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Skanska AB  
www.skanska.com

**Contact**  
Noel Morrin,  
Senior Vice President  
Sustainability  
noel.morrin@skanska.se

## Øresund Bridge, Sweden and Denmark

### Case Study 49

#### Aspects of Sustainability

This project highlights  
the following:

##### Social Aspects

Human Resources  
Corporate Community  
Involvement  
Business Ethics  
Health and Safety

##### Environmental Aspects

Energy and Climate  
Materials  
Ecosystems  
Local Impacts

##### Economic Aspects

Project Selection  
Supply Chain  
Value Added

The Øresund Bridge consists of a bridge, an artificial island and an underwater tunnel, which connect Sweden and Denmark across the Øresund strait. The bridge includes the longest immersed concrete tunnel and double-deck road and rail bridge in the world and was designed to have minimal impact on the sensitive marine environment.



### Project Introduction

The 16.4 km long Øresund Bridge consists of a bridge, an artificial island and a tunnel, which connect the Danish capital Copenhagen with Malmö in Sweden across the Øresund strait. The route opened in 2000 and carries the dual two-lane E20 European motorway on an upper deck and a double track high-speed railway on the lower level. The 7.7 km bridge links the Swedish coast with the 4 km long Peberholm Island in the middle of the Øresund strait, which was artificially created and is now an unpopulated nature reserve. A 3.5 km underwater tunnel was constructed to connect Peberholm with Denmark due to the close proximity of the Kastrup international airport. 25 million journeys were made across the bridge in 2007, which was 17 percent more than the previous year.

The Skanska-led consortium, Sundlink Contractors, constructed the US\$ 1.3 billion project between 1995 and 2000 for the Øresund Bridge Consortium, which owns and operates the bridge. The bridge was constructed on a design and build contract and was completed 6 months ahead of schedule. The project involved extensive compensational dredging work to maintain water flow in the strait, and dredged material was used to create the artificial Peberholm Island, bridge pier islands and a 430 m long artificial peninsula on the Danish coast for the tunnel to emerge through. The bridge has a navigable clearance of 57 m, maximum height of 203 m and the cable-stayed main span is 490 m, which is one of the longest in the world. All bridge components were prefabricated on land and assembled offshore. The tunnel consists of 20 concrete sections that

were lowered into a pre-dredged trench on the seabed at a maximum depth of 21 m. Sundlink Contractors were not responsible for the dredging work, construction of the artificial island or the tunnel.

The Baltic Sea is the world's largest body of brackish water with a unique marine ecosystem, which is dependent on the flow of saline and oxygenated water from the North Sea. The Øresund Bridge was consequently designed to have a zero net impact on the marine environment by minimising changes in the flow of water through the Øresund strait. The project is considered to be a model for mitigating the environmental impacts of mega-construction projects. The Øresund Bridge project won the IABSE (International Association for Bridge and Structural Engineering) Outstanding Structure Award in 2003 for the innovative planning and construction management techniques, and environmental considerations.

## Contributing Toward Sustainable Development

The Øresund Bridge has connected Sweden and Denmark with negligible impacts on the sensitive marine environment, and has benefited the environment by creating new habitats and reducing air pollution compared to old ferry transport across the strait. The route has promoted economic and social integration throughout the Øresund region and has contributed toward regional economic development by facilitating transportation between Sweden and Denmark. Regional and national governments, and environmental agencies, were thoroughly involved in the design and construction of the project and stakeholders were informed of the construction activities. The construction of the bridge engaged the regional construction industry, pioneered high standards of safety and initiated a local employment programme to meet the project's requirements for skilled labour. High standards of environmental protection were incorporated into the project and flora and fauna were closely monitored to avoid changes to the sensitive marine environment.

## Social Aspects

### Stakeholder communication and involvement

The consortium worked closely with regional and national governments throughout the project, and established several working groups to solve project issues and to keep regulatory bodies informed during construction. Public stakeholders,

such as local residents, recreational sailors, bathers and commercial fishermen were informed of the progress of construction work and planned activities through a media campaign. There were no disputes or significant complaints during construction, which is unusual for such a complex project.

### Occupational safety

The Øresund Bridge project was one of the first projects in Sweden to record the LTAR (Lost Time Accident Rate), which was around 11 accidents per million hours worked on the entire project, compared with an average of over 20 in Sweden at the time. Safety measures included the detailed planning of construction activities, safety training and education, inspections by safety managers and health checks. Sadly, a fatality occurred on site during the project.

### Public road safety

Road safety is controlled and managed 24 hours a day by a permanently staffed traffic centre and a Supervisory Control And Data Acquisition (SCADA) system, which automatically monitors the route. The SCADA is equipped with sensors and remote controlled cameras, which automatically detect traffic problems and is directly connected to both the Danish and Swedish emergency services. Sensors in the tunnel also monitor carbon monoxide, nitrogen dioxide and visibility. The traffic centre is able to accurately forecast wind and weather conditions and efficient procedures are in place to quickly deice the motorway when necessary. Electronic information signs at 1.5 km intervals advise motorists on road and weather conditions and motorists are advised to tune into a radio frequency during their journey across the bridge to allow the traffic centre to inform motorists of driving conditions. Well-marked emergency stations with telephones, fire extinguishers and fire alarms are situated every 90 m along the route, and the tunnel has emergency lighting and evacuation corridors. There is a 90 km/h speed limit in the tunnel and overtaking lorries on the route is forbidden. Between 2001 and 2007, 5 road accidents involving injury occurred. There were no fatalities.

### Promoting more sustainable transport

The Øresund Bridge allows high-speed international rail transport between Copenhagen and major cities in Sweden. 47,000 passenger trains and 8,850 freight trains used the route in 2007 and on average 140 trains per day cross the Øresund Bridge. Train passenger numbers increased by 25 percent in 2007 compared with the previous year.

## Bridge durability

The Øresund Bridge is designed to have an operational lifespan of 100 years. The truss girders and all exposed steel have been protected from corrosion with the maximum coat thickness possible. The design was modified to promote water runoff and to reduce water retention on the structure.

## Economic Aspects

### Local construction employment

Up to 2,000 workers were on site at any one time and around 95 percent of the site workforce was from the Øresund Region. During the peak of construction, around 5,000 workers were directly involved in the project, including the prefabrication of materials off-site primarily in Karlskrona and Spain, where the approach bridge steel girders and concrete deck were constructed.

### Regional construction subcontractors and materials

The Øresund Bridge was a mega project, which involved much of the regional construction industry, including subcontractors and construction material suppliers. As much of the bridge and tunnel was prefabricated as possible, which enabled many companies to tender for contracts and become involved in the project. Many subcontractors were from southwest Sweden and Copenhagen, such as electricians, painters and crane operators. Regional materials included sand

and steel from Denmark, granite shipped from southwest Sweden and quarried material for ballasting from Norway.

### Vocational training

An employment programme was initiated together with the regional governments to train local people in order to meet the skilled labour requirements of the project. The programme trained unemployed people to be carpenters and steel workers, and already qualified workers, such as civil engineers, were educated on the special quality requirements of the project. Regional technical colleges and universities were involved in the various stages of the project by participating in educational visits and various study projects.

### Regional economic development

The bridge has facilitated the transportation of goods and people between Sweden and Denmark, and has unified the Øresund region and the Copenhagen-Malmö urban conurbation, which is now Scandinavia's largest with 2.6 million people. Øresund is consequently able to compete for investment with other regions in northern Europe. The regional housing markets, businesses and labour markets have become more interrelated due to easier transport between Sweden and Denmark. The travel time across the Øresund strait has been reduced to 35 minutes from Copenhagen Central Railway Station to Malmö Central Railway Station, which has benefited businesses in both countries, and has facilitated commuting between



Copenhagen and Malmö. Around 17,000 people commute across the bridge each day to work or study, and approximately 70 percent of passengers across the bridge begin or end their journey in the Øresund Region. Easier commuting has alleviated labour shortages in Denmark by enabling Swedes to commute and has boosted the property market in southwest Sweden. The route has promoted tourism and short breaks in both Sweden and Denmark and the landmark Øresund Bridge has become a tourist attraction in its own right.

## Environmental Aspects

### High environmental standards

Due to the sensitive marine environment in the Øresund strait, the project exceeded the most stringent Swedish and Danish environmental regulations and in many cases double approval had to be granted from both governments. Various environmental and conservation organisations were consulted on the project, and the consortium partnered the Øresund Fund, which works to protect the marine environment in the strait. Most of the bridge sections were prefabricated on land to reduce the amount of time spent at the bridging line and the risk of damaging or polluting the marine environment. Over US\$ 300 million was spent on environmental protection measures during construction. In 2001 the Danish and Swedish authorities concluded that all environmental requirements related to the construction of the bridge had been fulfilled.

### Minimal impact on water flow

Following discussions with environmental organisations, such as the Swedish Water Court, the project was designed to have a minimal blocking effect in the Øresund strait. The bridge ensured that the flow of water, salt and oxygen would not be altered by more than 0.5 percent, in order to reduce the risk for potentially damaging changes in the Baltic Sea's composition. The Peberholm artificial island was situated in the shelter of an existing island and the artificial peninsula on the Danish coast was shortened. Two independent hydrographical models tested the design and identified areas where compensatory dredging was needed to offset the blocking effect of the bridge.

### Reducing the impact of dredging

In total, 7.5 million m<sup>3</sup> of material was dredged from the seabed in the Øresund strait, which was used to create the artificial islands. Dredging was done carefully and spillage was minimised to less

than 5 percent to avoid suspended sediment that could shade and potentially kill sensitive eelgrass and mussel beds. Eelgrass beds are vital to the strait's ecosystem, as they provide food for birds, reduce seabed erosion, and act as fish spawning and nursery grounds. The intensity and duration of any spillage was limited and a sediment distribution model was developed to help monitor sediment plumes and their effects on the marine ecosystem.

### Flora and fauna monitoring

Marine flora and fauna were monitored throughout the construction and the information was used to continuously update a computer model, which tracked the overall impacts of the project. Eelgrass and mussel populations were regularly monitored by divers, fish samples were made by using sonar and birds in the area were recorded from observation towers. Seabed monitoring showed that eelgrass and common mussels decreased in population following dredging works, but that populations recovered by the time the bridge was opened. A survey of sea plants, mussels, eider, greylag geese, mute swans and coastal morphology in 2000 concluded that the construction did not adversely affect biodiversity in the strait.

### Habitat creation

The 1.3 km<sup>2</sup> Peberholm artificial island is a designated nature reserve where flora and fauna have been allowed to develop naturally and undisturbed by human interference. The Lund Botanical Association identified over 450 plant species on the island in 2007, including young trees and rare plant species such as *Sisymbrium supinum* and *Erucastrum gallicum*. Over ten species of bird breed on the island, including little terns, pied avocets, barnacle geese and black-headed gulls. The Zoological museum in Copenhagen has also identified rare amphibians, butterflies, beetles and spiders on the island. A layer of sessile flora and fauna has established on the bridge pillars, including barnacles, algae and mussels, which provide food for fish and birds, filter the water and counteract deoxygenation.

### Minimising light disturbance

The bridge is constructed in sections of relatively shallow water. Therefore, bridge lighting has been designed to avoid direct illumination of the water surface so as not to deter fish. Bridge illumination is minimised during bird migration seasons to reduce the risk of distracting birds and potentially acting as an obstacle.

## Reduced air pollution

The bridge has reduced the total air pollution due to transport by almost 50 percent, whilst enabling quicker and greater volumes of passenger and goods transport to cross the Øresund strait. Prior to the project, ferries that produced a large amount of air pollution and greenhouse gases were the only means of transport across the strait.

## Learning From Good Practice

Best practice from the Øresund Bridge construction, including equipment selection and working methods were built into the Cooper River Bridge project in the US, which shares many common features. Skanska completed the Cooper River Bridge in 2005 (see Aspects of Sustainability Case Study #6). A small number of the Øresund Bridge project team were selected to work on the Cooper River Bridge project, and brought their considerable experience to the project alongside other experienced bridge builders from Skanska.

