John, A, Paraskevadakis, D, Bury, A, Yang, Z, Riahi, R and Wang, J
An integrated fuzzy risk assessment for seaport operations
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Figure Captions:

Figure 1: Sea-Land Interface of Maritime Transportation Systems

Figure 2: Framework for Risk Assessment of Seaport Operations

Figure 3: Generic Model for Disruption of Seaport Operations

Figure 4: Fuzzy Triangular Membership Function

Figure 5: Example of Converting Fuzzy Ratings to 5 Non-normalized grades

Figure 6: A Specific Model for Disruption Risks of a Seaport Operation

Figure 7: Sensitivity Analysis of the Model Output to the Variation of Each Sub-Criterion
FIGURE 1

Open Sea --- Water --- Land

Navigable waterways

Intermodal connection, Road, rail, pipelines, bridges

Public infrastructure, Highway, rail, pipelines system

Terminal operations

Port environment

FIGURE 2
Define a scaling system for likelihood and severity using fuzzy numbers

Estimate weight of each attribute in the hierarchy

Check the consistency of the matrices

CR≤0.10

No

Yes

Construct fuzzy pairwise comparison matrices using FAHP

Calculate risk of disruption based on the likelihood and severity of the identified factors

Implement ER to synthesise the risk results

Obtain a crisp number for the risk synthesis

Perform sensitivity analysis

Decision making

Are results logical?

Yes

No

Identify risk attributes and present them in a hierarchical structure
Disruption Risks of Seaport Operations

Operational Risk Factors
- Port Equipment/Machinery Failure
- Vessel Accident/Grounding
- Cargo Spillage
- Human Related Error

Security Risk Factors
- Sabotage
- Terrorism Attacks
- Surveillance System Failures
- Arson

Technical Risk Factors
- Lack of Equipment Maintenance
- Lack of Navigational Aid Maintenance
- Lack of IT System Maintenance
- Lack of Dredging Maintenance

Organisational Risk Factors
- Labour Unrest
- Dispute with Regulatory Body
- Berth Congestion
- Gate Congestion
- Storage Area Congestion

Natural Risk Factors
- Geologic/Seismic
- Hydrologic
- Atmospheric

Cranes
- Straddle Carriers
- RTGs
- Forklifts
- Terminal Tractors and Trailers

General Cargo
- Containerships
- Bulk Carriers
- Short-sea/RoRo Vessel
- Oil Field Supply Vessel

General Cargoes
- Bulk Cargoes
- Hazardous Cargoes
- Petroleum Products

Seafarers
- Stevedores
- Pilotage
- Port/Terminal

IT System
- Equipment
- Control System

Attack on Port Facilities
- Sinking of a large Vessel in a Port Channel

Earthquake
- Tsunami

Heavy Rainfall
- Flooding
- Snow

Hurricane
- Cyclone

FIGURE 4
FIGURE 5
FIGURE 6

Disruption Risks of a Seaport Operation

- **Operational Risk Factors**
  - Port Equipment/Machinery Failure
  - Vessel Accident/Grounding
  - Cargo Spillage
  - Human Related Error

- **Security Risk Factors**
  - Sabotage
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- **Technical Risk Factors**
  - Lack of Equipment Maintenance
  - Lack of Navigational Aid Maintenance
  - Lack of IT System Maintenance
  - Lack of Dredging Maintenance

- **Organisational Risk Factors**
  - Labour Unrest
  - Dispute with Regulatory Body
  - Berth Congestion
  - Gate Congestion
  - Storage Area Congestion

- **Natural Risk Factors**
  - Geologic/Seismic
  - Hydrologic
  - Atmospheric
FIGURE 7

Utility Values

10% Decrement  20% Decrement  30% Decrement