A Framework on Risk Mitigation for the Vulnerable Segments of a Population, under Short-Notice Disasters, Using Autonomous Vehicles

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INTRODUCTION-Problem Statement

- Newport County contains 3 coastal municipalities, Newport, Middletown and Portsmouth historically exposed to Atlantic hurricanes and tropical storms.
- High urban density, aging infrastructure, and a large elderly population increase Newport City's overall disaster vulnerability (NOAA, 2023).
- There is a need for mitigating risks to the vulnerable in Newport County.
- Newport County's diverse mix of vulnerable population makes it an ideal microcosm for developing and testing evacuation strategies for the vulnerable.

INTRODUCTION-Background

- Hazard exposure, population vulnerability, and adaptive capacity shape disaster risks.
- Vulnerable groups, including the elderly, children, the disabled, institutionalized individuals, migrants, and tourists, experience disproportionate risks due to limited coping capacity.
- Conventional evacuation strategies fail to boost the coping capacity of vulnerable groups, thus suffering worst outcomes in real-world disasters like Hurricane Katrina and Hurricane Sandy.
- Newer technologies, especially autonomous vehicles (AVs) and Edge AI, can extend resources to enact an early, coordinated evacuation of the vulnerable even under grid-down, boosting coping resources/capacity.
- Yet, these opportunities remain underexplored in emergency management research and practice.
- Memorandums of Understanding (MOUs) between Response Agencies and AV stakeholders/owners can secure transportation resources for the vulnerable toward enabling mandatory evacuation.
- At grid-down, Offline First Edge AI enables local route optimization until the intermitent synchronization of evacuation routes as and when the opportunity presents itself.

INTRODUCTION- Study Justification

Agreement between Social Science and an Early Vulnerable Evacuation Stage

Social science acknowledges that vulnerable groups are predisposed to evacuate early during disasters.

Further, the general population is predisposed to delay its evacuation to secure its livelihood/properties.

An early vulnerable evacuation supports the natural behavioral response and reduces risks for the vulnerable.

INTRODUCTION- Study Scope

At evacuation and under short-notice disaster

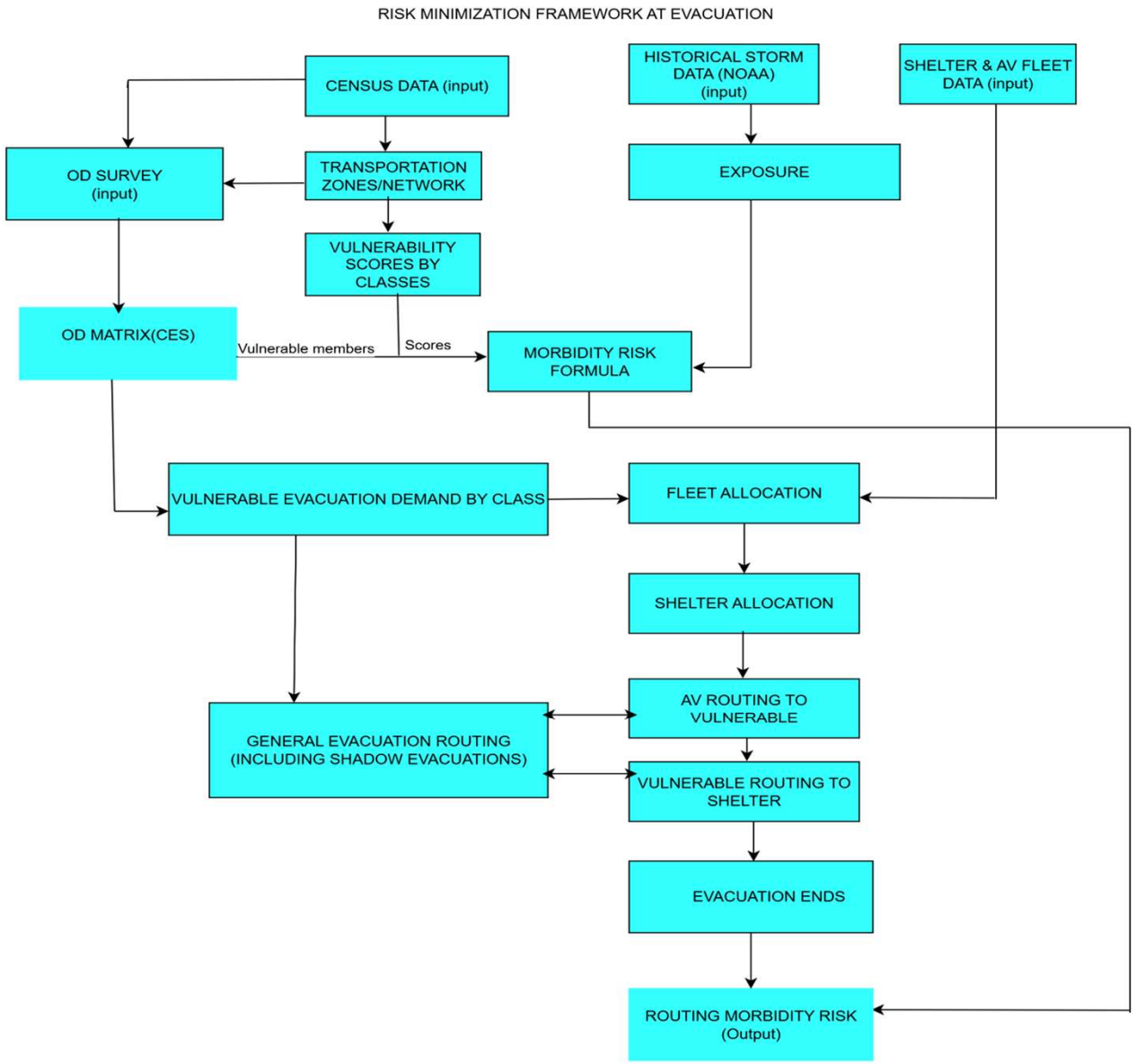
1. Propose a framework to reduce risk to the vulnerable
2. Develop recommendations for a phased, mixed-traffic strategy to transport the vulnerable

METHODOLOGY-Scenarios

- Scenario 1 assumes an early stage evacuation of the vulnerable, alongside the typical shadow evacuation, with a fleet of AVs assigned to enable this movement
- It is intended to evacuate the vulnerable according to their degree of vulnerability.
- Given an early evacuation in free flow or even overall steady state flow, fixed travel time could really be assumed.
- Otherwise, if unsteady state flows, a dynamic user optimal (DUO) plan can be enacted. While a dynamic system optimal (DSO) plan is enacted for the general population.
- Scenario 2 assumes the evacuation of the vulnerable simultaneously with the general population. A DSO plan is enacted.

METHODOLOGY FRAMEWORK

- The study models and quantifies the vulnerability of different population segments in Newport, RI, to coastal disasters.
- It further assesses and minimizes the risk faced by vulnerable groups within Newport County, RI, through their early evacuations using Autonomous Vehicles.
- Such an early wave aligns itself well with social science findings.
- It expresses risk in terms of a morbidity term expected to relate to the time spent in the evacuation zones beyond warning issuance and until reaching destination.
- The allocation and the routing of the vulnerable minimize this risk. While overall evacuation minimizes total travel time.



Vulnerable Risk-Minimization Framework at Evacuation

METHODOLOGY FRAMEWORK

- Scores derived from census/hospital/USPS data help classify the vulnerable into groups across origin zones to guide resource allocation, (AVs,) and evacuation strategies, (evacuation pick-up times,) to prioritize the most vulnerable groups at disaster evacuation.
- Survey data help determine an O-D matrix for the vulnerable groups and the general population, whether sheltering or evacuating inland.
- Hurricane exposure from NOAA's Historical Storm Dataset, archived warning issuance and evacuation end times along with death and hardship statistics help derive and calibrate morbidity risk formula.
- Early evacuation/sheltering of vulnerable groups using AVs mitigates disaster risks to these groups and overall.

Scenario Comparison/Framework Evaluation

- Percent Change/Decrease in Morbidity Risk between S1 and S2 for the vulnerable

  (MR2-MR1)/MR2

  where MR2 = morbidity before AVs intervention

  MR1 = morbidity after Avs intervention

RECOMMENDATIONS

- Memorandums of Understanding (MOUs) should be established between concerned parties to secure AVs
- The optimization models should be run to ensure the timely evacuation of all vulnerable groups per the secured fleet.
- Timeliness entails complete evacuation of the vulnerable prior to general/mass evacuation.
- Any infringement upon mass evacuation should induce an expansion in MOUs and secured AV fleet.
- The model itself should move vulnerable groups according to their morbidity risks, product of their vulnerability scores and exposure scores.

CONCLUSIONS AND FUTURE STUDIES

- Proposed framework conceptualizes an early stage evacuation of the vulnerable by degree of vulnerability anchored in disaster behavioral response.
- Anticipations are for no means of control of the proposed early stage evacuation. Natural predispositions will induce its emergence.
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- Autonomous vehicles—when deployed as part of coordinated shared fleets, integrated with informed by prioritization algorithms—offer transformative potential to mitigate evacuation risks for vulnerable segments during short-notice disasters.
- Future studies will focus on expressing and calibrating proposed models.

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