td>
<td>428</td>
</tr>
<tr>
<td>Environmental gate shallow</td>
<td>3783</td>
<td>102000</td>
<td>48000</td>
<td>156000</td>
<td>3,86E+08</td>
<td>386</td>
<td>463</td>
<td>182</td>
<td>590</td>
</tr>
<tr>
<td>Environmental gate large 20ft</td>
<td>6692</td>
<td>102000</td>
<td>48000</td>
<td>156000</td>
<td>6,83E+08</td>
<td>683</td>
<td>819</td>
<td>321</td>
<td>1044</td>
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<tr>
<td>Environmental gate large 40ft</td>
<td>9760</td>
<td>102000</td>
<td>48000</td>
<td>156000</td>
<td>9,96E+08</td>
<td>996</td>
<td>1195</td>
<td>468</td>
<td>1523</td>
</tr>
<tr>
<td>Navigational gate - large</td>
<td>8459</td>
<td>157000</td>
<td>97000</td>
<td>217000</td>
<td>1,33E+09</td>
<td>1328</td>
<td>1594</td>
<td>820</td>
<td>1835</td>
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<tr>
<td>Navigational gate - small</td>
<td>1162</td>
<td>157000</td>
<td>97000</td>
<td>217000</td>
<td>1,82E+08</td>
<td>182</td>
<td>219</td>
<td>113</td>
<td>252</td>
</tr>
<tr>
<td>Total cost (MEuro)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3856</td>
<td>2040</td>
<td>5673</td>
<td></td>
</tr>
<tr>
<td>Total cost (M$)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4627</td>
<td>4627</td>
<td>2448</td>
<td>6807</td>
</tr>
</tbody>
</table>

Table C-3. Width of various barrier sections

<table>
<thead>
<tr>
<th>Element</th>
<th>width (m)</th>
<th>Element</th>
<th>width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>total with combi wall</td>
<td>3929</td>
<td>navigational gates</td>
<td>473</td>
</tr>
<tr>
<td>total without combi wall</td>
<td>2313</td>
<td>environmental gates</td>
<td>1840</td>
</tr>
<tr>
<td>navigational gates</td>
<td>473</td>
<td>Dam</td>
<td>1616</td>
</tr>
</tbody>
</table>

Table C-4. Alternative cost estimate using the unit cost proposed by Mooyaart (2017) which is based on a unit cost of 2.47 MEuro/m per meter gate width.

<table>
<thead>
<tr>
<th></th>
<th>Expected</th>
<th>Lower bound</th>
<th>Upper bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (ME)</td>
<td>5713</td>
<td>2313</td>
<td>9251</td>
</tr>
<tr>
<td>Cost (M$)</td>
<td>6855</td>
<td>2775</td>
<td>11101</td>
</tr>
</tbody>
</table>

References


Mooyaart LF, Jonkman SN (2017) Overview and design considerations of storm surge. ASCE Journal of Waterway, Port, Coastal, and Ocean Engineering Vol. 143 Issue 4