PIANC
The World Association for
Waterborne Transport Infrastructure

Terms of References

Resilience of the Maritime and Inland Waterborne Transport System (MIWTS)

1. Background and Statement of Need

Both acute events and long-term progressive changes can significantly disrupt the international waterborne transportation system. To successfully operate with the uncertainty of these events, maritime and inland waterborne transport systems must be resilient: anticipate and plan for disruptions, resist loss in operations during disturbances and rapidly recover afterwards, and adapt to short- and long-term hazards, changing conditions and constraints. Hazards and constraints affecting the Maritime and Inland Waterborne Transport System (MIWTS) include environmental, human-induced, energy-related, and others. Environmentally, climate change, such as patterns of precipitation, changes in relative water level, and altering freeze/thaw patterns are long-term disturbances for which maritime and inland ports and harbors must plan and adapt. Short-term disturbances such as increasingly frequent and intense storms and flooding on inland waterways can cause major national and international disruptions. Other environmental hazards include invasive species, seismic disruptions and tsunamis, and hazardous spills, amongst others. Human-related hazards include population dynamics, aging infrastructure, and congestion at ports and harbors. Reliance on limited energy resources and the presence of offshore wind energy farms are constraints that can hinder port operations. Planning for mitigation to minimize disruptions and speed recovery from these and other potential hazards and constraints will serve to streamline operation of the MIWTS.

The attached paper “Background for PIANC Proposed Working Group - Resilience of the Maritime and Inland Waterborne Transport System (MIWTS)” includes an orienting summary of related PIANC reports, terminology, and how the proposed Resilience WG will leverage or compliment previous and ongoing PIANC work.

2. Objectives

The Task Group is targeted specifically at resilience of the Maritime and Inland Waterborne Transportation System, with recognition of interactions with the multi-modal transportation sector, at the regional and international level in the short-, medium, and long term. The TG will be a cross-Commission activity that will be guided by PIANC’s Permanent Task Group on Climate Change.

The aims of this Task Group (TG) are to:

- Develop a working definition of resilience for the MIWTS given the features and functions of this system and develop an understanding of the relationship between resilience and other systems management concepts including sustainability, risk, and vulnerability.

- Summarize international work on maritime and inland resilience to a broad range of known hazards, including socio-economic, technological, environmental, and chemo-biological events. In addition, identify actions taken in the international community to build general, non-hazard specific resilience.
- Identify resilience indicators for the MIWTS and methods to quantify resilience.
- Provide an overarching approach to guide consideration of resilience with respect to the MIWTS
- Summarize resilience concepts and future needs in a technical report for the MIWTS.

The outcomes will be presented in a useful, well structured and practical technical report targeted at the ports and navigation sector and the PIANC community.

3. Scope

The scope of the TG will extend to all aspects of maritime, estuarine and inland port and waterway operations and infrastructure, as these interact with broader multi-modal activities. It will cover a range of day-to-day activities and long-range planning such as the management, operation and maintenance of infrastructure; dredging and placement of dredged sediments; navigation; and engineering. It will also consider possible implications for the design and construction of new development projects, and will reflect on interdependencies with the multi-modal system that accesses the MIWTS.

The TG will not be structured or funded to perform new basic research. To meet the objectives, the TG will identify and review pertinent documentation and priority PIANC and third party reports and publications. As far as is practicable, the review will also cover unpublished literature, research, tools, etc. insofar as the latter are available and relevant. In addition, the TG will draw on the practical experience and expertise of its members (and their colleagues and contacts), and through an international workshop.

4. Intended product

The intended product is a technical report (TR) that can be used for understanding resilience of the MIWTS, knowledge to date, and future needs. The TR will be produced within one year of the formation of the TG and will include:

i) Background information, including definitions of resilience and related concepts;
ii) Case study examples of best practices and how the MIWTS can achieve resiliency;
iii) Information on the integration of conventional engineering, non-structural, and operational solutions available to achieve resilience of the MIWTS;
iv) Specification of the types of information and knowledge that should be analyzed to quantify existing resilience and identify opportunities for improvement; and
v) Identification of technical gaps and other needs of the sector for future development, potentially through working groups of the PIANC technical commissions.

5. Task Group membership

To maximize the usefulness of the publication across all sectors and in all countries, the TG should include members representing:

- Ports, harbors, navigation and waterways (engineers, Harbor Masters, operators), as well as the multi-modal system;
- Construction and dredging companies, consultants, other advisors to the sector;

- Governments, policy makers, public bodies, relevant international organizations; and
- Professional organizations, sector associations and representative bodies.

This TG should also include young professionals (YP) from national sections or Commissions.

6. Relevance to developing countries and countries in transition

The guidance and documentation will be particularly relevant to developing countries and countries in transition as these countries often have least existing experience and can learn most from what has been done elsewhere. However, the publication would also be pertinent more broadly because, although there is existing experience, levels of dissemination and sharing of information about climate change and adaptation options are often very low.

7. Relevance to climate change

The Resilience WG will consider climate change and associated consequences (e.g., drought, flooding, extreme precipitation, nuisance extreme tidal conditions, extreme storms, changes to water quality, ice, thaw, sea level change, new shipping routes, etc.) as potential short- and long-term hazards and/or constraints affecting resiliency of maritime and inland waterborne transport system.

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Resilience of the Maritime and Inland Waterborne Transport System (MIWTS)

1. Overview

To successfully operate, the maritime and inland waterborne transport system (MIWTS) must be resilient. Resiliency is the capacity to anticipate and plan for disruptions, resist loss in operations and/or absorb the impact of disturbances, rapidly recover afterwards, and adapt to short- and long-term hazards, changing conditions and constraints. Hazards and constraints affecting the MIWTS include environmental, human-induced, energy-related, and others. Environmentally, climate change, such as patterns of precipitation, changes in relative water level, and altering freeze/thaw patterns are long-term disturbances for which maritime and inland ports and harbors must plan and adapt. Short-term disturbances such as increasingly frequent and intense storms and flooding on inland waterways can cause major national and international disruptions. Other environmental hazards include invasive species, seismic disruptions and tsunamis, and hazardous spills, amongst others. Human-related hazards include population dynamics, aging infrastructure, and congestion at ports and harbors. Reliance on limited energy resources and the presence of offshore wind energy farms are constraints that can hinder port operations. Planning for mitigation to minimize disruptions from these and other potential hazards and constraints will serve to streamline operation of the MIWTS.

The purpose of this Background is to provide context for development of a PIANC Working Group (WG) on MIWTS Resilience. First, the proposed scope of a Resilience WG is summarized, followed by a discussion of related concepts including risk, vulnerability, and sustainability. Next, a brief review of related PIANC reports and WGs is provided with a discussion of how this proposed WG would provide new information. The Background concludes with a summary of the proposed WG focus and envisioned outcomes.

2. Scope of the Resilience WG

The scope of the Resilience WG will extend to all aspects of maritime, estuarine and inland port and waterway operations and infrastructure, as these interact with broader multi-modal activities. It will cover a range of day-to-day activities and long-range planning such as the management, operation and maintenance of infrastructure; dredging and placement of dredged sediments; navigation; and engineering design practices for resilience. It will also consider possible implications for the design and construction of new development projects, application of concepts within developing countries, and will reflect on interdependencies with the multi-modal system that accesses the MIWTS. Because of the broad nature of the topic, this Resilience WG will engage with other related PIANC WGs with input from a diverse group of members and stakeholders.

3. Related Concepts

a. Definitions of Resilience

The United Nations office of Disaster Risk Reduction (UNISDR) broadly defines resilience as –

> "The ability of a system… exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions."

The US National Academy of Science states this more succinctly as –

> "The ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."

These definitions are directed towards the general capacity to withstand an event and restore function across a system. Other entities have focused in on specific components of the system. The PIANC Inland Commission recently produced a report on the role of navigation structures in flood risk management (InCom Report 137, 2014). There, resilience was described as –

> "The capability of a component, unit or system to either
>
> a) withstand occasional small overloads that cause minimal permanent deformation, damage or cumulative degradation and which then essentially recovers its original state and function after the overloading event, or
>
> b) to sustain loads greater than the design load while achieving gradual failure modes over some duration rather than sudden failure modes.
>
> From Mechanics of Materials, it is the capability of a strained body to absorb energy and recover its size and shape after deformation (elastic behavior). Graphically, resilience is the area to the left of the resilience limit under the elastic region of a force/deformation curve, as shown in Figure 1. Resilience is about designing systems that 'fail gracefully' when overloaded, to avoid catastrophic failure but to allow for time to evacuate."

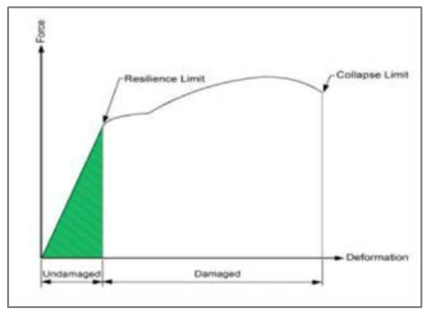

Figure 1. Resilience defined as elastic performance area (green) (PIANC Report 137, 2014).

Report 137 considers one category of the MIWTS (inland flood defense structures) and one type of forcing (flooding). Similar to the first definitions, this report includes concepts of *resisting* damage during flooding and being able to *recover* following the stress, although the concept of toughness recognizes that there may be some permanent damage to the structure. The MIWTS WG would expand the discussion of resiliency to include other elements of the MIWTS (e.g., maritime structures, navigation channel, environmental features, communications, natural processes, etc.), consider other stresses to the system (e.g., sedimentation, invasive species, weather-related, energy limitations, etc.), and incorporate other elements of resiliency: being *prepared* and being able to *adapt*. In order to address resilience across the MIWTS, a system of integrated engineered structures, natural features, and multiple socio-economic functions, adoption of an operational definition for resilience that accommodates both of these viewpoints will be necessary.

b. Related Concepts

Concepts that are related to resilience and may be utilized differently depending on context include sustainability, functional resilience, toughness, risk, and vulnerability. To avoid confusion, these terms are reviewed in this section as defined by previous PIANC WGs and any distinctions between these definitions and use of resilience herein are clarified.

Sustainability often is a long-term objective for many types of water resources projects. In a synthesis of guidance for inland waterways and navigation, PIANC's Environmental Commission (EnviCom) WG 6 (2003) discussed sustainability as follows. "*Water resource systems that can satisfy, to the greatest extent possible, the changing demands placed on them over time, without degradation, can be called "sustainable."* ***Sustainability****, as defined by PIANC (1996) and many other global organizations, means meeting the needs of the present without compromising the ability of future generations to meet their own needs."* Thus, sustainability recognizes the need for a system to continue functional performance given uncertain conditions, without adversely affecting other parts of the system.

In Report 137, PIANC Inland Commission further defined functional resilience, and toughness. ***Functional Resilience*** *is the capability of a component, unit or system to withstand occasional small overloads that cause minimal permanent deformation, damage or cumulative degradation and then essentially recover its original state and function after the overloading event.*

Toughness *is the capability of a component, unit or system to withstand extreme overloads that cause extensive permanent deformation, damage or cumulative degradation but do not lead to catastrophic failure and/or uncontrolled flooding...From Mechanics of Materials, it is the capability of a strained body to absorb energy before rupture, but the strained body will not fully recover its size and shape after deformation (inelastic behavior). Graphically, toughness is the entire area below the force/deformation curve, as shown in Figure 2.*

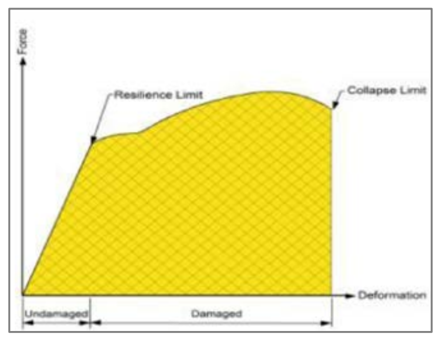

Figure 2. Toughness defined as area below force-deformation curve (yellow) (PIANC Report 137, 2014).

PIANC EnviCom WG 10 (2006) defined ***risk*** in relation to dredging and disposal operations as "*the combination of probability of an accidental occurrence and the likely magnitude of consequences in a given exposure."* Thus, risk is related to the likelihood of a disturbance and the magnitude of consequences. ***Vulnerability*** is not defined explicitly within any available PIANC reports, but is generally understood to be *the susceptibility for damage or loss in performance.*

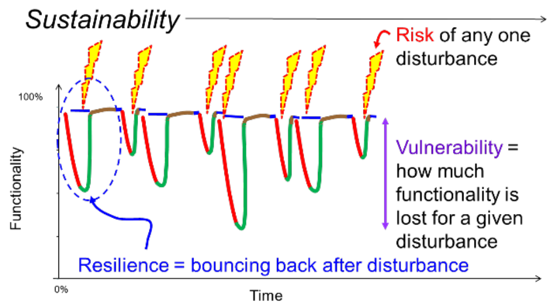

Figure 3. Example of one possible relationship between sustainability, functional resilience, risk, and vulnerability.

To summarize, the concepts of sustainability, resilience, functional resilience, toughness, risk, and vulnerability are interrelated. As examples, a vulnerable feature may not be sustainable, and a feature with high risk of future damage may not be resilient. Figure 3 provides one conceptualization of the relationship between these concepts. If the proposed PIANC WG on Resilience of the MIWTS is approved, one of the first actions will be to develop a PIANC-supported discussion for these concepts.

4. Related PIANC Reports

Table 1 provides a summary of PIANC reports concerning resiliency, including a column that defines how the proposed Resilience WG would complement the work presented in these reports.

5. Summary

If approved, the proposed PIANC WG on Resilience of the MIWTS will expand the discussion of resiliency to incorporate a broader spectrum of system elements and additional hazards and constraints than have been considered to date. Products of the Resilience WG would include discussion of resilience and related concepts, best practices, and design for resilience as garnered from PIANC international experts. Aspects of navigation resilience pertinent to developing countries and extremely vulnerable maritime and inland ports will be incorporated into the products. The accompanying Terms of Reference (TOR) provides more details on the scope of the proposed Resilience WG, membership and products.

Table 1. PIANC Groups and Reports Related to Proposed Resilience WG

WG	Report Name	Related Topics Covered	How Resilience WG will Leverage or Compliment
EnvirCom 6	Guidelines for Sustainable Inland Waterways and Navigation (2003)	• Five primary functions as screening tools for sustainable navigation decisions: ◦ morphological processes, ◦ maintenance of hydrological balance, ◦ maintenance of sediment balance, ◦ provision of habitat, and ◦ maintenance of biological and chemical processes • Evaluate both at local and river basin as a whole over long temporal scales • Each decision examined with respect to ecological, economic, and social trade-offs • Include wide participation in decision-making throughout project cycle, incorporating: ➢ Full access to information, ➢ Time schedule appropriate to local social and cultural conditions, ➢ Adequate resources, ➢ Capacity building by education and technical assistance.	• Examine performance with respect to short-term and long-term stresses to system • Incorporate maritime and inland • Consider structural design as well as natural processes, environmental conditions, and economic implications
EnviCom 176	A Guide for Applying Working with Nature (WwN) to Navigation Infrastructure Projects (ongoing)	• Practice to utilize natural process to supplement engineered approaches to projects to deliver more sustainable projects • Toward support of development of initiatives to characterize ecosystem goods and services.	• Resilience WG will consider WwN processes within the suite of actions to enhance resilience.
EnviCom 178	Climate Change Adaptation for Waterborne Transport Infrastructure (ongoing)	• Provides best practices for operating and investing in waterborne transport infrastructure based on future hazards of: ➢ Greater precipitation ➢ Greater storm severity ➢ Rising temperatures ➢ Rising Sea Levels	• WG 178 has generated an initial list of list of hazards to consider. • Resilience WG will explants on this list to consider additional threats

InCom 25	Maintenance and Renovation of Navigation Infrastructure(2006)	• Approach to overall navigation infrastructure asset management. • Decision process using indices for condition, specific use, and strategic use to prioritize repairs on infrastructure that is still being operated past the design life.	• Lessons learned from WG 25 efforts work on scorecard for investment can be leveraged in the development of a resilience scorecard.
InCom 137	Navigation Structures: their role within Flood Defense Systems – Resilience and Performance under Overloading Conditions (2014)	• Compilation of lessons learned concerning flooding beyond design conditions for structural flood defense measures (concrete and embankments in ground) • Recommends minimum system performance, "Performance Requirements," to reduce loss of life, environmental hazards, loss of lifeline services, or damage/risk to critical infrastructure • Resilience is normally provided in design through consideration of load factors (occasional slight overloads)	• Additional threats and constraints besides flooding • Additional features of the MIWTS besides concrete and embankments to include environmental features, navigation channels, port/harbor structures • Using the definition provided herein, designing for resilience would be considered not only through overloads (*resist/absorb*) but also through being able to *recover* and *adapt*
InCom 139	Value of Inland Waterways (2013)	• Assess possible additional value to society from direct and indirect use of navigable waterways	• Values of, and uses for, navigable waters ways generated in WG 139 can be utilized as a starting place for considering the full range of system functions that need to be resilient. • Resilience WG will expand to consider multiple functions and values for coastal regions as well.
MarCom 158	Masterplans for the development of existing ports (2014)	• Guidance for preparation of existing port masterplans to incorporate best international practice and key performance indicators	• Resilience WG will reference key performance indicators and response plans as optimal operating and recovery conditions, respectively, for development of best port resilience practices.
RecCom 130	Anti-sedimentation systems for Marinas and Yacht Harbors (2015)	• Guidance for design & modification of marinas to reduce sedimentation	• Resilience WG will utilize recommended measures to reduce navigation shoaling

6. References

PIANC Environmental Commission (EnviCom) Working Group 6. 2003. "Guidelines for Sustainable Inland Waterways and Navigation," PIANC General Secretariat, Brussels BELGIUM, 45 p. http://www.pianc.us/workinggroups/wgreports.cfm

PIANC Environmental Commission (EnviCom) Working Group 10. 2006. "Environmental Risk Assessment of Dredging and Disposal Operations," PIANC General Secretariat, Brussels BELGIUM, 40 p. http://www.pianc.us/workinggroups/wgreports.cfm

PIANC Environmental Commission (EnviCom) Working Group 176. "Terms of Reference: A Guide to Applying Working with Nature to Navigation Infrastructure Projects." http://www.pianc.org/envicomactivewg.php

PIANC Inland Commission (InCom) Working Group 137. 2014. "Navigation Structures: their Role within Flood Defense Systems – Resilience and Performance under Overloading Conditions," PIANC General Secretariat, Brussels BELGIUM, 43 p.

PIANC Inland Commission (InCom) Working Group 129. 2013. "Waterway Infrastructure Asset Maintenance Management," InCom Working Group 129, http://www.pianc.org/technicalreports.php.

PIANC Marine Commission (MarCom) Working Group 158. 2014. "Masterplans for the Development of Existing Ports," MarCom Working Group 158, http://www.pianc.org/technicalreportsbrowseall.php

PIANC Recreational Commission (RecCom) Working Group 130. 2015. "Anti-Sedimentation Systems for Marinas and Yacht Harbors," RecCom Working Group 130, http://www.pianc.org/technicalreportsbrowseall.php

United Nations Office of Disaster Risk Reduction. 2007. "Terminology." http://www.unisdr.org/we/inform/terminology

National Academies Press. 2012. "Disaster Resilience: A National Imperative" http://www.nap.edu/read/13457/chapter/2