Report

Risk Governance of Maritime Global Critical Infrastructure:

The example of the Straits of Malacca and Singapore

international risk governance council

Abbreviations used in the text:

AIS	Automatic Identification System
ASEAN	Association of Southeast Asian Nations
CTOS	Container Terminal Operating Systems
DPRI	Disaster Prevention Research Institute
EDI	Electronic Data Interchange
GCI	Global Critical Infrastructure
GEF	Global Environment Facility
GPS	Global Positioning System
HNS	Hazardous and Noxious Substances
ICT	Information and Communication Technology
ICS	International Chamber of Shipping
IMB	International Maritime Bureau
IMO	International Maritime Organisation
INTERTANKO	International Association of Independent Tanker Owners
IRGC	International Risk Governance Council
ISPS	International Ship and Port Facility Security
IT	Information Technology
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LRIT	Long Range Identification and Tracking System
MEH	Marine Electronic Highway
MIMA	Maritime Institute of Malaysia
MPA	Singapore Maritime and Port Authority
MGCI	Maritime Global Critical Infrastructure
NOSCP	National Oil Spill Contingency Plan
NSC	National Security Council (Malaysia)
ReCAAP	Regional Cooperation Agreement on Combating Piracy and Armed Robbery against Ships in Asia
SOLAS	Convention on the Safety of Life at Sea
SUA	Safety of Maritime Navigation
TEU	Twenty-foot Equivalent Unit
TSS	Traffic Separation Scheme
TTEG	Tripartite Technical Experts Group
UNCLOS	The United Nations Convention on the Law of the Sea
US	United States
VHF	Very High Frequency
VLCC	Very Large Crude Carrier
VTIS	Vessel Tracking and Information System
VTS	Vessel Tracking Service

Cover Photo: Malacca Strait, Port Klang, Malaysia.

Photograph by Cecilia Ho. Art by Michele Bristow.
Other pictures: IStock photo and Flickr

ISBN 978-2-9700772-0-6

Contents

Foreword

Global trading is rapidly increasing all over the world and our society greatly depends on maritime shipping infrastructure. As one of the world's foremost maritime shipping groups, Mitsui O.S.K. Lines contributes to our world's economic growth and sustainable stability through providing safety-assured transportation services.

The Straits of Malacca and Singapore comprehend one of the most important and busiest places for shipping, as well as a centre of biodiversity. Consequences of any severe incident along this region could be astronomical, while incident risks such as piracy, terrorism or cyber-attack are on the rise.

There is a limit to the achievement that one private company group can obtain by its efforts alone.

This report outlines necessary initiatives to enact global risk governance mechanisms in the Straits of Malacca and Singapore. It encompasses first-hand assessments on the possibilities of events triggering the closure of the Straits and potential environmental and economic impacts on the regional and international society. Most of the results are carefully derived from expert workshops which were attended by policymakers, academic researchers and private companies from littoral countries and several user countries. Thus, it provides both a profound risk assessment and rigorous attention to the crucial international cooperation mechanism among various stakeholders.

The safety and fair use of the Straits are basic requirements for our society in the future.

We hope this milestone document will be beneficial to all stakeholders as a source to obtain knowledge on risk governance and towards improving preparedness and resiliency.

Captain Yasumasa Kadota
Mitsui O.S.K. Lines

Captain Shinichi Oi
Mitsui O.S.K. Lines

Foreword from IRGC

One of the challenges of risk governance is when interests do not align or are in conflict in some way. Governance of the risks that may materialise in the Straits of Malacca and Singapore is an example of such a challenge, which is why IRGC has welcomed and supported the initiative of a Kyoto University team to point out some of the risk governance issues and to provide some recommendations for improvement.

The context is set by geography and the fact that the Straits represent a strategic maritime route for “users”, whereas the littoral states (Indonesia, Malaysia and Singapore) carry most of the burden for ensuring security in the Straits. Some elements are worth noting here:

- A fundamental risk governance challenge in the Straits comes from the fact that transit passage through the Straits is an international right under international law. However, the costs of maintaining and upgrading processes and infrastructure to ensure safe, secure and sustainable usage is an expense to the littoral states, not to the users, which are mainly large foreign shipping companies.
- While the littoral states are not the main users, they would be the ones affected in case of environmental damage caused by a shipping accident.
- The users are those who may be most severely affected by a complete closure of the Straits, which is possible considering its narrowness and lack of depth in some places. Attacking or deliberately attempting to close the Straits is thus an easy way to cause indirect damage to end-user states. Therefore, the Straits can be considered as strategic critical infrastructure and their closure, whether caused by an unintentional or an intentional accident, is an area of concern to both users and littoral states.
- Since 2005, a Cooperative Mechanism between the littoral states and the users has progressively cemented a strong foundation upon which specific projects have concretised steps towards a broader risk governance strategy.

The diversity of interests and conflicts involved necessarily imposes constraints on producing a report which reflects a consensus on all points. However, given that solutions to the major problems at hand require a much greater degree of cooperation (not least financial) and a greater sharing of sovereignty than exists at present, we believe that it is better to endorse what is working and to suggest potential means to achieve desirable outcomes rather than to enter into a debate over what is politically feasible.

IRGC’s indirect interest in supporting the Kyoto University initiative is to try to improve risk management in the Straits of Malacca and Singapore. As this is a specific case of a confined area, it can be helpful as a test zone to improve the overall, global safety and security of oceans. The principles and mechanisms that can be applied and experimentally implemented in the Straits could provide lessons for what could be done elsewhere.

Prof. Dr Wolfgang Kröger
Managing Director of the Risk Center at the Swiss Federal Institute of Technology (ETHZ), Zurich
Founding Rector of the International Risk Governance Council (IRGC)

Summary

The Straits of Malacca and Singapore[1] are one of the most important sea lanes in the world. They are a strategic passage for global trade, a source of oil, mineral and mangrove resources, and a centre for the Earth's marine and coastal biodiversity. Locally, Indonesia, Malaysia and Singapore derive different economic benefits from the Straits, but jointly shoulder the burden of environmental, safety and security risks. Globally, outsiders which depend on passage, especially Japan, China and Korea, would be negatively impacted by disasters that could lead to disruptions in the Straits. As such, the Straits constitute a prime example of a *Maritime Global Critical Infrastructure* that supports economies and societies locally and worldwide. Global Critical Infrastructure (GCI) offers a new perspective on emerging critical infrastructure systems characterised by globally and internationally connected critical infrastructure networks of a high level of complexity. Responsible risk governance of GCI requires a broadened perspective to creatively manage risks in increasingly complex, stressed systems. It can help improve resilience and the capacity of stakeholders in the Straits to cope with surprises. This may be accomplished by being proactive in the development of prevention, preparedness, response and recovery strategies to deal with known, uncertain and unknown hazards [adapted from IRGC, 2005].

The Tripartite Technical Experts Group (TTEG) in the Straits deploys and continues to develop technologies and processes to ensure undisrupted navigation, notably through the ship reporting system STRAITREP, the Traffic Separation Scheme and the Marine Electronic Highway. However, due to geographical constraints of the deep sea channels, the proximity to critical hinterland infrastructure, the high concentration of economic activities and the ecological importance, the Straits are vulnerable to hazards of natural, technological, human and malicious origin.

The risk governance of Maritime Global Critical Infrastructures is of interest to the Disaster Prevention Research Institute (DPRI) at Kyoto University and the International Risk Governance Council (IRGC). In this context, two expert workshops and initial scenario-based discussions were held in 2009 and late 2010 to specifically address the case of the Straits of Malacca and Singapore. These workshops and discussions showed that beyond traditional maritime casualties, there are trans-boundary threats and risk cascades that affect both land and sea with regional and global consequences. The Straits can be analysed as a "system of systems"[2] with multiple and overlapping circles of stakeholders from local to regional to global scales, including public, private and non-governmental organisations as well as civil society. The scenarios discussed were: an explosion in an industrial area of refineries and petrochemical facilities, a cyber-attack on marine electronic systems, and ship collisions. These scenarios revealed potential risk governance deficits, including: insufficient awareness to new threats, inadequacy of early warning systems, unequal organisational capacity and burden sharing among littoral and user states, and the difficulty of dealing with dispersed responsibilities among stakeholders with diverging interests. Some of these deficits have already been addressed by the landmark effort known as the Cooperative Mechanism[3]. A culture of cooperation among the littoral states has been critical in preventing and mitigating some hazards in the Straits, notably in the cases of piracy and oil spills, but it should be strengthened and expanded to deal with other hazards and to include other stakeholders. In fact, existing mechanisms are not adequate to deal with all identified hazards and emerging risks, leading the authors of this report to propose five major recommendations.

[1] Hereafter, also referred to as the Straits.

[2] That is, natural systems, infrastructure systems, transportation systems, management systems, and institutional systems.

[3] For a detailed briefing, please see Section I.

It is recommended that the littoral states, with user states, the maritime community and other concerned stakeholders:

#**1** ***Harmonise methodologies, tools and procedures for risk assessment of maritime infrastructure and operations*** that start with the identification of possible triggering events, notably in terms of attacks on cyber-security, based on generally accepted frameworks.

#2 ***Implement an integrated disaster risk management approach*** by extending the scope of the existing emergency response system from a specifically oil spill contingency plan to provide an all-hazards plan. This would include the specification and sharing of multi-hazards and risk maps, communication chains, and an appropriate tri-lateral (Indonesia-Malaysia-Singapore) emergency operations system, and regular training exercises.

#3 ***Prepare joint contingency plans in case of a closure of the Straits***, involving navies, coast guards, port authorities, shipping companies and communities, among other key players. The plans should include notification, alternative routes, and a tri-lateral (Indonesia-Malaysia-Singapore) effort to reopen the Straits.

#4 Conduct comprehensive, joint (Indonesia-Malaysia-Singapore and user countries) risk assessments of the environmental, societal and economic impact of major activities in the Straits**.** The aim of these assessments would be to verify the appropriateness, consistency and sufficiency of existing policies and their implementation. More broadly, they would contribute to develop long-term cooperation between the littoral states and other stakeholders.

#5 Create an observatory or ad hoc expert joint committees**,** embedded within the TTEG and Cooperative Mechanism, which would act as a representative and neutral platform for collecting and evaluating data to advise key stakeholder.

I Introduction: Risk Governance of Global Critical Infrastructures

Risk governance is defined as the identification, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed, evaluated and communicated and how and by whom management decisions are taken and implemented [IRGC, 2005].

Definition of Maritime Global Critical Infrastructure (MGCI)

Critical Infrastuctures, as defined in the USA Patriot Act of 2001 [US, 2001], are "those systems and assets, whether physical or virtual, so vital […] that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters". *Maritime Global Critical Infrastructures* are systems and assets as they relate to *marine* activities specifically and can impact international security, global economic security, public health or safety, or any combination of these.

The risks associated with and the vulnerabilities of critical infrastructures were addressed by the International Risk Governance Council (IRGC) in a 2005/2006 study analysing five critical infrastructures: electric power supply, gas supply, urban water supply and waste water treatment, rail transport and systems for general information and communication services (ICT). The analysis led to the development of risk governance options [IRGC, 2006; IRGC, 2007]. The experience and lessons learnt from this project [see also Kröger, 2008] provided IRGC with a knowledge base to identify emerging stressors on globally significant critical infrastructures.

More recently, the Disaster Prevention Research Institute at Kyoto University proposed to IRGC to investigate emerging threats related to Maritime Global Critical Infrastructures focusing on critical infrastructure systems characterised by globally (internationally) connected critical infrastructure networks of a higher level of complexity. Responsible risk governance of Global Critical Infrastructure (GCI) requires this kind of broadened perspective and needs a supporting framework to creatively manage risks in increasingly complex, stressed systems. By helping to improve resilience and the capacity of stakeholders to cope with surprises, responsible risk governance fosters a proactive development of prevention, preparedness, and response and recovery strategies. In this way, hazards can be better handled, whether they are identified and plausible, seen as highly uncertain, or are unknown [adapted from IRGC, 2005].

Recent trans-boundary incidents have revealed the vulnerability of internationally connected infrastructure systems. For example, following the Great Hanshin earthquake in Kobe, Japan in 1995, damages to Kobe port and consequential disruptions in commodity chains worldwide have served as early signs of such new global vulnerabilities. Cascading events in particular, such as the 2003 northeastern American blackout[4] that brought cities like Toronto and New York

[4]More than 50 million people in Canada and the US were affected [CBC, 2003].

to a standstill and the 2010 Icelandic volcanic eruption that instigated the closure of European airports[5], result in widespread and costly consequences. After the 9.0 magnitude earthquake and tsunami on 11 March 2011 in Eastern Japan knocked out vital cooling systems, the Fukushima nuclear power plant experienced severe damage and the no. 1 reactor suffered a near complete meltdown[6], triggering fears around the world of possible radiation contamination. Furthermore, the nuclear crisis forced some shipping firms to avoid Japan's key ports and sea lanes, and many feared it could upset the global supply chain and hamper the nation's recovery [The Brunei Times, 2011; Bloomberg News, 2011]. As more systems become highly integrated across borders, driven by "just-in-time" logistics and stressed beyond their capacities[7], it would be prudent to address the risk of such disruptions proactively, particularly as new hazards and threats have evolved.

Straits have historically been considered indispensable as international trading routes. In current terminology, the system of natural and built infrastructure in the Straits of Malacca and Singapore is a "Global Critical Infrastructure" within the context of global maritime transportation, global energy security, and more broadly the global economy. In this report, IRGC considers the Straits of Malacca and Singapore as a Maritime Global Critical Infrastructure (MGCI) and addresses the issue of risk governance relating to potential break-points in the GCI of global shipping and trade. Like other GCI, MGCI inherently encompasses a great variety of stakeholders, resulting in a high level of systemic complexity. Given that approximately 90% of world trade is transported by sea, the global economy is heavily dependent on the effective operation of the shipping industry. One of the busiest shipping lanes in the world is the Straits of Malacca and Singapore, carrying around 25% of all world trade and half of the world's shipped crude oil. Due to their strategic importance, the Straits are considered critical infrastructure and present an ideal case study for IRGC to develop recommendations for improved risk governance of MGCI [Rimmer and Lee 2007].

There are also several other geographically and economically important maritime routes in the world, such as those passing through the Suez and Panama canals, the English Channel, the Gibraltar Strait, the Strait of Hormuz, the Bosphorus and Dardanelles passages, the Tsugaru Straits and the potentially newly opening northwest passage through Arctic waters. Though they are less congested compared to the Straits of Malacca and Singapore, they are strategic assets for international trade as well. Canals, unlike straits bordered by more than one country, are owned and governed solely by one authority. Still, they may be considered global assets where multi-stakeholder frameworks to enhance cooperation among owner and user states could enhance the reliability and resilience of the MGCI system as a whole.

As in the case of the Straits of Malacca and Singapore, these MGCI would also benefit from broad international risk governance frameworks adapted to their regional conditions. Several international frameworks have already been introduced[8]. Also, recent reports on trans-boundary environmental risks of shipping impacts in the English Channel [Bahe et al., 2007], the Mediterranean Sea [Abdulla and Linden, 2008; Oral and Simard, 2008] and the Baltic Sea [Gilek et al., 2011] are notable steps in fostering international dialogue among stakeholders. The Cooperative Mechanism of the Straits of Malacca and Singapore detailed in the box on the next page sets the stage for the development and enhancement of a broad international risk governance system.

The approach used in this project work on the Straits of Malacca and Singapore could be applied to risk governance of other MGCI, and possibly also to other GCI, such as air and rail transportation, gas pipelines, electric power grids and ICT networks. Understanding

[5]Five million travelers were affected [Chittenden and Swinford, 2010].

[6]80,000 people within 20km were forced to evacuate [BBC, 2011].

[7] The true ship carrying capacity of the Straits is unknown. MIMA estimates that the Malacca Strait has an annual carrying capacity of transit vessel movements between 119,159 to 1,302,351, depending on the level of safety in terms of distance allowed between vessels [MIMA, 2010a,b]. This means that if the number of transit vessel movements in a year is 140,000, usage could be either 17% over or 90% under the true carrying capacity. The Ministry of Land, Infrastructure, Transportation and Tourism of Japan (MLITT) estimates that by 2020 141,000 ships will transit the Straits annually [MLITT, 2009].

[8]For example, Canada and the US codified their relationship in the 1909 Boundary Waters Treaty, which is an institutional framework that utilises the International Joint Commission to deal with any issues related to boundary waters [IJC, 2011]. The European Union has been working towards a more encompassing maritime policy through the Marine Strategy Framework Directive [Juda, 2007, 2010].

and managing trans-boundary risks related to GCI needs a comprehensive framework, which involves information sharing, preparation and response schemes among different countries and stakeholders to enhance societal coping capacities in the face of unexpected, potentially disastrous events.

This report intends to bring stakeholders across private and public sectors, across all levels of government and from communities connected to the Straits of Malacca and Singapore to a common understanding of the Straits as a Maritime Global Critical Infrastructure and of the current deficits in governing the complex system of natural and built infrastructure in response to natural hazards and malicious threats.

Strait of Singapore, (Flickr, by owaief89)

The Cooperative Mechanism of the Straits of Malacca and Singapore: Perspective

Since the 1960s with the first generation of super tankers and associated oil spill disasters, Indonesia, Malaysia, and Singapore have been attempting to coordinate policies to handle problems in the Straits of Malacca and Singapore.

In 1975, a Ministerial Council on the Safety of Navigation and the Control of Pollution was established by the littoral states. The same year, the Technical Expert Group on Safety of Navigation in the Straits of Malacca and Singapore, later known as the Tripartite Technical Expert Group (TTEG), was formed.

Adopted in 1982, the United Nations Convention on the Law of the Sea (UNCLOS) Article 43 stipulated the need for cooperation among littoral and user states in the "establishment and maintenance in a strait of necessary navigational and safety aids or other improvements in aid of international navigation; and for the prevention, reduction and control of pollution from ships" [UNCLOS, 1982].

Japan was the first user who voluntarily cooperated with the littoral states and the need for further cooperation with other users of the Straits was identified quite soon [Lim, 1998]. With the assistance of the International Maritime Organization (IMO), between 2005 and 2007, the littoral states worked on the development of the Cooperative Mechanism, a framework for cooperation between littoral states and users of the Straits. The framework contains three components [Ho, 2009]:

I. *Cooperation Forum (CF)* for dialogue and open discussion among littoral states and users. Projects are proposed in the Cooperation Forum and, if approved, passed on to the Project Coordination Committee.
II. *Project Coordination Committee (PCC)* for the implementation of the cooperative programmes in cooperation with the sponsors of the project
III. *Aids to Navigation Fund (ANF).*

Since 2007, the Project Coordination Committee has been working on six projects [PCC, 2010]:
Project 1: Wreck Removal (India, Germany):
Project 2: HNS Preparedness and Response (Australia, China, US)
Project 3: Demonstration Trial of AIS-B Transponders for Small Vessels (Australia, Japan, IMO)
Project 4: Wind/Tide/Current Measurement System (China, India)
Project 5: Replacement and Maintenance of Aids to Navigation (Japan, Korea)
Project 6: Replacement of Aids to Navigation Damaged by the Tsunami off the Sumatran Coast (China). The Indian Ocean Tsunami of December 2004 damaged five lighthouses and two beacons along the eastern coast of Sumatra, Indonesia [CM, 2010].

The amount of contributions (2008-2010) to the Aids to Navigation Fund has reached USD 8.10 million in total. The balance in 2010 was USD 2.8 million. Contributions still fall short of the estimated annual cost of USD 5.8 million per year required to maintain the Straits [CF, 2010].

The Cooperative Mechanism recognises the following principles [Djalal, 2008]:
(1) The respect of territorial sovereignty, sovereign rights as well as jurisdictions of littoral states.
(2) Conformity to Article 43 of UNCLOS.
(3) The TTEG will be the focal point for the activities to promote safety of navigation and marine environmental protection in the Straits.
(4) Recognition of the interest of the users and other stakeholders in the Straits as well as their roles and contributions in promoting cooperation in the Straits.

Djalal [2008] also notes that the implementation, the structure and the process within the Cooperative Mechanism should be simple and flexible in order to accommodate future developments.

Given the notable successes of the littoral states in terms of cooperation through the TTEG and with users of the Straits (including public and private organisations) through the Cooperative Mechanism, the findings and recommendations presented in this report intend to build upon these strong foundations.

II The case of the Straits of Malacca and Singapore as a Maritime Global Critical Infrastructure

Indonesia, Malaysia and Singapore have a long and rich geopolitical history, during which time there has been conflict as well as cooperation. Maritime boundaries, even in the Straits of Malacca and Singapore, have yet to be settled. In consideration of the various local, regional and international interests in the Straits of Malacca and Singapore, it is doubtful that agreements on the governance of risks in the area would be universally accepted by all. This leads to risk governance deficits. The challenges in this region require a much greater degree of cooperation among all users of this strategic passage (not least financial) than exists at present. Yet, the littoral states demand sovereignty, which must be respected and foreign users call for safe and secure passage, which must be provided.

The Straits of Malacca and Singapore (hereafter also referred to as the Straits), shown in Figure 1, link the Indian and Pacific Oceans via the Andaman and South China Seas and comprise the shortest maritime route between the Middle East and East Asia. The rise of Asia makes the Straits the most economically important waterway in the world [Bateman, 2009]. The United States (US) Energy Information Administration designated the Straits of Malacca and Singapore as one of the two most strategic chokepoints for world oil transit [US EIA, 2008; US EIA 2011].

With global economic growth, vessel traffic has steadily increased from 55,957 transiting ships in 2000 to 71,359 in 2009 [JAMS, 2010].

Moreover, in addition to the Straits' strategic and economic importance in international trade and global energy security, the Straits are ecologically significant as a centre of biodiversity. Renewable and non-renewable resources from coastal and marine ecosystems, mainly in the Malacca Strait, sustain the economic livelihoods of inhabitants.

The Straits and its coastal areas constitute a nexus for shipping, fisheries, aquaculture, mariculture, oil and gas, tin mining, forestry, agriculture, tourism and recreation [Burbridge, 1988; Thia-Eng et al., 2000a,b; Wong, 2000].

The Port of Singapore is located on the north side of the Singapore Strait, the narrowest width of which is 1.5 nautical miles (2.8 km), is the world's busiest container port (see Table 1). The Straits are a lifeline Singapore. Hence, a disaster of natural, technological, human or malicious origin in the Straits would have considerable global and local implications.

Figure 1: Map of the Straits [Adapted from CIA, 2005]

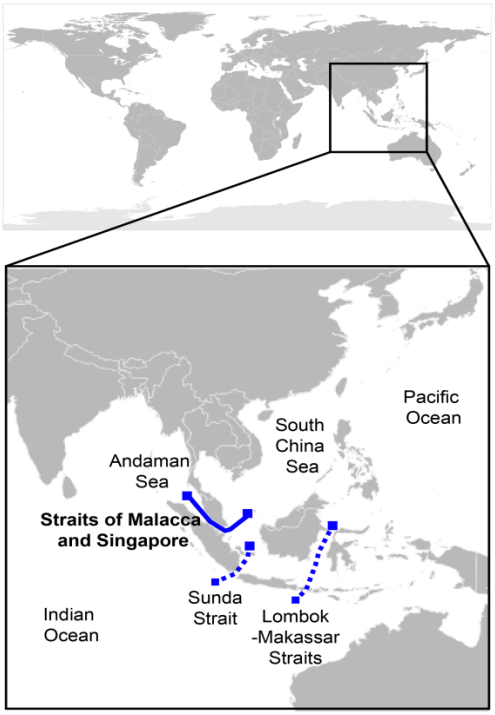


Table 1: Container Port Rankings [CIY, 2010]

Port	TEUs millions	Rank 2008
Singapore	29.92	**1**
Shanghai	27.98	**2**
Hong Kong	24.49	**3**
Pusan	13.45	**5**
Rotterdam	10.80	**9**
Klang	7.97	**15**
Los Angeles	7.85	**16**
Tanjung Pelepas	5.60	**18**
Tokyo	4.16	**24**
Johor	0.93	**102**

2.1 Major Infrastructure in the Straits of Malacca and Singapore

Straits used for international navigation are natural physical infrastructure for the flow of goods traded worldwide. The Straits of Malacca and Singapore offer an exceptional convenience for international shipping lines. Alternative routes add substantial distance, e.g. 1300 km through the Sunda Strait and 1800 km through the Lombok-Makassar Straits (see Figure 1). Moreover, development of the Straits as an international passage for worldwide trade has resulted in investments in infrastructure for the operation of ports, maintenance and the safe navigation of ships, and other economic activities that offer competitive services to multinational corporations [Lee and Ducruet, 2009]. The Straits, including its coasts, port areas and hinterlands, integrate a system of natural and built infrastructure that exists within the larger system of international maritime transportation, and more broadly within the global economy. In the following paragraphs, we present a brief summary of the main infrastructure that constitutes the Straits and position them as important maritime global critical infrastructure.

Singaporean Ports

Singapore has built the most advanced port infrastructure in the world. In particular, the Port of Singapore's operations, information technologies (IT) and governance structure contribute to its world-class competitiveness [Wan et al., 1992; Lee-Partridge et al., 2000; Gordon et al., 2005; Cullinane et al., 2007]. More than 200 shipping lines with connections to 600 ports in 123 countries choose to call on the Port of Singapore; its terminals handled 25.14 million TEUs (twenty-foot equivalent units) of containers in 2009 [PSA, 2010]. The Port of Singapore continues to grow as the world's top bunkering port, reaching 36.4 million tonnes in 2009 sales [Lim, 2010]. Jurong Port is Singapore's other smaller port (<1 million TEUs) located on Jurong Island. A new liquefied natural gas (LNG) re-gasification terminal is currently under construction on Jurong Island. The project is the first open-access multi-user terminal in Asia with a capacity of 3.5 mtpa (million tons per annum) expandable to over 6mtpa [Vaughan, 2010; Hydrocarbons Technology, 2010].

Malaysian Ports

Malaysia has five international seaports strategically situated along the northern side of the Straits. Port of Tanjung Pelepas, just west of Singapore, is designed for 8 million TEUs of container throughput, and employs state-of-the-art IT systems for its container terminal operations [PTP, 2010]. Pasir Gudang (Johor) Port is located to the east of Singapore and is the world's largest hub for palm oil and non-edible oils such as fuel oil, petrochemicals and gas [JP, 2010]. Port Dickson is a popular tourist spot and site for oil refineries and oil-related industries. Port Klang, located at One Fathom Bank where the Straits begin to narrow, handled over 7 million TEUs in 2009 and plans to grow as a regional trans-shipment base [PKA, 2010]. The Port of Penang, about 200 km south of the Thai-Malaysia border, handled just under one million TEUs in 2009 and expanded recently by adding seven post-Panamax cranes to its inventory [PPC, 2010].

Indonesian Ports

Indonesia has about 300 registered ports throughout the archipelago [Thia-Eng et al., 2000a,b]. Indonesia's largest is the Port of Jakarta near the Sunda Strait, and a number of other major ports are located along the Straits, such as Port of Lhokseumawe, Port of Belawan, Port of Dumai, Port of Tanjung Balai Asahan, Port of Tanjung Balai Karimun, and Kabil Container Port. These ports handle large volumes of exports, in addition to their main function as centres of crude and refined oil and natural gas distribution [Thia-Eng et al., 2000a,b].

Critical Hinterland and Subsea Infrastructure

Complementary to the ports, areas along the Straits have become important economic and industrial hubs. Major industrial facilities and power infrastructure are located along the Straits. A cluster of over 100 facilities on the reclaimed Jurong Island [EDB, 2010] was gazetted as a Protected Area in 2001 [Gov. Singapore, 2010a].

Leading global petroleum, petrochemical and specialty chemical companies including European, American and Japanese firms (e.g., BASF, BP, Celanese, ExxonMobil, Huntsman, Ciba, DuPont, Mitsui Chemicals, Chevron Oronite, Shell, Stolt-Nielson, Vopak, Mitsubishi Gas, and Sumitomo Chemical) own and operate facilities in the Straits. A Shell mono-ethylene glycol plant receives ethylene via a subsea pipeline from another ethylene and petrochemicals complex on Pulau Bukom [Shell, 2010]. Natural gas from Indonesia's West Natuna field arrives at Jurong Island via a 640 km undersea pipeline. Other islands along the Singapore Strait, namely, Seborak Island, Sambu Island, and Pulau Busing have infrastructure for the storage of bulk liquid and gas chemicals (e.g., Sakra Terminal, Banyan Terminal and Penyuru Terminal).

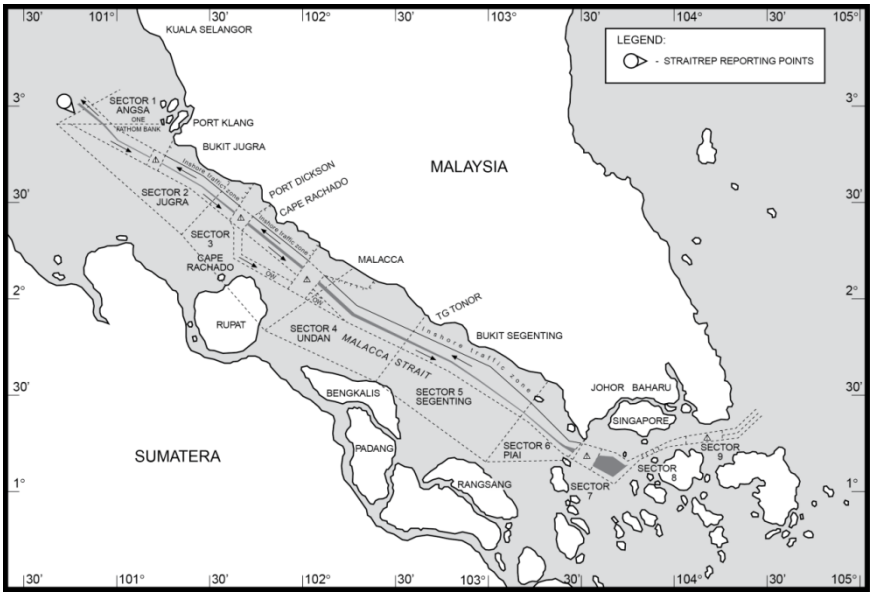
Navigational Infrastructure

Recognising the importance of the Straits, their geographical constraints, and concerned by the hazards that can lead to collision and oil spills, the littoral states have installed navigational aids (Figure 2); segregated westbound and eastbound lanes were established under the Traffic Separation Scheme (TSS) (Figure 3); and vessel tracking services (VTS) to monitor ship movements and communication systems between ports and ships are in operation. STRAITREP is the mandatory ship reporting system in the Straits.

Figure 2: Resilient Light Beacon at One Fathom Bank, Malaysia [photo taken in December 1986, courtesy of MLITT, Japan]

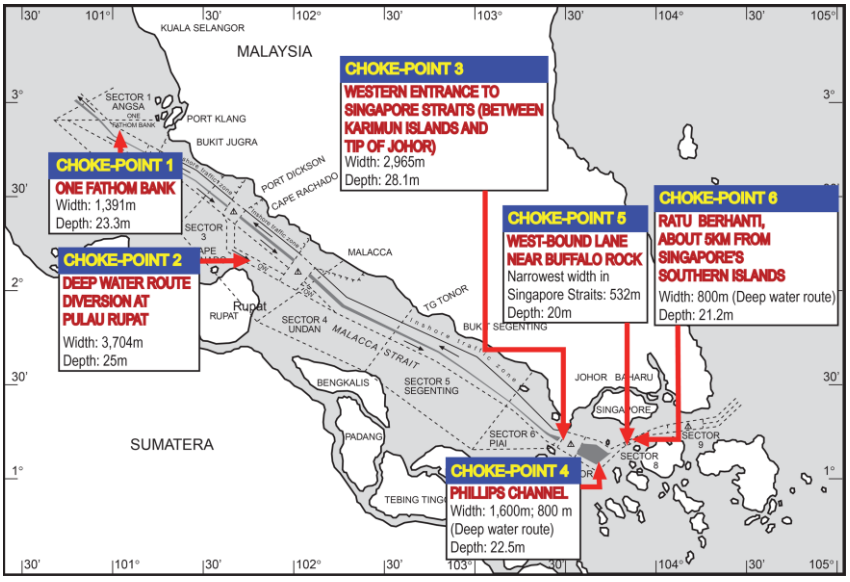
Figure 3: STRAITREP and Traffic Separation Scheme [adapted map: Singapore VTS, 2007]

STRAITREP operational areas from Sector 1 to Sector 9



The Maritime Institute of Malaysia (MIMA) identified six navigational choke-points. Disruptions in these zones could trigger cascading impacts through the Straits and further to global trade networks, thus affecting not only local coastal economies but also economies and societies elsewhere in the world. The choke-points are shown in Figure 4 [MIMA, 2009].

Figure 4: Chokepoints in the Straits of Malacca and Singapore [adapted map: Singapore VTS, 2007; information source: MIMA, 2009]



The geographical constraints of the deep sea channels, the high traffic, and the surrounding port and land infrastructure make the Straits considerably more vulnerable to various threats. The current institutions and navigational infrastructure in place are necessary and commendable achievements, but in light of the growing complexity and internationally connected maritime networks, they must be reviewed under a global critical infrastructure framework.

2.2 Key Stakeholders

The natural and constructed environment of the Straits constitutes a complex system in which multiple players sharing stakes, interests or influence may compete as well as cooperate. Players with a stake in the Straits include the littoral states' governments, coastal communities and users (including local and international shipping companies, ferry operators, logistics and industry, as well as the fishing, aquaculture and tourism sectors) but also indirect stakeholders such as financial institutions, insurance companies, and international organisations (e.g., UN International Maritime Organization, International Chamber of Shipping, International Maritime Bureau), environmental groups, and academics and researchers among others.

The littoral states and their citizens are the primary stakeholders in the Straits. The Malacca Strait is mainly bordered by Malaysia and Indonesia (partly by Thailand) and flows into and from the Singapore Strait, which is bordered by Malaysia, Indonesia and Singapore. In each state, there are also many stakeholders from public and private organisations. Locally, about 40 million people depend economically, socially and culturally on the Straits, and thus have a stake in the risk governance of the Straits. User states and their citizens, which include all countries that navigate ships through the Straits, must be counted as stakeholders as well. In particular, user states with major international shipping and strategic naval interests such as the US, Australia, India, China, Japan, Korea and countries in Europe are key stakeholders.

United Nations (UN) Convention on the Law of the Sea 1982 [UNCLOS, 1982]

Under the Convention, littoral states exercise sovereignty over their territorial seas which they have a right to establish up to a limit not exceeding 12 nautical miles measured from baselines determined in accordance with the Convention. Therefore, under international law, Malaysia and Indonesia (and Thailand in part) can claim sovereignty rights over the Malacca Strait, and with Singapore, over the Singapore Strait, although maritime boundaries are not yet agreed to [Bateman, 2009]. Under Article 38 of the Convention, "all ships and aircraft enjoy the right of transit passage, which shall not be impeded."

The international significance of the Straits obliges a number of international, regional and non-governmental organisations to play a role in ensuring safe passage through the Straits, combating piracy and robbery, and protecting the marine environment, especially from oil spills. International actors include the UN's International Maritime Organization (IMO, the regulator of the international shipping industry), the International Chamber of Shipping (ICS), the International Chamber of Commerce International Maritime Bureau (IMB), INTERTANKO (the International Association of Independent Tanker Owners) and the International Tanker Owners Pollution Federation. Other international actors are the Asia-Pacific Economic Cooperation, the Association of Southeast Asian Nations (ASEAN), the Federation of ASEAN Ship-owners Associations and the Information Sharing Centre of the Regional Cooperation Agreement on Combating Piracy and Armed Robbery against Ships in Asia (ReCAAP).

Regional stakeholders specific to the Straits are the Straits of Malacca and Singapore Tripartite Technical Experts Group (TTEG), committees implementing the Cooperative Mechanism, and the Malacca Strait Council. The Malacca Strait Council (as well as the Nippon Foundation) are Japan-based non-governmental organisations that have cooperated with and supported the littoral states to enhance safety of navigation and environmental protection in the Straits [Huffman, 2003]. The TTEG, comprising experts from the maritime administrations of the three littoral states, meets annually to discuss and collaborate on issues to enhance navigational safety and protection of the

marine environment, as well as other traffic management measures in the Straits [TTEG, 2010].

It is important to point out that within the Straits, decision making authority rests with the legitimate sovereign bodies. That is to say, stakeholders may work together, but it is assumed that they will respect the sovereignty of other stakeholders. Thus, the governments of Malaysia, Indonesia and Singapore have each established maritime port authorities to regulate their ports and a number of national enforcement agencies including coast guards, navies and marine police to secure their waterways.

Users such as shipping and logistics companies, port and ship operators, the chemical, petrochemical and oil industries, ferry operators, and the fishing, aquaculture, and tourism industries, among others, are also stakeholders in the responsible governance of safety, security and sustainability of the Straits.

Private and public sectors' interests are interrelated as open, safe, unimpeded passage through the Straits is necessary for international shipping lines and multinational corporations to operate safely and competitively, and for the national and economic security of countries that depend on international trade.While shipping has historically been the primary driver of strategic and economic interests in the Straits, they are also a centre of marine biodiversity [Thia-Eng et al., 2000a,b].

Ecosystem services and natural resources sustain local economic activities. Around 45% of Malaysian fishers are dependent on the Straits and 28% of revenues from beach use come from diving and snorkelling [Thia-Eng et al., 2000a,b]. Local stakeholders as well as the coastal communities have as much, if not more, at stake in the long term sustainability of the Straits and in creating and maintaining the required infrastructure to protect its ecological integrity. Coastal and marine ecosystem management in the Straits is also of international interest, with its importance recognised by the United Nations, the World Bank and the Global Environment Facility (GEF) [King and Adeel, 2002; Duda, 2006].

Finally, there are others who do not have a direct interest in the Straits, but rather an independent, objective role to provide data, information and knowledge products and services to inform decisions in the broader governance arena. This group includes scientists and researchers from universities, for example from the Centre for the Straits of Malacca within the Maritime Institute of Malaysia and the Centre for Maritime Studies at the National University of Singapore.

All of the above players must be involved in the risk governance of hazards and vulnerabilities in the Straits wherever decisions or consequences affect them.

III Scenarios of high impact events in the Straits

The Disaster Prevention Institute at Kyoto University organised two workshops in June 2009 and November 2010, attended by participants from Singapore, Malaysia, Indonesia, Japan, Korea, China, India, Canada, France, UK, Germany and Switzerland. Key stakeholders shared their knowledge and concerns from the perspectives of the littoral states, user states, port authorities, and shipping, logistics and insurance sectors. The first workshop[9,10] used the IRGC Risk Governance Framework [IRGC, 2005, 2008] to identify overall risk governance issues in the Straits. A regional cluster meeting[11] was then organised and it was suggested that the next workshop would work on developing scenarios of possible consequences and responses to certain specific hazards, with the view to identify specific recommendations for improving risk governance. The second workshop therefore focused on specific scenarios of high impact events that have never been experienced in the Straits, but that are real concerns for all stakeholders. Risk governance deficits were identified and five main recommendations were made.

The scenario-based approach was used to engage stakeholders to discuss events that would lead to the closure of the Straits. The scenario development was grounded by expert knowledge and, where possible, supported by evidence from current and reputable data sources. A review of the literature was conducted to ensure that concerns were based as much as possible on factual information. The possible closure of the Straits has been the focus of several studies involving scenario analysis [see: Coulter, 2002; Bergin and Bateman, 2005; Raymond, 2006; and Rimmer and Lee, 2007]. For example, Raymond [2006] evaluated various scenarios including the potential sinking of a ship in the Straits of Malacca and Singapore, the blocking of the Malacca Strait by mines, the use of a tanker as a floating bomb to strike the port of Singapore, and a missile launched at aircraft from a vessel.

The three scenarios discussed in November 2010 were:[12]

- An explosion in an industrial area of refineries and petrochemical facilities in the Singapore Strait;
- A cyber-attack on marine electronic systems in the Straits;
- Collisions in the Singapore Strait and in the Port of Singapore.

For each scenario, the participants were first invited to identify:

- What would be the “end” states or final outcome: immediate and ultimate consequences resulting from a course of events,
- What are the perceived likelihoods of the final outcomes, and
- Who are the individuals or groups that play a role in arriving at the final outcome in the event process or risk governance process.

Next, the participants performed an initial impact assessment to evaluate the existing mechanisms in terms of resiliency and coping capacity in responding to events in the imagined scenarios. This assessment identified risk governance deficiencies or failures, as defined in IRGC’s report on Risk Governance Deficits [IRGC, 2010] and further led to recommendations that are described in section V.

[9] DPRI and IRGC Summary Workshop Report, “Maritime GCI Summary Workshop Report, International Workshop on Risk Governance of the Maritime Global Critical Infrastructure: Straits of Malacca and Singapore Exposed to Extreme Hazards”, Japan 4-5 June 2010, IRGC, Geneva 2010 [DPRI and IRGC, 2010a]

[10] DPRI and IRGC Initial Insights Report, “Risk Governance of the Maritime Global Critical Infrastructure: An initial assessment of hazards in the Straits of Malacca and Singapore and plans for future work”, IRGC, Geneva 2010 [DPRI and IRGC, 2010b]

[11] DPRI and IRGC Report, "Regional Cluster Meeting on Straits of Malacca & Singapore as a Global Maritime Critical Infrastructure (MGCI)," Singapore, 30 April - 1 May 2010. [DPRI and IRGC 2010c]

[12] Extreme natural disasters such as earthquakes and tsunamis were not included in the examples of scenarios. Of course, natural disasters could be treated as initiating events and similarly analysed.

3.1 Scenarios and potential physical consequences

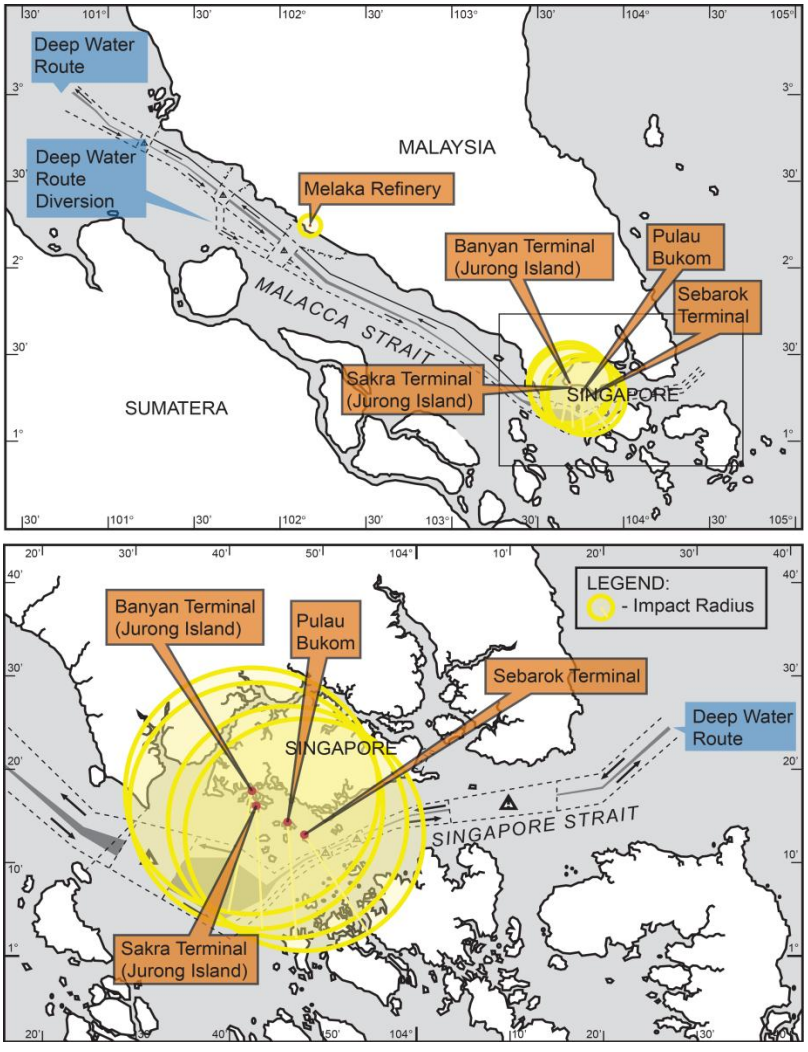
A – Explosion Scenario

An explosion in an industrial area of refineries and petrochemical facilities in the Singapore Strait

A preliminary risk assessment of potential explosions and toxic gas releases from major industrial establishments along the Straits was carried out before and during the workshop. Major industrial establishments that handle hazardous materials along the Straits near the six chokepoints described in Figure 4 were identified and mapped. Information with details about the facilities was obtained from several sources and used to ascertain industry-type, production volumes, types of chemicals, and quantities stored and processed. Accidental releases of toxic and flammable chemicals at these facilities were modelled and the areas that could be affected by these releases were mapped. While accidents involving explosions would greatly impact the port area of Singapore, Figure 5 shows that accidents involving toxic gas releases could result in impacts on much larger areas. By comparing the location of chokepoints to the estimated impact radii, chokepoints 4 and 5, which are along the navigation channel in the Singapore Strait, would be at a high risk for explosion hazards and toxic releases.

Figure 5: Radius of Impact for Toxic Release Threats [modified from Singapore VTS, 2007]

Circles indicate the maximum distance to the toxic endpoint, assuming complete release of the largest tank, filled to 75% capacity, and failure of mitigation measures.



Events involving an explosion and fire of flammable substances would generally impact the marine environment, port areas, industrial facilities and shorelines as well as the marine life, personnel and communities that populate these locations. Explosions have the potential to cause a great amount of property damage and could result in domino-chemical accidents, particularly if they are caused by vapour hydrocarbons [Kourniotis et al., 2000].

In the event that an accident is caused by a vapour cloud explosion, the potential for secondary impacts at other facilities, and/or physical impacts on passing vessels through the navigation channel would be physically possible.

A large toxic cloud passing over the Singapore Strait could result in health risks to ship crew and passengers, and could impact residents living in the area, possibly requiring the temporary evacuation of affected areas. Losses could be incurred by businesses due to lost production time, emergency shutdown and process upsets due to workers' need to take protective action. Possible liability costs would be incurred if residents and businesses were affected. Local government and local responders could be faced with a major health issue/disaster, which could impact public risk perception and risk tolerance, resulting in possible changes in regulations.

The likelihood of any of the above events occurring *due to human error or process upset* was generally considered relatively low by workshop participants due to the required safety and mitigation measures industry currently has in place in all of the littoral states. Nonetheless, the history of the petroleum, petrochemical and chemical industries shows that such accidents do occur and often with catastrophic consequences.

Table 2: Explosion Scenario. Final outcome, time frame, consequences of the event, perceived likelihood and key players

Final outcome and time frame	*Consequences of event*	*Perceived likelihood*	*Key players*
Explosion Scenario			
I. ● Major disaster caused by multiple chemical accidents involving several facilities and leading to complete blockage of the Straits (for more than 4 days) with possible inhalation hazard to nearby communities, other facility personnel, and vessel crews. ● Difficult access to affected area by sea, delay in hazmat response and containment, emergency response by air needed. ● Economic impacts including environmental and socio-economic impacts to local communities. ● Direct and indirect economic impacts to facilities involved, including liability costs. ● Complete disruption to handling of bulk chemicals, LNG, petrochemical or other industries at Pulau Bukom or Jurong Island, and neighbouring terminal islands. ● Major economic impacts with regional and global repercussions.	**Major economic and physical impacts with local, regional and global repercussions**	**Realistic likelihood** (in general) **Considered medium likelihood** (If caused by intentional acts either triggered within the company or outside) **Considered low likelihood** (If caused by human or technological failure at facility)	- Industrial facility(ies) owners and operators - Industrial facility(ies) employees - Providers, customers, users - Emergency response agencies and personnel - Vessel crews - Shipping companies - Fisheries in the area - Tourism companies - Ferry companies - Local communities - Littoral state governments - Communities, users and companies down the supply chain
II. Added impact on large vessels passing along the deep water channel, causing them to sink. Impacts for more than a month and even several months with major impacts to economic activities in Singapore and Malaysia. Disruption of port and Strait functions and systems. Major changes in regulations and insurance foreseeable.	**Major impact to local activities** **Major changes in regulations and insurance foreseeable**	**Considered low likelihood** (but considered to have long-term impacts)	
III. Added major oil spill resulting also in major environmental damage, loss of public trust, liability issues, and issues concerning responsibility, possibly triggering political repercussions. Major changes in regulations and insurance foreseeable.	**Major impact to local activities** **Major changes in regulations and insurance foreseeable**	**Considered low likelihood** (but considered to have long-term impacts)	

The events discussed above can serve as a starting point for further discussion on possible triggering mechanisms, final outcome and consequences, perceived likelihood, and potential players involved (see Table 2). Participants in the workshop agreed that a worst-case scenario would involve an explosion and fire triggering a secondary toxic release at the petrochemical complex on Pulau Bukom or on Jurong Island.

B – Cyber-Attack Scenario

A cyber-attack on marine electronic systems in the Straits

A cyber-attack is a threat of growing relevance to maritime information, communication and control systems. As automation processes for information and communication technology (ICT) are increasingly relied upon in the port and vessel control and management systems, the vulnerability increases. Remote and distributed controls have resulted in a trade-off between efficiency and security.

Many cyber incidents demonstrate the vulnerability of specific dedicated systems for infrastructure management. The Repository of Security Incidents maintains a database of cyber-related incidents as well as deliberate events such as external hacks, Denial of Service (DoS) attacks, and virus/worm infiltrations that did or could have resulted in loss of control, loss of production, or a process safety incident [RSI, 2010]. Discovered in 2010, the Stuxnet worm exploited hidden vulnerabilities of the Windows operating system via USB keys. It targeted and triggered re-programming of Siemens PLCs (programmable logic controllers) used in industrial control systems, infecting approximately 100,000 hosts from over 155 countries, 58% of which were located in Iran [Falliere et al., 2010].

A cyber-attack can compromise data confidentiality, data integrity, and data availability (blocked pathways). It can originate from anywhere in the ICT network, and any device embedded or connected to the network is inherently vulnerable if no security measures have been taken. In the maritime context, it is assumed that a cyber-attack is a means to two possible ends, proposed by Price [2004]:

1. Entry of persons, materials, or weapons through the seaport threshold (border), to wreak havoc and terror elsewhere in the country;
2. Gaining of access in order to damage or destroy port facilities and infrastructure, vessels and cargoes, to injure people and property in or near the port, and to cause economic disruption.

In terms of maritime infrastructure, there are three main potential system targets with cyber access points:

1. Sea and land-based systems such as Singapore's Vessel Tracking and Information System (VTIS), Automatic Identification System (AIS) or Long Range Identification and Tracking System (LRIT);
2. Container Terminal Operating Systems (CTOS);
3. Port Electronic Data Interchange (EDI) System for domestic and international trade.

A cyber-attack can be launched against vessel control systems, VTIS, AIS, LRIT, CTOS or EDI systems. In the case of vessel control and navigational breaches, these may cause loss of data integrity and data unavailability, rendering the captain confused and isolated. It may be possible to re-programme the vessel's control system in such a way that it gives incorrect information. The combination of these events may be serious and could lead to a collision if the captain loses control of the ship.

A cyber-attack targeting a CTOS could block the terminal completely for several days. In the case of a breach in the EDI system, with no backup records available for verification, there may be some impacts on global trade, but more disconcerting would be the free movement of illegal persons, materials or weapons. Relative to a cyber-attack on CTOS, an attack on the EDI system may be weaker in terms of immediate and direct impact on the functioning of the port. Table 3 summarises the final outcomes, consequences, perceived likelihood and key players of the cyber-attack scenario.

Table 3: Cyber-Attack Scenario. Final outcome, time frame, consequences of the event, perceived likelihood and key players

Final outcome and time frame	*Consequences of event*	*Perceived likelihood*	*Key players*
Cyber-Attack Scenario			
I. *Control system not answering:* A worm infection can affect the ship control system and cause the system to fail. The crew can take over the steering by manual manipulation, but this takes time – this time lapse must be considered.	**Consequences are not very severe**	**Considered medium likelihood**	- Ship Master - Crew -Maintenance employees - Suppliers -Land players: companies, port authorities, port personnel -System engineers and programmers *In decision-making, the last word is that of the Ship Master (captain).*
II. *Communication systems fail:* The captain becomes confused and isolated. If the Ship Master does not have sources of communication (i.e., he is isolated), he cannot check the veracity of the data and readings from the equipment. If the GPS, radar, VTS, or radio systems are not working or showing incorrect data, an accident could occur.	**Severe consequences are possible**, including a ship collision or an oil spill that can affect port and port area.	**Considered low likelihood**	
III. *Control system responds incorrectly to navigational commands:* A worm infection in the ship control system causes the ship to respond incorrectly, but shows that it is moving in the right direction in the tracking/monitoring system. Also, incorrect data is coming from the equipment.	**Severe consequences are possible**, including a ship collision or an oil spill that can affect port and port area.	**Considered medium likelihood**	
IV. *A shutdown of container terminal operating systems:* This could block the terminal completely for several days. - There may be possible gains for other unaffected ports. - However, a slow response time following the event could cause further delays to shipping.	**Affected ports could incur large losses** and container feeder transportation to/from the surrounding local ports could be disrupted.	**Considered medium likelihood**	
V. *A shutdown of the EDI system*: The automatic processes to exchange data for domestic and international trade can be replaced by paper work done by hand. However, once the information system has been introduced, it is very difficult to substitute paper documents for many of the functions the system performs.	**Large impacts on global trade**	**Rising likelihood** All networked information systems have medium to high probabilities of suffering some level of cyber-attack.	

C – Collision Scenario

Collisions in the Singapore Strait and in the Port of Singapore

This scenario considered two initiating events: collisions in the Singapore Strait and collisions in the port area of Singapore, involving several large vessels. If a collision involves a large vessel (e.g., a Very Large Crude Carrier-VLCC) near a chokepoint in the Straits, there is a significant chance that a partial blockage could result, obstructing vessels that are deemed to be too dangerous to transit through the Straits, due to physical constraints or unavoidable proximity to a hazard. In practice, if a ship cannot pass without maintaining one cable (185m) distance to a hazard, then it is considered very dangerous. The narrowest navigable width is 532m (see Figure 4, choke point 5) in the westbound lane of the TSS in the Singapore Strait. In the case of a collision, potential costs to the owners of ships involved in an incident may be incurred from damages to ships and cargo, marine salvage and in the worst of cases, oil spill contingency operations.

In the case of closure of the Straits, vessels could use alternative shipping routes. However, alternative routes add costs to the shipping industry with ramifications that would be felt throughout the global economy. Morisugi et al. [1992] estimated that the global cumulative value of the Straits from 1966 to 1985, compared to the Lombok and Sunda straits, was about 84 billion USD for all petroleum and bulk traffic. Morisugi et al. [1992] also projected that the global cumulative value of the Straits from 1990 to 2009 would increase by approximately three times based on projected growth rates. These estimated costs reflect the economic consequences of complete blockage of the Straits.

While the frequency of collisions in the Straits is relatively low compared to the number of transiting ships, in 2002, for example, of 60,034 ships that passed through the Straits, only 11 collisions were documented [JAMS, 2006], collisions have occurred nonetheless and sometimes resulted in oil spills or fatalities. Recent examples include the collision of an oil tanker carrying 58,000 tons of naphtha oil with a bulk carrier on 18 August 2009 in the Malacca Strait causing a massive explosion and fire which killed 9 people and resulted in an oil spill [The Nippon Foundation, 2009; Earth Times, 2009].

It was agreed in the workshop discussion that collisions due to human error or the intermingling of cross traffic with transiting ships would have a limited impact in causing cascading effects that would affect other traffic or surrounding infrastructure. Participants agreed that for a complete blockage of the Straits to happen, multiple coordinated collisions would have to occur, specifically at the narrowest point in the Singapore Strait and also near the Port of Singapore. Whether terrorist groups or networks with the capabilities of perpetrating such an attack exist is an important question that has received increasing attention. Nevertheless, there have been smaller-scale terrorist attacks in the past, notably the Laju hijacking [Chew, 2008] and a suicide attack on the MV Limburg oil tanker [Global Security, 2010]. A high-impact attack has not yet occurred at sea. However, in March 2010, Singapore's navy received indication that a terrorist group was planning attacks on oil tankers in the Malacca Strait [Pin, 2010].

Another threat concerns pirates. It is not uncommon to find that today's pirates are armed, dangerous and technologically sophisticated [Hong and Ng, 2010]. Concern is heightened if one considers the possibility of cooperation between pirates and terrorists. This linkage, however, is theoretical and any financial connection between pirates and a terrorist group has yet to be confirmed.

Based on this information, the collision scenario that was developed is triggered by a malicious attack (though human error and technical failure are not discounted as contributing factors). Attackers would target large vessels including VLCCs, tankers, LNG/LPG carriers, cargo vessels, container vessels, bulk carriers, car carriers, and/or passenger vessels, though smaller vessels may be used as conduits. It is assumed that the attackers have the intent and capabilities to cause multiple collisions in the Singapore Strait and in the port area of Singapore. However, if the vessels involved in the collision are unimpaired or marine response teams are able to clear damaged vessels fast enough, then no impact would be expected. On the other hand, in the event of a slow

response, a damaged vessel could sink very quickly[13]. If the cargo transports hazardous substances, a collision could cause a release of hazardous materials, posing a public health and marine pollution threat. However, spills do not generally impede transit passage. Ships involved in the collision would have to be strategically positioned and very large in order to block the Straits partially or completely. The time frame of the blockage would be equivalent to the time required to remove the shipwrecks. Table 4 summarises the final outcome, consequences, perceived likelihood and key players of the collision scenario.

[13] The car carrier Tricolor sank in less than half an hour after it collided with a container ship in the English Channel on 12 December 2004 [Kerckhof et al., 2004].

Table 4: Collision Scenario. Final outcome, time frame, consequences of the event, perceived likelihood and key players

Final outcome and time frame	*Consequences of event*	*Perceived likelihood*	*Key players*
Collision Scenario			
I. Multiple collisions in the Singapore Strait and port area of Singapore involving several large vessels (VLCC, max container ship, car carrier, bulk carrier, passenger vessel) leading to partial or complete blockage of the Straits (for more than 6 months, approximate time to salvage large wrecks). - Collisions lead to damage to ships and cargo, allowing release of potential contaminants into the Straits, classified as a major hazardous spill. - Physical damage could be inflicted on Port of Singapore infrastructure if released material is explosive. - Human injuries and casualties could be high if a passenger vessel is involved in the collision.	**Local impact:** **Effects on economic activities, physical damage** to ships and local infrastructure, **damage to the marine environment** due to hazardous spills, and **potential human injuries and casualties**	**Possible**; However, extremely low likelihood	- Attackers - Singapore, Malaysia, and Indonesia Governments - Shipping and Logistics Companies - Oil Spill Responders - Emergency First Responders (Coast Guards, Navies, Marine Police) - Salvage Operations - Port Authorities and Operators - Reinsurance Companies - United Nations (IMO; Security Council) - International Chamber of Commerce (IMB)
II. At the regional level, all other economic activities in the Straits would be affected including container feeder transportation to/from the surrounding local ports linking to the port of Singapore. - Tourism would decrease until travellers regain confidence. - Fishing stocks, which are already vulnerable, would decline rapidly with exposure to the high toxicity of a large contaminant release. - Businesses that depend on shipping activities would experience losses. - Other ports would be affected by either gaining or losing business.	**Regional impact:** **Effects on economic activities in the Straits and beyond** (in the transportation sector, tourism and fishing industries, and related businesses)	**Likely**, given final outcome I	
III. On the global level, there would be a two to three day delay in shipments that would be diverted through the Sunda or Lombok straits. - Container trans-shipment at the port of Singapore would be blocked. - A global economic response would be expected, involving speculation, logistics re-planning, and distribution network adaptation. - Insurance costs can be expected to increase.	**Global impact:** **Shipping delays and diversions, global economic responses, and expected increased insurance costs**	**Very likely**, given final outcome I and II	

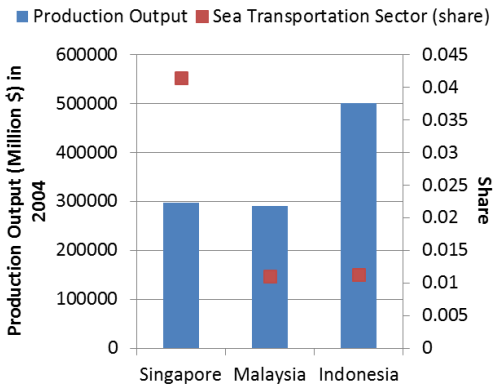
1.2 Potential economic impact of the Straits' closure

A closure of the Straits would have global as well as local economic impacts, increasing transportation costs and affecting the prices of many commodities in the world. Also, it is possible that oil refineries, constituting one of the major industries in Singapore, may not function if the Straits are closed, which would lead to severe impacts on both local and global scales. It has been observed that this kind of disaster triggers price increases in shipping services, in anticipation of delays and losses. A broad and elaborate calculation methodology would be required in order to estimate the total scale and costs of global impacts due to a closure of the Straits, and therefore this document focuses only on the impact on local economies.

Estimates of the expected economic impacts on the local economies caused by the reduction of port-related functions are presented here. Singapore especially and to a lesser extent Indonesia and Malaysia would lose competitive advantage for international cargo handling if the Straits were blocked.

Based on the database, output production for all sectors in 2004 and the importance of the maritime transportation sector, in particular, for Singapore, Malaysia and Indonesia are shown in Figure 6.

Figure 6: Production output of all sectors in littoral states (in millions of dollars per year) and share of the sea transportation sector[14] in total output



[14]The sea transportation sector is defined here as comprising all companies owned by the littoral states engaging in the transport of goods by sea both for domestic and international purposes (e.g. shipping and port facility operation). In comparison to the littoral states, the average ratio of the sea transportation sector to total output for all the countries used in the analysis is 0.0065.

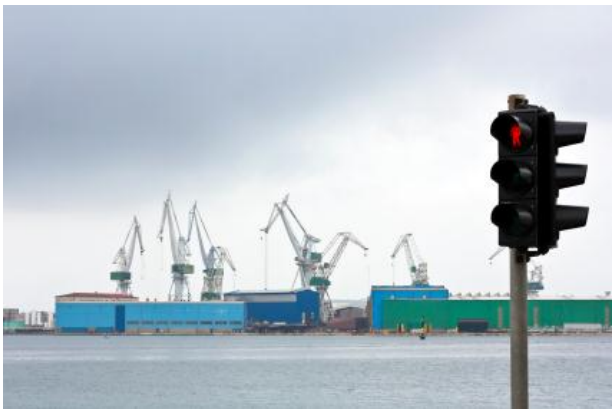
A relatively simple but standard input-output model was adopted for this analysis[15]. The database developed by Badri and Walmsley [2008] as part of the Global Trade Analysis Project was used to assess the impact on the local economy and the maritime transportation sector in particular. The database was developed recently, but is composed of relatively old statistics for each country due to the intricacies of data integration for international trade.

Due to a loss of international shipping services from littoral states in case of the Straits' closure, there would be a reduction in production output. Because inter-industry connections between the maritime transportation sector and other sectors are strong, the decrease of output would be largest in Singapore. The total loss across all three littoral states is roughly estimated at 18 billion USD for one year of disruption (50 million USD per day).[16] Of note is that the GDP in Singapore, for example, has doubled since 2004 (112,692.5 million USD in 2004 to USD 222,700.6 million in 2010) and this trend might continue in the future. The growth rate in the maritime sector is also rapid and the calculation result should be modified based on updated data.

[15]Please note that the analysis presented is just an example and adapted from the following input-output model: (I-M)AX+(I-M')F+E=X, where X: Production Output
A: technical coefficient for intermediate goods, M: Import coefficient for intermediate goods
M': Import coefficient for the domestic final demand, F: Final Demand, E: Exports excluding international shipping services, I: Unit Diagonal Matrix. Reduction of production output is obtained by reducing the exports of maritime sector (international shipping service) included in exports.

[16]Due to the propagating negative effect produced by input-output relationships, calculations did not reveal very high losses. This is partly because of the assumption that most of the export and import goods are not affected due to the damages to the sea transportation system. This assumption in part explains the reason for a relatively low impact.

Economic models such as this can be extended to international impact assessments, can contribute to understanding the externalities of the closure of straits, and can be used to calculate benefits not only to the littoral states but also to others potentially benefitting from the use of straits, including user countries and stakeholders in the international maritime sector, coastal communities and marine environment. Developing agreed-upon and standard economic models among the stakeholders could lead to setting a portion of fair-use fees for the straits. A percentage of the economic benefits to any country or user in the world from usage of the Straits could be earmarked in dedicated financial accounts so that a fair-use fee structure to support the safety, security and sustainability of the Straits may be derived.



3.3 Existing mechanisms to deal with high impact events

A scenario-based hazard and impact assessment not only helps to identify and characterise the main consequences, but also elucidates areas where problems might arise. A careful review of the existing mechanisms for prevention, mitigation, preparedness, response and recovery for the above proposed scenarios of high-impact events in the Straits is presented below in order to identify risk governance deficits.

Navigational Hazards – Promoting Safety

The littoral states have shouldered by far the greatest costs compared to user states. An exception is Japan, which, through the Malacca Strait Council, has made major contributions towards the installation and maintenance of navigation beacons since 1968 [Ho, 2009]. About 30 out of 50 beacons in operation were donated by the Council [JAMS, 2006]. After the establishment of UNCLOS in 1982, navigation aid facilities for the Straits have been cooperatively developed and maintained by the littoral states and some international organisations. In 1998, the IMO took the initiative in enhancing the Traffic Separation Scheme (TSS) to cover the length of the Straits and introduced the Ship Reporting System called STRAITREP.

As per the IMO's International Convention for the Safety of Life at Sea [SOLAS, 2004], the STRAITREP system requires international ships over 300 tonnes and domestic ships over 500 tonnes to report their unique identification, position, course, speed, and any hazardous materials on board, via an Automatic Identification System (AIS) transponder. The AIS broadcasts the information over radio VHF channels, which are received by VTS stations in Port Klang, Johor and Singapore. In 2006, the IMO adopted new regulations for Long-Range Identification and Tracking (LRIT), which is now mandatory for all passenger ships, high speed craft, mobile offshore drilling units and cargo ships over 300 gross tonnes under SOLAS. LRIT is based on satellite communication, which has two advantages over AIS: it can identify the position of ships which are not within range of radio stations and information can only be received by intended recipients. A summary of technologies employed in the Straits for safety of navigation is presented in Table 5.

In 2005, the IMO and the three littoral states organised a meeting in Jakarta for enhancing the safety, security, and environmental protection of the Straits of Malacca and Singapore (Jakarta Meeting). At the Jakarta Meeting, agreements to cooperate and collaborate to implement the Marine Electronic Highway (MEH) Project were signed. The Jakarta meeting was also the start of a process to create a new framework for international cooperation to ensure safety and environmental protection of the Straits, known as the Cooperative Mechanism. Two follow-up meetings took place in Kuala Lumpur in 2006 and Singapore in 2007. The Cooperative Mechanism is the first of its kind in the world–a framework for cooperation between littoral states and users to promote navigation safety and environmental preservation in the Straits. Several countries, including India, China, Australia, USA, Japan, Korea and the United Arab Emirates have committed resources to specific projects. As of October 2010, contributions to the Aids to Navigation Fund totalled 8.10 million USD [CF, 2010]. However, compared to how much the littoral states have already spent and still need to spend in order to maintain and upgrade systems in the Straits – estimated at 340 to 450 million yen per year (4 to 5 million USD) by the Ministry of Land Infrastructure, Transportation and Tourism (MLIT) of Japan – the Straits would not be maintained for more than a few years with this fund. Of the six projects currently underway, Project 3: A Demonstration Project of Class BAIS Transponders on Small Ships has been completed [TTEG, 2010]. The organisational achievement and new infrastructures for safety in navigation have been steadily improving; however, there is still a gap in terms of cost-sharing for the future installation and maintenance of navigation-aid systems.

Table 5: Technologies Employed in the Straits for Safety of Navigation

Technologies/ Navigational Infrastructure	Partnership	Year
Navigation Beacons	Littoral States, Malacca Strait Council	From 1968
TSS: Traffic Separation Scheme (500km Range) STRAITREP: Ship Reporting • VTS: Vessel Tracking Services (Port Authorities) • VTMIS: Vessel Tracking and Management Information System (Port of Singapore) • VTIS: Vessel Tracking and Information System (Port Klang and other stations) • AIS: Automatic Identification System • LRIT: Long Range Identification and Tracking (2006)	Littoral States and IMO	From 1998
MEH: Marine Electronic Highway [Marlow and Gardner, 2006] • DGPS (Differential Global Positioning System) Station • ENC: Electronic Navigational Chart • AIS and Telemetric Tidal Stations • VTS Data Centers	Littoral States, IMO, International Hydrographic Organization, INTERTANKO, ICS, World Bank, GEF	From 2005

The Marine Electronic Highway Demonstration Project [MEH, 2011]

Traditionally, information management related to navigation and emergency response in the maritime sector has been almost exclusively carried out by the individual littoral states. Advances in ICT are changing the way that the maritime sector uses information; however, many applications are local and unconnected to others. The Marine Electronic Highway (MEH) is envisioned as a regional network of marine information and safety technologies and marine environmental management and protection systems. The system utilises the internet to link navigational facilities, shared data centres, and on-board navigation systems.

The demonstration project aims to establish a regional mechanism in the Straits of Malacca and Singapore for enhanced maritime safety and marine environment protection with a sustainable financial component. It has five major components:

1. MEH Systems Design, Coordination and Operation
- System planning and IMO management
- Project management office
- Project steering committee support
2. MEH System Development
- Navigational and hydrographic facilities
- Hydrographic survey
- Electronic Navigation Charts
- Information Exchange System
3. Ship-board Equipment and Communications
- Testing by ships fitted with approved ICT systems with internet connectivity
4. Marine Environment Protection
-Oil spill and sand wave models
- Sensitive area mapping
- Emergency response systems
5. Information dissemination, Evaluation and Scale-Up Plan
- Website and Publicity
- Technical, institutional, legal, financial and socio-economic assessments
- Marketing strategies to package and market the MEH system

The total Project cost is projected to be 17.85 million USD, of which 46% will be financed by the Global Environment Facility, 34% by private sector participants (ship-owners), and 20% by the three littoral states and a grant from the Republic of Korea [MEH, 2011].

The results and outcomes of the demonstration project have significant influence on the future state of ICT systems in the Straits. In light of recent cyber-attacks, the MEH system should be tested against cyber-attack scenarios. Moreover, within the context of high impact events, such as blockage of the Straits, the adequacy of existing and planned communication systems should be assessed in order to plan for appropriate scaling-up.

Haze

Haze is a trans-boundary issue that originates from forest fires in Indonesia and migrates toward Malaysia and Singapore, creating a health hazard as well as a navigational hazard in the Straits. While some forest fires are accidental, recently, officials suspect that fires are being lit to illegally clear land for crops such as palm oil plantations [Wong-Anan, 2010]. To address these trans-boundary effects, there is the ASEAN Regional Haze Action Plan 1997 (not legally binding) as well as the ASEAN Fire Danger Rating System 1998, which was a Canadian-assisted project and acts as an early warning alert system [ASEAN, 2011].

The governments of the 10 ASEAN Member Countries signed the ASEAN Agreement on Transboundary Haze Pollution on 10 June 2002 [ASEAN], but it was only in June 2011 that Indonesia announced they would ratify it [Antara 2011]. Haze remains a continuing trans-boundary problem in the Straits because the source of the issue is not yet effectively addressed. Weak forestry law enforcement and illegal land clearing in Indonesia are cited as persistent problems [Wong-Anan, 2010].

Chemical Accident Prevention in Land Facilities

In Singapore, Malaysia and Indonesia there are a myriad of laws, rules and regulations to make sure that industrial facilities that handle hazardous substances take the necessary measures to ensure safe operation of processes and equipment and to protect workers from accidents involving hazardous substances[17]. These regulations are similar in that they require facility owners/operators to adopt engineering standards for the design and construction of plant facilities, safety and mitigation measures to prevent workplace accidents and chemical releases, including providing training and safe operating procedures to workers, establishing emergency response plans, and stipulating penalties and liability for non-compliance. In all three countries, government authorities at the local, regional and national levels also have a role in making sure that the industrial establishments follow the regulations.

However, there are differences among the three countries, for example, with Singapore having reached overall better levels of industrial risk management and accident prevention [Dali, 2007]. Furthermore, none of the regulatory frameworks in the three countries specifically requires facilities to assess potential consequences to the public (outside of a facility's fence line) from accidental toxic and/or flammable chemical releases. Local governments in these countries could benefit from a more in-depth risk assessment and hazard mapping of potential chemical accident hotspots, as well as from taking appropriate actions to minimise the risk to nearby communities, citizens, property, and the environment.

Oil Pollution Prevention and Oil Spill Contingency Planning

Oil spills and pollution can result from different sources ranging from small operational spills like overloading tanks and burst hoses to the more serious incidents involving the release from a large storage tank at a land-based facility, or the catastrophic failure in a large tanker's hull integrity due to a collision or grounding [Pyburn, 2010]. Singapore and Malaysia together have suffered at least 39 spills of 34 tons or more since

[17]Some examples include the Workplace Safety and Health (WSH) Act of 2007 (e.g., WSH Risk Management Regulation, WSH Incident Reporting Regulation) in Singapore; the Petroleum Safety Act 302 and the Occupational Safety and Health Act 514 in Malaysia; and the UNDANG UNDANG (ACT) NO. 13/2003 and the Permenaker No. 05/MEN/1996 in Indonesia.

1960, with the worst spill occurring in October 1997 due to the collision between the oil tankers Evoikos and Orapin Global, 5 km south of Pulau Sebarok, in Singapore's waters. The collision resulted in a spill of 28,500 tonnes of oil [Kiong, 2007; MPA, 2007].

Recognising the high vulnerability of the Straits to incidents leading to oil spills and subsequent pollution of the surrounding waters and shores, Singapore, Malaysia and Indonesia have oil pollution and oil spill contingency planning regulations in place to address incidents that can affect the Straits.

Singapore: The Maritime and Port Authority (MPA) has put in place a comprehensive system to ensure navigational safety in the Straits to minimise marine accidents and oil pollution. It has established an oil spill contingency plan, which is operationally ready to respond to any marine emergency or accident in Singapore. Furthermore, in 1992, the East Asia Response Private Limited (EARL) was established by several large companies in Singapore as a non-profit company to respond to major (Tier Three) oil spills [Pyburn, 2010]. At its Regional Centre in Jurong Island, EARL stores and maintains a wide range of oil spill response equipment capable of responding to a major incident.

Malaysia: The National Oil Spill Contingency Plan for the Straits of Malacca (SOMCP) and the Oil Spill Contingency Plan for the South China Sea (SCSCP) have been integrated into the National Oil Spill Contingency Plan (NOSCP). Furthermore, the Petroleum Industry of Malaysia Mutual Aid Group (PIMMAG), which enables the oil industry to pool its oil spill response resources, provides support to NOSCP in Malaysia [Rahmat and Yusof, 1999].

Indonesia: There are several regulations for oil spill prevention and oil spill response, including Decree No. KM 86 of 1990 concerning pollution prevention, Decree No. KM 4 of 2005 regarding oil pollution from ships, and the National Contingency Plan (NCP) for oil spill response.

In addition to the above mentioned mechanisms, there are various regional plans in place to address oil spills affecting the three littoral states[18].

Hazardous and Noxious Substances (HNS) Preparedness and Response

The Project Coordination Committee of the Cooperative Mechanism is currently working on Cooperation and Capacity building on HNS Preparedness and Response (Project 2) [CF-Annex14, 2010], which is enhancing the capabilities of the littoral states to deal with any ship-sourced pollution incidents.

The project scope consists of four parts:

1. Common HNS Data bank and Response Decision Support System
2. Standard Operating Procedure for Joint Response to HNS Incidents
3. HNS Response Centres with Specialised Equipment and Trained Personnel
4. Capacity Building through Joint Exercises among the Three Littoral States

Cooperation with users of the Straits has been notable:

- China and the US conducted a needs assessment study in 2007;
- The US conducted a short HNS awareness course in 2008 and has provided a model on standard operating procedures for HNS response;
- Australia contributed funds for an HNS Spill Risk Assessment in 2008, technical expertise on the creation of an HNS Databank, and proposed a risk assessment tool;
- China intends to conduct a "train the trainers" course in the near future.

As noted earlier, the Cooperative Mechanism has cemented a strong foundation upon which specific projects have provided concrete steps towards a broader risk governance strategy. Ensuring that these preliminary efforts are followed through with the required resources and are further developed to be proactive and preventive, rather than reactive, is still needed.

[18]Some examples include the Straits of Malacca and Singapore Revolving Fund, the Lombok-Makassar Oil Spill Contingency Plan, the Brunei Bay Spill Contingency Plan, the ASEAN Oil Spill Response Plan, and the ASEAN Council on Petroleum Oil Spill Contingency Plan.

Piracy, Armed Robbery, Terrorism - Securing the Straits

Maritime security is largely undermined by acts of piracy, armed robbery and terrorism. Attacks in the Straits showed a sharp increase after 2001. In response, the littoral states have been proactive on this matter. Since the installation of joint patrols[19], the number of attacks in the Straits has declined [Ho, 2006; Bradford, 2008].

Critical reviews [Beckman, 2002; Teo, 2007; Hong and Ng, 2010] of existing mechanisms for maritime security revealed several factors that affect the ability of states to address threats to maritime security: sovereignty, legislation, compliance and information sharing, but also the existence of effective early warning systems and response capabilities. Since 1990, the security concept has widened beyond the narrow focus of regulatory, political or military factors to include economic, societal and environmental dimensions and deepened from state centered (national/international security) [Buzan *et al*., 1998] to people centered (human and gender security) concepts [Brauch *et al.*, 2008, 2009, 2011]. As such, the security problems in the Straits of Malacca and Singapore require continuous negotiation processes involving all stakeholders to prevent conflicts and tensions.

Sovereignty: Many international agreements and initiatives[20] are not ratified by Malaysia or Indonesia because they believe the agreements would permit interdiction of vessels by foreign agents in their territorial waters, which would be a violation of their sovereignty rights [Beckman, 2002; Teo, 2007]. The Convention and Protocol for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA) and the Regional Cooperation Agreement on Combating Piracy and Armed Robbery against Ships in Asia (ReCAAP), however, are potential instruments to fill the gaps left by UNCLOS to penalise criminals at sea in the Straits. While Japan and the US have assisted the littoral states in developing maritime security capabilities, there still exists a large gap in organisational capacity, particularly between Singapore and Indonesia [Beckman, 2002].

Legislation: Any attack against a ship exercising its right of passage in territorial seas is an offence under the laws of the coastal state. If offenders escape into another jurisdiction, however, they can avoid prosecution. Under SUA, a person who commits an offence would be a criminal in all countries that are parties to the convention, whether attacks were committed in port, in territorial sea or exclusive economic zones. As stated above, Malaysia and Indonesia are not yet parties to the convention. A trilateral approach among the littoral states might be more appropriate. Beckman [2002] made several recommendations for harmonising legislation, with a view that any attack against transiting vessels is considered an offence under Malaysia, Singapore and Indonesia's laws, no matter in whose territorial waters the offence was committed. However, no legislation has yet been passed or proposed.

Compliance: Endorsement and enforcement of the International Ship and Port Facility Security (ISPS) Code rests with the designated authorities of each party to the SOLAS. Lack of coordination has resulted in highly diversified standards between different ports. Inconsistent implementation varies the security level from port to port across the world. Basic standards and training are needed to specify requirements and measures of effectiveness, to ensure a minimum safety and security level and to assess that it has been achieved [Hong and Ng, 2010].

Information Sharing: The IMO, the IMB and ReCAAP all maintain piracy and armed robbery reports on attacks on ships in the Straits. However, in each case, the information is inadequate for helping the shipping industry and marine patrols to react proportionately to events because there are no standards or requirements for data collection to analyse the data aggregately, and there are no dedicated lines of communication among the three organisations [Beckman, 2002].

[19] MALSINDO joint sea patrols launched in 2004 and Eye in the Sky joint air patrols launched in 2005.

[20] Such as the Convention and Protocol for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation (SUA), 1988, Regional Cooperation Agreement on Combating Piracy and Armed Robbery against Ships in Asia (ReCAAP), 2004, Proliferation Security Initiative (PSI), Regional Maritime Security Initiative (RMSI).

Disaster and Emergency Management

All three countries have mechanisms in place for disaster and emergency management.

Singapore: The responsibility for disaster and emergency management in Singapore lies with the Singapore Civil Defense Force (SCDF) within the Ministry of Home Affairs. The main role of SCDF is to provide fire-fighting, rescue and emergency ambulance services, to mitigate hazardous materials incidents, as well as to formulate, implement and enforce regulations on fire safety and civil defense shelter matters [Gov. Singapore, 2010b].

Malaysia: the National Security Council (NSC) Directive No. 20 established a national mechanism for the management of disasters including delineating the responsibilities and functions of the various agencies under an integrated emergency management system. The NSC structure includes the National Security Division (NSD) which is responsible for coordination of all activities related to disasters; and the Disaster Management and Relief Committee which carries out the responsibilities of the NSC in coordinating all the activities related to disaster management.

Indonesia: A national coordinating board for disaster management was established in 1966 and its constitution has been amended several times since that date. The National Coordinating Board for Disaster and Internal Displaced Persons Management coordinates disaster management. It operates under and is responsible to the President. Its main duties include the formulation of national disaster management policies and strategies, the coordination and implementation of disaster management activities and the provision of guidance on related policies during efforts to manage disasters.

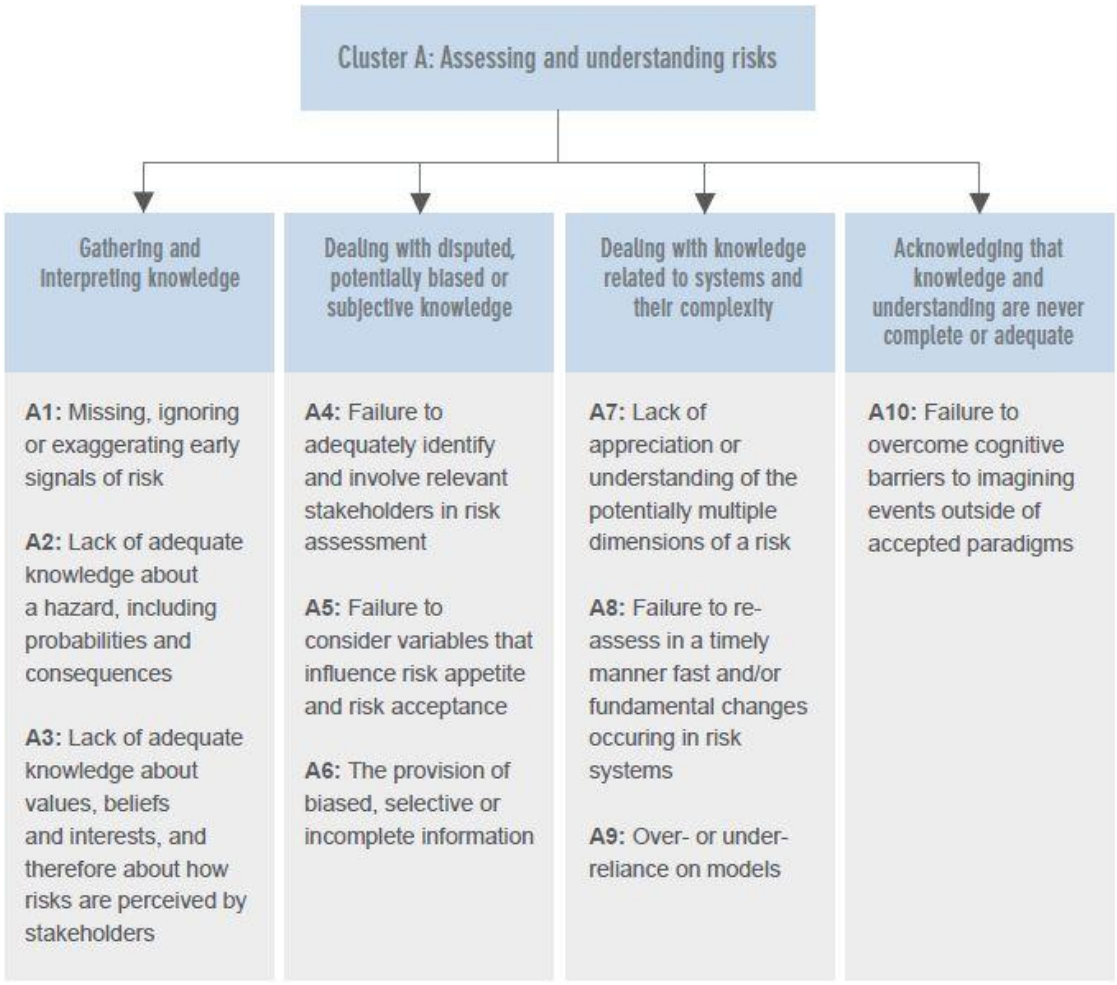
IV Deficits in the risk governance of high impact events

To formulate recommendations on the risk governance of MGCI in the Straits which could realistically be implemented and transferred to other systems, identification of issues that are likely to compromise the risk governance process is needed. Based on the understanding held by workshop participants and the knowledge gained from discussions of the scenarios and existing mechanisms, deficiencies and failures were identified in the current risk governance structures and processes for the Straits. The IRGC taxonomy of risk governance deficits served as a basis for the systematic identification and categorisation of these potential gaps.

In IRGC's report "Risk Governance Deficits: Analysis, illustration and recommendations," published in 2009, a total of 23 deficits related to assessing, understanding as well as managing risks were identified. A brief description of each deficit is presented in Figure 7 and Figure 8.

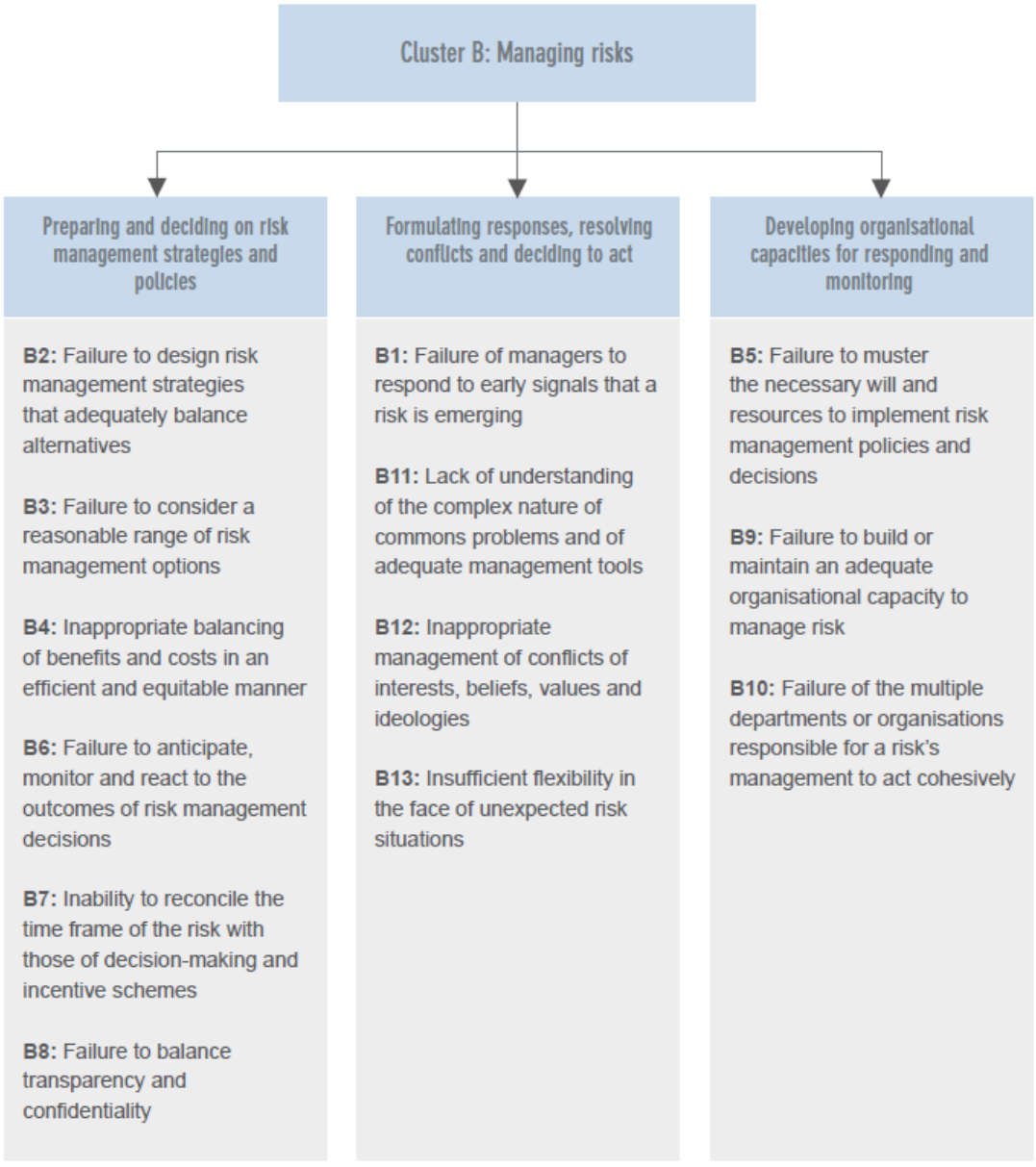
IRGC has identified 10 deficits related to assessing and understanding risks, including the collection and interpretation of knowledge. They can be grouped into four areas as illustrated in Figure 7.

Figure 7: Deficits relating to assessing and understanding risks
[From: "Risk Governance Deficits: Analysis, illustration and recommendations," IRGC, 2010]



IRGC has identified 13 deficits related to risk management, which can be grouped into three areas as illustrated in Figure 8. These include the acceptance of and responsibility for the risk, as well as taking action in order to reduce, mitigate or avoid the risk.

Figure 8: Deficits relating to managing risks
[From: "Risk Governance Deficits: Analysis, illustration and recommendations," IRGC, 2010]



In the context of risk governance in the Straits, the project team has identified a number of deficits relevant to this case to which decision-makers could pay special attention:

A. Involving Stakeholders and Ensuring Their Commitment in the Risk Governance Process

Stakeholder involvement (A4) and Organisational capacity (B9)

As the Straits are bordered by three countries and used for international navigation, there are multiple stakeholders who should be involved in all stages of the risk governance process to ensure safety, security and sustainability of the Straits. Cooperation is needed but not all stakeholders are currently participating or are equally supportive. Efforts to resolve all stakeholders' concerns are needed.

- The Cooperative Mechanism in the Straits has helped to set up a common platform, organisational and methodological framework so that user states, the shipping community and other stakeholders can cooperate with the littoral states. However, there is still a gap in burden sharing among all stakeholders. A financial gap of around 3 million USD at the end of 2010 was recorded to maintain aids to navigation [CF, 2010]. Dividing a larger project into smaller ones and leveraging in-kind contributions of expertise, training and equipment to facilitate burden sharing are needed [Ho, 2009].
- Organisational capacities among littoral states and user states vary drastically. For example, among the three countries, Singapore has overall better levels of industrial risk management and accident prevention [Dali, 2007]. Moreover, economic and social developments of the three countries are clearly not the same. Comparing the lengths of territorial coastlines and number of waterways, Indonesia has many more vulnerabilities than Malaysia and Singapore. Many pirates who attack ships in the Singapore Strait are alleged to reside on Indonesian islands [Gwin, 2007; Perry, 2001]. Perceptions of the erosion of law and order and inefficacy of security forces in Indonesia escalate to accusations of complicity, which, Beckman [2002] recommends, needs to be addressed by Indonesia and Singapore together. Different interests contribute to setting different priorities, which leads to different trade-off resolutions between security, shipping and environmental protection.

B. Information Collection, Interpretation and Management

Factual knowledge about risks (A2) and Perceptions of risks (A3)

No standard methodology for data collection, analysis and assessment of risks is followed across all hazards that are trans-boundary in the Straits. Moreover, different stakeholders have different perceptions of the risk of cyber-attacks and terrorism-related events.

- There is a lack of collection and evaluation of data on incidents, including land-based accidents, collisions and attacks affecting navigation in the Straits. This is probably because no one is responsible for this. Business entities such as shipping lines and industries in the maritime community are not always encouraged to provide data and information on incidents. There is a lack of a joint trilateral effort to evaluate data on industrial accidents, collisions, or near misses along the Straits. A poor sense of responsibility among stakeholders contributes to this deficit concerning the quality of data and information, resulting in poor risk appraisal. Efforts led by the International Chamber of Shipping, however, are currently underway to collect data on navigation-related incidents and assess high risk areas and factors in the Straits [ICS, 2010]. These efforts need to be increased and expanded.
- There is a clear need to identify potentially severe outcomes, multi-hazard scenarios, their consequences, as well as short, medium and long term impacts.
- There has been no formal assessment or public information on awareness of the risks of cyber-attack on vessel control and navigation systems, or IT systems used in ports.
- Terrorism may be a threat to security in the Straits, but it is not clear how to establish and agree on evidence of the threat. Singapore perceives the risk to be high, whereas Indonesia and Malaysia are more reserved; however, all three agree that maritime security is important [Tan, 2007; Teo, 2007].

C. Early Warnings and Building Capacity to Deal with Them[21]

Early warning systems (A1) and Responding to early warnings (B1)

There appears to be a need for improvement in the communication between the three littoral states and within the international maritime community for early warning and emergency management.

- The explosion scenario has identified that there seems to be limited means of communicating information on emergencies such as an explosion or toxic release to provide warning to vessels, cross traffic, local government authorities, and citizens of imminent or existing danger, or to provide emergency instructions.
- The cyber-attack scenario has indicated weaknesses with regards to a lack of awareness of the threat of cyber-attack. An integrated early warning system would be useful to detect threats in maritime information and telecommunication systems.
- Based on current practices of reporting piracy and armed robbery, an integrated early warning system that would be useful for helping the shipping community, governments, and authorities to react proportionately to incidents has not yet been established. Categorisation of reported incidents according to level of seriousness as defined in international law is not carried out, which leaves out valuable information [Beckman, 2002]. The IMB and governments do not share information in order to respond to reported incidents [Beckman, 2002].

D. Understanding Complex Systems (A7)

The Straits is a complex system, in which natural, human, and technological systems, interactions and interdependencies are not yet fully understood. A change in one system may lead to an undesired change in another system.

- Assessments and solutions are needed for dealing with complex situations. For example, e-navigation, particularly through the Maritime Electronic Highway in the Straits, is expected to play a significant role in reducing the risk of accidents and possible environmental damage [MFCA, 2010]; however, it may increase the risk of cyber-attack as more ships depend on electronic systems. The lack of security assessment or certification of technology against cyber-attack risks can lead to inappropriate trade-offs between safety and security.

E. Dealing with Unexpected Events

Assessing potential surprises (A10) and Acting in the face of the unexpected (B13)

In the case of the Straits of Malacca and Singapore, the complete blockage of the Straits is an appropriate example of an unexpected event as not one of the players expects or is prepared for this scenario. According to publicly available information:

- Shipping and logistics companies are unaware of any government contingency plans for a disaster that may result in the blockage of the Straits. There are currently no preparations or strategies to allow these sectors to respond to such an unexpected event.
- Governments do not have a joint contingency plan for responding to the potential scenarios imagined in which blockage of the Straits is the end result.

F. Putting in Place Risk Management Strategies and Policies

Designing effective risk management strategies (B2), Considering a reasonable range of risk management options (B3), and Designing efficient and equitable risk management policies (B4)

The deficits in the *risk assessments* of the Straits induce deficits in *managing the risks*. The participants in the workshop indicated that the link between risk assessments and contingency plans are not fully integrated among stakeholders or updated periodically.

- The risk assessment results need to be taken into account to design adequate emergency preparedness and response plans that are integrated as a coherent whole, as well as plans or strategies for recovery and reconstruction.

[21] Although this report does not deal with natural disasters, readers may be interested to know that the effectiveness of tsunami early warning systems installed after the Indian Ocean Tsunami in December 2004 is still to be determined. Officials reported that an early warning system was not working on 25 October 2010 when a tsunami hit the West coast of Sumatra in Indonesia where more than 300 people were killed [Izzard, 2010].

- There is a need for contingency plans for the whole area that are tested, evaluated and improved upon periodically with participation of stakeholders from the three littoral countries.

Balancing Transparency and Confidentiality (B8)

The trade-off between transparency and confidentiality creates a deficit in maintaining a complete, accurate and current database on incidents in the Straits. The shipping industry does not openly share information for various reasons, including fear of liability and protecting their reputation. Governments do not share information openly for reasons of national security.

- There appears to be little transparency on local electronic navigational systems and no reporting procedures on cyber-attack incidents.
- Reports on piracy and armed robbery in the Straits are collected separately by the IMO, the IMB and ReCAAP. Very little sharing of information occurs between these three organisations, despite their focus on the same problems [Beckman, 2002].

Dealing with dispersed responsibilities (B10)

Stakeholders in the Straits have a shared responsibility to ensure safe navigation and protection of the environment. They also have a role to play in maritime security and emergencies affecting all three countries.

No one stakeholder has overall responsibility.

- Littoral states, user states and the shipping community are attempting to carry out their obligations toward safe navigation and protection of the environment through the Cooperative Mechanism. It is still in its early stages and needs to be strengthened.
- Joint air and sea patrols in the Straits are great achievements by the littoral states. Their presence helps to prevent attacks; however, the response to attacks does not appear to have improved. The IMB recorded 38 reported attacks in the Straits in 2004, 19 attacks in 2005, 16 in 2006, and 10 in 2007 [Bradford, 2008].
- There do not appear to be standardised procedures, nor emergency management plans across the littoral states to address preparedness and response to natural, human or malicious intent disasters affecting all three countries along the Straits.
- Although there may be awareness of the need for risk governance among the littoral states, there are no existing risk governance mechanisms at the local and regional levels to deal with major incidents in the Straits.

Dealing with Commons Problems and Externalities (B11)

A fundamental risk governance deficit in the Straits comes from the fact that transit passage through the Straits is an international right that shall not be impeded under international law, but the costs of organising governance mechanisms and of maintaining and upgrading infrastructure to ensure safe, secure and sustainable usage are externalities to those who use the Straits.

The above risk governance deficits identified in the Straits lead the IRGC to propose five main recommendations in the next section.

V Recommendations

The authors of this report have formulated recommendations to address the deficits identified in understanding and managing the risks and vulnerabilities of MGCI in the Straits. These recommendations were elaborated by the participants in the previously mentioned workshop as well as by other external advisors who are familiar with the current systems in place. They were then further elaborated by DPRI. Their aim is to support the work of key players in the Straits in preventing and reducing risk wherever possible, in a proactive manner. They concern safety, security and sustainability in the Straits and include:

1. Harmonise methodologies, tools and procedures for risk assessment of maritime infrastructures and operations
2. Implement an integrated disaster risk management approach
3. Prepare joint contingency plans in case of closure of the Straits
4. Conduct joint and comprehensive risk assessments of the environmental, social and economic impacts of major activities in the Straits
5. Create an observatory or ad hoc expert joint committees

#1 Harmonise methodologies, tools and procedures for risk assessment of maritime infrastructure and operations that start with the identification of possible triggering events, notably in terms of attacks on cyber-security, based on generally accepted frameworks.

A point mentioned by several experts in the course of the DPRI-IRGC project work is that most actors perceived malicious human-made security threats in the Straits as potentially more disastrous than accidental or natural hazards. The ISPS code, which is now an integral part of SOLAS, provides an international framework for dealing with security threats at sea and in ports. According to the ISPS code, the starting point for any security measure is a "Security Risk Assessment". The exchange and sharing of security-relevant data across the involved countries and stakeholders is still rare and, moreover, there is no harmonised security risk assessment methodology. Therefore, it is recommended that the littoral states, with the cooperation of user states and the maritime community, create a road map for the identification, harmonisation and, if possible, standardisation of methodologies and information sharing protocols, using the ISPS code framework for trans-boundary risk assessment of maritime infrastructure and operations in the Straits.

- **Establish an ad-hoc expert committee to develop a harmonised security risk assessment framework** (ontology, method and metrics) for the implementation of the ISPS code in a uniform and fair manner across all three littoral states. The TTEG should be responsible for negotiating the terms of cooperation, confidentiality and a need-to-know basis for sharing information.
- **Implement a security incident multi-layer reporting system and network** through a multilateral partnership between the governments and the international maritime community; the access to particular information layers would be restricted to registered users, either private or public, according to specific access rights negotiated by the littoral states and the international maritime community.
- **Identify and enumerate scenarios** along a spectrum of events ranging from low probability/high consequence to high probability/low consequence in order to develop standard operating procedures for ports and ships based on consensually agreed responses and communication protocols.

Maritime security and safety are tightly interlinked. Security incidents can be the initiating events for extended catastrophes. Vice-versa, emergency or crisis situations can result in increased security vulnerabilities. The ISPS code establishes international cooperation to take preventive measures against any threats to human safety, infrastructures, and trade. Effective and efficient application of the maritime security regime, which is the ISPS code, requires standard risk analysis methodologies. At the same time, it provides an international framework / platform where such methodologies can be developed.

In the European Union, the ISPS code has been transposed to the Community legal framework by the Regulation 725/2004, and successively extended into the whole port area by the Directive 2005/65/CE. A Maritime Security Committee (MARSEC), composed of the European Commission and representatives from all European Union member states, sees to the implementation and follow up of all regulations and measures pertinent to maritime security.

For the ports and port facilities, the cornerstone for the implementation of ISPS is a sound port facility security plan (PFSP). The starting point for any such plan is a security risk assessment, performed by accredited private or state organisations. A matter of concern is that security risk assessments are not performed following scientifically established methodologies and statistical or other objective data, but by using practical methods based on expert judgment. Moreover, even these practical methods are not standard across the European Union or sometimes, not even across the same national administration.

#2 Implement an integrated disaster risk management approach by extending the scope of the existing emergency response system from a specifically oil spill contingency plan to an all-hazards plan. This would include the specification and sharing of multi-hazards and risk maps, communication chains, and an appropriate tri-lateral (Indonesia-Malaysia-Singapore) emergency operations system, and regular training exercises.

It is recommended that the littoral states, with the cooperation of user states and the maritime community, consider an integrated disaster risk management approach in which all hazards in the Straits related to navigation, protection of the environment and security at sea and in port are addressed concurrently and proactively (i.e. before they become disasters). This all-hazards approach should be integrated within the policies and institutions already in place regarding oil spill contingency plans, anti-piracy and armed robbery practices, the HNS preparedness project (through the Cooperative Mechanism), while at the same time respecting the sovereignty of the littoral states in their national affairs.

- **Share multi-hazard maps of physical, cyber and organisational systems** deployed in the Straits. Hazard maps are not just inputs to risk assessment and management, but are the result of a risk governance process. Therefore, in light of interdependent multiple hazards, proper methodologies throughout the process should be standardised and followed by all stakeholders. Risk maps should incorporate measures of consequence, probability, resilience (i.e., capabilities for countering hazards), and vulnerability.
- **Establish communication chains**, where key persons and notification systems are identified, in order to **provide early warning and emergency information to all stakeholders** along the Straits. This system should be based on sound emergency prevention, preparedness and response plans and operations procedures. It should facilitate communication and coordination among local, regional and national officials in the littoral states and international bodies when assistance is needed. Since the hazard landscape including vulnerability and resilience of critical systems will be evolving on a continuous basis, communication chains should also be capable of adapting to new, emerging issues.
- **Deploy an emergency preparedness and response management system** as well as disaster preparedness and response plans

(including standard procedures) for the management and response to events affecting more than one littoral state. This could be the responsibility of the TTEG who could utilise ad-hoc expert committees to address issues. Just as for communications, the system also needs to be adaptable to situations not known today.

- **Compile a booklet/CD of all recent accidents/hazards in the Straits and lessons learnt** to be distributed to all shipping companies and individual ships, made available on the worldwide web via the new Cooperative Mechanism Portal.
- **Encourage ships and ports to run drills regularly to test efficacy of procedures in the event of an incident**, e.g. cyber failure, steer by manual, measure time to respond and so on. An expert committee formed by the TTEG could be responsible for monitoring a variety of drills for testing response efficacy in the event of an incident and for providing feedback for improvement. Furthermore, the committee should conduct surprise inspections using a real-life simulation of a disaster event. The results of the inspection would be in the form of advice to ship and port operators and management on how to improve prevention and response capabilities. These exercises can be valuable in two ways: 1) to cordially share knowledge among navies, coast guards, port authorities, and the shipping industry, and 2) to provide unbiased evidence on effective risk reduction, thus making a case to lower insurance premiums.

#3 Prepare joint contingency plans in case of a closure of the Straits, involving navies, coast guards, port authorities, shipping companies, communities, among other key players. The plans should include notification, alternative routes, and a tri-lateral (Indonesia-Malaysia-Singapore) effort to reopen the Straits.

Currently, there are no known joint contingency plans in case of a complete blockage of the Straits. An interesting point that came out of the workshops was that a disruption in either the navigability of the Straits or the usability of the Port of Singapore would likely only result in temporary global impact. While such a disruption will affect the global economy only in the short term, the local economies would be badly and perhaps permanently affected. In the interest of international shipping and the local economies, it is recommended that the littoral states, with the cooperation of user states and the maritime community, consider instituting a joint contingency plan in the case of closure of the Straits. Planning and preparedness for very low-probability and very high-severity events contribute to capacity-building, more collaboration and overall improvement of risk assessment and risk management. Such efforts can improve the coping capacity of the stakeholders to deal with a complete blockage of the Straits and ensure that the region can recover as resiliently as possible.

- If there are **contingency plans** in case of a complete blockage of the Straits, governments should **communicate them** to the maritime industry on a need-to-know basis. If there are no plans, then **plans should be developed tri-laterally** by the littoral states in consultation with the international shipping industry and with the assistance of the IMO. This involves contingency passages and technical preparedness (i.e. an inventory of equipment and expertise, and if there are items missing or resources lacking, determine where and how to acquire them) to reopen the Straits.
- **Make available navigational charts for alternative routes** that are navigable and possibly better than the detour through the Sunda or Lombok Straits. There are several routes in between islands south of the Singapore Strait normally used for local traffic only. Those routes could be used as a contingency plan for international traffic, with some restriction on vessel size and draft or some traffic control such as a Traffic Separation Scheme by the IMO. The governments of Indonesia and Singapore should negotiate, at least, an assessment of such a contingency plan.
- **Disclose information publicly to deter attacks in the Straits and to support risk prevention and reduction efforts,** helping to build a case to decrease insurance premiums. With this information, insurers can create better products to distribute the burden and to reward clients that act to reduce the burden to the overall system. Not all information needs to be disclosed; detailed information should be guarded and only shared on

a need-to-know basis such that sensitive information does not get into the wrong hands and does not create panic in the media or among insurers.

#4 Conduct comprehensive, joint (Indonesia-Malaysia-Singapore and users) risk assessments of the environmental, societal and economic impact of major activities in the Straits. The aim of these assessments would be to verify the appropriateness, consistency and sufficiency of existing policies and their implementation. More broadly, they would contribute to develop long-term cooperation between the littoral states and other stakeholders.

- **Establish preventive measures and the collective sharing of risks and benefits among the major players** including the littoral and user countries as well as the maritime industry. The development of an international risk governance framework would encourage more involvement of user stakeholders in the Cooperative Mechanism. It would recommend the conduct of joint risk assessments involving the littoral and user states, the international maritime community, and researchers in government, academia and industry for risks of human origin, in order to pre-empt incidents including those resulting of terrorism. This would entail consulting with government security agencies and having a network of maritime intelligence specialists. The results of the assessments would bring evidence to bear on necessary modifications to the international agreements on the sea and in the existing laws of the littoral countries in view of the emerging new challenges posed by cyber-attacks, terrorism, potential surprises and other unexpected events of high consequences. The littoral and international community would benefit from these assessments, which would address burden-sharing and help to ensure smooth operations, reducing risks and impacts locally. The international maritime industry would also benefit as these assessments could be used as incentives to improve their operations.
- **Implement an international risk governance framework for achieving a desired operational mode of shared responsibilities among the littoral states, user states and industry** during normal day-to-day operations as well as in times of emergency. With the concept of risk governance, risk management measures should be formulated to balance risk, impacts and other objectives, not just for maintaining smooth operations. The business sector should be engaged in the process to implement system solutions and technologies. Recently, an assessment of maritime traffic effects on biodiversity in the Mediterranean Sea, which borders 22 countries, was published [Abdulla and Linden, 2008; Oral and Simard, 2008] and can serve as an example.
- **Test and support alternative solutions to the free-rider problem**, such as 1) a better policy than the voluntary contributions of 1 cent per dead weight tonne proposed by the Nippon Foundation, which was not favourably received by industry representatives [Ho, 2009], to be solicited from the shipping industry by the Aid to Navigation Fund Committee, 2) voluntary contributions from international port fees based on a dependence metric on the Straits, 3) credits and awards for voluntary contributions, or 4) a fee for services provided through the Maritime Electronic Highway and other initiatives completed by the Project Coordination Committee of the Cooperative Mechanism.

#5 Create an observatory or ad hoc expert joint committees, embedded within the TTEG and Cooperative Mechanism, which would act as a representative and neutral platform for collecting and evaluating data to advise key stakeholders.

The Tripartite Technical Experts Group and the Cooperative Mechanism are institutions through which ad hoc expert committees can be formed. Many of the tasks in recommendations 1 to 4 can be incorporated in the existing Cooperative Mechanism, which is simple and flexible enough to allow for such an enhancement. This enhancement could be in various forms. One model is the International Joint Commission between Canada and the US [IJC, 2011], which is mandated by the 1909 Boundary Waters Treaty. Traditionally, the

TTEG only focuses on safety of navigation and related environmental protection. With ministerial decree, its capability can be expanded to achieve cooperation on any issue concerning the safety, security or sustainability of the Straits. Since primary responsibility of safety of navigation, environmental protection and maritime security in the Straits lies with the littoral states, it is imperative that the Ministers of Foreign Affairs of the littoral states be active proponents who negotiate the required resources and agreements with other public and private organisations to mandate and fund this enhancement. Within the forum of the Cooperative Mechanism, it is recommended that the littoral states consider formalising the procedure for creating ad hoc expert committees to support projects that implement recommendations 1 to 4.

- **Ad hoc expert committees** would be commissioned by the TTEG **to act as neutral independent sources that collect, validate and analyse data** on accidents, security incidents, piracy incidents, and near miss events. Since such data would be sensitive, agreements would need to be negotiated among governments and industry to encourage good data collection and sharing protocols. These committees would ensure that confidentiality and a need-to-know basis is understood and respected. The IMO could play a similar support role that it offered for the Cooperative Mechanism meetings.
- It is recommended that the **TTEG consider formalising the procedure for creating ad hoc expert committees** to support projects that implement recommendations 1 to 4. The committee members are to be invited from governments, academia and industries of the international community. The user states and the international maritime community are strongly encouraged to provide the committee with the needed financial support, data and information on incidents.

These recommendations contribute to the implementation of a broader international risk governance system for the Straits. Establishment of ad hoc joint committees (recommendation 5) should be coupled with recommendations 1 to 4, as their purpose is to support initiatives rather than to be an objective in themselves. Regarding the order of implementation, it is reasonable to start with 1 and 2 as they provide a basis for implementing 3 and 4. In terms of expected benefits related to visibility and tangibility of outcomes, a joint contingency plan (recommendation 3) is ranked as a top priority for agenda setters. However, this does not discount the importance of the other recommendations to ensure the success of the contingency plan when it must be called on. In order to encourage stakeholders to actively assist the littoral states in implementing the recommendations, the above procedures need to be repeatedly conducted through a series of meetings based on a common platform.

All five recommendations are complementary and projects towards implementing them should not be considered mutually exclusive or the responsibility of only one stakeholder group. The key to the success of good risk governance in the Straits is cooperation, which we strongly encourage in order for all key stakeholders to thrive in the Straits and beyond in moving forward. As such, these suggestions can be made by interested stakeholders to the Cooperation Forum under the Cooperative Mechanism.

New perspectives and frameworks on governing GCI need to be further explored to provide (a currently missing) broadened common platform for involving prospective stakeholders. It is hoped that this report brings stakeholders to support the implementation of global risk governance of Maritime Global Critical Infrastructure as recommended for the Straits of Malacca and Singapore.

Glossary

Complexity: Refers to the difficulty of identifying and quantifying causal links between a multitude of potential causal agents and specific observed effects [IRGC, 2005].

Emerging risk: A new risk, or a familiar risk in a new or unfamiliar context (re-emerging). These risks may also be changing (in nature) rapidly.

Externalities: Externalities are implicated in commons problems and o ccur when an economic activity incurs external costs (negative externalities) or external benefits (positive externalities) to stakeholders who did not directly participate in the activity. For example, the economic activity of factories can release pollutants into waterways or produce greenhouse gas (GHG) emissions, which contribute to climate change – these negative impacts impose a cost on society, which is not borne by the factories; it is an external cost. Emissions trading schemes are a method of removing externalities related to GHG emissions, as they impose an internal cost on firms for the GHG they release.

Hazard: A source of potential harm or a situation with the potential to cause loss [Australian/New Zealand Risk Management Standard, cited in IRGC, 2005].

Knowledge: The Concise Oxford English Dictionary defines knowledge as: "(i) information and skills acquired through experience or education; the sum of what is known (ii) awareness or familiarity gained by experience". The classical definition of knowledge, as formulated by Plato, is "justified true belief". However, epistemologists continue to debate the meaning of "knowledge" and, as such, there is no agreed-upon definition.

Maritime Global Critical Infrastructures (MGCI): Critical Infrastuctures, as defined in the USA Patriot Act of 2001 [US, 2001] are "those systems and assets, whether physical or virtual, so vital […] that the incapacity or destruction of such systems and assets would have a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters". *Maritime Global Critical Infrastructures* are systems and assets as they relate to *marine* activities specifically and can impact international security, global economic security, public health or safety, or any combination of these.

Organisational capacity (assets, skills, capabilities): The ability of organisations and individuals within organisations to fulfil their role in the risk governance process [IRGC, 2005].

(Risk) Mitigation: Measures to reduce the impact of a realised risk [IRGC, 2005].

(Risk) Perceptions: The outcome of the processing, assimilation and evaluation of personal experiences, values or information about risk by individuals or groups in society [IRGC, 2005].

Risk: An uncertain (generally adverse) consequence of an event or an activity with regard to something that humans value [definition originally in Kates et al., 1985, cited in IRGC, 2005]. Such consequences can be positive or negative, depending on the values that people associate with them [IRGC, 2005].

Risk assessment: The task of identifying and exploring, preferably in quantified terms, the types, intensities and likelihood of the (normally undesired) consequences related to a risk. Risk assessment comprises hazard identification and estimation, exposure and vulnerability assessment, and risk estimation [IRGC, 2005].

Risk governance: The identification, assessment, management and communication of risks in a broad context. It includes the totality of actors, rules, conventions, processes and mechanisms concerned with how relevant risk information is collected, analysed and communicated, and how and by whom management decisions are taken.

Risk governance deficit: A failure in the identification, framing, assessment, management or communication of the risk issue or in how it is being addressed. Governance deficits are common. They can be found throughout the risk handling process and limit its effectiveness. They are actual and potential shortcomings, and can be remedied or mitigated.

Risk management: The creation and evaluation of options for initiating or changing human activities or (natural or artificial) structures with the objective of increasing the net benefit to human society and preventing harm to humans and what they value; and the implementation of chosen options and the monitoring of their effectiveness [IRGC, 2005].

Systemic risk: Risks affecting the systems on which society depends. The term "systemic" was assigned by the OECD in 2003 and denotes the embeddedness of any risk to human health and the environment in a larger context of social, financial and economic consequences and increased interdependencies both across risks and between their various backgrounds [IRGC, 2005]. Systemic risks are characterised by complexity, uncertainty and ambiguity. Most often, they are also trans-boundary.

Stakeholders (in risk issues): Socially organised groups that are or will be affected by the outcome of the event or the activity from which the risk originates and/or by the risk management options taken to counter the risks [IRGC, 2005].

Uncertainty: A state of knowledge in which the likelihood of any adverse effect, or the effects themselves, cannot be precisely described. (Note: This is different from ignorance about the effects or their likelihood [IRGC, 2005].)

Vulnerability: The extent to which the target can experience harm or damage as a result of the exposure (for example: immune system of target population, vulnerable groups, structural deficiencies in buildings, etc.) [IRGC, 2005].

References

[Abdulla and Linden, 2008] Abdulla, A., Linden, O., editors (2008). Maritime traffic effects on biodiversity in the Mediterranean Sea: Volume 1 - Review of impacts, priority areas and mitigation measures. Gland, Switzerland and Malaga, Spain: International Union for Conservation of Nature and Natural Resources.

[Antara, 2011] *Antara News*, Indonesia to ratify ASEAN agreement on trans-boundary haze pollution, 7 March 7 2011, accessed 2 September 2011. http://www.antaranews.com/en/news/68888/indonesia-to-ratify-asean-agreement-on-trans-boundary-haze-pollution

[ASEAN] ASEAN Agreement on Transboundary Haze Pollution, Environment Division of ASEAN Secretariat, 2010, accessed 6 September 2011. http://haze.asean.org/hazeagreement/

[ASEAN, 2011] ASEAN Haze Action Plan, Environment Division of ASEAN Secretariat, accessed 7 January 2011. http://haze.asean.org/

[Badri and Walmsley, 2008] Badri N.G., Walmsley, T.L.,editors (2008). Global Trade, Assistance, and Production: The GTAP 7 Data Base, Center for Global Trade Analysis, Purdue University.

[Bahe et al., 2007] Bahe, S., Sumser-Lupson, K., Rossiter, A., Kinch, M., Pardo, F., Lewey, S., Turbout, F., Winston, S., Thenail, B., Didierjean, R., Salaun, Y, Savean, N. (2007). The Management of Maritime Pollution in the English Channel: A Comparative Analysis of Risks and Contingency Planning, EspaceManche Development Initiative EMDI.

[Bateman, 2009] Bateman, S. (2009). Regime Building in the Malacca and Singapore Straits: Two Steps Forward, One Step Back, *Economics of Peace and Security Journal*, 4 (2), 45-51.

[BBC, 2011] BBC News. Japan nuclear crisis: Fukushima shutdown for January, 17 May 2011, accessed 18 May 2011. http://www.bbc.co.uk/news/world-asia-pacific-13423230

[Beckman, 2002] Beckman, R.C. (2002). Combatting Piracy and Armed Robbery Against Ships in Southeast Asia: The Way Forward, *Ocean Development & International Law*, 33 (3), 317-341.

[Bergin and Bateman, 2005] Bergin, A. and S. Bateman (2005). Future unknown: The terrorist threat to Australian maritime security. Canberra: The Australian Strategic Policy Institute.

[Bloomberg News, 2011] Bloomberg News (2011). Ship Rejected in China on Radiation Heads to Japan, Mar 29 2011, accessed 22 May 2011. http://www.bloomberg.com/news/2011-03-27/ship-rejected-in-china-port-on-abnormal-radiation-heading-back-to-japan.html

[Bradford, 2008] Bradford, J.F. (2008). Shifting the Tides Against Piracy in Southeast Asian Waters, *Asian Survey*, 48 (3), 473–491.

[Brauch et al., 2008] Brauch, H.G., Oswald Spring, Ú., Mesjasz, C., Grin, J., Dunay, P., Behera, N.C., Chourou, B., Kameri-Mbote, P., Liotta, P.H. (eds.) (2008). Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century, Hexagon Series on Human and Environmental Security and Peace, Vol.3, Berlin: Springer.

[Brauch et al., 2009] Brauch, H.G., Behera, N.C., Kameri-Mbote, P., Grin, J., Oswald Spring, Ú., Chourou, B., Mesjasz, C., Krummenacher, H. (eds.) (2009). Facing Global Environmental Change: Environmental, Human, Energy, Food, Health and Water Security Concepts, Vol.4, Berlin: Springer.

[Brauch et al., 2011] Brauch, H.G. Oswald Spring, Ú., Mesjasz, C., Grin, J., Kameri-Mbote, P., Chourou, B., Dunay, P.; Birkmann, J. (eds.) (2011). Coping with Global Environmental Change, Disasters and Security Threats, Challenges, Vulnerabilities and Risks, Vol.5, Berlin: Springer.

[Burbridge, 1988] Burbridge, P.R. (1988). Coastal and Marine Resource Management in the Strait of Malacca, AMBIO, 17 (3), 170-177.

[Buzan *et al*, 1998] Buzan, B., Waever, O., de Wilde, J. (1998). *Security: A New Framework for Analysis*, Boulder, Colorado: Rienner.

[CBC, 2003] Canadian Broadcasting Corporation. The great blackout of 2003, The National broadcasted on Aug. 14, 2003, accessed 8 March 2011. http://archives.cbc.ca/science_technology/energy_production/clips/13545/

[Chittenden and Swinford, 2010] Chittenden, M. and Swinford, S. Volcanic ash grounds Britain for days to come, *Times Online*, April 18, 2010, accessed 8 March 2011. http://www.timesonline.co.uk/tol/travel/news/article7101162.ece

[Chew, 2008] Chew, V. (2008). Laju Hijacking, Singapore Infopedia, National Library Board of Singapore, NLB, accessed 30 November 2010. http://infopedia.nl.sg/articles/SIP_1372_2009-01-15.html

[CIA, 2005] The World Factbook 2005. Washington, DC: Central Intelligence Agency, 2005.

[CIY, 2010] Containerisation International Yearbook (2010). London, UK: Emap Business Communications.

[CF, 2010] Report of the Meeting, 3rd Co-operation Forum under the Co-operative Mechanism on the Safety of Navigation and Environmental Protection in the Straits of Malacca and Singapore, Yogyakarta, Indonesia, 6 – 7 October 2010, accessed 19 May 2011. http://www.tteg-indonesia.com/download/cf/CF%203-Reportofthe3rdCo-operationForum.pdf

[CF-Annex 14, 2010] Annex 14: Project 2 Cooperation and Capacity Building on HNS Preparedness and Response, 3rd Cooperation Forum under the Cooperative Mechanism, Yogyakarta, Indonesia, 5 October 2010, accessed19 May 2011. http://www.tteg-indonesia.com/download/cf/Annex14-presentationonCapacityBuildingtoEnhancePreparednessandResponseCapabilities-Malaysia.pdf

[CM, 2010] Cooperative Mechanism Project Coordination Committee, Project 6: Replacement of Aids to Navigation Damage by the Tsunami Incident in the Straits of Malacca and Singapore, accessed 22 December 2010. http://www.inflexpoint.com/images/PDF/PCC/Projects/project-6.pdf

[Coulter, 2002] Coulter, Daniel Y. (2002). Globalization of maritime commerce: The rise of hub ports. Sam J. Tangredi, Globalization and maritime power, 133-142. Washington, DC: Institute for National Strategic Studies, National Defense University. http://kms1.isn.ethz.ch/serviceengine/Files/ISN/110803/ipublicationdocument_singledocument/35bd5a3f-5f01-479c-99ce-be91658c03b0/en/fulltext.pdf

[Cullinane et al., 2007] Cullinane, K., Yap, W.Y., Lam, J.S.L. (2007). The Port of Singapore and Its Governance Structure, in M.R. Brooks, K. Cullinane (eds.), Devolution, Port Governance and Port Performance: *Research in Transportation Economics*, Volume 17, 285–310.

[Dali, 2007] Dali, A. (2007). Disaster Risk Management in South-East Asia: Could a Bhopal-like accident happen again? Invited presentation at the 7th IIASA-DPRI Forum on Integrated Disaster Risk Management, Stresa, Italy, 17-21 September 2007.

[Djalal, 2008] Djalal, H. (2008). The Development of Cooperation on the Straits of Malacca and Singapore, Kuala Lumpur 24 November 2008, accessed 18 May 2011. www.nippon-foundation.or.jp/eng/current/malacca_sympo/6.doc

[DPRI and IRGC, 2010a] International Workshop on Risk Governance of the Maritime Global Critical Infrastructure: Straits of Malacca and Singapore Exposed to Extreme Hazards, Kyoto, Japan, 4-5 June 2009, Workshop Summary Report, IRGC, Geneva, 2010. http://www.irgc.org/IMG/pdf/Maritime_GCI_Summary_workshop_report.pdf

[DPRI and IRGC, 2010b] Risk Governance of the Maritime Global Critical Infrastructure: An initial assessment of hazards in the Straits of Malacca and Singapore and plans for future work, IRGC, Geneva, 2010. http://www.irgc.org/IMG/pdf/Maritime_GCI_Initial_insights_report.pdf

[DPRI and IRGC, 2010c] Regional Cluster Meeting on Straits of Malacca & Singapore as a Global Maritime Critical Infrastructure (MGCI), Report, Singapore, 30 April - 1 May 2010.

[Duda, 2006] Duda, A.M. (2006). Policy, Legal and Institutional Reforms for Public–private Partnerships Needed to Sustain Large Marine Ecosystems of East Asia, *Ocean & Coastal Management*, 49, 649–661.

[Earth Times, 2009] Earth Times (2009). Liberian oil tanker, British ship collide in Malacca Strait – Summary. *Earth Times*, Environment News, 19 August, accessed 11 December 2010. http://www.earthtimes.org/articles/news/281991,liberian-oil-tanker-british-ship-collide-in-malacca-strait--summary.html

[Falliere et al., 2010] Falliere, N., Murchu, L.O., Chien, E. (2010). W32.Stuxnet Dossier, Version 1.3 (November 2010), Symantec, accessed 22 December 2010. http://www.symantec.com/connect/blogs/w32stuxnet-dossier

[Gilek et al., 2011] Gilek, M., Hassler, B., Jönsson, A.-M.andKarlsson, M. (2011). Coping with Complexity in Baltic Sea Risk Governance: Introduction AMBIO: *A Journal of the Human Environment* 40 (2): 109-110.

[GlobalSecurity, 2010] Global Security.org, Limburg oil tanker attacked, Oct. 6, 2002, source: Director of National Intelligence, Sept. 6, 2006, accessed 11 December 2010. http://www.globalsecurity.org/security/profiles/limburg_oil_tanker_attacked.htm

[Gordon et al., 2005] Gordon, J.R.M., Lee, P.-M., Lucas Jr., H.C. (2005). A resource-based view of competitive advantage at the Port of Singapore, Journal of Strategic Information Systems, 14, 69–86.

[Gov. Singapore, 2010a] Government of Singapore, JTC Corporation, Safety and Security, accessed 15 December 2010. http://www.jtc.gov.sg/IndustryCluster/Chemicals/FastFacts/ComprehensiveInfra/Pages/index.aspx

[Gov. Singapore, 2010b] Government of Singapore, Singapore Civil Defense Force (SCDF), accessed 5 December 2010. http://www.scdf.gov.sg/content/scdf_internet/en/general/about-us.html

[Gwin, 2007] Gwin, P., Dark Passage: The Strait of Malacca, *National Geographic*, October 2007, Accessed July 22, 2011. http://ngm.nationalgeographic.com/2007/10/malacca-strait-pirates/pirates-text/1

[Ho, 2006] Ho, J.H. (2006). The Security of Sea Lanes in Southeast Asia, *Asian Survey*, 46 (4), 558-574.

[Ho, 2009] Ho, J.H. (2009). Enhancing Safety, Security, and Environmental Protection of the Straits of Malacca and Singapore: The Cooperative Mechanism, *Ocean Development & International Law*, 40 (2), 233-247.

[Hong and Ng, 2010] Hong, N., Ng, A.K.Y (2010). The international legal instruments in addressing piracy and maritime terrorism: A critical review, *Research in Transportation Economics*, 27, 51–60.

[Huffman, 2003] Huffman, J.L., (2003). KN Jadayat: a Little Ship with 20% of the World's Oil on its Shoulders, Indepth Articles, Nippon Foundation, accessed 21 December 2010. http://www.nippon-foundation.or.jp/eng /current/ 2003617/ 20036171.html

[Hydrocarbons Technology, 2010]Hydrocarbons Technology (2010). Singapore LNG Terminal, Singapore, accessed 15 October 2010. http://www.hydrocarbons-technology.com/projects/singaporelngterminal/

[ICS, 2010] Circular and Annex A sent by John Murray of the International Chamber of Shipping, 9 December 2010, accessed 19 May 2011. http://www.marisec.org/icsorange/icscirculars10/RN_10_17%20-%2035th%20meeting%20of%20the%20TTEG%20and%20the%203rd%20CF%20in%20the%20Straits%20of%20Malacca%20and%20Singapore.pdf

[IJC, 2011] International Joint Commission: Canada & United States, accessed 24March 2011. http://www.ijc.org/en/home/main_accueil.htm

[IRGC, 2005] Risk Governance: Towards an Integrative Approach, White Paper No. 1, IRGC, Geneva, 2005.

[IRGC, 2006] Managing and Reducing Social Vulnerabilities from Coupled Critical Infrastructures, White Paper No. 3, IRGC, Geneva, 2006.

[IRGC, 2007] Managing and Reducing Social Vulnerabilities from Coupled Critical Infrastructures, Policy Brief, IRGC, Geneva, 2007.

[IRGC, 2008] An introduction to the IRGC Risk Governance Framework, IRGC, Geneva, 2008.

[IRGC, 2009] Risk Governance Deficits, Report, IRGC, Geneva, 2009.

[IRGC, 2010] Risk Governance Deficits: Analysis, illustration and recommendations, Policy Brief, IRGC, Geneva, 2010.

[Izzard, 2010] Izzard, J. (2010). Indonesia tsunami: Claims early warning system wasn't working. News Asia Pacific, BBC News, 28 October 2010. http://www.bbc.co.uk/news/world-asia-pacific-11641512

[JAMS, 2006] Japan Association of Marine Safety, 2006 White Paper on Straits of Malacca and Singapore, <In Japanese>, Nippon Foundation and Japan Maritime Center, accessed July 22, 2011. http://www.nikkaibo.or.jp/nikkaibo-doc.jp/general/02_BusinessReport/PDF/H17/17_10.pdf

[JAMS, 2010] Japan Association of Marine Safety, Malacca and Singapore Straits Report 2010, <In Japanese>, Nippon Foundation and Japan Maritime Center, accessed July 22, 2011. http://www.nikkaibo.or.jp/nikkaibo-doc.jp/general/02_BusinessReport/PDF/H21/21_11.pdf

[JP, 2010] Johor Port, accessed 15 December 2010. http://www.johorport.com.my/

[Juda, 2007] Juda, L. (2007). The European Union and Ocean Use Management: The Marine Strategy and the Maritime Policy, *Ocean Development & International Law*, 38: 3, 259-282.

[Juda, 2010] Juda, L. (2010). The European Union and the Marine Strategy Framework Directive: Continuing the Development of European Ocean Use Management, *Ocean Development & International Law*, 41: 1, 34-54.

[Kerckhof et al., 2004] Kerckhof, F., Roose, P., Haelters, J. (2004). The Tricolor Incident: From Collision to Environmental Disaster, Atlantic Seabirds, 6 (3/S.I.), 85-94.

[Kiong, 2007] Kiong, J. (2007). Major oil spills in the Straits of Singapore. National Library Board of Singapore, NLB, accessed 6 September 2010. http://infopedia.nl.sg/articles/SIP_1101_2010-09-06.html

[King and Adeel, 2002] King, C., Adeel, Z. (2002). Strategies for Sustainable Coastal Management in Asia and the Pacific: Perspectives from a Regional Initiative, *Global Environmental Change*, 12, 139–142.

[Kourniotis et al., 2000] Kourniotis, S.P., Kiranoudis, C.T., Markatos, N.C. (2000). Statistical Analysis of Domino Chemical Accidents, *Journal of Hazardous Materials*, 71, 239-252.

[Kröger, 2008] Kröger, W. (2008). Critical Infrastructures at Risk: A Need for a New Conceptual Approach and Extended Analytical Tools, Reliability Engineering and System Safety, 93, 781-787.

[Lagadec, 2007] Lagadec, P. (2007). Crisis Management in the Twenty-First Century: “Unthinkable” Events in “Inconceivable” Contexts, in Rodriguez, H., Quarantelli, E.L., Dynes, R.R., editors. Handbook of Disaster Research, Chapter 30, 489-507.

[Lee and Ducruet, 2009] Lee, S.-W.Ducruet, C. (2009). Spatial Glocalization in Asia-Pacific Hub Port Cities: A Comparison of Hong Kong and Singapore, *Urban Geography*, 30 (2), 162-184.

[Lee-Partridge et al., 2000] Lee-Partridge, J.E., Teo, T.S.H., Lim, V.K.G. (2000). Information technology management: the case of the Port of Singapore Authority, *Journal of Strategic Information Systems*, 9, 85-99.

[Lim, 1998] Lim, L.T. (1998). Safety of navigation in the Straits of Malacca and Singapore - Modalities of Co-operation - Rapporteur's Report, *Singapore Journal of International & Comparative Law*, 2, 254-268.

[Lim, 2010] Speech By Mr Raymond Lim, Minister for Transport and Second Minister for Foreign Affairs, at Opening Ceremony of the 16th Singapore International Bunkering Conference and Exhibition, 27 October 2010, 9:00am at Resorts World Sentosa, accessed 15 December 2010. http://www.news.gov.sg/public/sgpc/en/media_releases/agencies/mot/speech/S-20101027-1.html

[Marlow and Gardner, 2006] Marlow, P.B., Gardner, B.M. (2006). The marine electronic highway in the Straits of Malacca and Singapore—an assessment of costs and key benefits, *Maritime Policy & Management*, 33 (2), 187-202

[MEH, 2011] MEH Demonstration Project Website, accessed 20 September 2011, http://www.meh-project.com/

[MFCA, 2010] Ministry of Fisheries and Coastal Affairs, Norwegian perspectives on maritime safety – by the Ministry of Fisheries and Coastal Affairs, 6 May 2010, accessed 29 December 2010. http://www.regjeringen.no/nb/dep/fkd/aktuelt/taler_artikler/ovrig_politisk_ledelse/statssekretar-vidar-ulriksen/2010/Norwegian-perspectives-on-maritime-safety--by-the-Ministry-of-Fisheries-and-Coastal-Affairs.html?id=604309

[MIMA, 2009] Maritime Institute of Malaysia Study, from keynote presentation by HM Ibrahim at the International Workshop on Risk Governance of Maritime Global Critical Infrastructure, Kyoto University, June 4-5, 2009.

[MIMA, 2010a] Maritime Institute of Malaysia, Centre for the Straits of Malacca (SOM), 2010 Project Highlights, Study on Ship Carrying Capacity of the Strait of Malacca (abstract), accessed July 22, 2011, http://www.mima.gov.my/images/stories/ResearchCentres/SOM/Research_Project/som01%20-%20study%20on%20ship%20carrying%20capacity%20of%20the%20strait%20of%20malacca.pdf

[MIMA, 2010b] Maritime Institute of Malaysia, Ship Carrying Capacity of the Strait of Malacca (SCC-SOM), presented at the 35th Tripartite Technical Experts Group (TTEG) Meeting on the Safety of Navigation in the Straits of Malacca and Singapore, held in Sheraton Mustika Hotel, Yogyakarta, Indonesia, 4-5 October 2010, accessed July 22, 2011, http://www.tteg-indonesia.com/download/tteg/TTEG35ANNEXOPresentationonShipCarryingCapacityoftheStraitofMalacca%20byMIMAbyMalaysia.pdf

[MLITT, 2009] Ministry of Land, Infrastructure, Transport and Tourism of Japan, from keynote presentation by K. Yamaguchi at the International Workshop on Risk Governance of Maritime Global Critical Infrastructure, Kyoto University, June 4-5, 2009.

[Morisugi et al., 1992] Morisugi, H., Marsh, J.B., Miyatake, N. (1992). Economic Value of the Malacca Strait, in Marsh, J.B. (editor), Resources and environment in Asia's marine sector, Washington and London: Taylor and Francis, pp. 307-34.

[MPA, 2007] MPA Singapore (2007). Factsheet on Memorandum of Understanding (MOU) on Oil Spill Resources, Maritime and Port Authority of Singapore, accessed 5 December 2010. http://www.mpa.gov.sg/sites/pdf/icopce_fact_sheet_240907.pdf

[Oral and Simard, 2008] Oral, N., Simard, F., editors (2008). Maritime traffic effects on biodiversity in the Mediterranean Sea: Volume 2 - Legal mechanisms to address maritime impacts on Mediterranean biodiversity. Gland, Switzerland and Malaga, Spain: International Union for Conservation of Nature and Natural Resources.

[PCC, 2010] Report of the Meeting, 3rd Project Coordination Committee Meeting under the Cooperative Mechanism on the Straits of Malacca and Singapore, held at the Sheraton Mustika Hotel, Yogyakarta, Indonesia, 8 October 2010, accessed 19 May 2011. http://www.tteg-indonesia.com/download/pcc/PCC3-Reportof3rdPCC.pdf

[Perry, 2001] Perry, A. Buccaneer Tales in the Pirates' Lair, *Time* (Asia Edition), Vol. 158, No. 8, August 20-27, 2001, pp. 62-64.

[Pin, 2010] Pin, Y.K. (2010). Terrorist Group Planning Malacca Oil-Tanker Attacks (Update2), Bloomberg, 4 March 2010, accessed 30 November 2010. http://www.bloomberg.com/apps/news?pid=21070001&sid=aYrh2Rgb9zZU

[PKA, 2010] Port Klang Authority, accessed 15 December 2010. http://www.pka.gov.my/

[PPC, 2010] Penang Port Commission, accessed 15 December 2010. http://www.penangport.gov.my/

[Price, 2004] Price, W. (2004). Reducing the Risk of Terror Events at Seaports, *Review of Policy Research*, 21 (3), 329–349.

[PSA, 2010] Port of Singapore Authority, accessed 15 December 2010. http://www.singaporepsa.com/

[PTP, 2010] Port of Tanjung Pelepas, accessed 15 December 2010. http://www.ptp.com.my/

[Pyburn, 2010] Pyburn, B. (2010).Contingency Planning for Oil Spills, East Asia Response Pte. Ltd. (EARL), 1999, accessed 23 November 2010. http://www.pcs.gr.jp/doc/esymposium/12169/95_brent_pyburn_e.pdf

[Rahmat and Yusof, 1999] Rahmat, B. H., Yusof, M. R. B. (1999). Industry, Government, and Regional Efforts in Oil Spill Contingency Planning: Malaysia's Perspectives. National Petroleum Corporation (Petronas), Malaysia.

[Raymond, 2006] Raymond, Catherine Z. (2006). Maritime terrorism in Southeast Asia: Potential scenario. Global Terrorism Analysis, 4(7). The Jamestown Foundation. http://www.jamestown.org/programs/gta/single/?tx_ttnews%5Btt_news%5D=725&tx_ttnews%5BbackPid%5D=181&no_cache=1

[Rimmer and Lee, 2007] Rimmer, P. J. and Lee, P. T. W. (2007). Repercussions of impeding shipping in the Malacca and Singapore Straits. *Journal of International Logistics and Trade*, 5 (1), 7-26.

[RSI, 2010] The Repository of Security Incidents, accessed 22 December 2010. http://www.securityincidents.org/

[Shell, 2010]Shell Corporation (2010). Shell Eastern Petrochemicals Complex (SEPC). Major Projects, Shell, accessed 24 October 2010. http://www.shell.com/home/content/aboutshell/our_strategy/major_projects_2/eastern_petrochemicals_complex/

[Singapore VTS, 2007] Singapore VTS, STRAITREP, World VTS Guide, accessed 15 December 2010. http://www.worldvtsguide.org/MenuPages/SingaporeMenu/StraitRep.html

[SOLAS, 2004] International Convention for the Safety of Life at Sea, 1974 SOLAS Convention and 1988 SOLAS Protocol, consolidated edition 2004, accessed 13 December 2004. http://www.shmsa.gov.cn/UserFiles/File/e%20SOLAS%20consolidated%20edition2004.pdf

[Tan, 2007] Tan, A.T.H. (2007). Singapore's Cooperation with the Trilateral Security Dialogue Partners in the War Against Global Terrorism, *Defence Studies*, 7 (2), 193-207.

[Teo, 2007] Teo, Y.Y. (2007). Target Malacca Straits: Maritime Terrorism in Southeast Asia, *Studies in Conflict & Terrorism*, 30 (6), 541-561.

[The Brunei Times, 2011] *The Brunei Times* (2011). Global supply chain at risk. Singapore, Friday, April 1, 2011, accessed 22 May 2011. http://www.bt.com.bn/business-asia/2011/04/01/global-supply-chain-risk

[The Nippon Foundation, 2009]. The Nippon Foundation (2009).Tanker Collision in the Malacca Straits. The Nippon Foundation, Maritime Affairs, Indepth Articles, 21 August, accessed 11 December 2010. http://www.nippon-foundation.or.jp/eng/current/20090821AidstoNavigation.html

[Thia-Eng et al., 2000a] Thia-Eng, C., Gorre, I.R.L., Ross, S.A., Bernad, S.R., Gervacio, B., Ebarvia, M.C. (2000). The Malacca Straits, *Marine Pollution Bulletin*, 41 (1-6), 160-178.

[Thia-Eng et al., 2000b] Thia-Eng, C., Gorre, I.R.L., Ross, S.A., Bernad, S.R., Gervacio, B., Ebarvia, M.C. (2000). The Malacca Straits, in Sheppard, C. (editor), Seas at the Millennium: An Environmental Evaluation Vol. 2, Amsterdam and New York: Pergamon, 309-329.

[Times, 2010] *Times online* (2010). Oil spill from ship collision in Singapore contained. The Sunday Times, 26 May, accessed 12 December 2010. http://www.timesonline.co.uk/tol/news/world/asia/article7136779.ece

[TTEG, 2010] Report of the Meeting, The 35th Tripartite Technical Experts Group (TTEG) Meeting on the Safety of Navigation in the Straits of Malacca and Singapore, held in Sheraton Mustika Hotel, Yogyakarta, Indonesia, 4-5 October 2010, accessed 30 November 2010. http://www.tteg-indonesia.com/download/tteg/TTEG35REPORT.pdf

[UNCLOS, 1982] United Nations Convention on the Law of the Sea of 10 December 1982, accessed 15 December 2010. http://www.un.org/Depts/los/convention_agreements/texts/unclos/closindx.htm

[USA, 2001] United States of America Patriot Act of 2001. Public Law 107–56—Oct. 26, 2001, accessed 21 December 2010. http://news.findlaw.com/cnn/docs/doj/oig71703patactrpt.pdf

[US EIA, 2008] US Energy Information Administration (2008). World Oil Transit Chokepoints, Country Analysis Briefs, updated January 2008, accessed 15 December 2010 and obtained from http://www.eia.doe.gov

[US EIA, 2011] US Energy Information Administration (2011). World Oil Transit Chokepoints, Country Analysis Briefs, updated February 2011, accessed 24 August 2011 http://www.eia.doe.gov/cabs/world_oil_transit_chokepoints/Full.html

[Vaughan, 2010] Vaughan, V., 3rd Tank for LNG Terminal, The Straits Times, November 2, 2010, accessed 15 December 2010. http://www.straitstimes.com/BreakingNews/Singapore/Story/STIStory_598265.html

[Wan et al., 1992]Wan, T.B., Wah, E.L.C., Meng, L.C. (1992). The Use of Information Technology by the Port of Singapore Authority, *World Development*, 20 (12), 1785-1795.

[Wong, 2000] Wong, P.P. (2000). Malacca Strait including Singapore and Johore Straits, in Sheppard, C. (editor), Seas at the Millenium: An Environmental Evaluation Vol. 2, Amsterdam and New York: Pergamon, 331-344.

[Wong-Anan, 2010] Wong-Anan, N. (2010). Worst haze from Indonesia in 4 years hits neighbors hard, Reuters, 21 October 2010, accessed 7 January 2011. http://www.reuters.com/assets/print?aid=USTRE69K1WF20101021

About the Project

Launched by IRGC in collaboration with our project partner, the Disaster Prevention Research Institute (DPRI) at Kyoto University in Japan, this project addressed the issue of risk governance relating to potential break-points in the global critical infrastructure of global shipping and trade. The project's focus was on one of the busiest shipping lanes in the world, the Straits of Malacca and Singapore, carrying around 25% of all world trade and half of the world's shipped crude oil. This system inherently encompasses a great variety of stakeholders, resulting in a high level of systemic complexity and uncertainty.

In 2009 and 2010, the project sponsored expert workshops in Kyoto, Japan. Their purpose was to gather participants from North and Southeast Asia and India, as well as from academia, industry, government and NGOs in order to provide a neutral platform for dialogue between various stakeholders on the risk governance of MGCI. Following the first workshop in June 2009, IRGC and Kyoto University published two reports: the Maritime GCI Summary Workshop Report summarising workshop presentations and discussions, as well as the Maritime GCI Initial Insights Report on Risk Governance of the Maritime Global Critical Infrastructure, providing an initial assessment of hazards in the Straits of Malacca and Singapore and plans for future work. The second expert workshop took place in November 2010, with final outcomes and recommendations presented in the current report.

Acknowledgements

IRGC projects are led by its Scientific and Technical Council, chaired by Prof. M. Granger Morgan (Head, Department of Engineering and Public Policy, Carnegie Mellon University, USA). The leader of this project was Professor Norio Okada (Director, Disaster Prevention Research Institute, Kyoto University, Japan), who received considerable support from Professor Wolfgang Kröger (Managing Director of the ETH Risk Center, at ETH Zürich).

IRGC's reports are developed as a result of projects which include workshops at which experts provide their knowledge and opinions, contributing to the formulation of key recommendations. These recommendations do not necessarily represent the views of all workshop participants, members of a project's leadership, or their employers. For this project, IRGC invited a number of individuals with expert knowledge in the fields of Maritime Global Critical Infrastructure and risk governance to participate in two workshops. They collectively provided the intellectual basis for IRGC's risk governance recommendations on this topic. We thank workshop participants for their contribution in providing expertise and different opinions to inform this report.

The principal authors of this report are Professor Norio Okada, Professor Wolfgang Kröger, Yoshio Kajitani (Disaster Prevention Research Institute, Kyoto University, Japan), Michele Bristow (Systems Design Engineering, University of Waterloo, Canada), Ana Maria Cruz (Natech Disaster Risk Management Consulting, France). Additional support to the project was provided by IRGC's Secretariat: Diane Boulay, Christopher Bunting, Marie-Valentine Florin, Malin Samuelsson and David Urbach.

IRGC's reports are published only after a rigorous external peer review. On behalf of IRGC's Scientific and Technical Council, Dr Timothy Walker (Chair of the Accountancy and Actuarial Discipline Board (AADB) and an executive director of the UK's Financial Reporting Council) acted as review coordinator of a peer review in which the comments and critiques received led to a number of significant improvements in the text. We thank the peer reviewers for their valuable insights and suggestions.

Project work on Maritime Global Critical Infrastructure would not have been possible without the generous support of IRGC's donors, including the Swiss State Secretariat for Education and Research, the Swiss Agency for Development and Cooperation, Swiss Reinsurance Company and Oliver Wyman Inc.

About IRGC

The International Risk Governance Council (IRGC) is an independent organisation based in Switzerland whose purpose is to help improve the understanding and governance of emerging, systemic global risks. It does this by identifying and drawing on scientific knowledge and the understanding of experts in the public and private sectors to develop fact-based recommendations on risk governance for policymakers. IRGC believes that improvements in risk governance are essential if we are to develop policies that minimise risks and maximise public trust and effectiveness in the processes and structures of risk-related decision-making. A particular concern of IRGC is that important societal opportunities resulting from new technologies are not lost through inadequate risk governance.

About DPRI

The Disaster Prevention Research Institute was established at Uji Campus, Kyoto University in 1951. It carries out research on a variety of problems related to the prevention and reduction of natural disasters. The Institute employs more than one hundred research staff members. Consequently, nearly all aspects of natural disasters, including earthquakes, volcanic eruptions, landslides, debris flows, floods, storm surges, and strong winds, are extensively investigated. Meanwhile, in addition to earth science and engineering points of view, human and sociological factors have also been studied, the aim being to develop software to strengthen our communities against disasters. For more details, see http://www.dpri.kyoto-u.ac.jp

international risk governance council

Chemin de Balexert 9
1219 Châtelaine
Geneva ▪ Switzerland

tel +41 (0)22 795 17 30
fax +41 (0)22 795 17 39

info@irgc.org
www.irgc.org

ISBN 978-2-9700772-0-6