Foreword

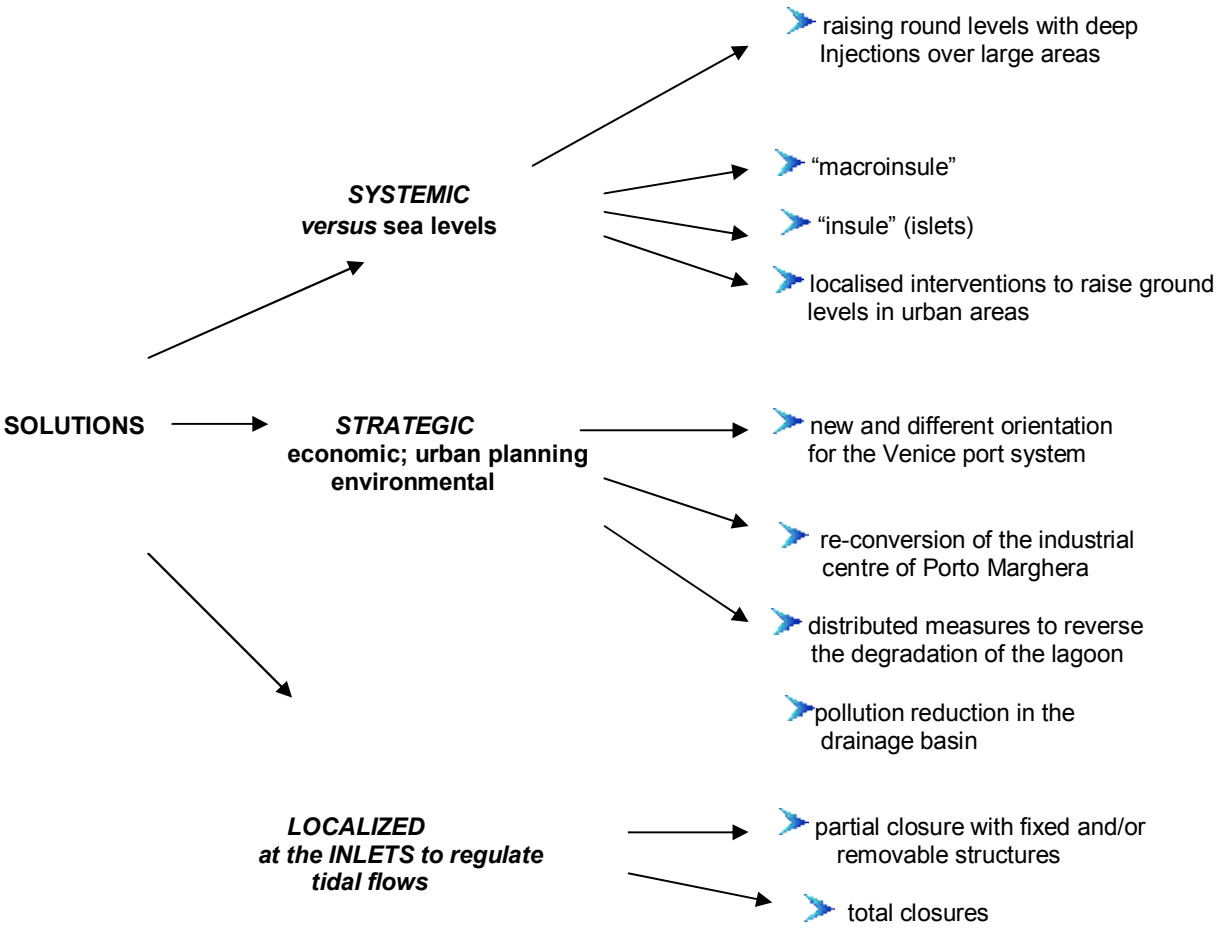
The Mayor of Venice, in a provision dated 6 June 2005, nominated a Working Group to be consulted on the guidelines and works for safeguarding Venice. The Group is constituted as follows:
Maurizio Calligaro (urban planner), coordinator and head of the Mayor's office; Paolo Canestrelli (engineer), director of the Tide Forecasting Centre, Venice Town Council; Prof Lorenzo Bonometto (ecologist), Environmental Planning Dept, Università IUAV di Venezia; Prof. Luigi D'Alpaos, Chair in Hydraulic Engineering, Dept of Hydraulic, Marine, Environmental and Geotechnical Engineering, Università di Padova; Armando Danella, Export of the Special Laws for Venice; Giorgio Pilla (architect), Urban Planning dept, Venice Town Council; Prof. Antonio Rusconi (engineer), Ground Protection Dept, Università IUAV di Venezia; Prof. Andreina Zitelli, Project Analysis and Environmental Assessment, Urban Planning Dept, Università IUAV di Venezia. Secretary: Antonella Stocco, Mayor's Office.

Tasks established for the Working Group include "*to propose ways for organising a public comparison of alternatives to the Mo.S.E System*", with the explicit objective of *"fully reinstating the central role of local residents in determining safeguarding policy"*.

1. Framework for synergistic interactions.

To carry out their remit, the Working Group decided to formulate the *Framework for Synergistic Interactions* which distinguishes and highlights the various levels of measures necessary to fulfil the long term and complete approach to safeguarding Venice.

FRAMEWORK for the SYNERGISTIC INTERACTIONS and MEASURES FOR SAFEGUARDING VENICE



The ***Framework for the Synergistic Interactions and Solutions*** schematically outlines *"works aimed at re-establishing the hydro geological equilibrium of the lagoon; arresting and reversing the processes of degradation of the drainage basin and eliminating its causes; attenuating tide levels in the lagoon; protecting via localised measures the islets of the historic settlements; protecting the lagoon settlements from exceptional 'high waters', also via interventions at the inlets with mobile barriers to regulate the tides, taking into consideration the criteria of experiment ability, reversibility and gradualism, as outlined by the vote of the Upper Council for Public Works n. 209/1982*" (L. 798/84, art.3, letter a).

The Framework therefore highlights that:

1 – Measures at the inlets, with regard to an overall and systematic approach, represent a localised solution, aimed primarily at regulating flows through the inlets.

2 – Altering port functions, re-conversion of productive activities at Marghera, measures to re-stabilise the lagoon are all deemed to be systematic and strategic actions, essential with regard to stabilising the environmental, urban and economic scenarios.

3 – Localised measures in urban areas, on the *insule*, the *macroinsule*, projects to increase quota relative to water level in portions of the territory via deep injections are considered to be synergistic with respect to the above and strategic as regards some of them in terms of significantly resolving the relative water level of the city.

N.B. The ***Framework*** also serves to characterise the reference level for the planned projects and proposals.

PROJECTS AND PROPOSALS SUBMITTED TO THE TOWN COUNCIL

- ***MEASURES AT THE INLETS TO REGULATE TIDAL EXCHANGES*** **- INTERVENTI ALLE BOCCHE LAGUNARI PER LA REGOLAZIONE DEI FLUSSI DI MAREA (Mo.S.E.) -** proposed by Consorzio Venezia Nuova – Magistrato alle Acque di Venezia, Definitive Project of 25/09/2002 – submitted to the Town Council on 06/02/2003.
- ***GRAVITY SLUICE GATES*** **- PARATOIE A GRAVITA' –** proposed by Ing. V. Di Tella – submitted to the Town Council on 16/12/2003.
- ***ABOVE SURFACE BARRIERS WITH HINGED ARMS*** **- BARRIERE EMERSE A RIPOSO CON BRACCI A TRALICCIO -** proposed by *Tec Norconsult*, represented by Arch. F. De Simone (same system as Rotterdam) – submitted to the Town Council on 15/07/05.
- ***SELF REGULATING BARRAGE WITH EVOLVED MANAGEMENT*** **- DIGHE OMEODINAMICHE A GESTIONE EVOLUTA (DOGE)** - proposed by Prof. A. Tamburrino – submitted to the Town Council on 5/07/05, but already presented previously.
- ***VENICE PORT SYSTEM AND RE-EQUILIBRIUM OF THE LAGOON*** **- VENEZIA PORTUALITA' E RIEQUILIBRIO LAGUNARE (VE. PERLA) –** proposed by C. De Piccoli - submitted to the Town Council on 14/08/2002.
- ***REMOVABLE SYSTEM FOR ACQUA ALTA*** **- APPARECCHIATURE RIMOVIBILI CONTRO L'ACQUA ALTA (ARCA) –** proposed by A. Ieno - submitted to the Town Council on 29/08/2002.
- **NAVAL DESIGNS -** 3 tide control measures – proposed by *TMT Italia spa* **-** submitted to the Town Council on 02/09/2002.
- ***RUBBER BARRAGES FOR VENICE*** **- DIGHE IN GOMMA PER VENEZIA** – proposed by *Tec Norconsult*, represented by arch. F. De Simone - – submitted to the Town Council on 15/07/05.
- ***SHIP GATES*** **- NAVI PORTA** – proposed by Ing. A. Pellegrinotti - submitted to the Town Council on 05/08/2004.
- ***STUDY TO SAVE THE HISTORIC CENTRE OF VENICE FROM HIGH TIDES AND THE RISK OF OIL TANKER POLLUTION*** **- STUDIO PER SALVARE VENEZIA CENTRO STORICO DALLE ALTE MAREE E DA EVENTUALI INQUINAMENTI DI PRODOTTI PETROLIFERI** – proposed by Ermenegildo Massimo's *Servizi Tecnici srl* - submitted to the Town Council on 30/08/2005.

DECLARED COSTS (in million Euro)

1 Measures at the inlets to regulate tidal flows	2 Gravity sluice gates	3 DOGE	4 Ship Gates	5 ARCA	6 Ve.PERLA	7 Study to Save Venice…
3440,74	400/753	300	900	450	1200	932

The figure relating to the *Measures at the inlets to regulate tidal flows* comes from the budget approved by CIPE[1]. Costs for the other projects are proposers' estimates.

[1] CIPE (Comitato interministeriale per la programmazione economica) is an interministerial economic planning committee of the Italian government, chaired by the Prime Minister, Berlusconi. It directly finances *major infrastructural strategic* projects as outlined in the 2001 Objective Law for stimulating productive activities.

2. Projects and Proposed Projects presented to the Town Council

Following an initiative of the relevant Commission (X and IV), the Town Council issued a public statement (30/6/2005), via the "Town Council Press Office – multimedia agency", announcing forthcoming hearings concerning projects alternative to Mo.S.E., which had to be presented by 15/7/2005.
By this date and within the terms established by the Council Commissions for the consultation process, the following projects were submitted, in addition to the Definitive Project for *Measures at the inlets to regulate tidal flows* (commonly known as Mo.S.E. and from here on referred to as such) which had already been submitted to the city administration.
The projects and proposed projects deposited were presented as alternatives to the Mo.S.E solution, the only project to have been examined by an organ of the State.

2.1. Proposed alternatives and Mo.S.E. shortcomings

Many of the alternative proposals signal shortcomings regarding the Mo.S.E. project. These issues were raised during the presentations to the Council Commissions; and the Working Group collected the observations expressed.
The shortcomings are presented at various levels: procedural, project-related, management, and the construction phases.

At the procedural level the critical shortcomings are as follows:

1. Strictly with reference to the inlets, a comparison in technical and economic terms is lacking as regards different possible solutions put forwards by competing bodies. Assignment of the project took place privately without any public competition.
2. Alternative projects characterised by different planning concepts and management approaches have never been considered/compared.
3. Only variations of the same design solution have been considered.
4. Irregularities with regard to current urban planning regulations are noted; conflicts with Community Directives regarding conservation and habitat protection are also highlighted.
5. Variations introduced by the "complementary measures" distinctively interfere with planning regulations, environment, port activities, morphological and landscape aspects.
6. An Executive Plan for the overall project, as deliberated by the "Comitatone"[2] (April 2003) is missing;
7. 11 construction sites have been set up at the inlets, not on the basis of an articulated Executive Plan but in "executive phases" approved from time to time by the Comitato Tecnico di Magistratura (CTM)[3] which are not within the context of a complete Executive Plan.

[2] Instituted by the second Special Law (1984), the *Comitatone* decides strategy, coordination and control of the implementation of all measures to safeguard Venice and the lagoon, not least division of the budget. The committee is chaired by the President of the Council of Ministers (the Italian Prime Minister) and consists of the heads of five ministries, their executive branches and the various local administrations, including the President of the Venice Water Authority (Secretary), the Minister for Infrastructure and Transport, the Minister of the Environment, the Minister of Cultural Heritage, the Minister of Transport and Navigation, the Minister of Universities and Scientific and Technological Research, the President of the Veneto Region, the Mayor of Venice, the Mayor of Chioggia and two representatives of the many other local authorities bordering the lagoon.
[3] Comitato Tecnico di Magistratura (CTM) is a consultative body of Magistrato alle Acque, the local division of the Ministry for Public Works which has responsibility for safeguarding the Venice lagoon and flood protection. It offers technical approval of planned projects and interventions.

At the project/planning level the study reveals the following critical factors.

1. The invasive nature of the mobile barriers over an extended area and their difficult management due to non-conformity of the Mo.S.E. project to "*The Feasibility Study – Outline plan for the protection of the lagoon from flooding*", approved by the Consiglio Superiore dei Lavori Pubblici (Upper Council for Public Works, which is the central government equivalent to the Comitato Tecnico di Magistratura).[4]
2. Mo.S.E. requires a radical reduction, nearly to the point of complete removal, of the fixed sides at the inlets with a consequent, visible increase in the mobile barriers intervention from 1070m to 1760m.
3. The enormous, irreversible and intrusive character of the foundations (casons and foundation piles) as well as the accessory works.
4. There are doubts about the function ability of the modular panels with respect to the declared objectives.
5. Key elements of the experimental module have been exposed to negative evaluations of technological relevance (panels, hinges, substitution mode of the panels) with highlighting of possible weaknesses regarding conceptual, know-how, experimental aspects and consequent risk analysis.
6. Grave doubts have been expressed concerning the persistent lack of executive planning for the mobile components and functional appendages, on the effective possibility of completing the project and its correct functioning.
7. At a planning and management level, the Mo.S.E. does not meet the prescriptions of gradualism, experiment ability and reversibility (approval vote no. 209 of 27 for the Feasibility Study by the Consiglio Superiore dei Lavori Pubblici, a vote called for by Law 798/84, *art. 3 comma 1*, *letter a*, and by the subsequent vote of the Consiglio Superiore LL.PP. no. 48 of 18 October 1994).
8. Irreversible impacts on the consolidated sub-lagoon geo-morphological layers (*caranto*) are associated with the installation of the foundation piles and housing casons.
9. Technological planning and management aspects not dealt with in the Definitive Project leave problems regarding safety to the extent that all the sub-lagoon functional areas need to be classified as dangerous due to possible gas infiltrations (methane, sulphur dioxide) via the concrete base.
10. Irreversible impacts on the environmental system, aquatic and terrestrial ecosystems.
11. The net loss of territory and loss of levels of ecosystem complexity in sites of the highest value protected by European Habitats and Birds Directives (Special Protection Areas and Special Areas of Conservation).

[4]The "Feasibility Study – Outline Plan for protecting the Venice Lagoon from high waters" prepared by the design group Ghetti, Marchi, Matildi, Passino, Pezzoli, Agema, Frassetto, presented to the Public Works Ministry on 26 May 1981, examined and passed by the Upper Council of Public Works at their meeting of 27 May 1982, vote no. 209, "*sought to limit to the minimum the mobile part of the barriers, due to the difficulty of foundation works and the flap panels hinged to the lagoon bottom, which is less reliable than the fixed structure as it is conditioned by the tide forecasting system and more costly in terms of construction, maintenance and management. The length of the mobile barriers was 1070m...*" . The "Preliminary outline plan of the works to be carried out at the lagoon inlets to regulate tide flows" (Consiglio Superiore dei LL.PP. – audience of 15/3/1990) *".....planned for a radical reduction, to the point of nearly eliminating, fixed structures to narrow the inlets with the consequent significant increase in the mobile component, for which the overall development was brought to 1760m".*

At the management level the main critical factors are the following:

1. Incompatibility of the timing and mode of manoeuvring barrier closure in the flooding seasons with respect to their frequency and repetitiveness.
2. Lack of an attenuating effect on tide levels by the fixed works.
3. Non resolvable problems of Mo.S.E. as regards increasingly high frequency of closures due to sea levels, already higher in the current decade.
4. Unresolved issues regarding the system's response to forecast tide levels and closure level (+100cm in initial plans; now +110cm).
5. The Mo.S.E. project does not satisfy the precautionary principle as regards forecasts of sea level rise estimated as probable by national and international organisations specialised and expert in the field. The project designer underestimates sea level rise (+22cm).
6.
7. Difficulty regarding maintenance of the underwater structures (thousands of m^2 of uneven surfaces) and deterioration of the structures due to growth of biological incrustations, fouling[5], and uncertain maintenance costs, which will surely be higher than the declared figure.
8. Strong direct impact on port activities both during the construction phase and in the subsequent management phase, and the strong indirect impact that this will have on the competitiveness of Venice's port, notably the "announcement effect" of closure of the inlets.

At the construction level the critical factors of the Mo.S.E project are as follows:

1) Works done to date at the inlets do not satisfy the gradualism prerequisite and highlight the uselessness of the outer breakwaters, *lunate*, as regards their purpose to *attenuate tide levels in the lagoon.*
2) Experimentation is considered non essential at the Malamocco inlet, with the installation of 5 casons, costing 15 million Euros.
3) High environmental impacts of the individual construction sites and cumulative effects of several construction sites being activated at once in a sensitive environment.

[5] The mass of these components has been estimated by the Proponents, on an experimental basis, at values equivalent to c. 0,25KN/m^2 equal to 25 kg/m^2 of fouling, a thickness of c. 10cm, with variation in the net weight of the panels of 10-15 % (see Progetto Definitivo Relazione Tecnica-Paratoie-pg.12 (the weight of a single panel at Malamocco is 3499 KN, Lido 3044 KN, Treporti 2026 KN, Chioggia 3084 KN), with a persistent quantity on the surfaces where this material is not removable, about double both in terms of weight and thickness (see Progetto di Massima Relazione Tecnica, Bocca di Lido, Condizioni Ambientali, pg. 110-116).

3. THE WORKING GROUP'S CHOSEN METHOD: MULTICRITERIA COMPARATIVE ANALYSIS OF PROJECT OUTLINES

1 The selected methodology of the Working Group was a techno-comparative multicriteria examination of the **project outlines** underlying the individual plans and projects presented (determination and examination of project guidelines are in chapter 5).
2 This approach addresses the fact that not all proposals have been developed to the same degree nor with a standard methodology: *ad hoc* contributions are considered, characterised by different layouts and methodologies, different levels of refinement and adaptation to local conditions, different development timescales and amounts of financial support.
3 The valuations given to the selected project outlines have taken account of claims provided by the designers and/or those who developed the various concepts which have been compared.
4 The Working Group uses an existing methodology for multicriteria comparative evaluation which provides an overview of aspects and problems, albeit characterised by intrinsic limitations which are noted and accepted.
5 The Working Group consists of capabilities in the various relevant disciplines and has access to specialist means and systems for development of the study.

4. Evaluation scenarios, Indicators, Ordinal Values, Valuations

4.1. Scenarios

Reference weighted evaluation scenarios have been considered as follows:

- 1. Socio-economic Scenario
- 2. Flexibility Scenario
- 3. Engineering Scenario
- 4. Environmental Sustainability Scenario
- 5. Costs Scenario

Scenarios

The **Scenarios** reflect the orientation and objectives for Safeguarding Venice, the techno-engineering requirements and economic costs (according to proposers' estimates).

Weighted Values

The total weighted value of the Scenarios is 100; for each scenario, in relation to the total value, a weighted value has been assigned according to the table below:

1. Socio economic Scenario	25% weighting
2. Flexibility Scenario	12,5% weighting
3. Engineering Scenario	25% weighting
4. Environmental Sustainability Scenario	25% weighting
5. Costs Scenario	12,5% weighting

Attribution criterion

The attribution criterion for the weighted value distinguishes the following:

- Scenarios which respond to primary objectives: the *socio-economic* and *environmental* scenarios reflect the Safeguarding priority given by the Special Laws; the *engineering* scenario refers to technical functionality. The weighted value of 25% has been applied to each of these scenarios;
- Scenarios which respond to guideline values: *flexibility* and *costs* scenarios have been given the equivalent of the above (25 %); 12,5 % each.

4.2. Indicators

Each Scenario is broken down into several Indicators, each of which has been associated with a weighting.

The indicators that characterise the scenarios are considered to be essential and represent the requirements to which each proposal must answer in order to be evaluated.

The weightings of the indicators are expressed in numbers from 5 to 10^6. The significance of each indicator and its relative weighting is explained in the appendix.

[6] This choice was made in order to stagger assigned weightings progressively and such that only the last is a multiple of the first.

1 – SOCIO-ECONOMIC SCENARIO ***Indicators***	***Weighting***
1.1 Compatibility of inlet interventions with port functions during the construction phase	10
1.2 Compatibility of inlet closure operations and port functions	10
1.3 Compatibility of inlet maintenance operations and port functions	10
1.4 Response to the objective of separating *navigation* requirements of the port and *safeguarding* requirements as regards reducing depth of the lagoon at the inlets	10
1.5 Compatibility of port activities and "announcement" effect	10
1.6 Compatibility with safeguarding port activities, in view of future sea level rise	10
1.7 Safeguarding urban areas and historic buildings	10
1.8 Safeguarding mobility, urban socio-economic activities and local residents	8
1.9 Revalorization of urban areas	8

2 – FLEXIBILITY SCENARIO ***Indicators***	***Weighting***
2.1 Experimentability	10
2.2 Gradualism	10
2.3 Reversibility	10
2.4 Adaptability to seasonal conditions	8

3 – ENGINEERING SCENARIO ***Indicators***	***Weighting***
3.1 Stage of project development	10
3.2 Analogous experience on an international level	5
3.3 Compatibility of construction time for the works in relation to expected positive effects, including intermediate effects	8
3.4 Duration of the works	8
3.5 Technological, functional and operational simplicity of the works	10
3.6 Reliability of the service infrastructure and accessory plant equipment	8
3.7 Safety of works at the inlets	10
3.8 Reliability regarding collapse or sinking	5
3.9 Reliability and simplicity of maintenance	10
3.10 Efficacy with regard to eustacy and subsidence according to various future scenarios	10

3.11 Effects on dissipating the current at the three inlets, reduction in tidal peaks in the lagoon and complementarity with local measures (insulae, macroinsulae, etc.)	10
3.12 Efficacy in blocking sea-lagoon exchange	8
3.13 Morphological stability of the lagoon bottom with regard to sandy deposits and/or works-associated excavation	9
3.14 Protection of the stable geological aspect (e.g. caranto)	9
3.15 Relation with the hydrodynamic aspect of the coastal currents and transport	10

4 – ENVIRONMENTAL SUSTAINABILITY SCENARIO *Indicators*	***Weighting***
4.1 Arresting and reversal of degradation process and elimination of causes	10
4.2 Environmental impacts during the construction phase	7
4.3 Environmental impacts in final form	10
4.4 Sustainability of landscape impacts	8
4.5 Sustainability of intrusion of permanent works and removable elements	7
4.6 Resilience and sustainability of the activities at several construction sites simultaneously and other impacting events	6
4.7 Compatibility with regard to polluting effects	8
4.8 Effects on the sedimentology, morphology and functioning of the lagoon	10
4.9 Impacts on lagoon archaeology and historic structures	8
4.10 Reactivation of principal, secondary and peripheral hydraulic circulation	10
4.11 Compliance with the Habitats Directive	10

5 – COST-BENEFIT SCENARIO *Indicators*	***Weighting***
5.1 C/B for attenuation of tide levels in the lagoon	10
5.2 C/B with regard to inlet closures	10
5.3 C/B for effects on re-equilibrium of the lagoon	10
5.4 C/B with regard to local defence measures	10
5.5 C/B with regard to sea level rise and subsidence for the next century	7

4.3. Ordinal Values (o.v.)

Comparison of the Project Outlines begins by attributing each Outline, for each indicator, one of the following Ordinal Values and corresponding parameter:

ORDINAL VALUE: high negative	**parameter: 1**
ORDINAL VALUE: medium negative	**parameter: 2**
ORDINAL VALUE: low negative	**parameter: 3**
ORDINAL VALUE: low positive	**parameter: 4**
ORDINAL VALUE: medium positive	**parameter: 5**
ORDINAL VALUE: high positive	**parameter: 6**

4.4. Evaluation

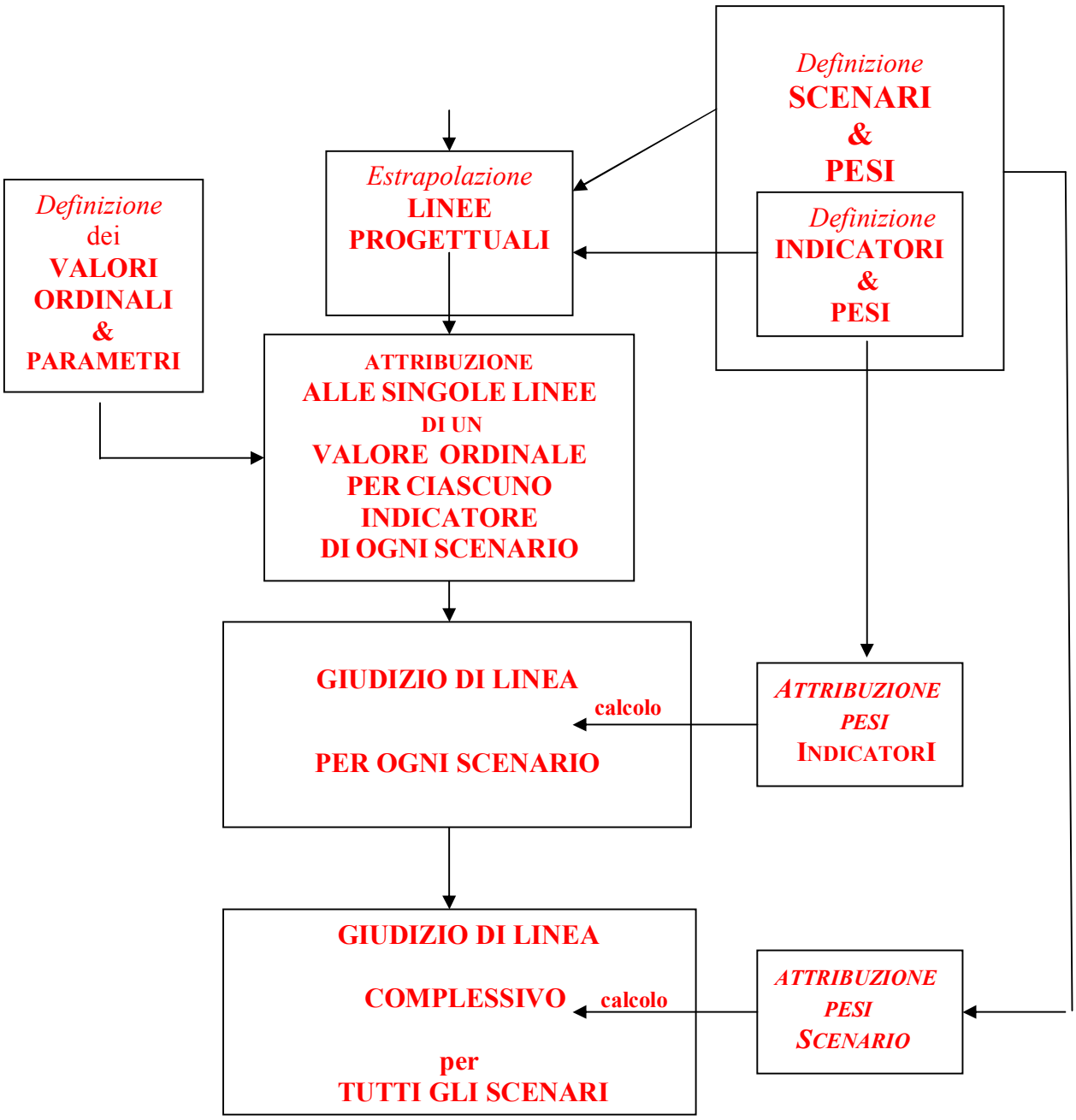
The valuation was carried out according to the following procedure.

For each project outline:

1. An **Ordinal Value** was attributed for each Scenario;
2. A **Weighted Value (sum of the weighted ordinal values)** was derived for each Scenario, extrapolated from the weight of the indicators and parameters of the assigned ordinal values;
3. An **Overall Weighted Evaluation** was determined for the set of Scenarios.

The procedure for multicriteria comparative analysis is summarised in the following Flow Chart.

FLOW DIAGRAMME OF THE
MULTICRITERIA EVALUATION METHODOLOGY



5. From examining the alternative proposals to evaluation of the Project Outlines

5.1. Examination of projects and proposals submitted to the Town Council

In the first instance, the Working Group examined all the material presented to the Town Council. Subsequently, in order to complete the documentation necessary for evaluation of the project proposals, the Working Group asked the project proponents to complete a questionnaire regarding the following elements and evaluations:

a) Description of the proposal: key concepts, strengths and critical factors;
b) Experiment ability, gradualism and reversibility of the proposed project;
c) Effect of inlet measures on attenuating tide levels with reference to reducing tidal peaks and modifying the volumes of water exchanged between the sea and lagoon in normal conditions and also when there is "*acqua alta*";
d) Environmental impacts and effects of the works;
e) Relation to the objectives of re-establishing equilibrium and halting the degradation of the lagoon;
f) Cost of the works and operation;
g) Construction timescale.

5.2. Identifying characteristics of the planned solutions

On the basis of the submissions and completed questionnaires, the projects and proposals were analysed with a view to evidencing the particular identifying characteristics of the projects and in relation to the economic, social and environmental system. To this end the following table was compiled.

IDENTIFYING CHARACTERISTICS OF THE PROJECTS AND PROPOSED DESIGNS

Proposers and **PROJECTS**	**1** **CVN-MAV** Measures at the inlets to regulate tidal flows	**2** **Di Tella** Gravity sluice gates	**3** **Tec Norconsult** (cf. Rotterdam Project) Hinged arm barriers	**4** **Tamburrino** DOGE	**5** **De Piccoli** Ve.Perla	**6** **Ieno** ARCA	**7** **Nav.Designs TMT** Tide control solutions	**8** **Tec Norconsult** Rubber barriers	**9** **Pellegrinotti** Ship Gates	**10** **E. Massimo Serv.Tec. Srl** "Study to Save Venice"
Barriers with "lifting pane Submerged when resting	X						X			
Barriers with "Gravity based panels" Submerged when resting		X								
Barriers with mobile panels operated mechanica Submerged when resting										**X**
Barriers of floating elements Submerged when resting				X				X		
Semi mobile protruding floating barriers			X		X	X			X	
Seasonally removable barriers					X	X			X	
Fixed interventions to moderate tide levels	X				X	X		X	X	
Permanent closure of the inlets	X	X		X	X	X		X	X	
Partial closure of the inlets		X			X	X			X	
Relocation of passenger terminal to the Lido inlet					X					
Partitioning of the lagoon										X

5.3 Project outlines and Evaluation

The identifying characteristics shown in the table synthesise the various projects and proposals according to category of solution represented by the various **project outlines** on which the Working Group has based its multicriteria analysis.

CATEGORIES OF THE PROPOSED SOLUTIONS

PROPOSED SOLUTIONS

- total closure of the inlets with barriers made of lifting and floating panels submerged when resting
- total or partial closure of the inlets with submerged gravity barriers
- total closure of the navigation Channel with hinged arm barriers
- total or partial closure of the inlets with inflatable rubber barriers submerged when resting
- partial restriction of the inlets with fixed structures and/or mobile closures (ship-gates, self sinking tanks, incl. semi-fixed) removable, seasonally, protruding when resting
- partial restriction of the inlets with permanent interventions, seasonal measures associated with relocation of the passenger terminal (cruise ships etc) to the Lido inlet
- temporary partition of the Lagoon and total closure of the Inlets with mechanical barriers, Submerged when resting

Comparison of the proposed solutions within the *Framework for Synergistic Safeguarding Interactions* (see section 1) shows that:

- All the solutions examined include measures to regulate tidal flows at the inlets, albeit with significant differences in the extent, seasonality and gradualism of the measures.

It is worth noting that:

- The third line <total closure of the navigation channel with hinged arms> based on the project executed at Rotterdam Port, is not evaluated in the following comparative analysis since it has not been adapted to the context of the Venice lagoon. The Rotterdam case can still be taken as an example of a selection procedure based on a comparison of several types of project (coincidentally, it seems, one of these is substantially similar to the only solution that has so far been adopted for Venice).

- The solution <total or partial closure with inflatable barriers submerged when resting> seems to be more suited to blocking tides in secondary canals, according to one of its proponents, i.e. to protect *macroinsule* or main channels in the lagoon.

- The proposal <relocation of the passenger terminal>, hypothesising a different aspect of port activities with respect to the Lido inlet, represents an innovative strategic extension of the set of measures for partial or complete closure of the inlets using ship-gates or auto-sinking vessels.

5. 4. Attribution of values to the project outlines

From the syntheses, the Project Outlines were determined, and the working group has based the multicriteria comparison on these.

The project outlines arising from the alternative proposals were considered on the basis of their potential positive values, despite some incongruities which were perceived for some of the proposals due to their relatively early stage of development and which are deemed resolvable. For the Mo.S.E. project, the indications of the designer were used.

The project outlines (LP) examined were as follows:

LP I **Closure of the inlets with lifting floating panels, submerged when resting.**

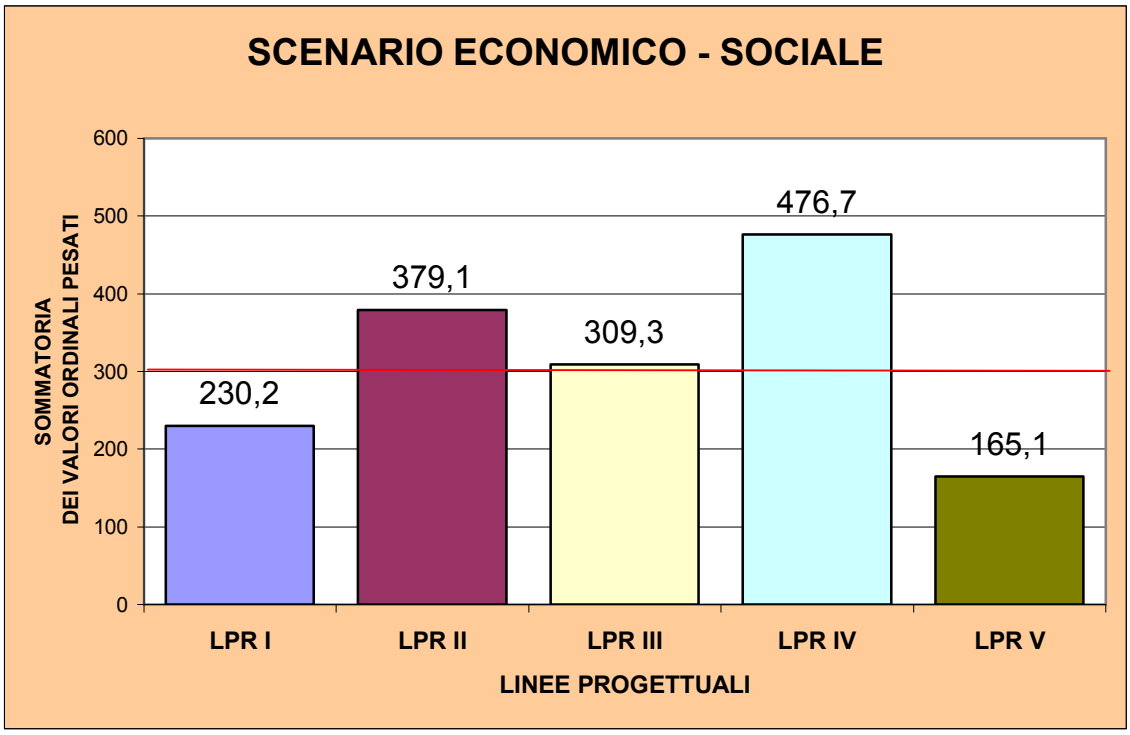
LP II **Closure of the inlets with gravity panels, submerged when resting.**

LP III **Total closure of the inlets with inflatable mobile barriers, submerged when resting and possibility of partially reducing cross section of sections of canals.**

LP IV **Reduction of inlet cross section with fixed elements, emergent structures when open, with the possibility of partial or total closure with ship-gates, auto-sinking or self-propelled vessels (also including relocation of passenger terminal to the Lido inlet).**

LP V **Temporary partition of the lagoon and total closure of the inlets with mechanical mobile barriers, submerged when resting.**

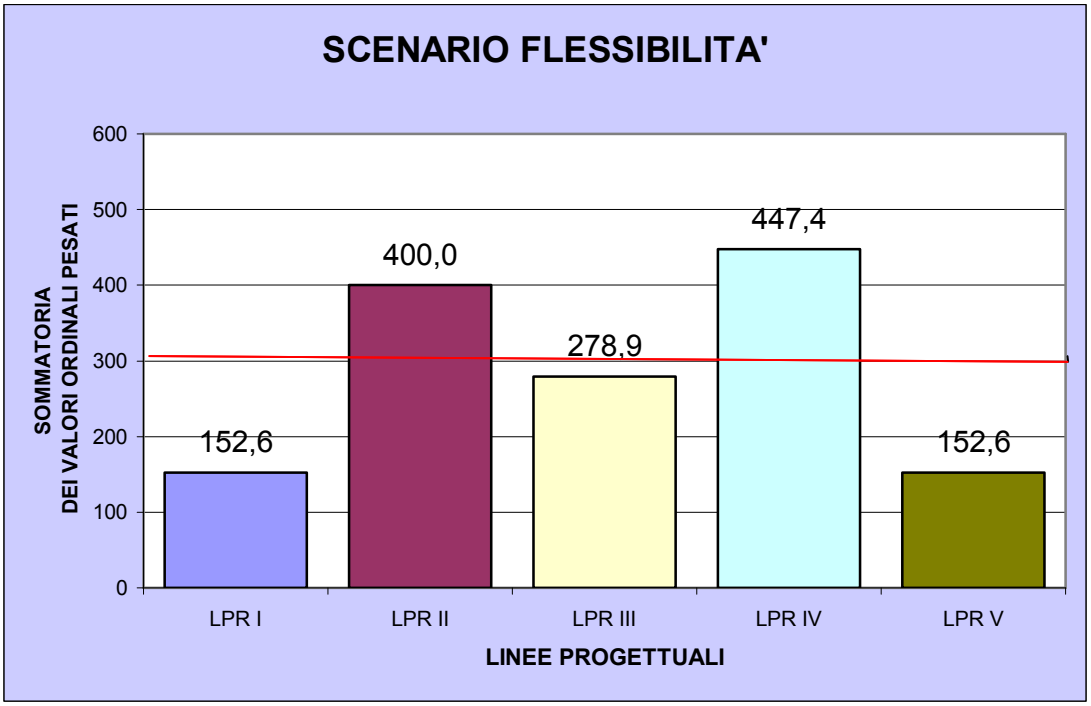
Each of the five Lines has been compared within the context of the five Scenarios: socio-economic, flexibility, engineering, environmental sustainability, costs.



INDICATORS, WEIGHTINGS AND ORDINAL VALUES

SCENARIO 1 socio-economic

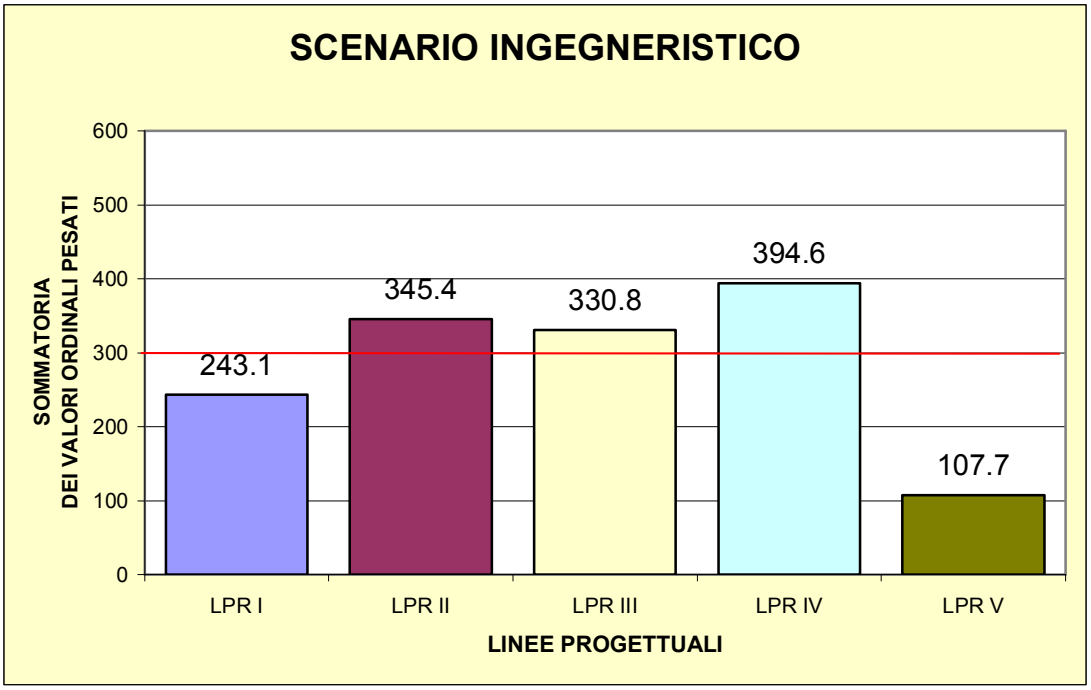
INDICATORS	weighting	wt (%)	LPR I	LPR II	LPR III	LPR IV	LPR V	
1.1	10,0	11,6	2,0	4,0	4,0	4,0	2,0	
1.2	10,0	11,6	2,0	4,0	3,0	5,0	2,0	
1.3	10,0	11,6	2,0	4,0	2,0	6,0	1,0	
1.4	10,0	11,6	2,0	4,0	3,0	5,0	2,0	
1.5	10,0	11,6	2,0	4,0	3,0	4,0	2,0	
1.6	10,0	11,6	2,0	3,0	2,0	4,0	1,0	
1.7	10,0	11,6	3,0	4,0	4,0	5,0	1,0	
1.8	8,0	9,3	3,0	4,0	4,0	5,0	1,0	
1.9	8,0	9,3	3,0	3,0	3,0	5,0	3,0	
	86,0	100,0						
1.1			23,3	46,5	46,5	46,5	23,3	
1.2			23,3	46,5	34,9	58,1	23,3	
1.3			23,3	46,5	23,3	69,8	11,6	
1.4			23,3	46,5	34,9	58,1	23,3	
1.5			23,3	46,5	34,9	46,5	23,3	
1.6			23,3	34,9	23,3	46,5	11,6	
1.7			34,9	46,5	46,5	58,1	11,6	
1.8			27,9	37,2	37,2	46,5	9,3	
1.9			27,9	27,9	27,9	46,5	27,9	
Total			**230,2**	**379,1**	**309,3**	**476,7**	**165,1**	
Total (%)			**14,8**	**24,3**	**19,8**	**30,6**	**10,6**	**100**
	Scenario 25%		**3,7**	**6,1**	**5,0**	**7,6**	**2,6**	**25,**



INDICATORS, WEIGHTINGS AND ORDINAL VALUES

SCENARIO 2 flexibility

INDICATORS	weighting	wt (%)	LPR I	LPR II	LPR III	LPR IV	LPR V	
2.1	10,0	26,3	2,0	4,0	3,0	4,0	2,0	
2.2	10,0	26,3	2,0	4,0	3,0	4,0	2,0	
2.3	10,0	26,3	1,0	4,0	3,0	5,0	1,0	
2.4	8,0	21,1	1,0	4,0	2,0	5,0	1,0	
	38,0	100,0						
2.1			52,6	105,3	78,9	105,3	52,6	
2.2			52,6	105,3	78,9	105,3	52,6	
2.3			26,3	105,3	78,9	131,6	26,3	
2.4			21,1	84,2	42,1	105,3	21,1	
Total			**152,6**	**400,0**	**278,9**	**447,4**	**152,6**	**1431,6**
Total (%)			**10,7**	**27,9**	**19,5**	**31,3**	**10,7**	**100,0**
Scenario 12,5%		**0,125**	**1,3**	**3,5**	**2,4**	**3,9**	**1,3**	**12,5**

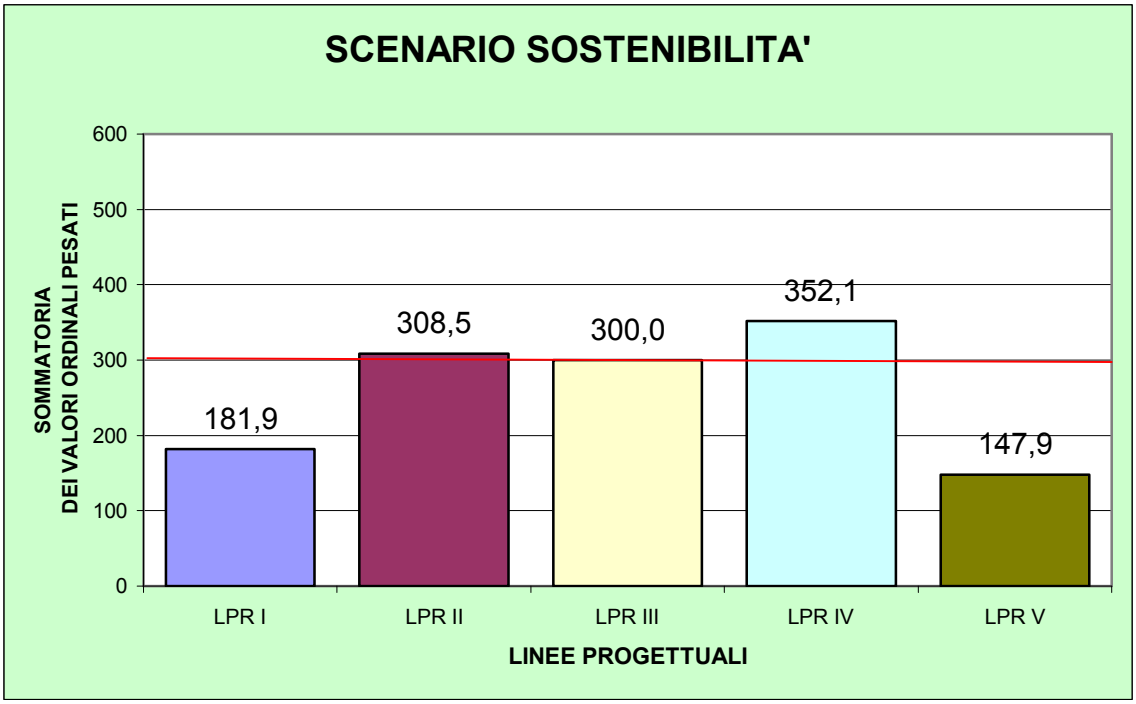


INDICATORS, WEIGHTINGS AND ORDINAL VALUES

SCENARIO 3 engineering

INDICATORS	weighting	Wt (%)	LPR I	LPR II	LPR III	LPR IV	LPR V
3.1	10,0	7,7	4,0	4,0	2,0	4,0	1,0
3.2	5,0	3,8	2,0	2,0	4,0	4,0	1,0
3.3	8,0	6,2	3,0	4,0	4,0	4,0	1,0
3.4	8,0	6,2	2,0	4,0	3,0	5,0	1,0
3.5	10,0	7,7	2,0	3,0	3,0	4,0	1,0
3.6	8,0	6,2	2,0	3,0	3,0	4,0	1,0
3.7	10,0	7,7	3,0	4,0	4,0	4,0	2,0
3.8	5,0	3,8	2,0	3,0	3,0	3,0	1,0
3.9	10,0	7,7	2,0	3,0	2,0	4,0	1,0
3.10	10,0	7,7	2,0	3,0	3,0	3,0	1,0
3.11	10,0	7,7	3,0	4,0	4,0	4,0	1,0
3.12	8,0	6,2	3,0	4,0	4,0	4,0	1,0
3.13	9,0	6,9	2,0	2,0	3,0	4,0	1,0
3.14	9,0	6,9	2,0	4,0	4,0	4,0	1,0
3.15	10,0	7,7	2,0	4,0	4,0	4,0	1,0
	130,0	100,0					
3.1			30,8	30,8	15,4	30,8	7,7
3.2			7,7	7,7	15,4	15,4	3,8
3.3			18,5	24,6	24,6	24,6	6,2
3.4			12,3	24,6	18,5	30,8	6,2
3.5			15,4	23,1	23,1	30,8	7,7
3.6			12,3	18,5	18,5	24,6	6,2
3.7			23,1	30,8	30,8	30,8	15,4
3.8			7,7	11,5	11,5	11,5	3,8
3.9			15,4	23,1	15,4	30,8	7,7

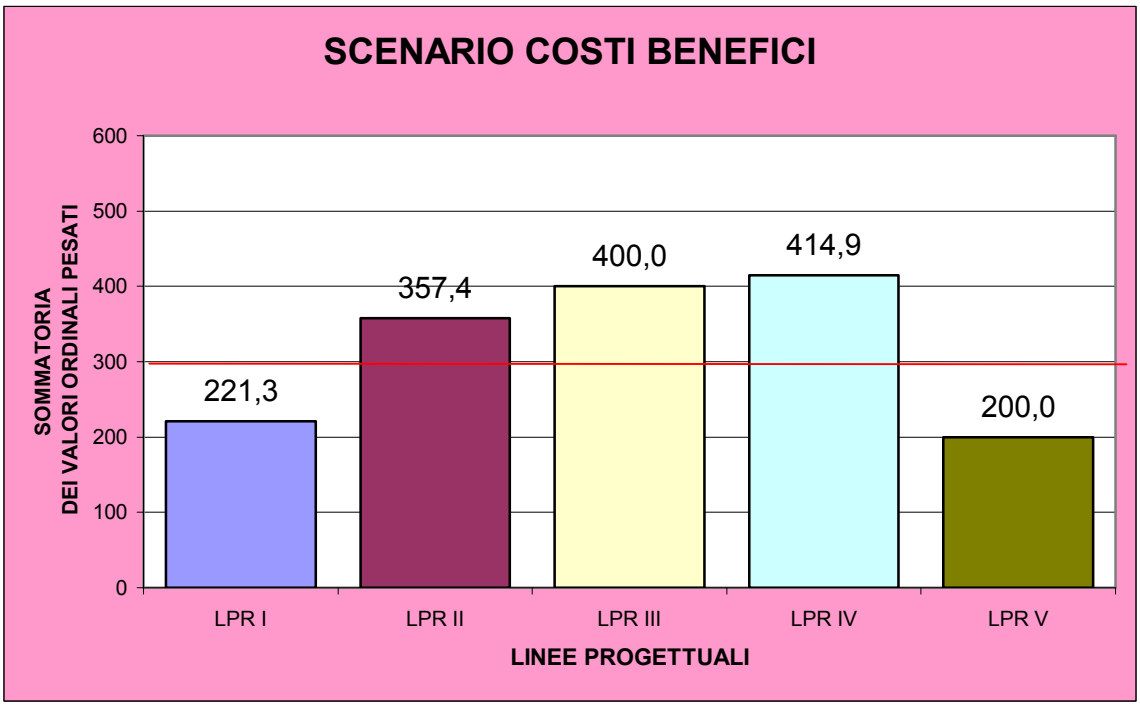
3.10			15,4	23,1	23,1	23,1	7,7	
3.11			23,1	30,8	30,8	30,8	7,7	
3.12			18,5	24,6	24,6	24,6	6,2	
3.13			13,8	13,8	20,8	27,7	6,9	
3.14			13,8	27,7	27,7	27,7	6,9	
3.15			15,4	30,8	30,8	30,8	7,7	
Total			**243,1**	**345,4**	**330,8**	**394,6**	**107,7**	**1421,5**
Total (%)			**17,1**	**24,3**	**23,3**	**27,8**	**7,6**	**100,0**
Scenario 25%		**0,25**	**4,3**	**6,1**	**5,8**	**6,9**	**1,9**	**25,0**



INDICATORS, WEIGHTINGS AND ORDINAL VALUES

SCENARIO 4 sustainability

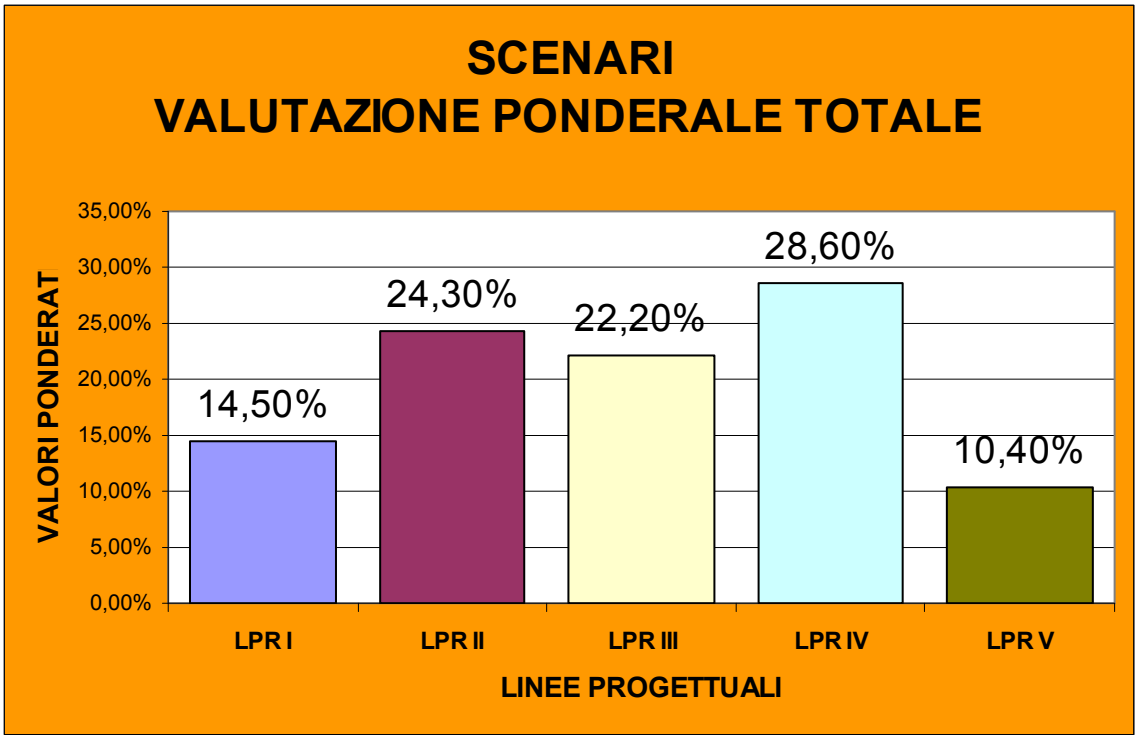
INDICATORS	weighting	wt (%)	LPR I	LPR II	LPR III	LPR IV	LPR V	
4.1	10,0	10,6	2,0	3,0	3,0	4,0	1,0	
4.2	7,0	7,4	1,0	3,0	3,0	3,0	2,0	
4.3	10,0	10,6	2,0	3,0	3,0	4,0	1,0	
4.4	8,0	8,5	2,0	4,0	3,0	4,0	2,0	
4.5	7,0	7,4	2,0	3,0	3,0	4,0	1,0	
4.6	6,0	6,4	2,0	3,0	3,0	4,0	1,0	
4.7	8,0	8,5	3,0	3,0	3,0	4,0	1,0	
4.8	10,0	10,6	2,0	3,0	3,0	3,0	1,0	
4.9	8,0	8,5	1,0	3,0	3,0	3,0	1,0	
4.10	10,0	10,6	2,0	3,0	3,0	3,0	2,0	
4.11	10,0	10,6	1,0	3,0	3,0	3,0	3,0	
	94,0	100,0						
4.1			21,3	31,9	31,9	42,6	10,6	
4.2			7,4	22,3	22,3	22,3	14,9	
4.3			21,3	31,9	31,9	42,6	10,6	
4.4			17,0	34,0	25,5	34,0	17,0	
4.5			14,9	22,3	22,3	29,8	7,4	
4.6			12,8	19,1	19,1	25,5	6,4	
4.7			25,5	25,5	25,5	34,0	8,5	
4.8			21,3	31,9	31,9	31,9	10,6	
4.9			8,5	25,5	25,5	25,5	8,5	
4.10			21,3	31,9	31,9	31,9	21,3	
4.11			10,6	31,9	31,9	31,9	31,9	
Total			**181,9**	**308,5**	**300,0**	**352,1**	**147,9**	**1290,4**
Total (%)			**14,1**	**23,9**	**23,2**	**27,3**	**11,5**	**100,0**
Scenario 25%		0,25	**3,5**	**6,0**	**5,8**	**6,8**	**2,9**	**25,0**



INDICATORS, WEIGHTINGS AND ORDINAL VALUES

SCENARIO 5 cost - benefits

INDICATORS	weighting	wt (%)	LPR I	LPR II	LPR III	LPR IV	LPR V	
5.1	10,0	21,3	1,0	3,0	4,0	4,0	1,0	
5.2	10,0	21,3	2,0	3,0	4,0	4,0	1,0	
5.3	10,0	21,3	2,0	3,0	3,0	3,0	1,0	
5.4	10,0	21,3	4,0	5,0	5,0	5,0	5,0	
5.5	7,0	14,9	2,0	4,0	4,0	5,0	2,0	
	47,0	100,0						
5.1			21,3	63,8	85,1	85,1	21,3	
5.2			42,6	63,8	85,1	85,1	21,3	
5.3			42,6	63,8	63,8	63,8	21,3	
5.4			85,1	106,4	106,4	106,4	106,4	
5.5			29,8	59,6	59,6	74,5	29,8	
Total			**221,3**	**357,4**	**400,0**	**414,9**	**200,0**	**1593,6**
Total (%)			**13,9**	**22,4**	**25,1**	**26,0**	**12,6**	**100,0**
Scenario 12,5%		**0,125**	**1,7**	**2,8**	**3,1**	**3,3**	**1,6**	**12,5**



SUMMARY TABLE
OVERALL WEIGHTED EVALUATION OF THE SCENARIOS IN PERCENTAGES

	LPR I	LPR II	LPR III	LPR IV	LPR V	Total
Scenario 1	3,7	6,1	5,0	7,6	2,6	25,0
Scenario 2	1,3	3,5	2,4	3,9	1,3	12,5
Scenario 3	4,3	6,1	5,8	6,9	1,9	25,0
Scenario 4	3,5	6,0	5,8	6,8	2,9	25,0
Scenario 5	1,7	2,8	3,1	3,3	1,6	12,5

Total	14,6	24,4	22,2	28,6	10,3	100,0

6. Conclusions

1. This Report on "Comparison of Alternative Measures" is the first instance in which the various project outlines for measures at the inlets are directly compared.

2. It has been noted that there is clear inequality between the only project examined formally by the State and others proposed by various bodies. Until now, none of the alternative proposals had been in a condition to be developed at least to the preliminary project level, even though some of the proposals presented seem interesting and worth being explored further.

3. The necessity for a proper comparison is clearly shown by the results, summarised in the diagrams and tables of this report.

4. The main concepts expressed in the legislation do not separate measures at the inlets from the general safeguarding objectives for the lagoon, Venice and the lesser urban settlements. A new approach is necessary, which is more articulated and integrated, and which delineates solutions that are coherent in terms of the overall safeguarding objectives. In relation to measures at the inlets, according to the Working Group (Mayor's provision of 6 June 2005 n. 2004/200458) the following is noted:

   The three inlets have distinct characteristics due to environmental and hydraulic aspects, and present different issues and priorities with regard to urban settlements and economic activities, port business above all. Contrary to what has happened so far, different solutions for each of the three inlets are being considered according to the specific environmental conditions and specific functions.

   Works at each inlet should be designed in the context of overall solutions able to meet the contextual safeguarding objectives regarding local residents and port activity, tide regulation, re-equilibrium of the lagoon, including areas far from the inlets.

   Among the solutions examined some are not alternatives with respect to each other, but potentially integrated and synergistic. In particular, solutions for partial and total closure can and/or must be integrated with each other, and in opportune ways have synergies with strategic solutions and systemic approaches on different scales.

5. Particular interest lies in the planning hypotheses that take account of future scenarios which include the relocation of significant marine traffic from the lagoon.

6. Closure of the inlets cannot be considered a medium-long term solution for the expected changes due to sea level rise and subsidence over the next century. Systems to regulate tide flows through the inlets, already by 2050, will need to function with such frequency as to compromise lagoon ecosystem and port activities.
   Considering this, all international experience, analysis and investigations – theoretical and experimental – must be directed at making it possible to raise ground levels in areas of the urban settlements and the lagoon.

   Venice, 15 November 2005

Appendix

Description of the indicators and valuations

<u>Examination of the indicators, relative weights and reasons for the valuations given to the various project outlines for each indicator</u>

For each indicator the following are summarised below:

- Weighting and description;
- Explanation of reference indicator in relation to the issues under examination;
- Reasoning behind the valuation in terms of the ordinal values attributed to the various outlines with their corresponding numerical value.

ORDINAL VALUE: high negative	**parameter: 1**
ORDINAL VALUE: medium negative	**parameter: 2**
ORDINAL VALUE: low negative	**parameter: 3**
ORDINAL VALUE: low positive	**parameter: 4**
ORDINAL VALUE: medium positive	**parameter: 5**
ORDINAL VALUE: high positive	**parameter: 6**

1 – *SOCIO-ECONOMIC SCENARIO*

1.1 Compatibility of inlet interventions and port functions during the construction phase
1.2 Compatibility of inlet closure operations and port functions
1.3 Compatibility of inlet maintenance operations and port functions
1.4 Response to the objective of separating navigation requirements of the port and safeguarding requirements as regards reducing depth at the inlets
1.5 Compatibility of port activities and "announcement" effect
1.6 Compatibility with safeguarding port activities, considering future sea level rise
1.7 Safeguarding urban areas and historic buildings
1.8 Safeguarding mobility, urban socio-economic activities and local residents
1.9 Revalorization of urban areas

The safeguarding and development of port traffic represents a key and determining aspect for the design of interventions at the inlets. This is considered to be of the highest level of importance in all the indicators which refer to the port and is determined on the basis of the impacts the inlet closure system has on the transit of ships.

1.1 Compatibility of inlet interventions and port functions during construction phase

The indicator assumes the highest importance (10).

- Construction at the inlets that requires foundations and underground structures necessitates long and heavy interventions which infringe upon port traffic in relation to the magnitude of the works.
- The interference depends on the timescale of the works and also considers possible solutions to be adopted during the construction phase to overcome the obstacles to navigation. The presence of the navigation lock at Malamocco through which all traffic should pass, "permanently", still has consequences on port accessibility. The lock at Malamocco is necessary during the construction phase for those solutions that foresee

interference to navigation from the building site, the extent of which depends on the duration of the works.

The ordinal value is high-positive in as much as the shorter the duration of the construction, the lower the interference to navigation.

The assigned ordinal values are:

o.v. negative medium **parameter 2: LP I , LP V**
o.v. positive low **parameter 4: LP II, LP III, LP IV**

1.2 Compatibility of the inlet works with port functions during closure (total or partial)

This indicator has the maximum weighting (10).

- Where significant moderation of water levels in the lagoon is not planned via fixed structures or seasonally movable structures, interruption of the port activities will be as frequent as the occurrence of tides of + 100 cm /+110 cm.
- During total closure of the openings, albeit with different barrier systems (panels, ship-gates etc.), transit through the inlets will be subject to delays both coming into and leaving the lagoon. The impact of waiting times must be considered within the economic costs of the stopover. The cost is measured in terms of length of time traffic is interrupted, increase in waiting time and the increase in time taken for ships to pass through the lock, as well as delays in the activities at the harbour.
- Interference of the total closure on port activities is based on the duration of the tide event, time necessary to carry out the opening and closing manoeuvres at the inlets and the incidence of false alarms (false alarm with brief closure of the inlets and mistaken announcement without closing the inlets).
- In conditions of very frequent and prolonged closures the navigation lock is not considered a valid alternative without also considering a cost for the port economy (comparison of closure times can be made considering the consistent and repeated high tides above 100-110 cm of 2002 and the cautious scenario for possible sea level rise this century of 35 cm).
- Winter positioning of the ship-gates or sunken caissons would allow modular management of ship transit and introduce the possibility of verifying the effects of inlet closure measures via gradualism; regulation of water flows using (re)movable structures and calibration of the inlets using fixed elements limits the number of total closures to purely exceptional events,
- Redirection of cruise traffic to the Lido inlet adds a further element to economic development, provided it was done in an environmentally compatible way.

A high-positive ordinal value is given to those projects that only require total closure of the inlets during exceptional high tides**.**

Assigned ordinal values are:

o.v. negative medium **parameter 2: LP I, LP V**
o.v. negative low **parameter 3: LP III**
o.v. positive low **parameter 4: LP II**
o.v. positive medium **parameter 5: LP IV**

1.3 Compatibility of inlet maintenance operations and port functions

Maximum weighting is assigned (10).

- Maintenance operations of the barrier structures can obstruct port traffic. Such operations, albeit of different types (routine and/or special, carried out on site fully or partially), should not constitute an obstacle to navigation.

Maximum compatibility is attributed to projects that create less difficulty for transit through the inlets. Solutions that involve removable structures combined with fixed structures, will have lower maintenance.
Lower values are assigned to the project outlines that require complex and elaborate maintenance, the presence of special vessels in the port channel, presence of underwater workers (divers).

Ordinal values assigned are:

o.v. negative high	**parameter 1: LP V**
o.v. negative medium	**parameter 2: LP I, LP III**
o.v. positive low	**parameter 4: LP II**
o.v. positive high	**parameter 6: LP IV**

1.4 Response to the objective of separating navigation requirements of the port and safeguarding requirements as regards reducing depth of the lagoon at the inlets

Maximum weighting has been assigned (10).
The indicator expresses the degree of differentiation of the solution at the 3 inlets in relation to port access in whatever conditions, and the effective raising of inlet depth to the levels prescribed by safeguarding priorities.
The system of accessibility to the various port terminals is set by the access channels at the 3 inlets – Lido, Malamocco and Chioggia connected via a navigation channel: canale di S. Nicolò, canale di Treporti, canale di S. Elena, bacino S. Marco, canale Vittorio Emanuele, canale di Malamocco-Marghera and canale Lombardo.
Currently, port activities in the lagoon are organised by the *Maritime Station*, which is strictly associated with cruise traffic and ferries; the *commercial port at Marghera*, which has several docks for goods traffic (containers, bulk goods, etc.), the *industrial zone of Marghera* which ensures the functional autonomy of the supply of raw materials and the exportation of semi-processed goods, the *port at S. Leonardo* for the supply of oil industry products, the *Port of Chioggia-val di Rio* for commercial traffic and bridgehead for the Paduan river and canal system, the *fishing port of Chioggia*.

A positive value is assigned to those project outlines that foresee modification of the logistical organisation of the port to avoid penalising both the port as well as safeguarding of the lagoon.

The assigned ordinal values are:

o.v. negative medium	**parameter 2: LP I, LP V**
o.v. negative low	**parameter 3: LP III**
o.v. positive low	**parameter 4: LP II**
o.v. positive medium	**parameter 5: LP IV**

1.5 Compatibility of port activities and "announcement" effect

The indicator carries the highest level of importance (10).

- The indicator evaluated the effect of announced closure (real or false alarm) as regards the shippers stopping, or intending to stop at Venice. Interrupted access on an unspecified number of occasions, and not necessarily always foreseen or foreseeable, could take away the incentive of stopping at Venice.
- Lack of certainty of reaching the Port of Venice according to established plans could provoke some operators to abandon the Venice port.
- Intensification of false alarms increases with weather turbulence and expected sea level rise.

Compatibility increases for types of structure and management scenario that reduce the required number of closures, control the "announcement effect" and don't produce damage associated with false alarms.

Assigned ordinal values are:

o.v. negative medium	**parameter 2: LP I, LP V**
o.v. negative low	**parameter 3: LP III,**
o.v. positive low	**parameter 4: LP II, LP IV**

1.6 – Compatibility with safeguarding port activities under conditions of sea level rise

The indicator has fundamental importance (10).

- To evaluate the influence of future sea level scenarios, a reliable estimate for the expected rise over the next century is needed. The reference level assumed and estimated as the probable increase according to accredited international agencies is +35cm s.l.r. (30cm eustacy and 5 cm subsidence). Meteo-climatic perturbations at a local level will become more intense and frequent. Increasing sea level is inevitably connected to the frequency of "acque alte", from which Venice must be protected.
- Fixed and/or removable structures designed to moderate water levels in the lagoon are indispensable for addressing, in a gradual way, the effects of the meteorological perturbations and s.l.r. phenomenon.

Positive values are for versatility and flexibility in adapting to rising sea levels and the gradualism of the intervention. Certain project outlines propose measures that can be adjusted in the case of rising seas, with contained costs and timescales, and within the construction scheme.

Assigned ordinal values are the following:

o.v. negative high	**parameter 1: LP V**
o.v. negative medium	**parameter 2: LP I, LP III**
o.v. negative low	**parameter 3: LP II**
o.v. positive low	**parameter 4: LP IV**

1.7 Safeguarding of urban areas and buildings

Safeguarding is given the highest weighting (10) as regards the physical aspects of the city, primary objective of the Special Law as regards the ongoing and progressive damage to the city's fabric.

- Regarding the efficacy of mitigating measures for medium and medium-high tides which are the most frequent and prevention of exceptionally high tides for the purpose of not damaging the stability of and/or causing degradation of the embankments and building foundations, underground infrastructure network, and degradation of building walls and buildings generally, and deterioration of wiring, plasterwork renderings, the accessibility and conditions of ground floor levels.
- Efficacy of safeguarding the urban fabric depends firstly on the dissipative and regulating capacity of the inlets and, over the longer term, restoration of the quota relative to water level of the ground, buildings, and large areas of the territory.
- Considering significant sea level changes, stable long term protection comes in the form of systematic measures at ground level and underground, to raise buildings and broader areas to make them less susceptible to flooding.

All the project outlines address the issue of medium-high tides, while they are substantially different in the way they deal with medium level tides, including those between + 90 cm and 110 cm (*currently assumed level for total closure of the inlets)*. Assigned values consider the capacity to make medium tides less frequent (while the efficacy of blocking sea-lagoon exchanges completely in the case of an exceptional tide is considered in the "Engineering Scenario"), with dissipating measures which result in an effective and significant reduction in tidal peaks.
A positive ordinal value is given to project outlines that can partially block the inlets with fixed narrowing structures and mobile portions that can be regulated on a seasonal basis.

Assigned ordinal values are:

o.v high negative **parameter 1: LP V**
o.v. low negative **parameter 3: LP I,**
o.v. low positive **parameter 4:LP II, LP III**
o.v. medium positive **parameter 5: LP IV**

1.8 Safeguarding urban mobility, socio-economic activities and residency

Indicator of significant incidence, tied to the temporary and reversible characteristics of the "acqua alta" phenomenon (8).

- With respect to the 1970s, the housing crisis in terms of families living in apartments at ground floor level and therefore vulnerable to flooding has now been mostly resolved.
- Raising ground levels towards +120 cm (where possible) is definitely useful but not a definitive solution, especially in view of rising sea levels.
- Ongoing development of the tide alert and forecasting system, run by the Town Council, is extremely useful for the city and islands as regards mobility and socio-economic activities.
- Reinforcement of sea defences, warning systems and services for the handling of emergency situations, and risk control – in terms of human risks – to within very low levels.
- Even in the presence of total closure of the inlets, as in the Mo.S.E. system, problems remain in the lowest areas of the city which lie at quotas below the protection level criterion (this was fist set at +100 cm, then raised to + 110cm).

- Measures at the inlets must, according to the Special Law, moderate water levels in the lagoon in order to cancel or reduce difficulties associated with flooding in the lowest parts of the city (about 25-30% of urban areas).
- This objective can be realised best via fixed measures at the inlets to attenuate tide levels, and definitively via systemic measures affecting ground levels, for islets (*insule*) and *macroinsule*, projects for raising ground levels for the whole lagoon area, using the most advanced technological resources available.

A medium-high ordinal value is assigned to project outlines which include attenuation of medium level tides with narrowing of the inlets and/or installation of movable structures on a seasonal basis. A negative ordinal value is reserved for those measures which set closure of the barriers at the "safeguarding level", currently + 110 cm, with the consequent acceptance of partial flooding of the city.

Assigned ordinal values are:

o.v. high negative **parameter 1:LP V**
o.v. low negative **parameter 3:LP I**
o.v. low positive **parameter 4:LP II, LP III**
o.v. medium positive **parameter 5: LP IV**

1.9 Revalorisation of urban areas

Indicator of significant weighting (8), albeit not a priority as regards the physical safeguarding objectives, the strategic aspect of protection and socio-economic development of the city is considered.

- Concerns the level of appreciation of urban areas which can be transformed or returned to functions which are different to current uses with the possibility of new land use scenarios.
- The possibility, outlined in one of the projects, to relocate the cruise passenger terminal, which would bring a significant advantage in terms of this indicator and is compatible with all the various proposed solutions for blocking tidal flows.
- The positive value is attributed to projects which are most adapted to the relocation of the passenger terminal. Considering projects carried out at other ports, this hypothesis would allow areas of the *Marittima* (25-30 hectares) in the Historic Centre to be used for new developments with a strategic impact on social and economic effects.

Assigned ordinal values are:

o.v. low negative **parameter 3: LPI, LP II, LP III, LPV**
o.v. medium positive **parameter 5: LP IV**

2 – *FLEXIBILITY SCENARIO*

2.1 - Experimentability
2.2 - Gradualism
2.3 - Reversibility
2.4 – Adaptability to seasonal conditions

The first three indicators are of basic importance since they are explicitly required by the State Law n. 798 of 29 November 1984 (art. 3, comma 1, letter a) which carries all the votes of the Upper Council for Public Works n. 209 of 27 May 1982; these acts are the defining and conceptual basis of this Study and its evaluation methodology.

2.1 - Experimentability

- Maximum weighting (10) since it is explicitly required by the Special Laws.
- Experimentability in Vote n. 209 /82 refers to "*the possibility of constructing fixed barriers to facilitate the attenuation of tide levels, before proceeding with the construction of mobile barriers, with the possibility to modify the width of the opening without substantial cost changes*".
- Development of the experimentability must be concluded during the planning stage rather than be interpreted as the *"experimental aspect of the works"* which *"does not finish with the planning phase but continues during the equally important construction and management phases of the works*" (Environmental Impact Study 1998 Appendix 6 Theme 2). This last interpretation subverts the planning process which must end with the complete executive project; variants to the executive project can be made if needed.

Assigned ordinal values are as follows:

o.v. medium negative	**parameter 2: LP I, LP V**
o.v. low negative	**parameter 3: LP III,**
o.v low positive	**parameter 4: LP II, LP IV**

2.2 - Gradualism

Maximum weighting (10) due to the explicit requisite of the Special Laws.

- Vote no. 209/82 underlines the need for carrying out " *by degrees to allow all necessary comparisons and verifications of the real model*"… and "*to obtain by degrees precise answers regarding the real behaviour of the planned works before moving onto the successive phase*".

The indicator therefore doesn't only refer to a phase by phase procedure but to the fact that the outcome of the works must be amenable to evaluation in stages, as a function of their efficiency and achievement of expected results.

Assigned ordinal values are as follows:

o.v. medium negative	**parameter 2: LP I, LP V**
o.v. low negative	**parameter 3: LP III**
o.v. low positive	**parameter 4: LP II, LP IV**

2.3 - Reversibility

Maximum weighting (10) due to the explicit requisite of the Special Laws.

- Reversibility as intended for the carrying out of works lies in the possibility to remove the works and return the environment to its pre-existing state. At the functional level, reversibility could be interpreted as referring to the removable parts of the structure placed *in situ* to modulate the expected effects of the intervention and to restore pre-existing conditions. *"Sterilisation of the works left inoperative in situ"* (Environmental Impact Study 1998 Appendix 6 Theme 2) cannot be considered equivalent to reversible, especially if the intervention involves interference with the geomorphological system, if it conditions possible future works, if it is characterised by intrinsic structural risks relating to the safety of the system (*methane, sulphur dioxide, which may accumulate in the structures under the lagoon via infiltration through the concrete base*).

Maximum reversibility depends on the time scale of the installation and consequent reversibility of its effects on the environment and safety conditions.
(For reversibility as regards effects on biological systems see section 4.6).

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP I, LP V**
o.v. low negative	**parameter 3: LP III**
o.v. low positive	**parameter 4: LP II,**
o.v. medium positive	**parameter 5: LP IV**

2.4 Adaptability to seasonal conditions

Significant weighting (8) given the strategic and functional importance; it isn't maximum since it wasn't a primary requisite.

- It refers to the possibility of adjusting the system in a way that responds to seasonal variations, which characterise the "acqua alta" phenomenon and result in the attenuation of tide levels in the lagoon, reserving the need for total closure of the inlets only for exceptional events.
- It allows the partial reduction in inlet dimensions according to hydraulic and ecosystem functions (e.g. the need for flushing; various demands on oxygen availability according to ambient temperature; various phases in the biological cycle of species and ecological community (biocenosis).

Positive ordinal values are attributed to solutions which allow restriction of the inlets on a seasonal basis without impacting other basic functions; negative values when inlet restriction interferes with other inlet functions and to those solutions which do not consider seasonal adaptability at all.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP I, LP V**
o.v. medium negative	**parameter 2: LP III**
o.v. low positive	**parameter 4: LP II**
o.v. medium positive	**parameter 5: LP IV**

3 – *ENGINEERING SCENARIO*

3.1 - Stage of project development
3.2 - Analogous experience in an international dimension
3.3 – Compatibility of timescale for construction in relation to positive effects, including intermediate effects
3.4 – Lifetime of the works
3.5 – Technological, functional and operational simplicity of the works
3.6 – Reliability of service infrastructure and accessory machinery
3.7 – Safety of the works at the inlets
3.8 – Reliability in terms of collapse and giving way
3.9 – Maintenance, reliability and level of simplicity
3.10 – Efficacy with regard to different future scenarios for sea level rise and subsidence
3.11 – Dissipating effects at the three inlets, reduction in tidal peaks inside the lagoon and synergy with regard to local interventions (insulae, macroinsulae, etc.)
3.12 – Efficacy at blocking sea-lagoon exchange
3.13 – Morphological stability of the lagoon bottom as regards sand deposits and/or excavations relating to the works
3.14 – Protection of the stabilised geological aspect (e.g. caranto)
3.15 – Relation with the hydrodynamic aspect of the coastal currents and coastal transport

3.1 – Stage of project development

This indicator has been given the highest weighting since it is tied to the feasibility of the proposal (10)

- Considers the relationship between the project concept and the stage of development (feasibility study, preliminary outline, definitive plan, executive plan)
- The indicator seeks to highlight the relationship that must exist between the degree of detail and extent to which this has been investigated during the planning process.
- In general, more advanced planning/design should correspond to a greater degree of investigation, analysis of planning aspects and resolution of critical factors.
- It is assumed that the executive planning level must precede the construction phase and include a detailed and explicit resolution of all technical problems affecting the feasibility and viability of the entire project. Clearly the absence of a complete executive plan encompassing all aspect of the project makes it impossible to verify the hypothetical characteristics against the real feasibility/efficacy of the project's stated features.
- The relationship between stage of development and time/resources available for project development is also considered.

The indicator refers to project outlines characterised by differing stages of development. Positive values are assigned to those outlines that, even if lacking in resources, have displayed a potential that is worthy of further investigation. Negative critical values are assigned to the project LPI I, which has only formally reached the executive stage. The complete executive plan has not yet been submitted, therefore neither has it been approved, while works at the inlets have begun on the basis of "executive phases" which are only partial, and do not equate to stages of an overall executive plan.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1:LPV**
o.v. medium negative	**parameter 2:LP III**
o.v. low positive	**parameter 4: LPI, LPII, LP IV**

3.2 - Analogous experience in an international dimension

This indicator has been assigned a weighting of 5: analogous experience in an international dimension is considered important, but not essential.

- The existence of systems analogous to the proposed project provides useful knowledge which could improve planning of the inlet measures. Structures, or parts thereof, that have not been experimented previously must be based instead on a degree of experimentability, prior to execution of the works and especially in the case of works which must guarantee security and timely functioning.
- From a methodological and procedural point of view it is wrong to embark upon innovative solutions with the idea that certain design issues can be resolved during the construction phase, or even once the works are operational.

Works which can refer to existing, comparable solutions are given a positive value; negative valuations are reserved for innovative solutions that have not been sufficiently defined and tested as regards the critical structural elements.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1:LPV**
o.v. medium negative	**parameter 2: LP I, LP II**
o.v. low positive	**parameter 4: LP III, LP IV**

3.3 - Compatibility of timescale for construction in relation to positive effects, including intermediate effects

The weighting assigned to the indicator is medium relevance (8).

Once construction has begun, the indicator refers to the expected timescale for the completion of the various stages until the structure at each inlet is functional.

- This refers to the possibility of obtaining intermediate effects which attenuate and regulate tides *during* construction.
- Construction times are important in terms of achieving expected results.

Positive ordinal values are given to the project outlines that allow a rapid achievement of expected results, either intermediate or definitive.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1:LPV**
o.v. low negative	**parameter 3: LP I**
o.v. low positive	**parameter 4: LP II, LP III, LP IV**

3.4 - Lifetime of the works

The indicator is important but not essential (8).

- The duration of the works over time is important, considering their function and the investment necessary for building them.
- Technically simple and modular solutions can involve maintenance and substitution of parts that compensate for the shorter durability.
- Untested, complex technological solutions that cannot be substituted as regards the bearing structures, which pose issues for durability of the works are incompatible with alternatives.

Negative ordinal value is attributed to the outlines that indicate uncertainties regarding the behaviour over time of the structure; its non substitutable parts and materials used, also in

relation to uncontrollable phenomena/processes (e.g. leakages, gas infiltration through the concrete foundation).

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP V**
o.v. medium negative	**parameter 2: LP I**
o.v. low negative	**parameter 3: LP III**
o.v. low positive	**parameter 4: LP II**
o.v. medium positive	**parameter 5: LP IV**

3.5 - Technological, functional and operational simplicity of the works

The indicator carries maximum importance (10).

- The indicator takes account of determinant aspects for all civil engineering works. Technological simplicity of the solution, ease and safety of functioning which ensures the system will work in all conditions and guarantee expected effects, regarding all tide events or states of the sea and other details.

Positive values are assigned to the project outlines that meet these requisites; negative values to those solutions that present major uncertainties for the machinery, as well as solutions involving highly complex designs both for the fixed and moving parts, present doubts about the functional safety in relation to the forces they must work against.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP V**
o.v. medium negative	**parameter 2: LP I**
o.v. low negative	**parameter 3: LP II, LP III**
o.v. low positive	**parameter 4: LP IV**

3.6 - Reliability of service infrastructure and accessory machinery

The indicator is considered relevant for the overall reliability of the works (8).

- This indicator is directed at valuing solutions which involve the insertion, in the area of the inlets and adjacent to them, of permanent infrastructure and machinery which must be reliable and easy to manage.
- The presence of machinery considered to be an intrinsic risk (e.g. energy generation, dangerous gas deposits) constitutes a limitation for reliability inasmuch as it is a possible source of additional functional uncertainty.

A positive ordinal value is attributed to project outlines that have relatively simple service structures. The ordinal value attributed to LP I is primarily determined by the technology necessary for the functioning of the mobile parts.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP V**
o.v. medium negative	**parameter 2: LP I,**
o.v. low negative	**parameter 3: LP II,LP III**
o.v. low positive	**parameter 4: LP IV**

3.7 - Safety of the works at the inlets

Highest level indicator (10).

This indicator relates to the works in general, and in particular the moving parts that permit the attenuation/regulation of tide levels in the lagoon. Security of the inlet measures is associated with the overall proposed solution, for some aspects.

- These are positive aspects, intrinsically favourable for avoiding works failures during operations:
  - Structural security in relation to any condition at sea and wave energy as regards the ability to block tidal flow,
  - Ease of intervention for the substitution and/or repair of damaged parts.
- Untested structural prototypes constitute an uncertainty factor as regards correct functioning.

Assigned ordinal values are as follows:

o.v. medium negative **parameter 2: LP V**
o.v. low negative **parameter 3: LP I, LP II,**
o.v. low positive **parameter 4: LP III, LP IV**

3.8. - Reliability in terms of collapse and giving way

The indicator considers the possible collapse of the structures (5).
Collapse or giving way of the interventions planned at the inlets represents a real possibility. Theoretically possible events include: overbalancing, collapse, torsion, dislodgement of one or more panels, dislocation *in situ* of one or more sinking modules, flattening of inflatable structures, accident or human error, terrorist or sabotage actions.

- Collapse can bring different consequences depending on whether the effect is reversible/repairable or whether it is tied to structural characteristics which can jeopardise the functionality and reliability of the system as a whole, over time.
- In the case of mechanically floating panels, a problem which was signalled long ago by authorities on the subject, and has yet to be resolved, is represented by the possibility that the modular structure can start to resonate, due to wave energy.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

3.9 - Maintenance reliability and level of simplicity

The indicator carries the highest importance (10).
The indicator considers the conditions for maintenance of the works which must take place in a marine environment or at the workshop; depend on the presence of removable (and replaceable) elements; are subject to encrustations and biological deterioration, and the presence of and sandy deposits.

- Differing techno-operative conditions correspond to differing cost levels for maintenance (evaluated in point 5.2).

For all the requirements, positive values are assigned to the outlines that allow maintenance activities out of the water and respond to traditional naval maintenance practices.
Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I, LP III,**
o.v. low negative **parameter 3: LP II,**
o.v. low positive **parameter 4: LP IV**

3.10 - Efficacy with regard to different future scenarios for sea level rise and subsidence

- This aspect has high relevance (10), since planned interventions at the inlets must be able to function under current conditions as well as during the entire engineering lifetime of the works themselves.
- Sea level rise is expected during the next century (see point 1.6) associated with natural and human-induced subsidence. Works to protect against flooding must be able to adapt to the maximum foreseen eustatic variations without compromising systemic, environmental and port related functions.
- In the case of significant s.l.r., the importance of specific measures at the inlets becomes less significant, and instead can be synergistic with stable long term protection via systemic measures across the territory at ground level and underground, in order to raise the relative height of entire areas of Venice to make them resistant to flooding.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. low negative **parameter 3: LP I, LP II, LP III, LP IV**

3.11 - Dissipating effects at the three inlets, reduction in tidal peaks inside the lagoon and complementary with regard to local interventions (insulae, macroinsulae, etc.)

This indicator has high relevance (10) given that it relates to fundamental objectives.

- Generally speaking, introduction of fixed structures at the inlets also increases resistance to tidal currents passing through them.
- This indicator underlines the extent and manner in which planned fixed structures to reduce inlet cross-section (depth and width), increase bottom roughness and generally increase dissipative effects under various sea conditions.
- This takes account of complementary effects of works for flood protection which are complementary to other local measures in the lagoon which, in turn, but over a limited area, bring positive effects on containment of flooding. Optimal synergy reduces the frequency of complete closure of the inlets.
- A positive ordinal value is attributed to project outlines that involve a fixed reduction in inlet dimensions (possibly adjustable on a seasonal basis) which can deal with medium tides, without blocking off the lagoon completely.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. low negative **parameter 3: LP I**
o.v. low positive **parameter 4: LP II, LP III, LP IV**

3.12 - Efficacy at blocking sea-lagoon exchange

The indicator is significant (8)

- The indicator evaluates the efficacy of the sea/lagoon closure in the case of total closure of the inlets. While closed, the devices used by the various solutions, especially if oscillating, may allow the passage of water to differing extents through leakage or as a result of one of the mobile elements becoming unfastened.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. low negative **parameter 3: LP I**
o.v. low positive **parameter 4: LP II, LP III, LP IV**

3.13 – Morphological stability of the lagoon bottom as regards sand deposits and/or excavations relating to the works

The indicator is important (9) since sand deposits in the underlying structure can compromise functionality.

- Currents can cause solid materials to be deposited or erosion of the lagoon in zones which are otherwise critical for the correct functioning of regulation devices at the inlets; this indicator refers to the effectiveness of the proposed solution with respect to problems connected with interactions between measures, currents and sediments.
- Although these can be controlled via specific interventions, these will never be adequate in the face of various meteo-marine conditions that can render ineffective any maintenance interventions as well as inflate costs.

Negative ordinal values have been given to outline projects where mobile elements are designed to sit on the lagoon bottom, producing sediment traps, which can be displaced by rough sea conditions.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I, LP II**
o.v. low negative **parameter 3: LP III**
o.v. low positive **parameter 4: LP IV**

3.14 – Protection of the stabilised geological aspect (e.g. caranto)

Indicator of high importance (9).
Evaluates the extent to which interventions at the inlets interfere with geological structures that characterise the lagoon bottom in the area of the lagoon access canals.

- Particularly negative are solutions which involve breaking through the layer of "caranto" and more generally the other impermeable layers that boundary on the pressurised fluid containing layers.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low positive **parameter 4: LP II, LP III,LP IV**

3.15 – Relation with the hydrodynamic aspect of the coastal currents and coastal transport

This indicator is highly important (10) due to the delicate problem of coastal equilibriums, which today are precarious.

- The presence of works outside the inlet, necessary for some planned solutions for the correct functioning of the closure system, raises some issues. Interference with coastal currents, such interventions can change, with uncertain consequences, the current solid transport regime in proximity to the inlets.
- No less worrying are their effects on currents – ebb and flow tides and the dispersion at sea of the fine particles carried out of the lagoon by the ebb tide.

Negative ordinal values are given to project outlines that involve fixed interventions beyond the inlets, of uncertain effects on the abovementioned phenomena.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP V**
o.v. medium negative	**parameter 2: LP I**
o.v. low positive	**parameter 4: LP II, LP III,LP IV**

4 – *ENVIRONMENTAL SCENARIOS*

4.1 ***Arrest and inversion of degradation processes and elimination of its causes***
4.2 ***Environmental impacts during the construction phase***
4.3 ***Environmental impacts of the definitive system***
4.4 ***Environmental impacts on landscape***
4.5 ***Impacts of permanent interventions and removable interventions***
4.6 ***Resilience and environmental impacts of the presence of several construction sites at once and simultaneous other activities with environmental impacts***
4.7 ***Compatibility of the works and pollution effects***
4.8 ***Effects on sedimentology, morphology and lagoon functioning***
4.9 ***Impacts on lagoon archaeology and historic structures***
4.10 ***Reactivation of the principal, secondary and peripheral hydraulic circulation in the lagoon***
4.11 ***Respect of the Habitats Directive***

Positive valuations of these indicators depend on actions to limit, mitigate, compensate and improve, according to requirements of European legislation for environmental impact assessment, protection of flora and fauna and habitats; these are virtually absent from all the project outlines examined.

4.1 Arrest and inversion of degradation processes and elimination of its causes

This indicator has a high weighting because it relates to a primary objective, set also by law (10).

- A checklist of all factors that determine the degradation of the lagoon in terms of functionality and identity is required, taking into account its natural characteristics which have been managed and set by history. An examination, item by item, of critical issues, interference between items, relationships between these and conservation prospects, trends – past, current and potential, possibilities to eliminate imbalances. For each item foreseeable interferences must be examined, direct and indirect, w.r.t. the plans under examination. This is further developed in the following points.

None of the project outlines considers this aspect in a satisfactory and integrated fashion.
Negative valuation is assigned to project outlines that involve rigid structures on the lagoon bed which contrast the prospects for inverting degradation processes, with maximum negative valuation for the project that plans extended constructions that involve division of the lagoon.

Assigned ordinal values are as follows:

o.v. high negative	**parameter 1: LP V**
o.v. medium negative	**parameter 2: LP I**
o.v. low negative	**parameter 3: LP II, LP III**
o.v. low positive	**parameter 4: LP IV**

4.2 Environmental impacts during the construction phase

Moderately weighted index due to the temporary aspect of the impacts considered (7).
The indicator concerns both the aqueous and terrestrial environments, with reference to the inlet works as well as impacts at other sites associated with the production and transport of suspended solids. To be considered are the following:

- Turbidity during the construction phase in terms of effects on the lagoon bottom biology (e.g. seagrass meadows); significant impacts are at play which can also cause loss of reversibility also as a result of the cumulative effect of other actions (e.g. movement of the lagoon beds, clam[7] harvesting using abrasive methods) or dystrophic imbalances;
- Temporary impacts on water exchange and fish migration (impacts are not expected to be major);
- Destruction of prized habitats (highest impact on banks and dunes, with the risk of extinction for individual endemic/indigenous species and irreversible loss of primary characteristics)
- Disturbance to flora and fauna (due to noise, gaseous emissions and dust, trampling, anthropic pressure: potentially elevated impacts are involved, especially in the nesting season).

A high-negative ordinal value is attributed to the projects that necessitate loss of precious habitats, which have already been reduced to their vital minimum extent (one of which includes the last known site of fauna close to extinction[8]), with consequent risks for the more threatened species, and proposed works which extend across and invade lagoon areas.

Assigned ordinal values are as follows:

o.v. high negative **parameter 1: LP I, LP V**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

4.3 Environmental impacts of the definitive system

The value is high given the definitive character of the impacts. (10)

- This regards the definitive loss of prized habitats, permanent interferences with the exchanges and consequently variations in the boundaries of the aqueous environments, interference with exchange during closure (in the current aspect and considering predicted sea level rise scenarios, with associated risks and trophic imbalances).
- Potentially very high impacts, maximum for definitive, irreversible and non compensatable losses of primary habitats already at their vital limits in terms of size (including risk of extinction for endemic species). The indicator also values risks f insufficient water exchange in the case of sea level rise scenarios that require inlet closure also in the warm season.

Assigned ordinal values are:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III**
o.v. low positive **parameter 4: LP IV**

[7] Harvesting of the invasive clam species, *vongole fillipine*, in the Venice lagoon is carried out by highly impacting mechanical means which cause erosion of the lagoon as well as damaging the lagoon bed.
[8] A group of coastal coleopteris (beetles) is under threat throughout the Mediterranean due to recreational use of beaches; the Adriatic subspecies is now known only at Ca' Roman, site of the northernmost lagoon inlet.

4.4 Environmental impacts on landscape

The weighting is significant (8).

- Visual obstructions are considered (e.g. blockage of the sea view), loss of visual identity of the area, temporary or permanent encumbrance, especially if they stick up from the horizon, loss of the benefits from or access to particularly appreciated areas or paths).

Moderately negative value is assigned to those outlines that involve the construction of visually intrusive elements, and that determine the reduction or removal of the possibility to enjoy/use areas that have traditionally been appreciated and used (e.g. the jetties (*dighe*), *Bacan* area shallows and mudflats).

Assigned ordinal values are:

o.v. medium negative **parameter 2: LP V LP I**
o.v. low negative **parameter 3: LP III**
o.v. low positive **parameter 4: LP II, LP IV**

4.5 Impacts of permanent interventions and removable interventions

Weighting 7, high but not decisive relevance.

- Considers the non-visual (already considered in 4.4.) but structural encumbrance as regards interference and limits to current activities and in terms of possible future works given various sea level rise scenarios.

Particularly negative judgements are assigned to the project outlines that involve kilometres of permanent, mechanical structures, the creation of an artificial island within the Lido inlet and fixed works at sea.

Assigned ordinal values are:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III**
o.v. low positive **parameter 4: LP IV**

4.6 Resilience and environmental impacts of the presence of several construction sites at once and simultaneous other activities with environmental impacts

The indicator refers to synergistic effects due to interference between impacts which have been individually evaluated above (6).

The presence at the same time of several construction sites means the effects on the level of disturbance are compounded (summed), putting the resilience capacity of biological components at risk.

- The negative impact on resilience must be considered in reference to the amplification effect, possibly exponential, of multiple disturbance parameters (turbidity, noise and other effects on fauna, effects on induced anthropic pressures…) in the case of simultaneous, multiple construction sites and other impacting activities (e.g. clam harvesting).
- To be evaluate in particular:
  - Which works, according to design, involve multiple, simultaneous construction sites;

- What are the differences between impacts in the case of construction sites that are either simultaneous or staggered over time, given also the possible compensations for the "lung effect" that inner surface waters can bring to perturbed waters.

None of the projects considered explicitly refers to this indicator. Negative ordinal values are given to those outlines with the highest expected impacts and disturbances, due to excavation works, which are much higher in the case of multiple, simultaneous construction sites.

Assigned ordinal values are:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III**
o.v. low positive **parameter 4: LP IV**

4.7 Compatibility of the works and pollution effects

The indicator is given significant weighting as regards the biological component and accumulation effects along the food chain (8)

- Two aspects present themselves:
  - Polluting emissions as a direct consequence of the works and their management (release of metal ions from the sacrificial anodes or varnish; effluents from operating motors etc.);
  - interference with lagoon contamination (accumulation, interference with residence times and flushing especially with repeated closure).

  Negative values are attributed to the outline plans that consist of submerged structures due to the presence of protection systems for those structures.

Assigned ordinal values are:

o.v. high negative **parameter 1: LP V**
o.v. low negative **parameter 3: LP I, LP II, LP III**
o.v. low positive **parameter 4: LP IV**

4.8 Effects on sedimentology, morphology and lagoon functioning

Highly important indicator due to the significance of the hydro-morphological aspect of the lagoon (10).

- For whichever works and/or actions, the implications for the functional morphology of the lagoon are considered on two scales:
  - The intervention site and adjacent area (effects of demolition, dredging, interruptions, imposition of unnatural elements etc.);
  - Implications for the general environment (each inlet in relation to respective sub-basins) following variations to fluxes, as well as water exchanges, sediment dynamics, ecosystem functions etc.).

Negative ordinal values are given to those lines that involve major excavations in protected areas, dredging, covering over of protected areas, subdivision of the lagoon.

Assigned ordinal values are:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

4.9 Impacts on lagoon archaeology and historic structures

Indicator with significant weighting due to the historical significance of the Venice Lagoon (8).

- Refers to archaeological sites (effectively ubiquitous in the lagoon) and sites of historic importance, starting with the jetties, forts and sea walls.
- Low negative for all plans due to probable interference with the historical orientation of the inlets; high negative for projects with implicate the demolition of parts of the historic jetties, or which have a high probability of infringing upon archaeological sites due to mechanical structures at their base.

Assigned ordinal values are:

o.v. low negative **parameter 1: LP V, LP I**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

4.10 Reactivation of the principal, secondary and peripheral hydraulic circulation in the lagoon

Highest weighting (10).

- Values the extent to which planned works alter the hydrodynamic aspect of tidal currents within the lagoon, with particular reference to the conditions arising at the periphery of the lagoon, characterised by longer residence times. Secondary circulation, i.e. that induced by a different water level in different parts of the lagoon, as a consequence of wave propagation, has a significant role as regards water exchange/residence times, especially for the water bodies which are "hydraulically" furthest from the inlets.
- Due to the long timescales for construction of some proposed solutions, effects must be considered also during the transition (construction) phase as well as for the completed project.

Negative evaluation for all proposals. High negative for those outlines that cause greatest obstruction to a hydraulic re-equilibrium of the lagoon, by maintaining inlet depths and plans which interrupt flows in inner canals.

Assigned ordinal values are:

o.v. medium negative **parameter 2: LP I, LP V**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

4.11 Respect of the Habitats Directive

Highest weighting due to international significance (10).

Nearly all of the lagoon forms part of the Nature 2000 network, including Special Areas of Conservation (SAC) and Special Protection Areas, also in terms of the Birds Directive, with extended areas of priority habitats of exceptional importance and designated as coastal SACs (sandy shores and dunes) at all three inlets.

- The indicator refers to compatibility with the terms of the Directive and the obligations and prescriptions imposed regarding interventions in priority habitat areas, with the explicitly underlying principle that imposes conservation and/or attainment of a "satisfactory state of conservation". (Specific impacts on biocenosis are not examined here, since they were already considered in points 4.2. and 4.3.).

A negative ordinal value is assigned to the project that creates impacts next to and inside SACs, with the removal of primary habitats which is in direct conflict with the Directive and goes

against the objective to tend towards a satisfactory state of conservation. This is all at a time when the degeneration of the area had been arrested and recovery of its environmental state begun – thanks to the institution of an "oasis"[9].

Assigned ordinal values are:

o.v. high negative **parameter 1: LP I**
o.v. low negative **parameter 3: LP II, LP III, LP IV, LP V**

5 COST-BENEFIT SCENARIOS (C/B relationships)

5.1. C/B associated with attenuation of tide levels in the lagoon

The indicator carries highest importance (10).

- It refers to the cost/benefit relationship as regards safely achieving the objective of attenuating tide levels in the lagoon.
- With measures to reduce cross-section of the inlets, relatively low cost, it is possible to achieve significant and durable results in terms of reducing tide levels.

Negative values are assigned to projects that, in the face of elevated costs (construction and/or maintenance and operating costs), obtain modest reductions in this regard.

Assigned ordinal values as follows:

o.v. high negative **parameter 1: LP I**
o.v. medium negative **parameter 2: LP V**
o.v. low negative **parameter 3: LP II**
o.v. low positive **parameter 4: LP III**
o.v. medium positive **parameter 5: LP IV**

5.2 C/B as regards closure of the inlets

This indicator corresponds to the objective delineated in the 2nd Special Law to protect lagoon settlements from the exceptional high tides, also via measures at the inlets with mobile barriers (10).

- The necessity to close the inlets to reduce the impacts and costs of flooding must be examined, for the purposes of establishing a cost/benefit relationship, with reference to the effects of closure.
- Benefits must be considered in relation to the number of forecast closures, considering the costs of each closure operation (infrequent closures can make single investment costs/closure very high, also for management/maintenance, so as not to be able to justify the solution itself);

[9] The Venice Town Council has assigned management of two areas, Ca' Roman and Alberoni, to the local branch of WWF and LIPU (bird protection association) respectively.

- High investments w.r.t. low benefits detract from the full range of measures necessary for safeguarding Venice and the lagoon.

Med-high negative valuation is attributed to outline projects that involve high costs relative to results; positive judgement is passed for the outlines that, for the same technical results, are set to be more economic.

Assigned ordinal values as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II**
o.v. low positive **parameter 4: LP III, LP IV**

5.3 C/B of effects on re-establishing equilibrium in the lagoon

This indicator corresponds to a primary general objective (10).

- National and Community legislation for environmental assessments require specific attention to induced effects of proposed works at a systemic level. This applies also to economic factors' given that the pursuit of these objectives necessarily requires a financial onus.
- The indicator considers the relationship between costs and effects (positive and negative) on re-establishing equilibrium, restoration of the quality of the lagoon, revival of traditional and compatible economic activities.
- Reduction of inlet depth, protection of (or damage to) prestigious habitats, restoration of morphological aspect of intertidal and submerged areas, implications for sustainable fishing and tourism are examined.

None of the projects presents an outline plan that covers a broad area of issues relating to re-equilibrium of the lagoon system. A high negative ordinal value is attributed to solutions that add further alterations to the ecosystem and make the prospects of re-equilibrium even fainter (with modulation of the ordinal value connected with re-use of displaced sediments).

Assigned ordinal values as follows:

o.v. high negative **parameter 1: LP V**
o.v. medium negative **parameter 2: LP I**
o.v. low negative **parameter 3: LP II, LP III, LP IV**

5.4 C/B for the local defence measures

The indicator considers society's needs of primary importance (10).

- Attenuation of tide levels and closures, reducing flooding frequency, bring benefits for the usual usefulness of walkways, ground level, and buildings.
- A modest additional benefit is connected with controlling the negative effects of salinity levels on solid materials, also considering that this factor is already part of Venice and its physical-chemical character.
- The possible revival of urban areas could be a further positive factor in the cost/benefit relationship.

All the project outlines foresee positive effects; the relationship with costs (taken as assumed in the outlines), however, differentiates the judgements.

Assigned ordinal values as follows:

o.v. low positive **parameter 4: LP I**

o.v. medium positive **parameter 5: LP II, LP III, LP IV, LP V**

5.5 C/B for sea level rise + subsidence scenarios for the next century

The indicator should justify the economic validity of the investment over time (7)

- The higher the required investment, the more necessary it seems to evaluate functionality over time of the inlet measures, in view of significant sea level changes.
- The indicator calls upon the logic examined in the flexibility scenario (especially gradualism and reversibility) and the engineering scenario (indicator 3.10, 3.11), and relates back to the economic framework.

Negative ordinal values are attributed to the project outlines that for their complexity, monolithic nature, lack of flexibility and intrinsic risks of the works give rise to grave doubts about the suitability over time as regards sea level rise and elevated costs.

Assigned ordinal values as follows:

o.v. medium negative **parameter 2: LP I, LP V**
o.v. low positive **parameter 4: LP II, LP III,**
o.v. medium positive **parameter 5: LP IV**