City Profiles
Venice, Italy

Climate Resilient Cities

47810

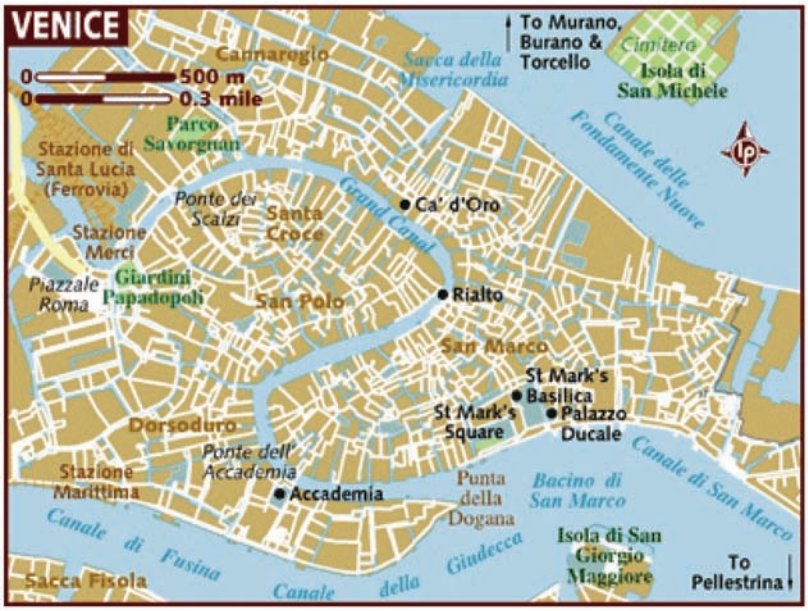
A Primer on Reducing Vulnerabilities to Disasters

I/ CITY DESCRIPTION

The Municipality of Venice has 269,000 inhabitants, only 62,000 in the central part of the old town or *centro storico*, with a population density of 658 people per square kilometer.[1]

The Venetian Lagoon extends for 212 square miles and comprises the city of Venice and 50 smaller islands together with sandbanks and mudflats, making the wetland area one of the most rich and fragile ecosystem in the Mediterranean Sea.

FIGURE 1. Map of Venice



Source: www.comune.venezia.it

Venice, built on millions of wooden piles driven into marshy ground, has been sinking into the Adriatic for 1,000 years. Venetians have coped with the *acqua alta*—high water—but the floods of November 1966, much deeper than usual, highlighted the fact that the old flood defense methods will soon fail. Moreover, the November 2008 flood, one of the highest in the last 20 years, underlined the necessity to make new flood defense system work and to invest even more in adaptation strategies.

Venice has been sinking into the Adriatic for 1,000 years.

THE WORLD BANK

Global Facility for Disaster Reduction and Recovery

ISDR
International Strategy for Disaster Reduction

II/ PRIORITY HAZARDS/VULNERABILITIES

The 20th century strengthened Venice's links to solid land. At the beginning of the century, a road bridge was built parallel to the railway bridge. The shift of business and industry to Mestre and Marghera regions established Venice as an industrial city. Petrol refineries and metallurgy, chemical, and plastics industries grew in the Marghera region, which brought thousands of jobs to Venice and plenty of environmental problems, too. The disastrous floods of 1966 focused the world's attention on Venice's watery plight. The ensuing years have seen a succession of debates on a range of solutions, from floating barriers to platform soles.

MOSE involves the construction of 79 hollow gates at three lagoon inlets.

In the last century, the city sank 11 inches, mostly due to the pumping of groundwater and methane gas for local industries. But it is also being affected by rising sea levels. The same tides that were not flooding the city 100 years ago are now high-tide events. *Acqua alta* afflicts Venice mostly in the winter. A century ago this happened maybe seven times a year; now it is more like 100.[2]

The city of Venice is facing at least two challenges:

- The city infrastructure, historical buildings, people's homes, and businesses must be saved; and
- The lagoon and its wetland are of extreme environmental value.

If Venice is to be saved, the lagoon must be protected.[3]

The lagoon is an ever-changing environment due to erosion, sediment movement, and human activity. This trend is compounded by the influence of greenhouse gases. Global warming will produce a change in the local thermo conditions (and therefore in the currents). In the next 50 years, a rise in temperature of 0.7–4.1°C is foreseen for the Upper Adriatic.[4]

III/ ADAPTATION MEASURES

The approved plan to protect Venice is called MOSE (Modulo Sperimentale Elettromeccanico, or Experimental Electromechanical Module).[5] MOSE involves the construction of 79 hollow gates at three lagoon inlets. When waters rise 1.1 meters (43 inches) above normal, air will be injected into the hollow gates, forcing water out and causing them to rise, blocking seawater from entering the lagoon and thereby preventing the flooding of Venice. The floodgates will take approximately 10 years and €4.3 million to construct.[6] In May 2003, the MOSE project was set in motion in the hope that its mobile flood barriers would protect the city from further damage.

At the Malamocco inlet, the walls of the MOSE project are being built just like the original walls in Venice. But workers are driving 125 foot-long steel and concrete pilings into the lagoon bed instead of wooden pilings. When the giant doors are at rest, they will be lying on the bottom of the inlet channel, invisible to the world. Each gate will be up to 92 feet long, 65 feet wide, and will weigh 300 tons. The gates are managed to accommodate need. Depending on sea tides, wind, and rain, they can close one inlet and not the others. In many instances, it will not be necessary to close the whole lagoon, thus, the exchange of water from the open sea to the inlet will continue to flow.

The MOSE project received its final approval by the *Comitatone*, the special committee for the safeguard of Venice, which includes the former Italian premier, the mayor of Venice, the president of Veneto Region, and many specialists and technical experts. Politicians, together with technical experts, had to express their thoughts about MOSE, define a common view, and then decide whether or not to move forward with the project.

Nevertheless, MOSE is controversial, on the grounds of effectiveness, cost, and environmental impact. And that is before facing the fact that global warming might lead to flooding well beyond the capacity of MOSE.

Some critics of MOSE, such as Paolo Antonio Pirazzoli of the French Centre National de la Recherche Scienti-

fique (CNRS), are skeptical as to whether the gates will actually prevent flooding. In his *Eos* article, Pirazzoli states that the design of the gates is based on outdated predictions of sea-level change, utilizing a scenario that differs by nearly 0.26 meters (10 inches) from recent estimates of rise in sea level over the next century made by the Intergovernmental Panel on Climate Change (IPCC).[7] Pirazzoli also asserts that the MOSE designers did not consider sea-level rise associated with land subsidence or increased water levels associated with extended rainy or windy periods.

Pirazzoli argues that once sea-level rise exceeds 0.31 meter (12 inches), possibly within the next 100 years, MOSE will become obsolete and will need to be replaced with watertight gates. Therefore, Pirazzoli contends, the Italian Government should follow "soft" techniques, such as raising street-level elevations, and await further assessment of sea-level rise to find "an updated, wise solution, more able to cope with foreseeable sea-level change."

In the same issue of *Eos,* MOSE supporters Rafael L. Bras, Donald R.F. Harleman, and Paola Rizzoli of the Massachusetts Institute of Technology comment on Pirazzoli's view. Bras, Harleman, and Rizzoli, who worked on the design and assessment of MOSE, state that the gates will indeed be effective barriers to flooding. They note that the sea-level rise scenario they utilized was based on recent research and that the floodgates are designed for a 0.3- to 0.5-meter (12 to 20 inches) rise. Furthermore, they say it is not necessary to consider more land subsidence because it was the result of groundwater removal that ended in the 1970s and has not been a problem since.

Bras and his colleagues note that as flooding occurs with greater frequency, steps will have to be taken to protect Venice, and the cost of doing nothing may be greater than the cost of constructing the MOSE gates. They believe that "the barriers, as designed, separate the lagoon from the sea in an effective, efficient and flexible way, considering present and foreseeable scenarios." With regard to Pirazzoli's contention that the mobile floodgates would eventually have to be replaced with watertight gates, they respond that if water levels continue to rise, the gates would just remain closed more often, in effect serving as "permanent" barriers.

Environmentalists argue, however, that keeping the gates closed for increasingly longer periods of time could be detrimental to the lagoon's ecosystem, which relies on exchange of waters between the lagoon and the Adriatic Sea to flush pollutants from the lagoon. Without this cleansing flow, they say, toxic substances may build up in lagoon waters, damaging its delicate ecosystem.[8]

Monitoring, Warning, and Altering for High Tide

The Centre for Forecast of Tide Level and High Water Alerting of Venice was launched in 1981 and it is responsible for monitoring tides and sea-level rise and issuing warnings in case of hazardous activity. The Centre continually monitors and provides updates to the citizens of Venice. In case of high tides the citizens are informed by a call manager, alarm system, and phone (SMS text messaging) system. On a daily basis, citizens can stay informed by visiting the Centre web site or calling the answering service.

The Monitoring and Warning system is run through:

- Central station: Centre;
- Repeater: S. Nicolò di Lido; and
- Measurement stations: nine stations inside the lagoon, three stations on the dam, one station in the Adriatic Sea.

Observed parameters are (a) tide level and (b) meteorological parameters (air pressure, wind velocity and direction, humidity, air temperature) with a near realtime acquisition (at five-minute frequency).

The cost of doing nothing may be greater than the cost of constructing the MOSE gates.

Daily notification activities of the Centre include the following:

- 48-hour tide forecast available on Centre web site, www.comune.venezia.it/maree;
- Graphic displays showing level of high tides and next 48 hours of maximum and minimum tide forecasts;
- Published reporting in newspaper, local radio, local and national TV programs;
- Fax updates sent automatically to police, firefighters, public offices, and the media with tide forecast for 48 hours; and
- Telephone service with 120 lines with automatic answering for 20,000 received phone calls per hour.

Alert activities in case of high tides include the following:

- *Call manager*: in case of an expected high tide over 110 centimeters, it warns some particular user like residents or businesses on ground floors;
- *Alarm system:* a network of 16 sirens in Venice and main islands warns citizens at least three or four hours before tide reaches over 110 centimeters high. Since 2006, sirens have been substituted by an electronic system in 15 spots around the city; the sound will have a different tone related with the different color code for level of emergency—from white to red code; it changes sound intensity depending on the tide/high water; and
- *Phone alarm*: operators inform institutions, public corporations, and the most important operative services. It activates the emergency plan for the possibility of the *passerelle* (small bridges) when high tides are over 80 centimeters.

Notes

This "City Profile" is part of *Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters*, published by the World Bank. The analysis presented here is based on data available at the time of writing. For the latest information related to the Primer and associated materials, including the City Profiles, please visit www.worldbank.org/eap/climatecities. Suggestions for updating these profiles may be sent to climatecities@worldbank.org.

1 Unione Statistica Comuni Italiani (statistic bureau for municipalities), 2008.

2 The builders of Venice 1,300 years ago used materials for foundations that could withstand water. But with the seabed sinking, brick walls at ground-floor levels are being corroded and waterlogged buildings are crumbling.

3 Today, rising seas threaten the Venice lagoon. All along the Grand Canal, windows of buildings near sea level have been closed and filled with cement. No Venetian lives on the ground floor any more.

4 IPCC, Climate Change 2007: Synthesis Report Summary for Policymakers, Assessment of Working Groups I, II, and III to the Third Assessment Report of the IPCC (IPCC: Cambridge University Press, 2007).

5 MOSE also recalls the biblical Moses, who parted the Red Sea.

6 Data from Ministry of Finance, Corte dei Conti, 2007, available from the web site www.finanze.it

7 *Eos,* Italian technical magazine, 2002, www.spie.org/Documents/ConferencesExhibitions/ers-eud06-abstracts.pdf

8 In order to understand how frequent closing of the gates would impact the lagoon's ecosystem, it is necessary to understand water-flow patterns and exchange rates through the lagoon inlets. Miroslav Gacic and colleagues have taken preliminary steps in addressing these issues. Their research, published in the same edition of *Eos* (2002), is based on a series of ship-borne surveys of water flowing through the inlet over an approximately 45-day period. Although the results are preliminary, the authors conclude that flow through the inlets is controlled primarily by tides. They also determine that the lagoon waters have an exchange rate of about one day, meaning that the lagoon is well ventilated and quickly flushed. The researchers note that better assessments will be made when data representing several seasons become available.

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