

Appendix C: Disruption analysis of port operations

1 Port-warehouse System

1.1 Scenario: BASELINE

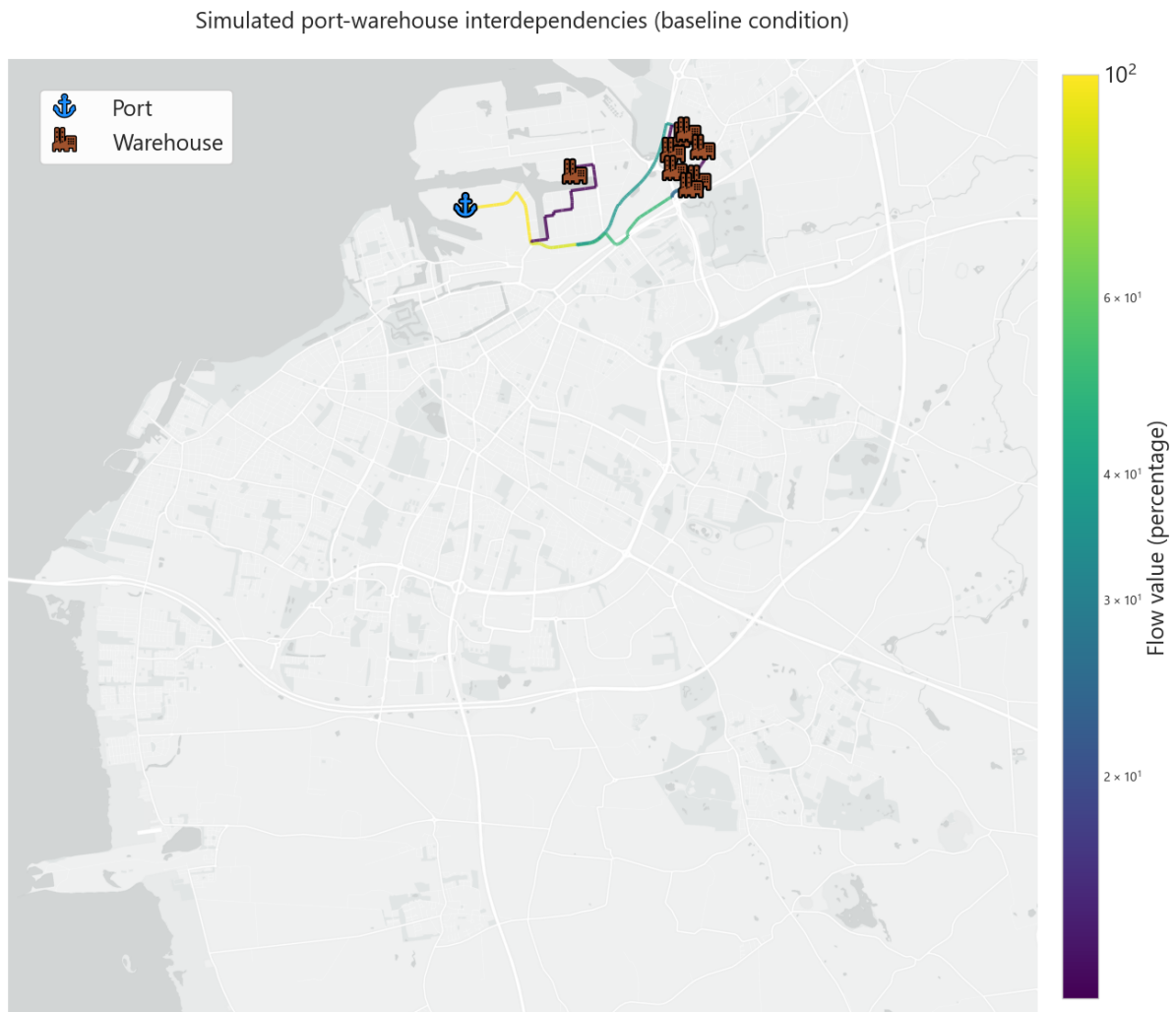


Figure C-1: Simulated port-warehouse interdependencies for the baseline scenario.

1.2 Scenario: MHW

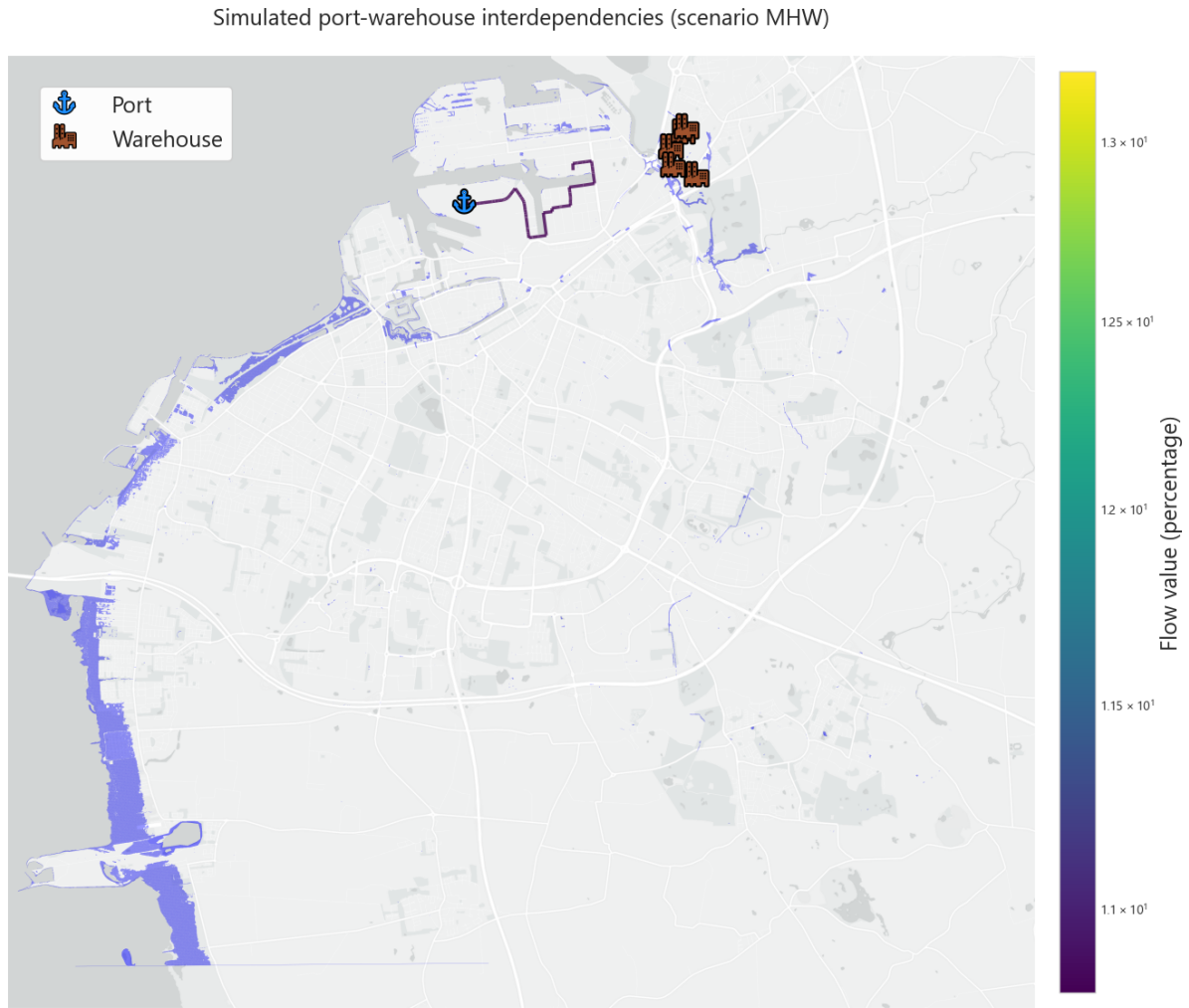


Figure C-2: Simulated port-warehouse interdependencies for the MHW scenario.

Automated Impact Analysis A severe flood scenario (MHW) in Malmö by 2125 could lead to an 88% unmet demand for port accessibility, severely disrupting warehouse access and supply chain operations.

The infrastructure interdependency model for Malmö reveals a critical vulnerability in the port system under the MHW (Mean High Water) hazard scenario, where an 88% unmet demand for port accessibility is projected. This indicates that under extreme flood conditions, the port (PO00001) would experience a near-total disruption, effectively rendering warehouse storage inaccessible. The high unmet demand suggests a cascading failure where the port's inability to function would ripple through the supply chain, exacerbating the impact of the flood. The data underscores the necessity for robust flood mitigation strategies, particularly for coastal and drainage infrastructure, to prevent such severe disruptions. The analysis is constrained to the provided dataset, which focuses on the top 1 percentile of unmet demand under the MHW scenario, highlighting the port as a critical bottleneck in the city's resilience framework.

Table C-1: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	88	Malmö Port	Port

Table C-2: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00756	12	nan	nan
PO00757	12	nan	nan
PO00758	12	nan	nan
PO00760	12	nan	nan
PO00761	12	nan	nan

1.3 Scenario: EV

Simulated port-warehouse interdependencies (scenario EV)

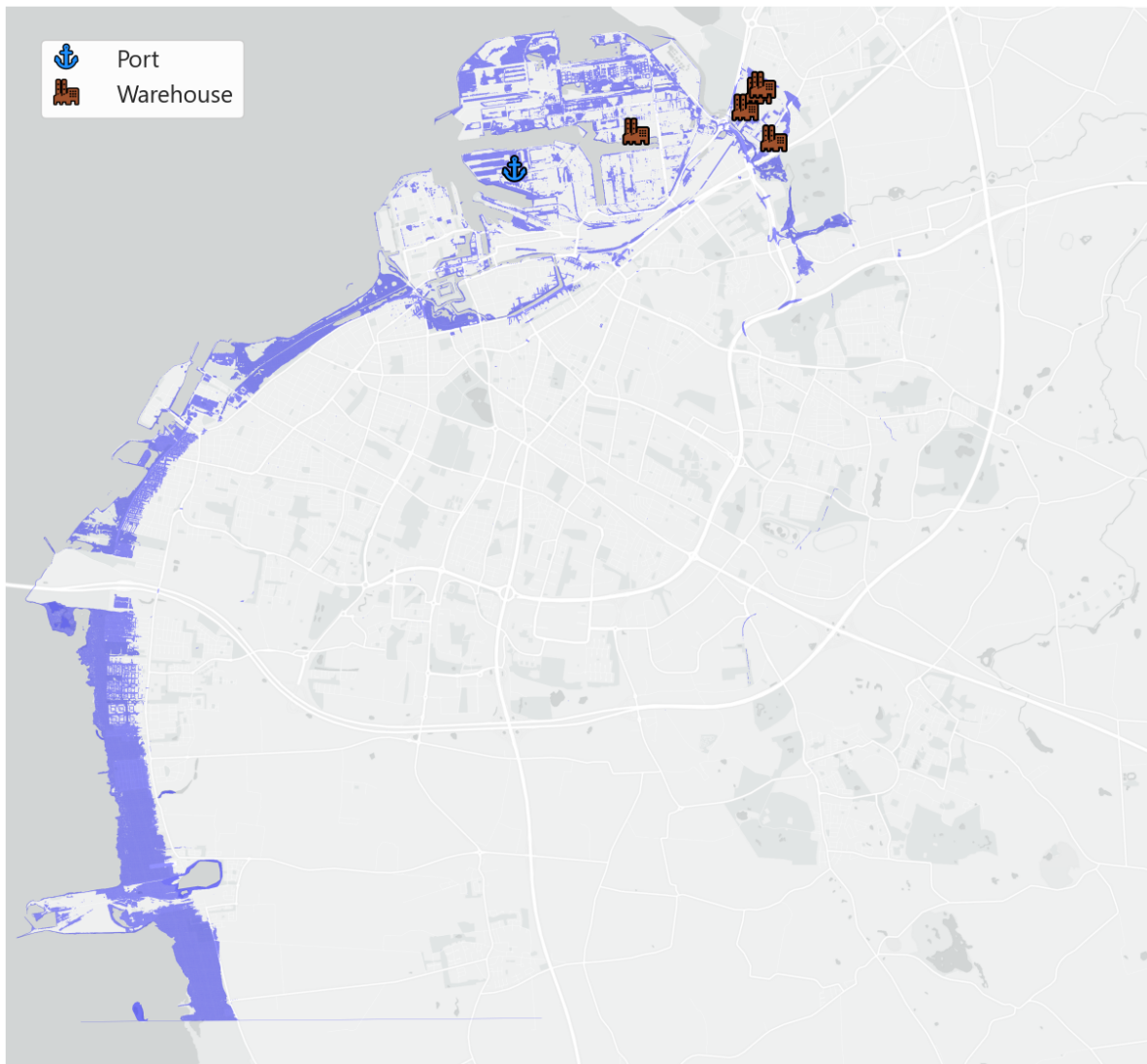


Figure C-3: Simulated port-warehouse interdependencies for the EV scenario.

Automated Impact Analysis A severe storm surge event (EV) in 2125 under RCP 8 could result in complete unmet demand (1000) for port services in Malmö, indicating total disruption of warehouse accessibility. The provided data indicates that under the EV hazard scenario—a major storm surge event—the port infrastructure (PO00001) experiences a normalized unmet demand of 1000, representing a complete failure to meet the demand for

warehouse accessibility. This suggests that the port’s critical functions, including the ability to store and distribute goods, would be entirely compromised due to flood-related disruptions. The model’s simulation of cascading failures implies that such an event would likely trigger a domino effect, where the loss of port functionality could further strain other interconnected infrastructures. The severity of this outcome underscores the vulnerability of Malmö’s portware system to extreme coastal flooding, highlighting the need for robust adaptive measures to mitigate such risks in long-term urban planning. The analysis is constrained strictly to the provided data, which focuses solely on the top 1 percentile of unmet demand within the Portware infrastructure under the EV scenario.

Table C-3: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	100	Malmö Port	Port

Table C-4: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00756	12	nan	nan
PO00757	12	nan	nan
PO00758	12	nan	nan
PO00759	12	nan	nan
PO00760	12	nan	nan

1.4 Scenario: EN

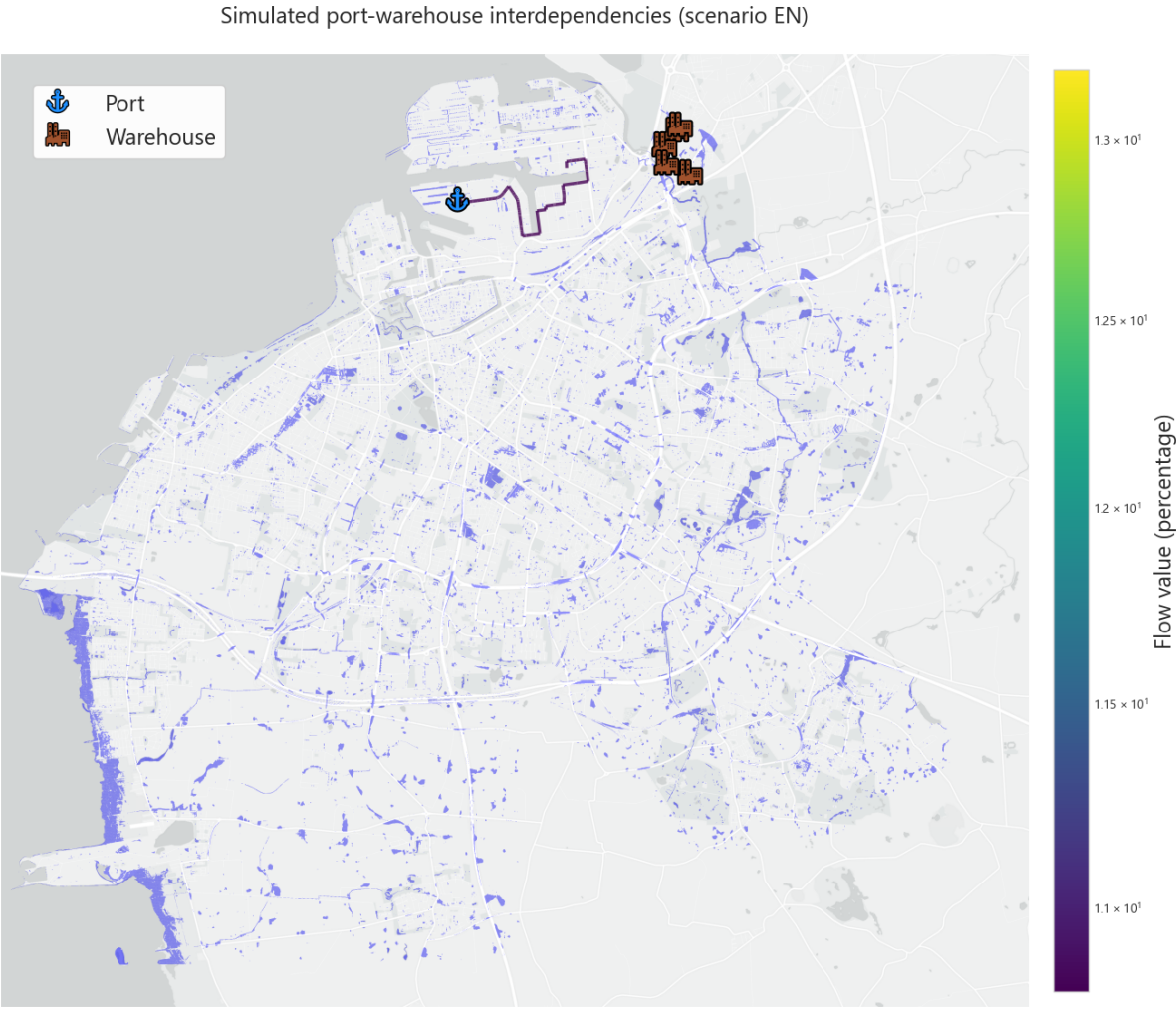


Figure C-4: Simulated port-warehouse interdependencies for the EN scenario.

Automated Impact Analysis A severe cloudburst event (EN) in Malmö by 2125 under RCP 8 could lead to a catastrophic 88% unmet demand for port services, severely disrupting warehouse accessibility. The infrastructure interdependency model for Malmö reveals a critical vulnerability in the port system (PO00001) under the EN hazard scenario, where a severe cloudburst overwhelms the city’s drainage capacity. The data indicates an 88% unmet demand for port services, meaning that only 12% of the total demand (1000 units) can be met during such an event. This disruption stems from the cascading failures triggered by the cloudburst, which likely inundates key infrastructure nodes, cutting off access to warehouses and halting critical supply chain operations. The high unmet demand suggests that the port’s reliance on interconnected systems—such as transportation networks and drainage infrastructure—exacerbates the impact of extreme weather events. Without adaptive measures, such as enhanced flood defenses or decentralized storage solutions, the port’s operational resilience will remain severely compromised under future climate scenarios.

Table C-5: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	88	Malmö Port	Port

Table C-6: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00756	12	nan	nan
PO00757	12	nan	nan
PO00758	12	nan	nan
PO00760	12	nan	nan
PO00761	12	nan	nan

2 Port-silo System

2.1 Scenario: BASELINE

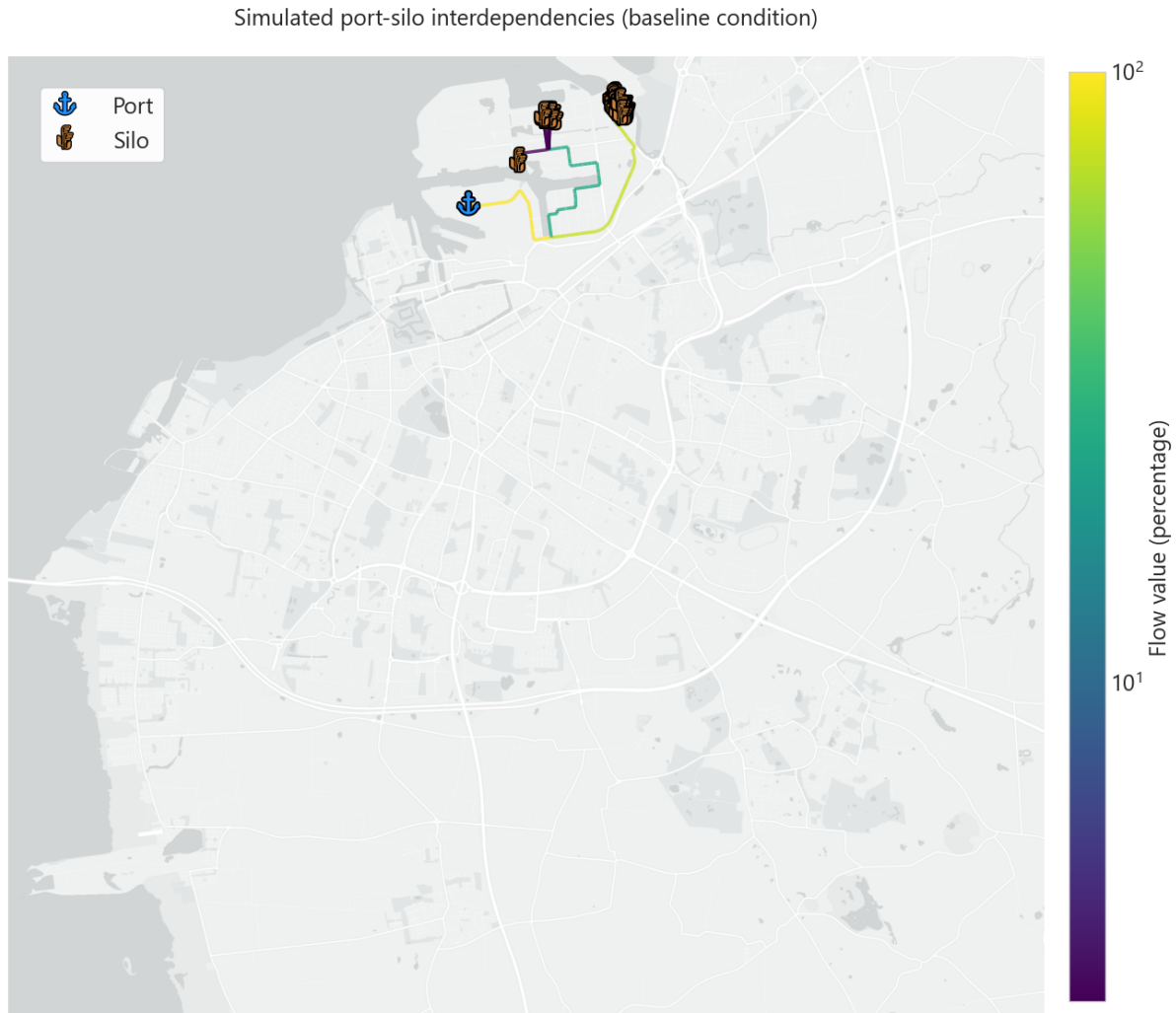


Figure C-5: Simulated port-silo interdependencies for the baseline scenario.

2.2 Scenario: MHW

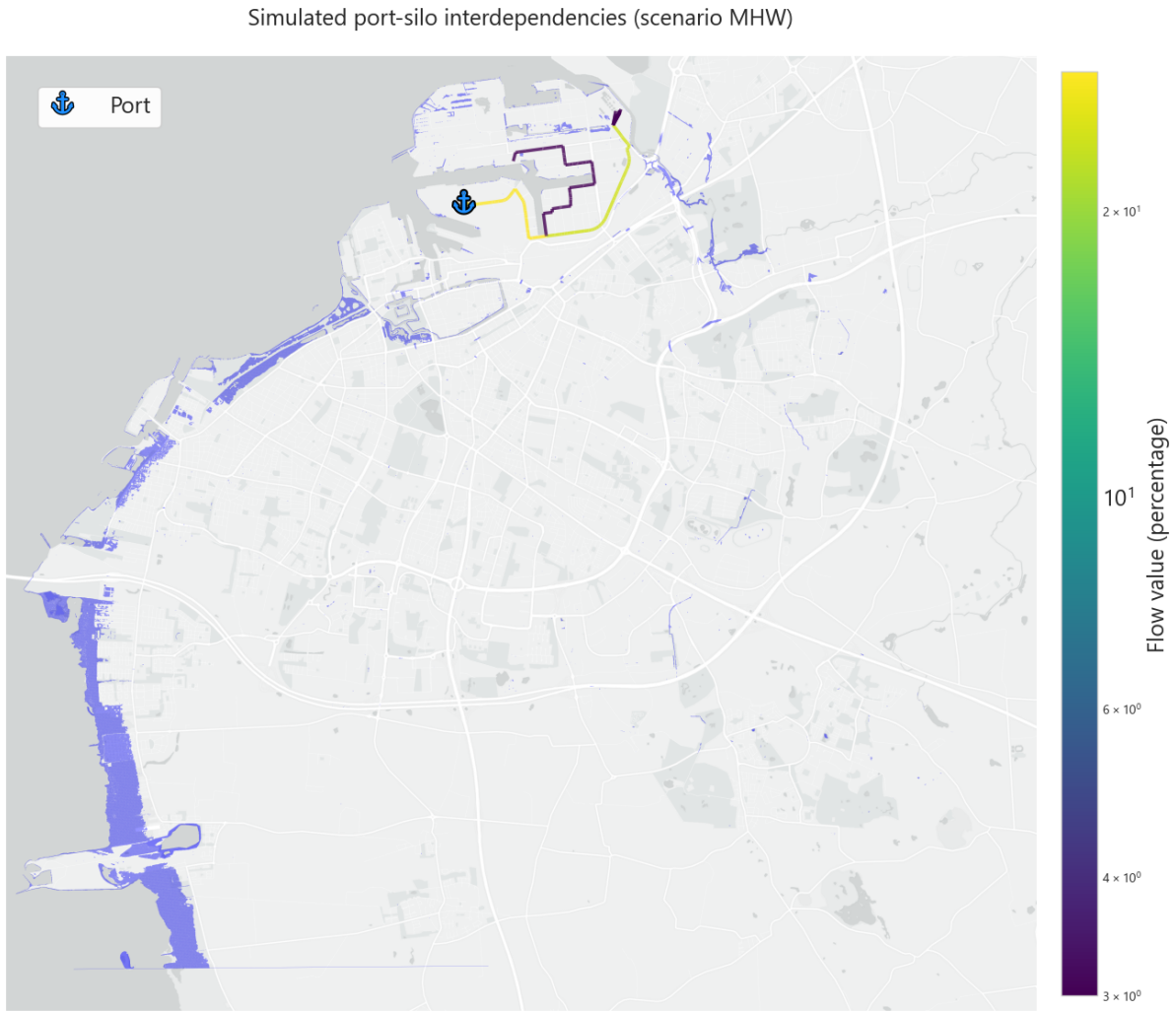


Figure C-6: Simulated port-silo interdependencies for the MHW scenario.

Automated Impact Analysis Under the MHW hazard scenario in 2125, the port silo infrastructure (PO00001) faces a catastrophic 72% unmet demand, indicating severe accessibility loss due to flood-induced disruptions. The provided data reveals a critical vulnerability in Malmö's port silo infrastructure under the MHW (Mean High Water) scenario, where a 72% unmet demand signifies a near-total disruption in service accessibility. This extreme value, positioned in the top 1 percentile of unmet demand, underscores the port silo's (PO00001) susceptibility to cascading failures triggered by combined high tide and heavy rainfall. The analysis suggests that under RCP 8 climate projections, the port's reliance on silo storage could be severely compromised, with implications for supply chain continuity and economic stability. The normalized unmet demand metric indicates that nearly three-quarters of the port's storage capacity would be inaccessible, likely due to direct flood damage or indirect infrastructure interdependencies. This finding highlights the urgent need for climate adaptation strategies, particularly in reinforcing coastal flood defenses and improving drainage systems to mitigate such extreme disruptions. The absence of other infrastructure types in the top percentile further emphasizes the port silo's singular vulnerability in this scenario.

Table C-7: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	72	Malmö Port	Port

Table C-8: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00737	4	nan	nan
PO00729	4	nan	nan
PO00730	4	nan	nan
PO00731	4	nan	nan
PO00732	4	nan	nan

2.3 Scenario: EV

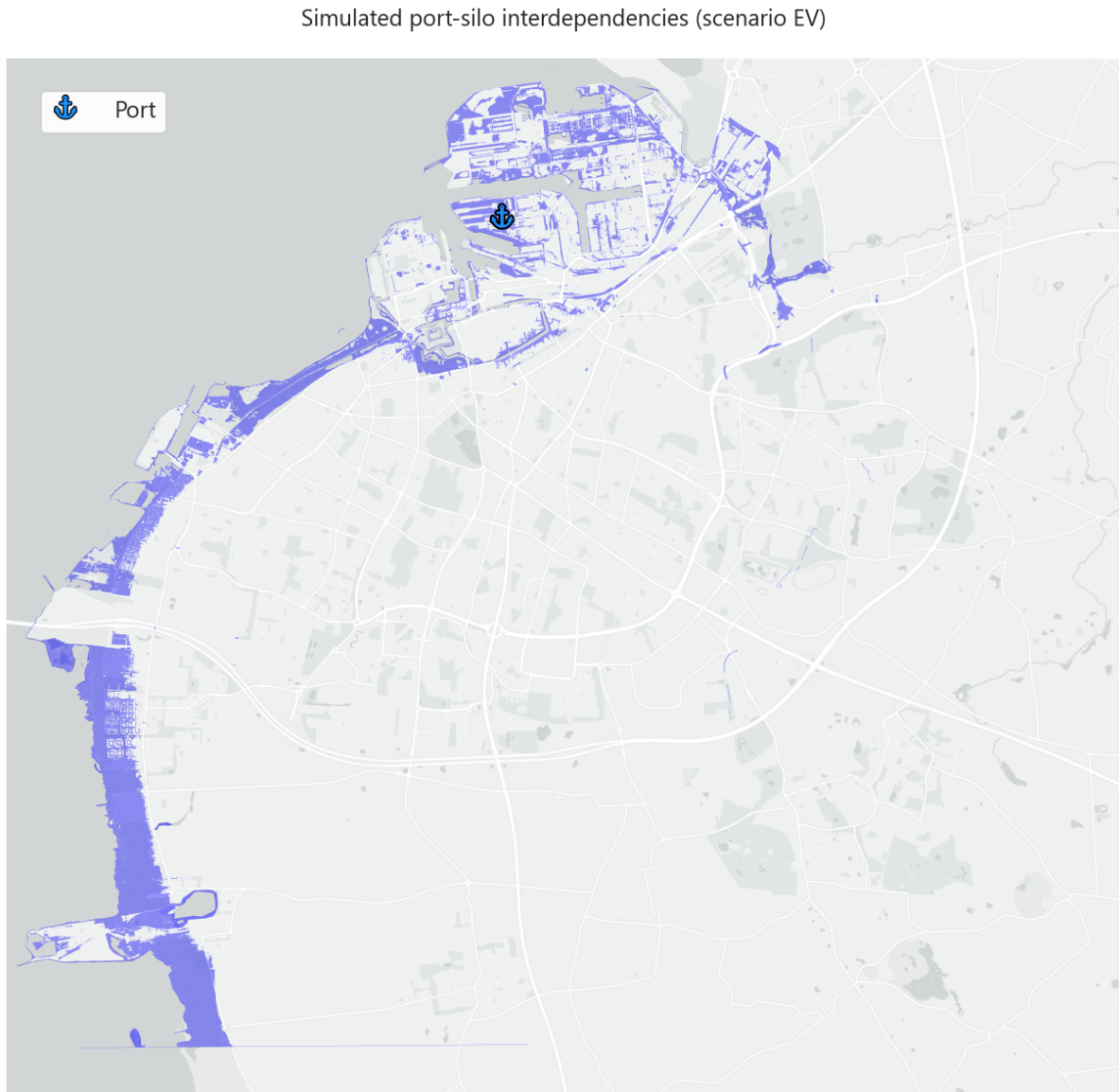


Figure C-7: Simulated port-silo interdependencies for the EV scenario.

Automated Impact Analysis During an extreme storm surge (EV) scenario in 2125, the port experiences complete loss of access to silo storage. The Portsilo infrastructure system, specifically port facility PO00001, experiences an unmet demand of 1000 during the EV hazard scenario, placing it within the top 1 percentile of impacted infrastructures. This indicates a total loss of accessibility to silo storage from this port location, as unmet demand represents the proportion of the total service demand of 1000 that cannot be met. The EV scenario, which simulates a major storm surge, highlights the vulnerability of port silo accessibility to extreme coastal flooding.

Table C-9: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	100	Malmö Port	Port

Table C-10: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00741	4	nan	nan
PO00735	4	nan	nan
PO00728	4	nan	nan
PO00740	4	nan	nan
PO00739	4	nan	nan

2.4 Scenario: EN

Simulated port-silo interdependencies (scenario EN)

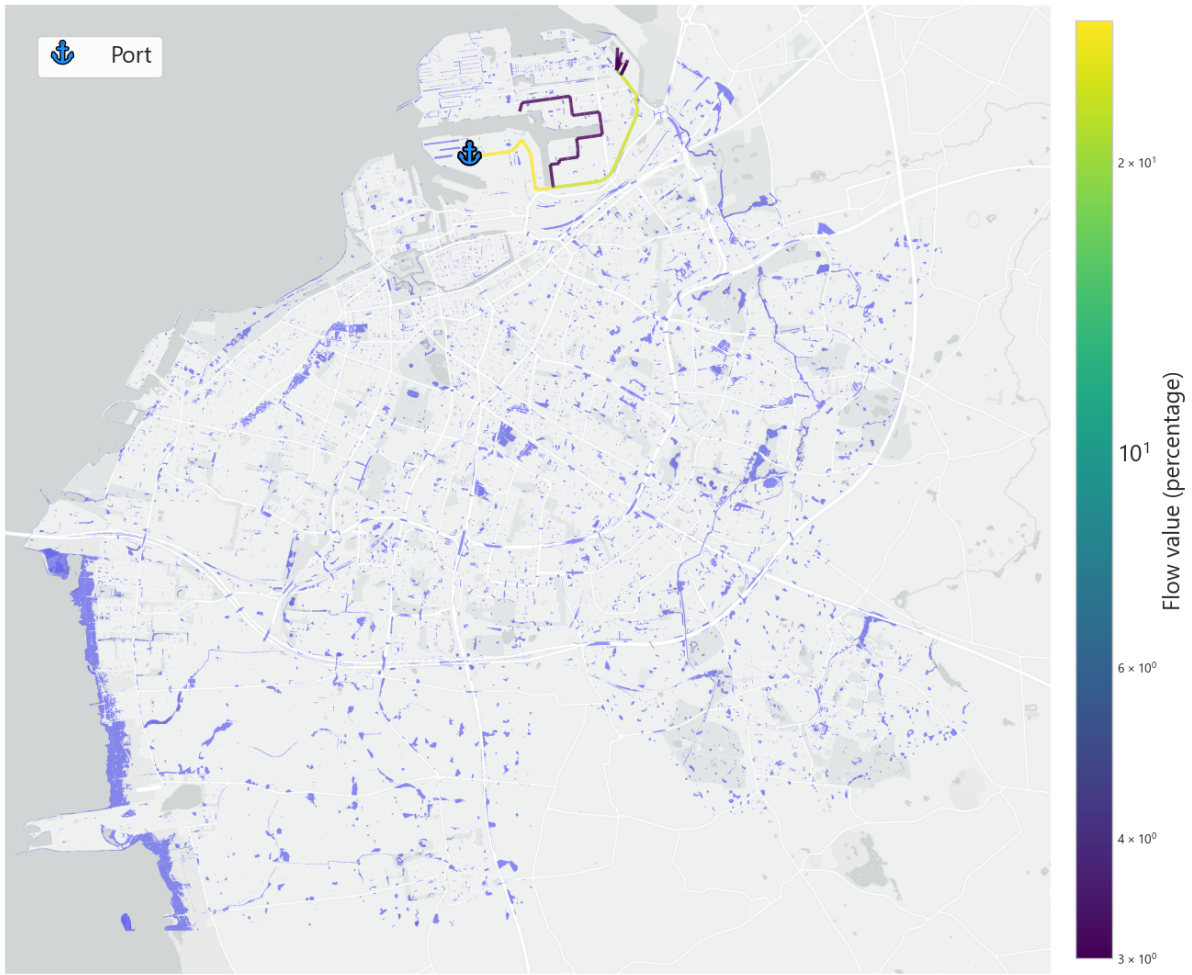


Figure C-8: Simulated port-silo interdependencies for the EN scenario.

Automated Impact Analysis During a severe cloudburst event (EN) in 2125 under RCP 8, the port (PO00001) experiences a substantial loss of silo accessibility, indicated by a high unmet demand. The analysis reveals that the most critical challenge to the port's silo accessibility (Portsilo infrastructure system) stems from an extreme cloudburst event (EN). Within the top 1 percentile of impact, the port (PO00001) demonstrates an unmet demand of 718, representing a significant service disruption for the port under the EN scenario. This unmet demand directly correlates with a loss of access to silo storage.

Table C-11: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	72	Malmö Port	Port

Table C-12: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00738	4	nan	nan
PO00729	4	nan	nan
PO00730	4	nan	nan
PO00731	4	nan	nan
PO00732	4	nan	nan

3 Port-office System

3.1 Scenario: BASELINE

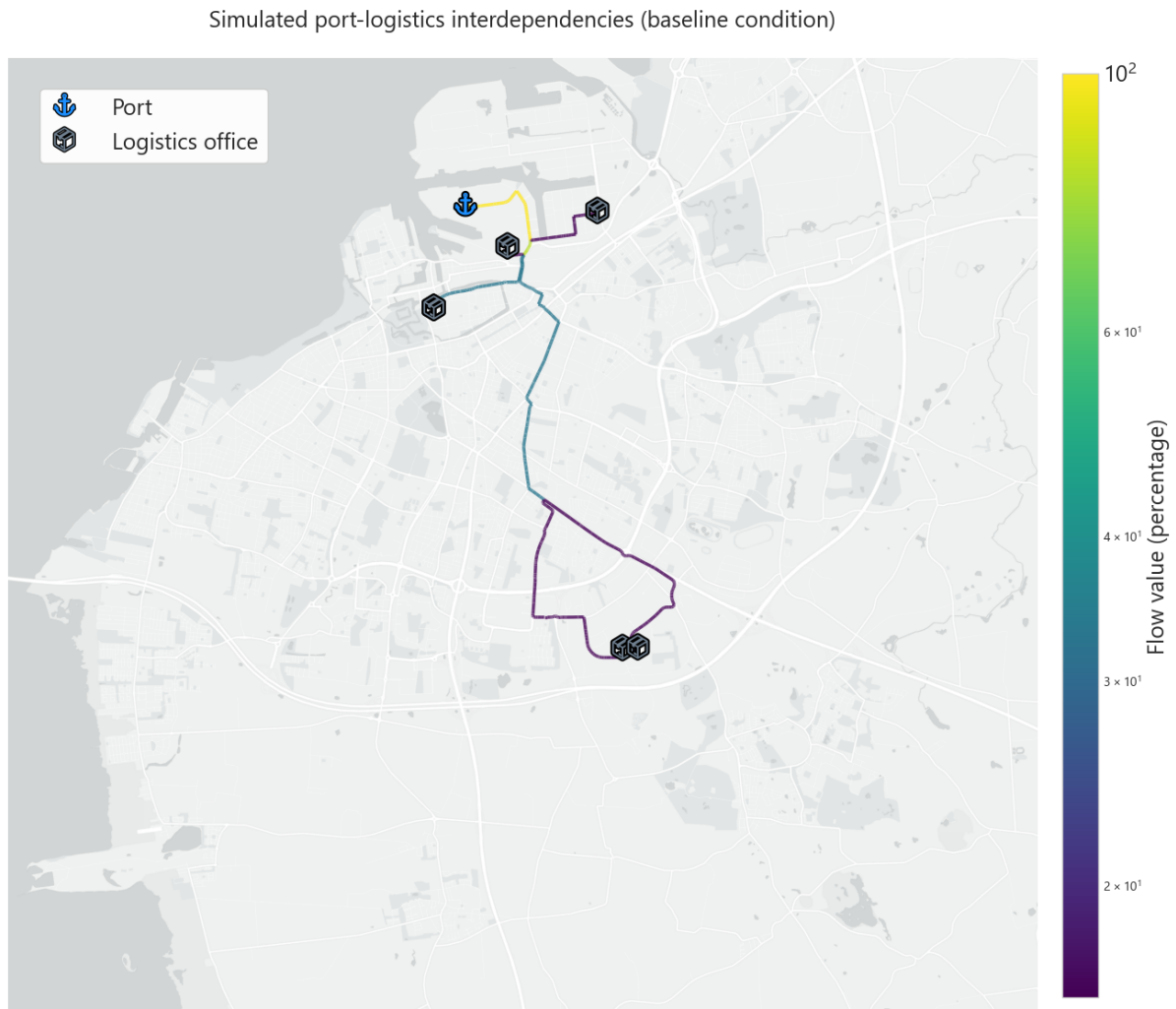


Figure C-9: Simulated port-office interdependencies for the baseline scenario.

3.2 Scenario: MHW

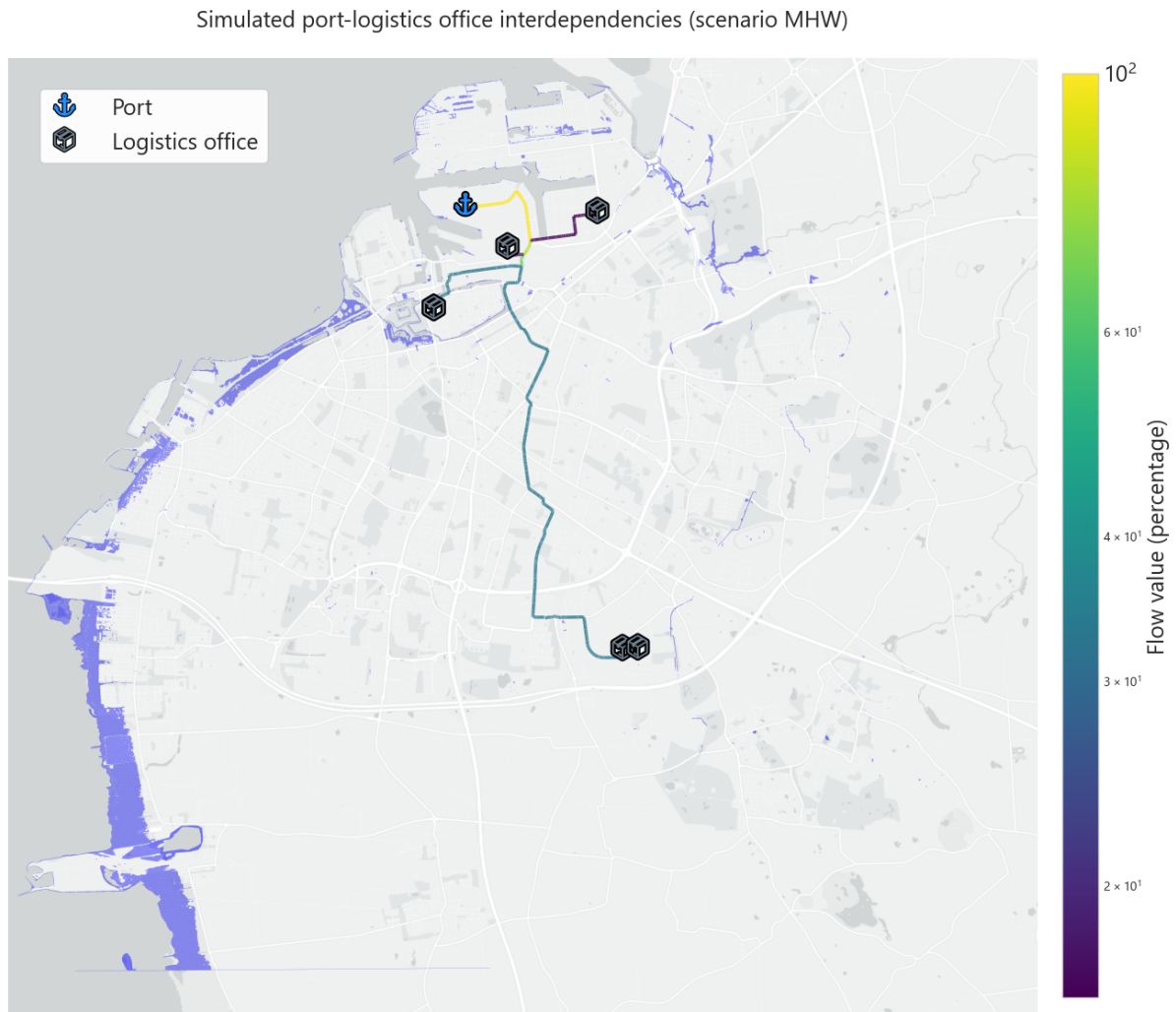


Figure C-10: Simulated port-office interdependencies for the MHW scenario.

No significant unmet demand detected for this scenario.

3.3 Scenario: EV

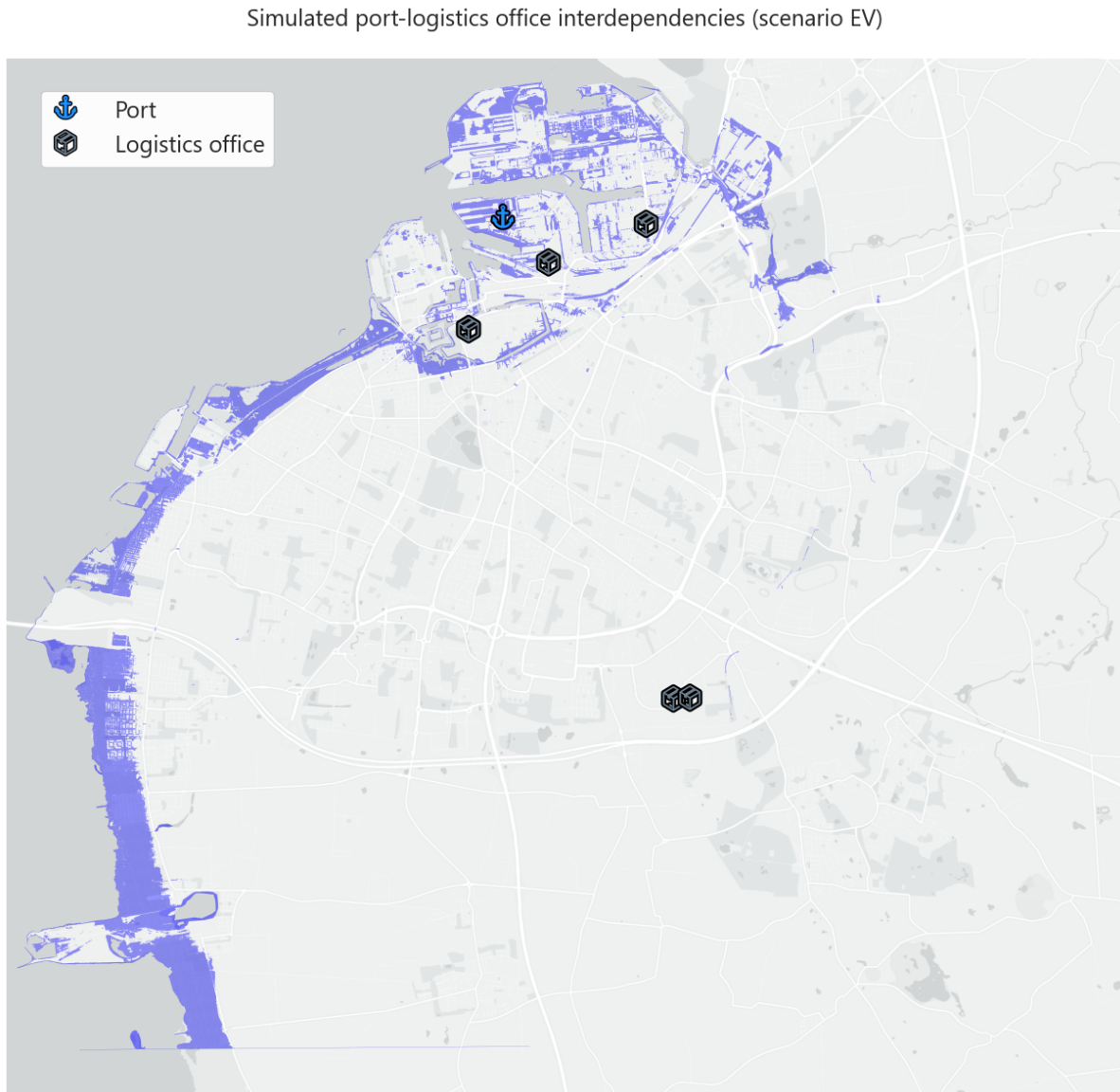


Figure C-11: Simulated port-office interdependencies for the EV scenario.

Automated Impact Analysis Under the extreme storm surge scenario (EV) in 2125, the port office (PO00001) faces a complete unmet demand (1000 normalized units), indicating a total disruption to logistics operations due to flood-related infrastructure failures.

The data reveals that under the EV hazard scenario—a major storm surge event—the port office (PO00001) experiences a 100% unmet demand, signifying a complete inability to meet operational requirements. This disruption is likely a result of cascading failures triggered by the storm surge, which overwhelms coastal defenses and disrupts critical infrastructure dependencies. The port's logistics offices, which rely on uninterrupted access to the port, are rendered inoperable, highlighting the vulnerability of Malmö's port infrastructure under extreme climate conditions. The normalized demand value of 1000 underscores the severity of the impact, as it represents the maximum possible disruption within the modeled system. This finding emphasizes the need for robust flood mitigation strategies and resilient infrastructure design to safeguard logistics operations in future climate scenarios.

Table C-13: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	100	Malmö Port	Port

Table C-14: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00003	17	Tolvans flytt & städ	Logistics office
PO00004	17	Schenker Dedicated Services	Logistics office
PO00005	17	Wramfelt Mritime	Logistics office
PO00006	17	S. Ingstad & Co	Logistics office
PO00007	17	No Name	Logistics office

3.4 Scenario: EN

Simulated port-logistics office interdependencies (scenario EN)

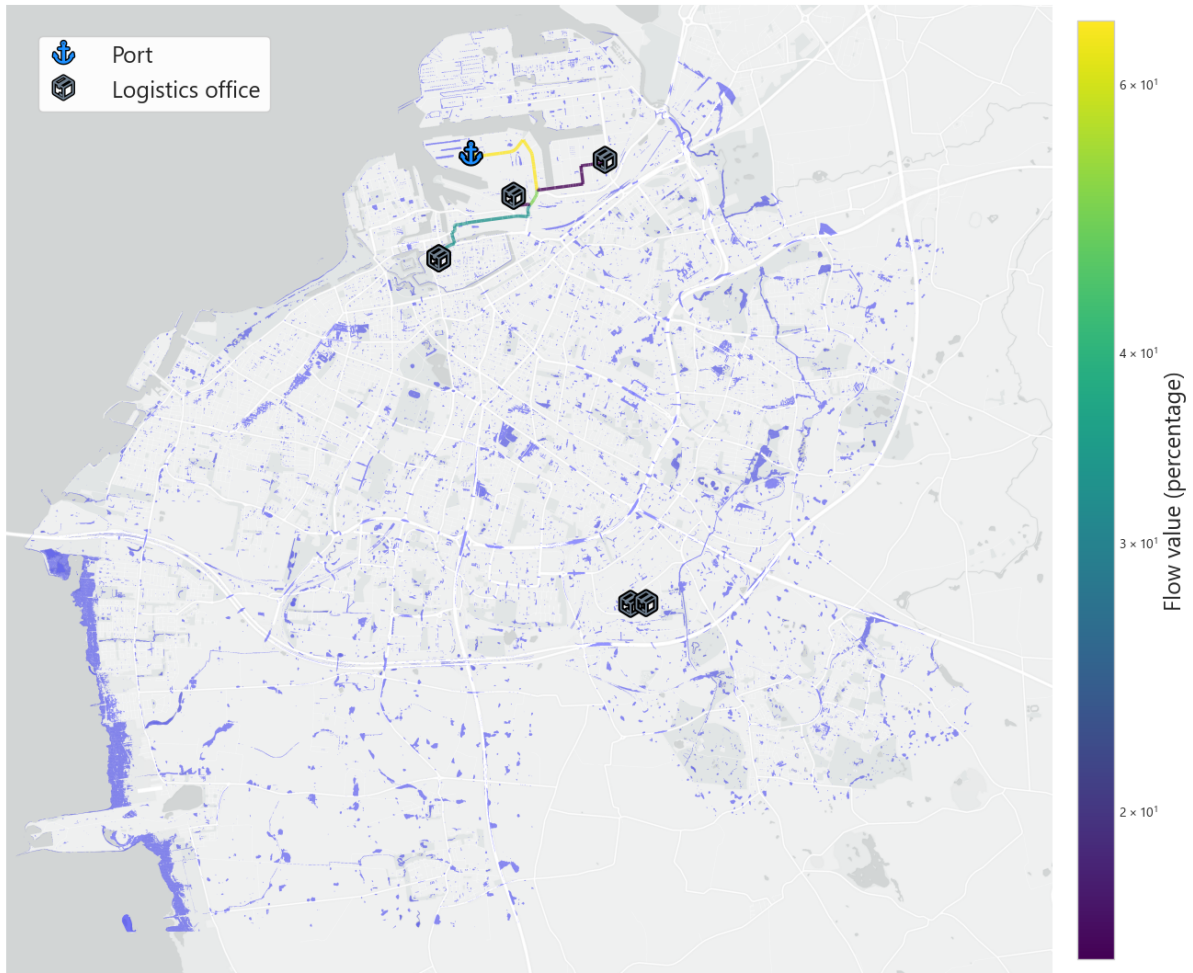


Figure C-12: Simulated port-office interdependencies for the EN scenario.

Automated Impact Analysis A severe cloudburst event (EN) is projected to significantly impact the accessibility of logistics offices to the port, with one port logistics office (PO00001) experiencing a normalized unmet

demand of 331 in the top 1 percentile of impacted infrastructures.

Under the severe cloudburst (EN) scenario in the year 2125, the "Portoffice" infrastructure system experiences substantial disruption to logistical operations. Specifically, port logistics office PO00001 registers an unmet demand of 331, placing it in the top 1 percentile of affected infrastructures. This high unmet demand indicates a severe limitation in the ability of this logistics office to access the port and perform its duties. The disruption suggests significant impediments to port accessibility due to the cloudburst event.

Table C-15: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	33	Malmö Port	Port

Table C-16: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00007	17	No Name	Logistics office
PO00002	16	FedEx Express	Logistics office

4 Port-tank System

4.1 Scenario: BASELINE

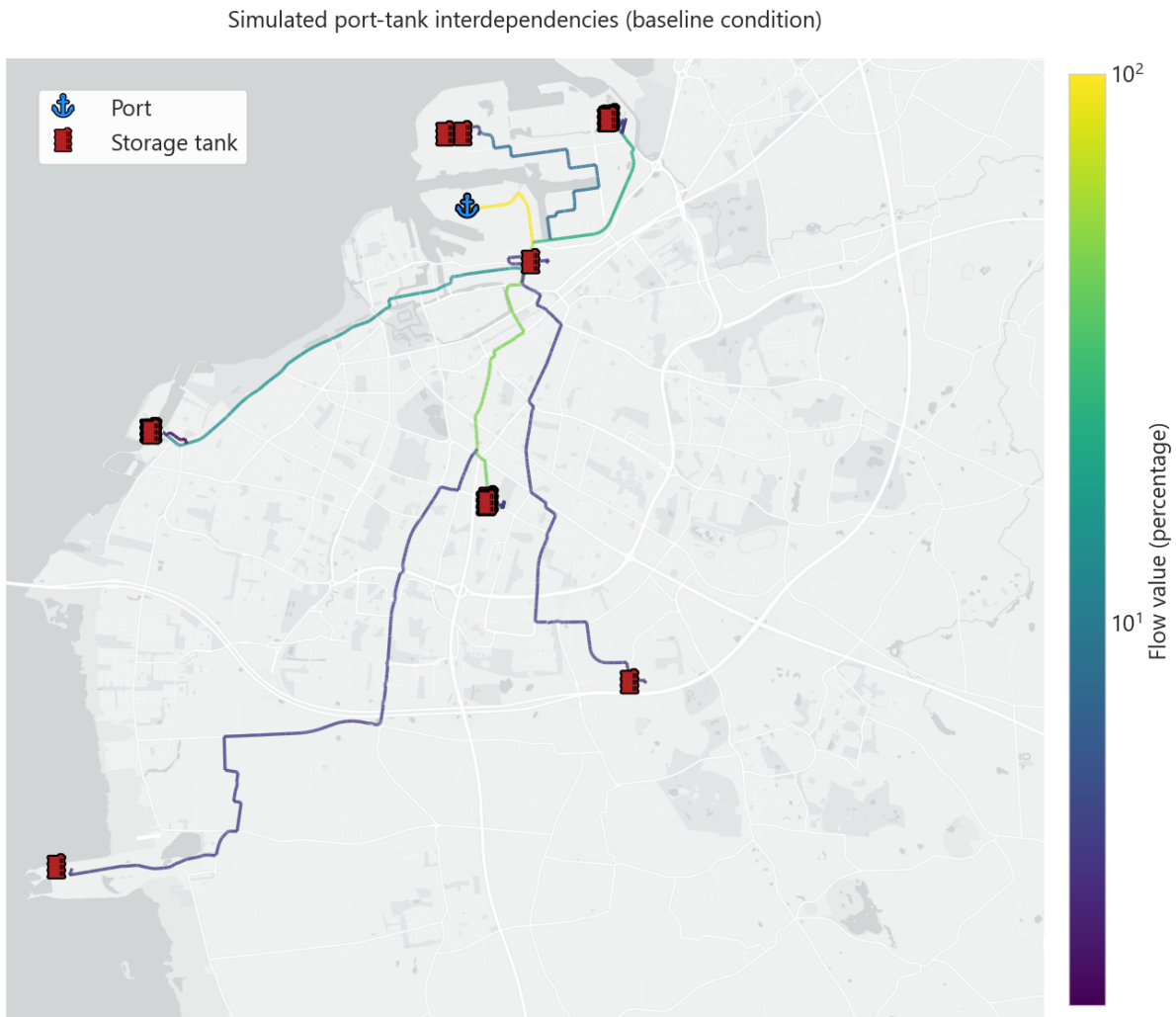


Figure C-13: Simulated port-tank interdependencies for the baseline scenario.

4.2 Scenario: MHW

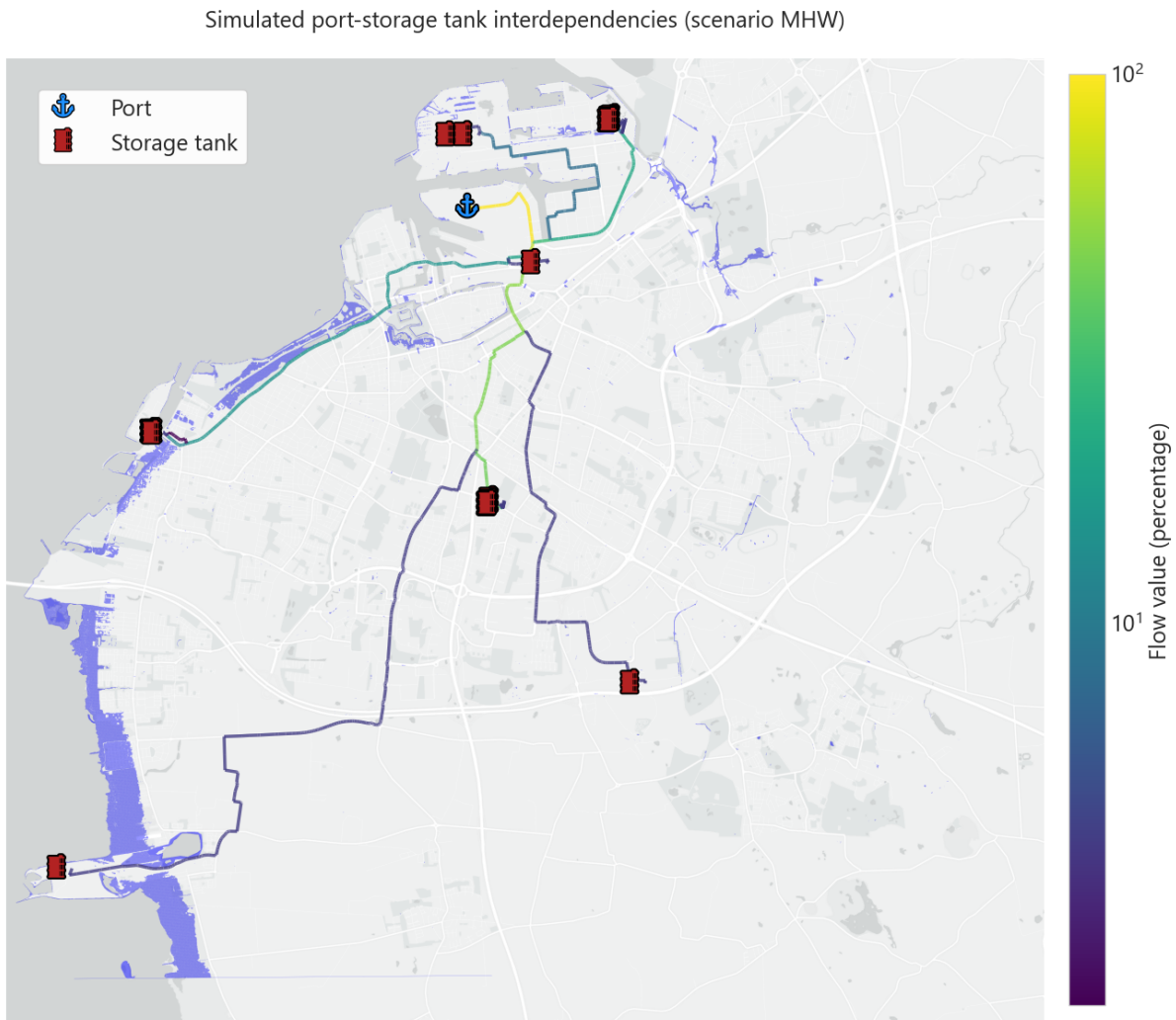


Figure C-14: Simulated port-tank interdependencies for the MHW scenario.

No significant unmet demand detected for this scenario.

4.3 Scenario: EV

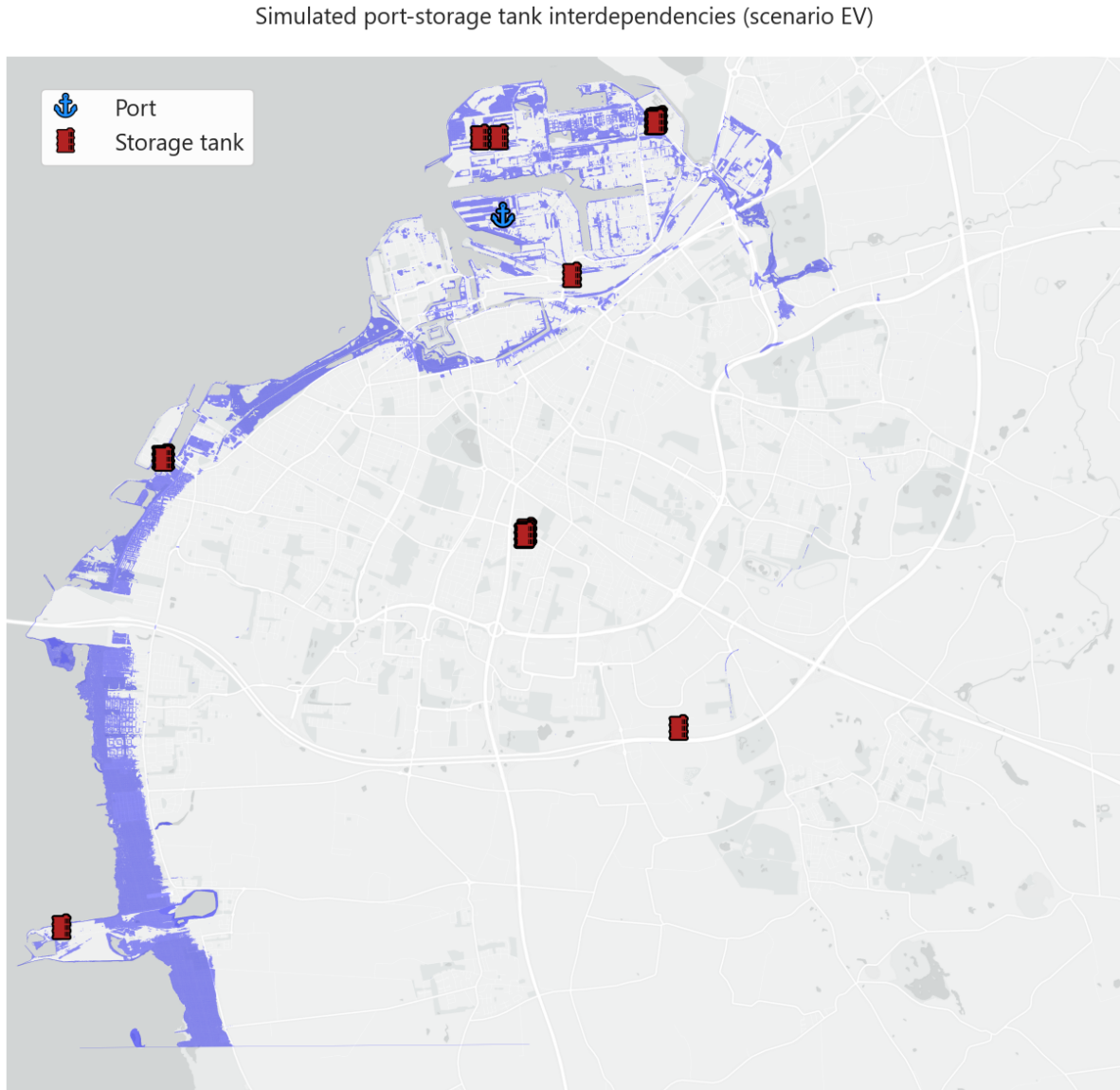


Figure C-15: Simulated port-tank interdependencies for the EV scenario.

Automated Impact Analysis Under the extreme storm surge scenario (EV) in 2125, the port infrastructure (PO00001) faces a complete loss of fuel storage accessibility, with unmet demand reaching 1000 (normalized), indicating total disruption.

The analysis reveals that the port infrastructure (PO00001) is critically vulnerable to severe storm surge events (EV) under the RCP 8 climate scenario by 2125. The normalized unmet demand of 1000 signifies that the port's fuel storage tanks become entirely inaccessible, likely due to cascading failures triggered by coastal flooding. This disruption implies a total loss of fuel supply to the port, which could have cascading economic and logistical consequences for Malmö's critical operations. The data underscores the need for robust flood mitigation and adaptive infrastructure strategies to safeguard port resilience against extreme weather events in the long-term future.

Table C-17: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	100	Malmö Port	Port

Table C-18: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00705	4	nan	nan
PO00706	4	nan	nan
PO00707	4	nan	nan
PO00708	4	nan	nan
PO00709	4	nan	nan

4.4 Scenario: EN

Simulated port-storage tank interdependencies (scenario EN)

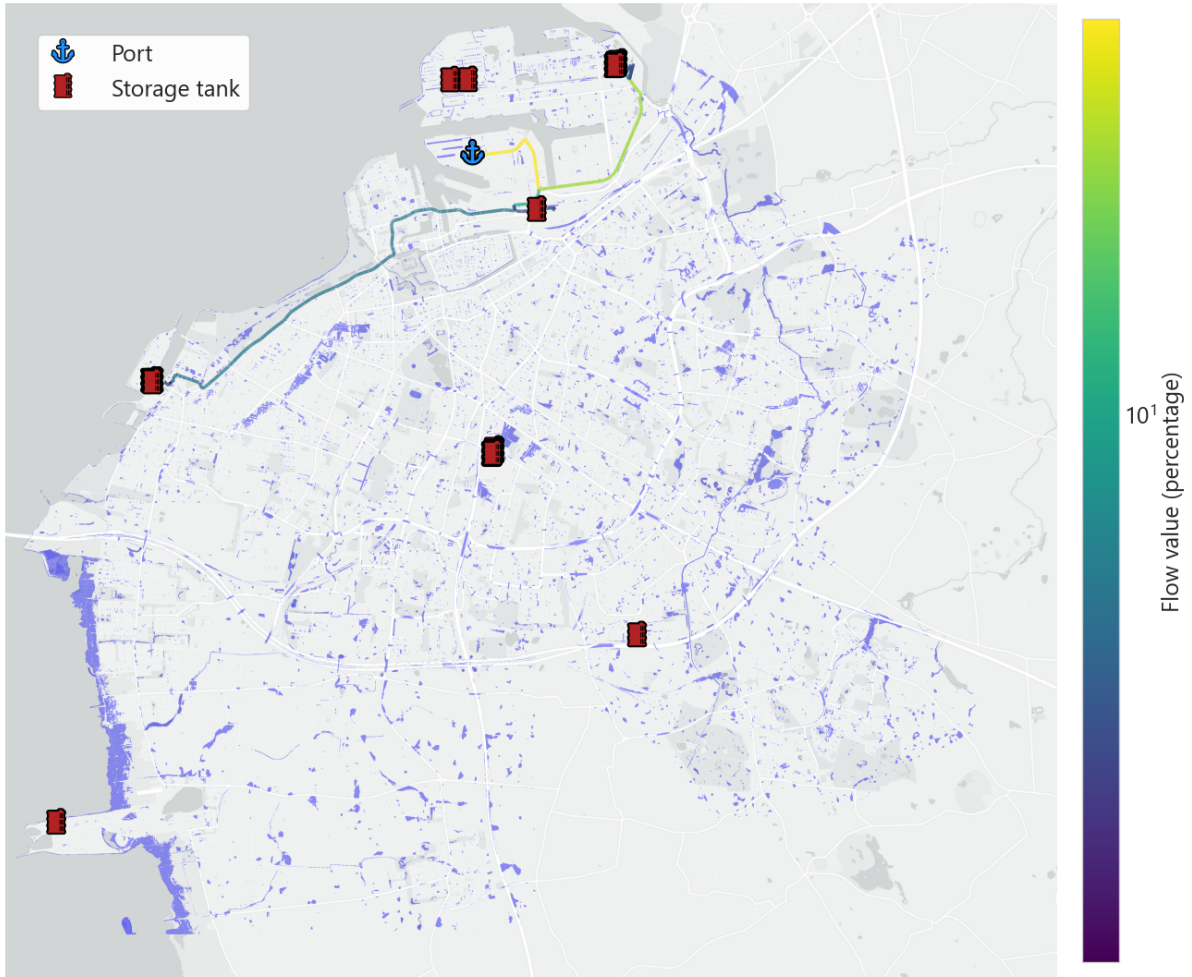


Figure C-16: Simulated port-tank interdependencies for the EN scenario.

Automated Impact Analysis Under the severe cloudburst scenario (EN) in 2125, the port infrastructure (PO00001) faces a critical unmet demand of 679 normalized units, indicating a severe disruption to fuel stor-

age accessibility.

The analysis reveals that the port infrastructure in Malmö is highly vulnerable to severe cloudburst events (EN) under the RCP 8 scenario in 2125. The unmet demand of 679 normalized units for the port (PO00001) signifies a substantial loss of accessibility to fuel storage, which could have cascading effects on the city's critical services. This disruption is likely due to the overwhelming drainage capacity exceeded by the cloudburst, leading to flooding that impedes the functionality of the port's storage facilities. The high unmet demand underscores the need for robust flood mitigation and adaptive infrastructure strategies to ensure the resilience of the port's operations in the face of extreme weather events. The data strictly reflects the top 1 percentile of unmet demand, highlighting the port as a critical bottleneck in the city's infrastructure network under this hazard scenario.

Table C-19: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	68	Malmö Port	Port

Table C-20: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00704	4	nan	nan
PO00705	4	nan	nan
PO00706	4	nan	nan
PO00707	4	nan	nan
PO00708	4	nan	nan

5 Port-rail System

5.1 Scenario: BASELINE



Figure C-17: Simulated port-rail interdependencies for the baseline scenario.

5.2 Scenario: MHW

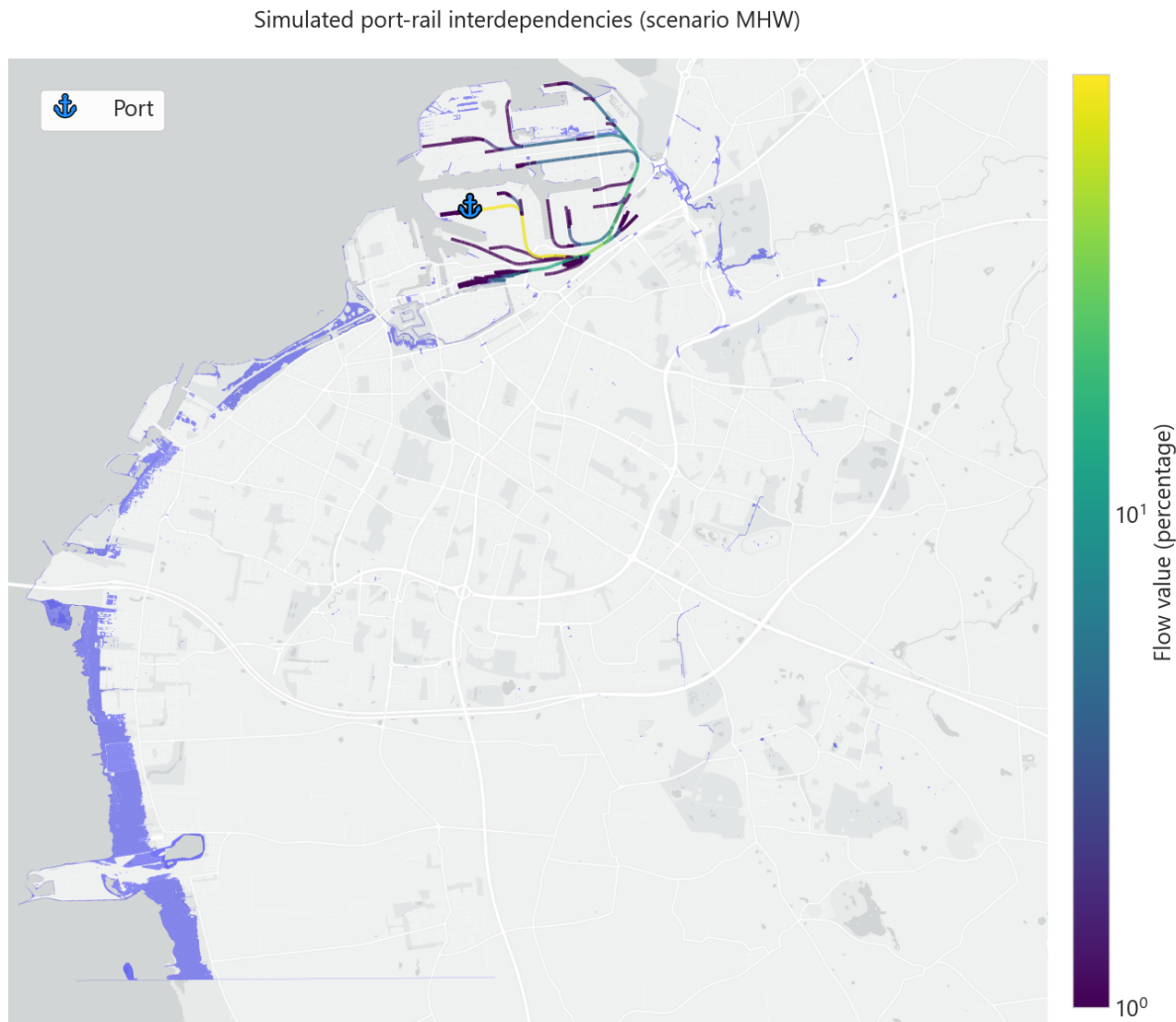


Figure C-18: Simulated port-rail interdependencies for the MHW scenario.

Automated Impact Analysis The MHW hazard scenario in 2125 results in a top 1 percentile unmet demand of 212 normalized units at the Portrail infrastructure (PO00001) in Malmö, representing a critical disruption to railway access to the port during extreme flood conditions.

The model's findings for the MHW scenario in 2125 highlight a disproportionate vulnerability of the port's railway connection under combined high-tide and heavy-rain flood conditions. The 212 normalized unmet demand at PO00001—among the highest in the top 1 percentile across all analyzed infrastructures—indicates a severe breakdown in service continuity for railway access to the port. This aligns with the cascading failure mechanism of the interdependency model, where direct flood-induced disruption to critical supply nodes (here, the port infrastructure) propagates to downstream services reliant on railway logistics. The normalization of unmet demand suggests that PO00001's railway access was impaired to a degree exceeding typical disruptions under less extreme scenarios, such as storm surges (EV) or cloudbursts (EN), which likely tested different vulnerabilities in Malmö's infrastructure. Crucially, the data underscores that even a single key node like the port can become a systemic bottleneck under MHW conditions, with unmet demand levels suggesting near-total service unavailability for a significant portion of the 1000-units total demand allocated to this supply node. This outcome emphasizes the necessity of prioritizing flood-resilient design and redundancy in port-railway infrastructure to mitigate climate-driven cascading failures.

Table C-21: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	21	Malmö Port	Port

Table C-22: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00062	1	Rail Terminal	Railway
PO00064	1	Rail Terminal	Railway
PO00071	1	Rail Terminal	Railway
PO00072	1	Rail Terminal	Railway
PO00073	1	Rail Terminal	Railway

5.3 Scenario: EV

Simulated port-rail interdependencies (scenario EV)

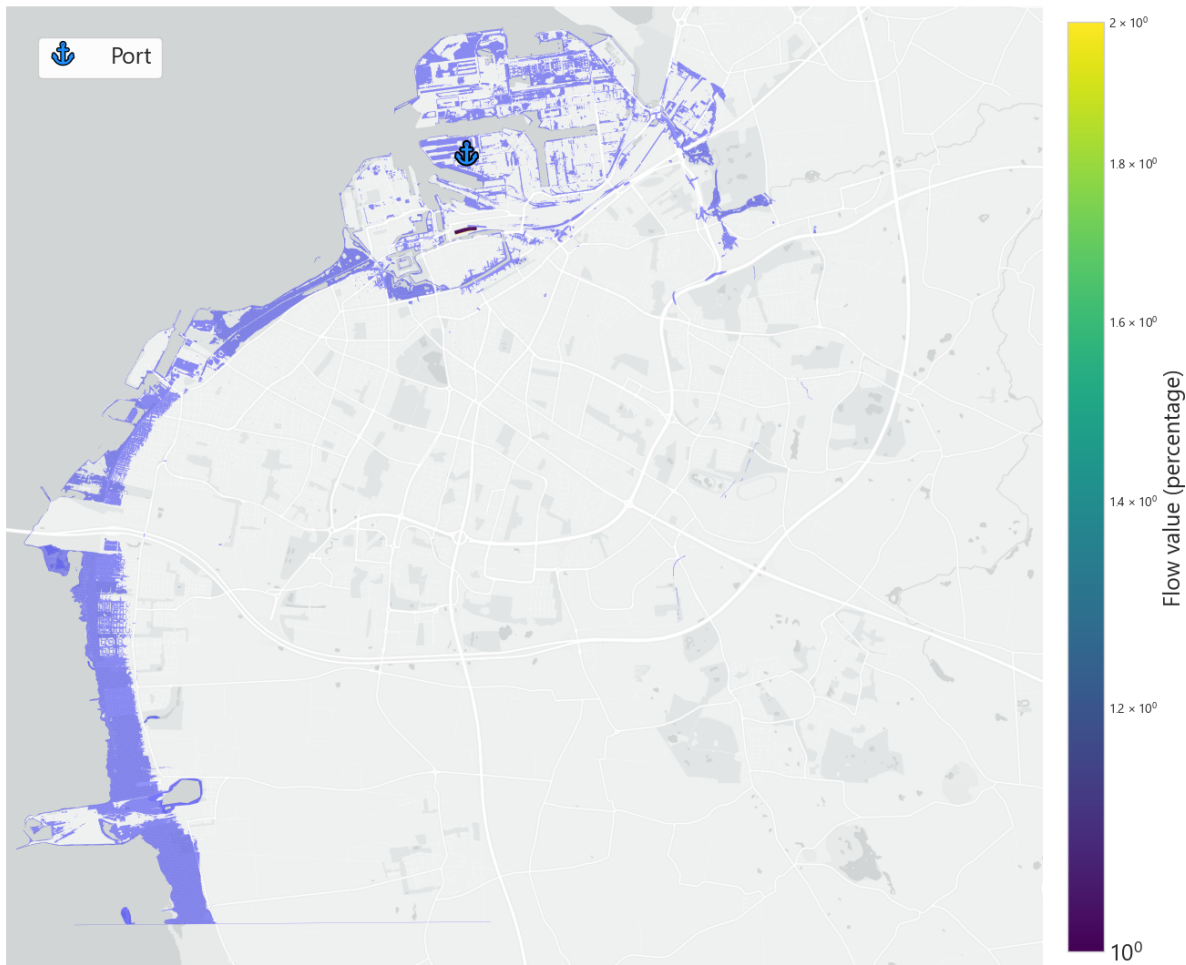


Figure C-19: Simulated port-rail interdependencies for the EV scenario.

Automated Impact Analysis Under the major storm surge (EV) scenario in 2125, the Portrail infrastructure in Malmö experiences complete service disruption, with 100% unmet demand for railway access to the port at the

top percentile of system failures.

The data reveals a critical failure state within Malmö's Portrail infrastructure during the EV hazard scenario, where flood-related disruptions lead to total unmet demand (normalized to 1000 units) at node PO00001. This node, categorized under the "Port" supply entity, reflects a cascading failure wherein flood damage directly incapacitates railway services critical to port accessibility. The even distribution of demand across supply nodes suggests a systemic collapse rather than localized issues, indicating that the entire network's capacity to meet demand is eradicated under this scenario. The model's focus on the top 1 percentile of unmet demand underscores that this outcome represents an extreme but plausible worst-case condition tied to EV-induced flooding. Given the deterministic nature of the modeled relationship between flood impact and service interruption, the 100% unmet demand at this node highlights the portrail system's vulnerability to high-magnitude storm surges compounded by climate projections under RCP 8. This findings aligns with the interference of flood-induced physical damage disrupting critical supply nodes, thereby severing access to the port via railway networks.

Table C-23: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	100	Malmö Port	Port

Table C-24: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00062	1	Rail Terminal	Railway
PO00072	1	Rail Terminal	Railway
PO00063	1	Rail Terminal	Railway
PO00080	1	Rail Terminal	Railway
PO00079	1	Rail Terminal	Railway

5.4 Scenario: EN

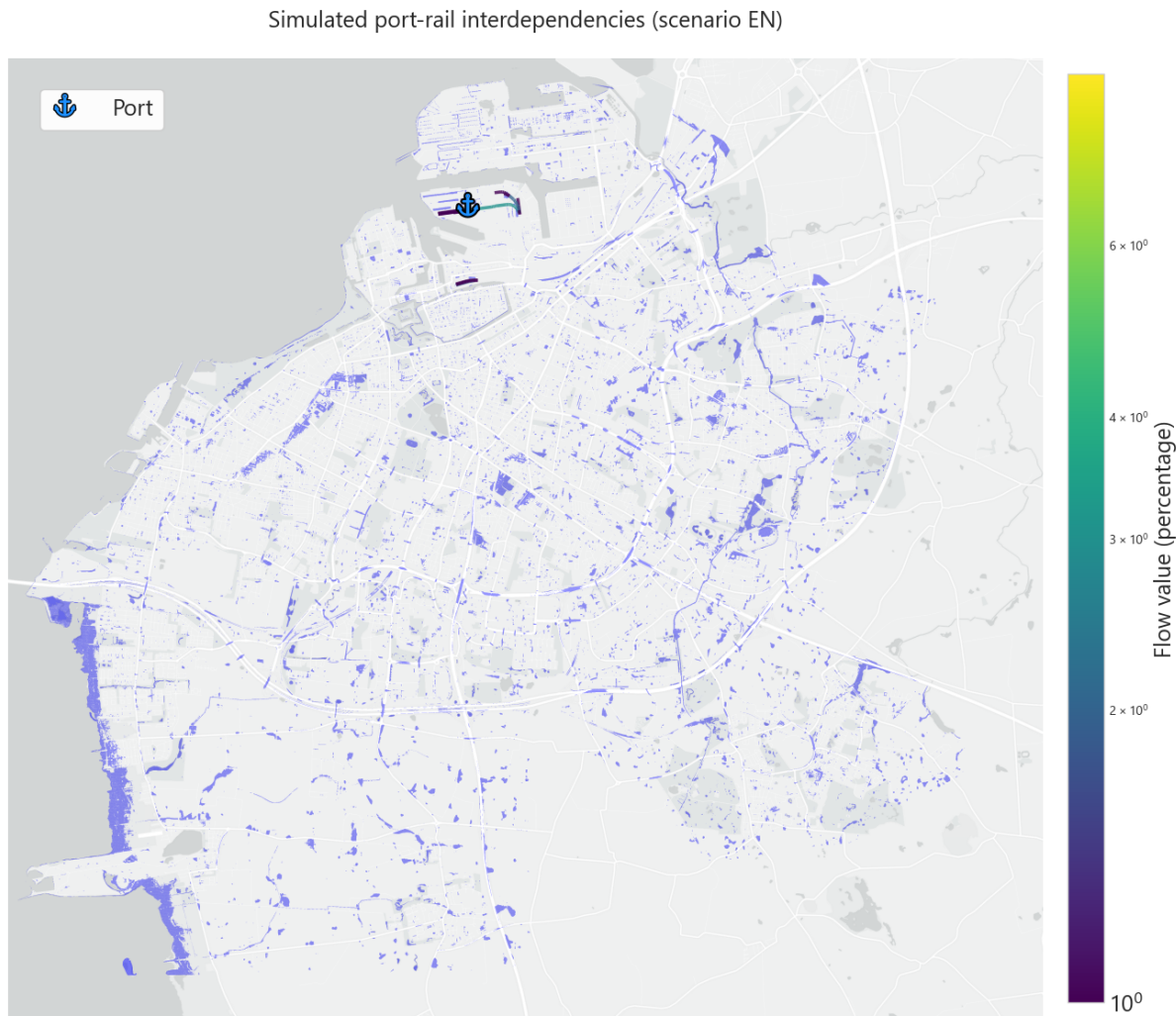


Figure C-20: Simulated port-rail interdependencies for the EN scenario.

Automated Impact Analysis The severe cloudburst scenario (EN) in 2125 causes a critical disruption in railway service accessibility to Malmö's port-rail infrastructure, resulting in 90% unmet demand at the highest-priority node (PO00001).

The data reveals that under the extreme EN scenario, the port-rail's railway system experiences a catastrophic shortfall in service delivery, with node PO00001 exhibiting 904 out of 1000 units of unmet demand. This normalized value indicates an extreme cascading failure within Malmö's infrastructure network, where the cloudburst's impact on drainage capacity directly compromises the port-rail's operational integrity. The high unmet demand ratio underscores the vulnerability of this critical service node, which serves as a primary hub for freight and passenger movement to the port. Given that unmet demand reflects the proportional inability to meet service requirements due to network disruptions, the 90% threshold suggests a near-total collapse in railway accessibility to the port under this hazard. This finding aligns with the model's focus on cascading effects, as the EN scenario—designed to test drainage vulnerabilities—exacerbates congestion or physical damage in the port-rail system, triggering surging disruptions across dependent services. The PO00001 node's prominence in the top 1 percentile further emphasizes its systemic importance, where failure risks triggering broader economic or logistical failures in Malmö's port operations. The analysis is constrained to the provided metrics, emphasizing the direct correlation between hazard severity (EN) and unmet demand in this specific infrastructure.

Table C-25: Top Infrastructure with Unmet Demand

Code	Unmet demand (%)	CI Name	CI Type
PO00001	90	Malmö Port	Port

Table C-26: Top Infrastructure with Supply Restrictions

Code	Supply loss (%)	CI Name	CI Type
PO00062	1	Rail Terminal	Railway
PO00072	1	Rail Terminal	Railway
PO00063	1	Rail Terminal	Railway
PO00080	1	Rail Terminal	Railway
PO00079	1	Rail Terminal	Railway