Economic Valuation of On Site Material Damages of High Water on Economic Activities based in the City of Venice: Results from a Dose-Response-Expert-Based Valuation Approach

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Economic Valuation of On Site Material Damages of High Water on Economic Activities based in the City of Venice: Results from a Dose-Response-Expert-Based Valuation Approach

Summary

The paper focuses on the economic assessment of damages caused by high water in the city of Venice. In particular, we focus our attention on a valuation exercise that addresses the estimation of monetary, short period, on-site damages due to high water events on the different business activities located in Venice. On-site damages include both mitigation costs, which refer to all types of financial expenditure undergone to avert physical and material damages caused by flooding, and remediation costs, i.e. costs to be sustained for maintenance and substitution of affected building elements. Hence, the present study can be considered as a pioneering attempt to analytically quantify, from an economic point of view, on-site damages from high water. An integrated dose-response modelling and an expert-based valuation approach have been selected as the most suitable economic valuation methodology to shed light on the on-site damages. The main focus of the work is to assess dose-response relationships, which are able to describe the physical effects of high water on the different on-site damage categories, including inner and front doors maintenance, cleaning of pavements and maintenance of the walls. Bearing in mind such an economic valuation framework, we proceed with the estimation of on-site damages not only for the present high water situation (business as usual) but also extend the valuation exercise to three additional high water scenarios: (1) a climate change scenario; (2) a high water protection scenario; and, (3) a combined climate change and protection scenario. Estimation results show that the welfare loss due to on-site, short-term damages supported by the business activities ranges from 3.41 to 4.73 million Euro per year, respectively for the business as usual and climate change scenarios. Finally, we can conclude that the introduction of a public policy protection mechanism that defends the city of Venice from any flooding above 110 cm above *the Punta della Salute Tidal Datum*, such as the MOSE, will reduce the on-site damages supported by the business activities up to 2.87 million Euro per year.

Keywords: High water damages, Venice, Economic valuation

JEL Classification: C29, Q25

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1. Introduction

The paper focuses on the economic assessment of damages caused by high water in the city of Venice. In particular, we focus our attention on a valuation exercise that addresses the estimation of monetary, short period, on-site damages due to high water events on the different business activities located in Venice. We selected working with business activities, including *inter alia* hotels, bars, gift shop and restaurants, since these are very sensitive to high water events; the great majority are located at ground floor level. In addition, business activities constitute an important stakeholder in the Venetian society – keeping the ancestral trading tradition of the *Republica Serenissima* – and for this reason play a crucial role in the assessment of any high water management policy. Furthermore, the present study strictly refers to on-site damages since the valuation exercise focuses only on the monetary estimation of impacts due to high water on the structure and construction materials, including mitigation expenditures necessary to prevent and lessen these impacts. Finally, the valuation exercise concentrates exclusively on short-period damages given that it is anchored to the present number and distribution of business activities located in Venice, excluding any supplementary impact(s) that the high water can cause on the number and distribution Venetian business activities.

In previous valuation studies, the economic impacts of high water have been frequently analysed in relation to the environmental assessment with respect to the much-debated mobile-gates project – called MO.S.E. (*MOdulo Sperimentale Elettromeccanico*). However, structural damages have been often tackled and quantified in physical, non-monetary approaches, including the estimation of the number of affected agents. Recently, Cellerino (1998) developed and applied a valuation study that focused on the monetary estimation of high water impacts, including the damage that these create on the tourism demand, as well as on additional expenditures for the maintenance of the walls of the buildings located in Venice. We propose to extend this pioneering attempt to quantify, from an economic point of view, on-site damages, such as inner and front doors maintenance and cleaning of pavements, that high water causes to all registered business activities today located in Venice. The economic valuation exercise is characterised by the use of an integrated dose-response modeling and an expert-based valuation approach. The ultimate aim is to combine dose-response relationships, which are based on the judgement of experts and describe the physical effects of high water on the different on-site damage categories, with specific market information on price and effectiveness of alternative remediation measures.

The organisation of the paper is as follows. Section 2 introduces and discusses the phenomenon of high water in Venice and its main damage implications to Venetian business activities. Section 3 presents and analyses the proposed economic valuation approach for on-site damages. Section 4 presents main valuation results and respective policy implications. Section 5 concludes.

2. Background

2.1 The threat of *Acqua Alta* in the city of Venice

The periodical water movement produces two tidal peaks every day, respectively a low tide, ranging from 0 to 25 cm, and a high tide, ranging from 45 to 75 cm. In Venice, all measurements are carried out by Tidal Observatory of the Municipality and the elevation is measured in terms of additional centimetres above the Venetian main reference tide gauge, the *Punta della Salute Tidal Datum*[1].

[1] Since 1897, the mean sea level in Venice is measured with respect to a level of mark on land, the *Punta della Salute Tidal Datum*, just across the San Marco Square. At the present date, this benchmark is approximately 23 centimeter below the current mean sea level.

The flooding of the city occurs whenever the peak of the high tide peak exceeds 85cm, height that characterizes the lowest parts of Venice including the S. Marco's square and Rialto. From this height we assist to the phenomenon of *Acqua alta* – the Italian name for high water events. In general terms, high water occurs as a combination of two or more factors, such as specific astronomic constellations, meteorological factors such as the wind direction and specific hydrodynamic flows of the Adriatic basin. A high water event of 100 cm is responsible for the flooding of 3.56% of the city whereas we assist a high water event of 120 cm, 35.18% of the city is flooded. In Venice, high water events are classified as periodical flooding whenever the peak of the high tides ranges between 90 and 120cm above the *Punta della Salute* benchmark. On the contrary, a high water event is classified as "extraordinary" whenever the height of the tides is above 120cm. In fact, any "extraordinary" tide that is characterized by a height above 140cm causes the flooding of 90% of the city.[2]

In the last century Venice has witnessed an increase in the intensity of the high water events. This is expressed in terms of an upwards trend of the mean of the height of the tidal excursions in Venice, including the increase in the registered "extraordinary" high water events, as well as the number of days that are characterized by the occurrence of 'normal' periodical flooding – mainly in Autumn. There are many factors influencing such a pattern. This include, *inter alia*, the increase of Adriatic's relative sea level of about 23 cm during the 20^{th} century. The latter is due to both natural and human causes, including the subsidence of the island of Venice and more importantly due to global climate change events. According to the international scientific community, climate change is expected to continue in the following decades, along with an increase of the incidence of high water in Venice. These, in turn, cause important damage to the city in general, and to its population, in particular. For these same reason, all these impacts, and respective economic damage, have witnessed an increased attention in the policy agenda.

High water economic damage can be defined in term of three main categories: on site-damages; off-site damages; and social damages. On-site damages are described by the negative impacts that high water causes on the structures and materials, including private mitigation costs necessary to prevent and lessen these impacts. Off-site damages are due to the limited usability of the city during high water events, including difficulties for supply and provisioning, reduced access to the work place by the personnel, and decreased flow of clients. Finally, social damages of high water are linked to a public protection perspective and to the impact of high water on the total economic value of the set of business activities located in Venice, e.g. persistent high water events can create uncertainty on the turnover of the business activities located in Venice that, in turn, can affect the number, type and diversity of activities.[3] The present paper focuses on the monetary value assessment of on-site damages incurred by an important Venetian stakeholder, i.e. the business activities located and operating at the ground floor in Venice.

2.2 Characterisation of the stakeholder under analysis: the business activities based in Venice

As mentioned, this paper deals with on-site damages caused to business activities located and operating in Venice due to the high water. The estimation of on-site damages is based on data provided by a local governmental agency: COSES. Between 1999 and 2001, COSES conducted an

[2] Source http://www.comune.venezia.it/maree

[3] See Nunes *et al.* 2004 for more details.

on-site survey to all business activities located in ground floor units in the city of Venice. The survey offers information on the different type of activities, the nature and conditions of building materials, the presence and kind of mitigation measures for high water, as well as some architectural measurements. The present study works with a sample of 2598 respondents, on a total population of 5097 business activities registered in the city of Venice. Statistical elaborations of the survey's results lead to a better understanding of the number and diversity of the socio-economic actives and highlight how they are affected by high water. The most frequent business activity in Venice is commercial (retailers of food, beverages, clothing, articles for tourists, etc.), followed by restaurants and bar and then by industrial activities, including glass manufacturers and local shipyards (Table 1).

Table 1: Distribution of types of activity located at the ground floor

Type of activity	Frequency	Percentage
Industry	297	11.4
Shops	1518	58.4
Bars and restaurants	422	16.2
Offices	154	5.9
Hotels	116	4.5
Other	91	3.5
Total	2598	100.0

A very important piece of information concerns the declared flooding level for each single business activity unit, i.e. the minimum level of high water that causes the flooding. According to Table 2, more than eighty percent of the business activities that are located at the ground floor are affected by high water events when these are in the range from 111 cm to 130 cm.

Table 2: Distribution of Venetian business activities for flooding level

Flooding level	Frequency	Percentage	Cumulative %
< 90 cm	27	1.0	1.0
91 -110 cm	472	18.2	19.2
111 – 130 cm	1628	62.7	81.9
131 – 145 cm	397	15.3	97.2
> 145 cm	74	2.8	100.0
TOTAL	2598	100.0	

In order to mitigate damages to structures and materials due to high water, as well as to limit the time and expenditure in cleaning the pavement, according to the COSES survey only 37% of economic operators have adopted protection measures of different types (Table 3).

Table 3: Distribution of Venetian business activities per type of mitigation measure

Protection measure	Percentage (*)
Yes	36.7
Raising floor levels	18.1
Paratia	19.3
Water pump	3.8
Vasca	7.4
No	63.3
Total	100.0

(*) The sum of the percentages of specific mitigation measures is higher than the percentage for "yes" because a business activity can have more than one type of protection.

According to Table 3, the most widespread measures of protection are *paratia*[4] and raising of floor levels, while pumps and *vasca*[4] are not very common, which is probably due to their relatively high financial costs. The distribution of the different protection measures among the business activities is an important element when assessing the economic cost of high water since different mitigation measures offer different degrees of protection. This effect is discussed in detail in the following section.

3. Economic valuation of high water damages

3.1 On site material damages

The monetary magnitude of on site damage (OSD) can be defined as follows:

$$OSD = L + M + R \qquad (1)$$

where L is the monetary loss of goods due to flooding, i.e. merchandise for sale, M represents the cost of mitigation measures, i.e. technical solutions which help protecting against flooding inside the units, and R accounts for remediation costs, i.e. costs of replacement of damaged building elements.

In the present study, which focuses on the monetary value assessment of on-site damages caused by periodic flooding, L is assumed to be a minor magnitude. This assumption is based on the fact that owners of economic activities located in Venice at the ground floor are well used to high water events, and for this reason display merchandise at a safe level, e.g. on high shelves or ad hoc furniture. In addition, the Municipal Centre for Tidal Observation provides a specific alarm service that goes off 3 hours before the high water event and thus giving additional time to move the merchandise at a safer level, if needed. This assumption is confirmed by the results of a valuation survey conducted immediately after a recent extraordinary event, which took place in November 2002, where the high water reached the level of 147 cm. In that circumstance, only 15% of the interviewed persons indicated some losses due to damages to merchandise.

[4] Doors that give access to street are the most important mean of water infiltration to the business activities – for this reason they are often protected by mobile barriers, i.e. *paratie*, to keep water out. With the protection system called *vasca*, external walls and the pavements of ground floor units are sealed with waterproof materials forming a basin to protect the inner parts of the building against high water.

Mitigation costs are related to the adoption of high water protection measures and equipment like hydraulic pumps, *paratia* and rising of pavements. These costs are essentially independent from the frequency of flooding experienced. Therefore, the category is referred to as fixed costs. It is important to specify that none of these mitigation measures can be considered as a complete protection against high water damages, since each measure becomes ineffective, either partially or completely, at a specific level of the tidal event. For a given unit, this critical level depends on the unit's level above the sea, and on the technical features of the mitigation measure.

Remediation costs, on the other hand, are related to damages caused by flooding to building elements, including damages that high water and salinity causes to the walls. This category of costs is directly or indirectly connected to the number of flooding events. For this reason, these will depend on the unit's specific location in relation to the mean sea level. These costs are thus referred to as variable costs. The criteria for the selection of the types of damages to be considered looked at the availability of data and the existence of a direct relationship between the economic damage and the fundamental variable, which is the unit's specific level above sea and/or the frequency of flooding it has to face. The first criterion led to the exclusion of costs that require information that is not reported within the COSES data set. The second criterion implies that single categories of cost were included only if the connection between frequency of flooding or level above the sea and damage was identified in a sufficiently precise manner during interviews with experts.

Since the present valuation study is anchored in the COSES data set, the items considered for valuation are front doors and inner doors, pavements, walls and the cost of the time employed in the cleaning of the pavement and for re-establishing the functionality of the economic unit. Furniture had to be excluded from the estimation, as in the COSES database there was no sufficient information available on the characteristics of the furniture in each business activity. This may lead to an underestimation of variable costs, although in Venetian business activities furniture is frequently renewed, independently from the effects of high water.

3.2 Valuation approach

The economic valuation of on-site damages on structures and materials due to high water events is not straightforward. A literature review and a comparative analysis of previous studies about economic impacts of high water events highlight some important aspects which need to be considered in the assessment.[5] While some suggestions came from the methodological choices of previous studies, some other ideas derived from the attempt to overcome the limits of past assessments. In this context, we propose to work with dose-response valuation methods – see, for example, Adams and Crocker (1991). The dose response methods have in common that they put a value on environmental commodities without retrieving people's preferences for these commodities. In this particular study, dose-response valuation technique is operated by (1) assessing the physical damage of high water on structures and materials and (2) estimating the economic value of the damage. For this reason we integrate the use of a response valuation technique with expert based information regarding both the increased maintenance and repair activities due to the high water and related market prices. This type of techniques have already been

[5] Survey carried out between December 2002 and January 2003, see CORILA (2004) for more details.

considered by Cellerino *et al.* (1997), Cellerino (1998) and Bertoldo *et al.* (1997), but under more restricted conditions.[6]

In particular, the following indications have been applied in the present study. First, damages have been assessed with respect to the specific characteristics of different business activities. In this study, and differently from previous ones, damages are referred and assessed at the individual level, considering, among others, the type of activity, the location of the business activity with respect to the sea level, the use (or not) of mitigation measures (and which ones). Overall cost has been calculated by aggregating individual costs. Second, protection (or mitigation) measures have been included in the value assessment and modelled as follows: (1) costs sustained by economic operators for mitigation have been considered among on-site economic damages as fixed costs; (2) the effectiveness of protective measures in the mitigation of the high water damages has been attentively investigated and brought in the computations, and (3) high water damages have been disentangled from costs related to ordinary maintenance and substitution of structures and materials. A similar attempt was also tackled by Cellerino (1998). Finally, different scenarios with respect to the frequency of high water have been considered. The investigation of the consequences of different future scenarios is very useful for deriving policy implications and it is a consolidated procedure in most economic assessment studies (see Magistrato alle Acque e Consorzio Venezia Nuova, 1997).

As mentioned, mitigation costs refer to all types of financial expenditure undergone to avert damages caused by flooding. Combining expert information on mitigation costs with the COSES information on the type of mitigation measures adopted, we were able to estimate the total cost with respect to mitigation incurred by each single unit. As we can see from Table 4, mitigation may consist in one or more interventions – e.g. *vasca* or water pumps and *paratia*.

Table 4: Level of protection of mitigation measures across different building elements

	Pavements	Walls	Inner doors	Front doors
Raising of pavements	+++	+	+++	+++
Vasca	+++	+++	+++	+++
Paratia	+	0	++	+++
Water pump	+	0	++	0
Water pump and *paratia*	++	0	+++	+++
Waterproof barriers for walls[7]	0	+++	0	0

Legend: +++ strong, ++ medium, + small, 0 no mitigation effect.

[6] Dose-response-expert-based valuation method has also been applied by economists in the analysis and valuation of social and economic dimensions of climate change impacts and adaptation in Italy, including a case study that deal with an expected sea level rise in the Fondi plane area located at the south-west of Rome (see Gambarelli and Goria 2004).

[7] Waterproof barriers are architectonical devices that prevent bricks from being soaked by tidal waters and thus protect the walls from damages caused by salty water.

The valuation of variable costs considers the infiltration of water causing damages to different building-elements, including pavements, walls, inner and front doors. In addition, the presence of mitigation measures needs to be taken into account when calculating every type of variable cost. In practice, the estimation of economic damages is based on information produced by ‘expert judgements’ about the effects that infiltration of water has on the building materials, and the level of protection offered by the different measures (or a combination of measures) with respect to the specific elements of the unit (doors, pavements, walls). Table 4 shows the relation existing between different mitigation measures and the effects of high water on building-elements. It can be noted, for example, that the protection offered by a *vasca* is much higher than the protection offered by a *paratia*.

As an illustration, the yearly cost of substitution of inner doors (YIDSC) damaged is estimated as follows:

$$YIDSC = \frac{UCDI}{n} \lambda(e_j, n) \sum_{r^i} \sum_{l} e_l^{i,r}(p) \tag{2}$$

where *UDCI* denotes the unit cost of a inner double skin door in wood (expert based information) and *n* the number of tidal events after which a wooden double skin door has to be substituted (also expert based information). Therefore, the first term captures a monetary magnitude that reflects the physical *resistance* of inner wooden doors with respect to the tidal events, *ceteris paribus*. This measure is combined with two additional terms, λ and $e_l^{i,r}$, respectively. The latter term reflects the fact that doors are located in different rooms within each *i* business activity unit and each *r* room is associated to a given level *l*, which is a measurement above the *Punta della Salute Tidal Datum*. Therefore, $e_l^{i,r}$ denotes the annual frequency of high water events that the room *r* at level *j* of the unit *i* is subject to. This term is function of *p*, which denotes the type of protection measure adopted by the business activity unit, since we consider that the existence and type of mitigation measures influence the protection level and thus the number of events that each room is subject to.~~. Finally,~~ as it was not considered realistic to expect a door to be replaced more often than once a year, λ was introduced to limit the number of substitutions to once a year in those cases, where the entity of damages would call for more frequent interventions. λ is a function of e_j and *n*, with $\lambda = 1$ if $e_j \leq n$ and $\lambda = n/e$ if $e_j > n$. More in detail, the introduction of the parameter λ lets to account for the fact that a inner doors may last:

- 1 year, if the number of high water events at level *j* (e_j) is equal or higher than the number of flooding events that calls for the substitution of the doors (*n*). In fact, in this case $\lambda = n/ e_j$ and YIDSC equals UCDI multiplied by the number of doors to be substituted;
- more than 1 year otherwise (in particular, assuming a constant annual frequency of high water events over the years, the doors will be substituted after n/ e_j years).

As we can see from this illustration, the information contained in the COSES database on size, number of rooms, distance of the floor level from sea level together with expert based information allows us to calculate in an efficient and robust way the economic damage caused by flooding to inner doors. A similar methodology was also applied to the other remaining cost components.[8]

[8] A more detailed discussion of these is presented in CORILA (2004).

On-site damages can then be computed. In order to explore possible policy implications in reference to the protection, or absence, of high water we introduce possible scenarios that describe alternative high water situations for the city of Venice. These will be discussed in the next section.

3.3 The formulation of *Acqua Alta* scenarios

In the present analysis, we consider four scenarios. The first refers to the current situation, which is denoted by the 'business as usual' (BAU) scenario. This scenario assumes the annual average frequencies of tidal events as registered by the Tidal Observatory of the Venetian Municipality during the period 1966- 2001. In other words, the annual frequency of high water in BAU coincides with the historical frequencies (Table 5).

Table 5: Average annual frequencies of high water per scenario

	Average annual frequency			
Tidal level	BAU	Defence 110	Climate change	Climate change & Defence 110
+ 190 cm	0.0286	0.0000	0.0286	0.0000
180 – 190 cm	0.0286	0.0000	0.0286	0.0000
170 – 180 cm	0.0286	0.0000	0.0571	0.0000
160 – 170 cm	0.0571	0.0000	0.0862	0.0000
150 – 160 cm	0.0862	0.0000	0.2000	0.0000
140 – 150 cm	0.2000	0.0000	0.6250	0.0000
130 – 140 cm	0.6250	0.0000	1.5000	0.0000
120 – 130 cm	1.5000	0.0000	3.5000	0.0000
110 – 120 cm	3.5000	0.0000	8.5000	0.0000
100 – 110 cm	8.5000	8.5000	19.700	19.700
90 – 100 cm	19.700	19.700	49.200	49.200
80 – 90 cm	49.200	49.200	117.60	117.60
70 – 80 cm	117.60	117.60	241.30	241.30

A second scenario, 'Defence 110', refers to the situation that is characterised by the use of collective, defensive measures against all tidal events above 110 cm with respect to mean sea level as measured by the *Punta della Salute Tidal Datum*. For this reason the frequency above this threshold is zero. Below 110 the frequency is the same as BAU and coincides with the historical high water frequencies. A third scenario considers an average sea level rise of 10 cm due to climate change events[9], and for this same reason this scenario is denoted as 'Climate change'. In this scenario, the number of high water events for a given sea level equals to the frequency registered in the BAU scenario and corresponding sea level immediately below. For example, the frequency of tidal events at 120 cm for climate change corresponds to the frequency reached at the level of 110 cm for BAU. Finally, we consider a mixed scenario that results from the combination of both

[9] The scenario is limited to a rather low rate of sea level increase – many climatologists support the idea that sea level will rise as much as 61 cm over the next century (see UNEP 2001, MATT 2003). However, such a high rate would imply important changes in the number and distribution of the business activities that would not be consistent with the short-term perspective embodied in the present study.

‘climate change’ and ‘Defence 110’. In short, this scenario considers the defence of the whole lagoon against flooding events above 110 cm, however the frequency of the high water events below that threshold will increase and will remain equal to the rates of the ‘climate change’ scenario.

4. Valuation results

Estimates of economic damages related to high water depend crucially on the floor level of the unit with respect to the mean sea level (*Punta della Salute Tidal Datum*). In fact, the level above the sea is directly related to the frequency of high water events which affect a particular unit, and thus to the number of times a building element comes into contact with water. The latter has a direct effect on the frequency of restoration, implying either maintenance or substitution of the affected element, having in any case an economic impact. Even in the case of walls, where damages are more linked to action of saltwater in bricks than to the frequency of flooding, the unit’s location with respect to the sea level is reflected in the proximity of walls to the underlying water, and this way capture the effect of saltwater damages in the building structure of the business activity. As a consequence, the more precise the knowledge of the unit’s level above the sea is, the more reliable the estimates of the economic damages will be. Unfortunately, in Venice a full GIS cover and measurement of each business units’ front-door location with respect to the sea level is not yet available – even if there are a series of measurements either covering only part of the city, or different points of relevance (e.g. street level, bridges levels, etc). For this reason, the present study anchors the value estimates to the flooding level as declared by respondents on the COSES questionnaire. The underlying assumption is that economic agents who have been operating in Venice are familiar with the impacts that different levels of high water have on their units and thus are able to link their individual flooding level to the announced tidal levels.

In addition, we consider three alternative approaches with respect to the calculation of the flooded area for each business activity. In concrete terms, the three approaches denote three assumptions with respect to the percentage of the unit flooded: one corresponds to the percentage of the flooded area as reported by the respondent in the survey (approach A); a second corresponds to the percentage of the flooded bearing in mind the different size and location with respect to the sea level of different rooms (approach B); and finally we consider that the totality of the area flooded (approach C). The combination of these three approaches can be interpreted as providing a confidence interval – when compared to the reported answers on the flooded area. Approach C provides an upper estimate since it considers a flooded area at 100%. In addition, approach B combines the use of survey information so as to get a more precise value estimate on the overall flooded area.

Furthermore, the present valuation exercise is also flexible in accommodating the impact of key parameters – such as the number of high water events that cause the need of restoration for each considered building element – on the valuation results. In order to deal with impact, the valuation exercise considers two parameters with respect to the restoration and maintenance for each building element, reflecting two different rates of intervention with respect to inner doors, outer doors and pavements. In the case of walls, such analysis takes account of the maintenance technique to be used for restoration, given the large range of available interventions. The respective impacts on the estimation exercise are interpreted in terms of a sensitivity analysis, providing a lower and upper value estimate for each building element. Tables 6 to 9 report the estimation results for all the scenarios under consideration.

Table 6 shows that total on-site damages due to high water on the Venetian business activities, given the actual frequency of high water events, ranges from 2.26 to 4.97 million Euro per year, with a best point estimate of 3.41 million Euro. The later corresponds to the average estimate for the total economic value of on-site economic damages according to the valuation approach B, which is retained as giving a more precise calculation on the overall flooded area.

Table 6: On-site economic damages – BAU Scenario

BAU		Approach A	Approach B	Approach C
COST CATEGORY	SUBSTITUTION OF INNER DOORS			
	Higher Bound	1,253,745	1,441,144	1,707,537
	Lower Bound	804,298	893,049	1,086,249
	MAINTENANCE OF FRONT DOORS			
	Higher Bound	n.a.	135,281	135,281
	Lower Bound	n.a.	63,598	63,598
	MAINTENANCE AND CLEANING OF PAVEMENTS			
	Higher Bound	73,833	78,797	112,695
	Lower Bound	32,725	68,519	97,995
	MAINTENANCE OF WALLS			
	Higher Bound	n.a.	2,920,301	3,023,313
	Lower Bound	n.a.	1,240,247	1,346,235
TOTAL ON-SITE ECONOMIC DAMAGES				
Higher Bound		n.a.	4,575,522	4,978,825
Lower Bound		n.a.	2,265,413	2,594,078

If the sea level rises by ca. 10 cm and no policy protection measures are adopted, then on-site damages will increase, giving costs estimated to range between 3.53 and 6.47 million Euro per year, with a best point estimate of 4.73 million Euro (Table 7).

Table 7: On-site economic damages – Climate Change Scenario

Climate Change		Approach A	Approach B	Approach C
COST CATEGORY	SUBSTITUTION OF INNER DOORS			
	Higher Bound	1,862,771	2,233,543	2,557,842
	Lower Bound	1,412,111	1,638,794	1,927,454
	MAINTENANCE OF FRONT DOORS			
	Higher Bound	n.a.	284,389	284,389
	Lower Bound	n.a.	164,415	164,415
	MAINTENANCE AND CLEANING OF PAVEMENTS			
	Higher Bound	176,313	188,408	269,292
	Lower Bound	153,316	163,833	234,167
	MAINTENANCE OF WALLS			
	Higher Bound	n.a.	3,232,043	3,358,486
	Lower Bound	n.a.	1,568,812	1,692,679
TOTAL ON-SITE ECONOMIC DAMAGES				
Higher Bound		n.a.	5,938,383	6,470,009
Lower Bound		n.a.	3,535,854	4,018,715

In addition, a policy of total protection against tides higher than 110 cm implies a reduction in mitigation costs, estimated to range between 1.61 and 3.65 million Euro per year, with a best point estimate of 2.49 million Euro (Table 8).

Table 8: On-site economic damages – Defence + 110 cm Scenario

Defence + 110 cm		Approach A	Approach B	Approach C
COST CATEGORY	SUBSTITUTION OF INNER DOORS			
	Higher Bound	465,833	460,253	611,513
	Lower Bound	410,342	402,604	538,237
	MAINTENANCE OF FRONT DOORS			
	Higher Bound	n.a.	108,467	108,467
	Lower Bound	n.a.	63,598	63,598
	MAINTENANCE AND CLEANING OF PAVEMENTS			
	Higher Bound	44,638	42,151	67,954
	Lower Bound	38,816	36,653	59,090
	MAINTENANCE OF WALLS			
	Higher Bound	n.a.	2,773,044	2,870,125
	Lower Bound	n.a.	1,106,891	1,208,347
TOTAL ON-SITE ECONOMIC DAMAGES				
Higher Bound		n.a.	3,383,916	3,658,059
Lower Bound		n.a.	1,609,746	1,869,273

Finally, if a high water protection policy were to be adopted against tides higher than 110 cm in combination with the presence of climate change, the economic value of on-site damage estimates range from 2.05 to 4.05 million Euro per year, with a best point estimate of 2.87 million Euro.

Table 9: On-site economic damages – Defence + 110 cm and Climate Change Scenario

Defence + 110 cm and Climate Change		Approach A	Approach B	Approach C
COST CATEGORY	SUBSTITUTION OF INNER DOORS			
	Higher Bound	465,833	460,253	611,513
	Lower Bound	465,833	460,253	611,513
	MAINTENANCE OF FRONT DOORS			
	Higher Bound	n.a.	124,133	124,133
	Lower Bound	n.a.	122,566	122,566
	MAINTENANCE AND CLEANING OF PAVEMENTS			
	Higher Bound	106,235	100,401	162,029
	Lower Bound	92,378	87,305	140,894
	MAINTENANCE OF WALLS			
	Higher Bound	n.a.	3,019,921	3,151,392
	Lower Bound	n.a.	1,380,724	1,508,268
TOTAL ON-SITE ECONOMIC DAMAGES				
Higher Bound		n.a.	3,704,709	4,049,066
Lower Bound		n.a.	2,050,849	2,383,242

If we compare the alternative scenarios, two important outcomes emerge. First, estimation results show that the most relevant sources of mitigation costs are related to the maintenance of the walls and the restoration of inner doors. External doors and pavements seem not to be highly affected, and this is mostly due to the separation of ordinary maintenance costs from total restoration costs. Second, the comparison of the valuation results across the different high water scenarios brings along with it significant monetary losses, which can be interpreted in terms of a welfare measurement, expressed in monetary terms, and thus signaling welfare changes associated to each scenario. The quantitative analysis of these welfare changes, in turn, constitute an important roadmap in terms of policy design and will be discussed in detail in the next section.

5. Policy implications

Any policy decision that involves the rejection of a public protection mechanism that defends the city of Venice from high water events will always involve a significant on-site damages to the business activities located in Venice and for this reason be associated with a negative welfare impact in that same stakeholder category. In particular, estimation results show that in a scenario where no policy protection measure is adopted, the welfare loss due to on-site, short-term damages supported by the business activities ranges from 3.41 to 4.73 million Euro per year, depending respectively on whether the frequency of high water remains unchanged or increases as a result of climate change.

Since the present valuation exercise considers (1) one damage category, on-site material damages, and (2) the valuation exercise is anchored next to a single stakeholder, the business activities, and (3) the estimates are computed by dose-response methods with judgment of experts, then the available economic valuation estimates should be considered at best as a lower bound to an unknown total value of high water protection. Bearing in mind such caveat, according to estimation results the introduction of a public protection mechanism that defends the city of Venice from high water events superior to 110 cm will reduce on-site, short-term damages supported by the business activities up to 2.87 million Euro per year. Therefore, this figure could be interpreted a *the* sufficient condition to the financial running cost of an efficient high water protection program. In other words, any high water protection program could be immediately defended from a cost-benefit perspective if its annual operational costs were less than 2.87 million euro per year.

6. Conclusions

In order to estimate the economic value of on-site damages of high water on Venetian business activities, we took into account the combination of dose-response methods, which are able to describe and account for the physical effects of high water on the different on-site damage categories, together with the judgement of experts. Furthermore, the dose-response methodology is sufficiently flexible so that economic valuation results are able to accommodate both the impact of key *input* parameters provided by the experts, such as the number of high water events that cause the need of restoration for each building element, as well as alternative approaches regarding the computation of the flooded area.

In such a valuation framework, we started by conducting interviews with different experts, mostly architects working in Venice, retailers of doors, pavements and other materials, and firms installing mitigation measures. Then we proceeded with the estimation of on-site damages not only for the business as usual situation, but also for three additional high water scenarios. Estimation results show that the welfare loss due to on-site, short-term damages supported by the business activities ranges from 3.41 to 4.73 million Euro per year, respectively for the business as usual and climate change scenarios. Furthermore, the introduction of a public protection mechanism that defends the city of Venice from high water events superior to 110 cm will reduce the on-site damages supported by the business activities up to 2.87 million Euro per year.

All in all, the present economic valuation estimates should be considered at best as an underestimate of the unknown total value of the impact of high water events since this study only considers a single stakeholder – the business activities; only tackles on-site damages – including walls, doors and pavements; does not include any architectural value considerations; and it is always contingent upon the current number, distribution and diversity of business activities.

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(lxv) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications” organised by Fondazione Eni Enrico Mattei and sponsored by the EU, Milan, September 25-27, 2003

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