

Urban Resilience and Disaster Risk Reduction: How Serious Games Enhance Evacuation Procedures in Transport Networks

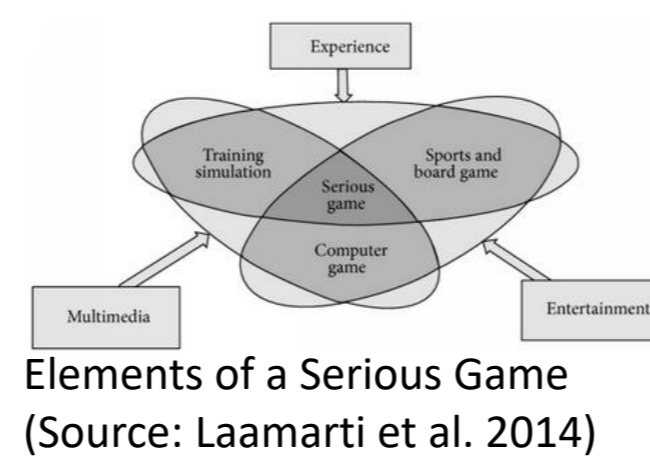
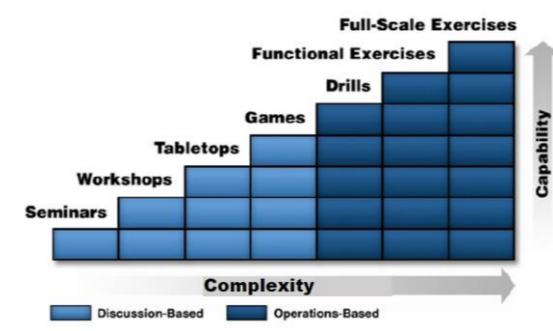
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INTRODUCTION & AIM

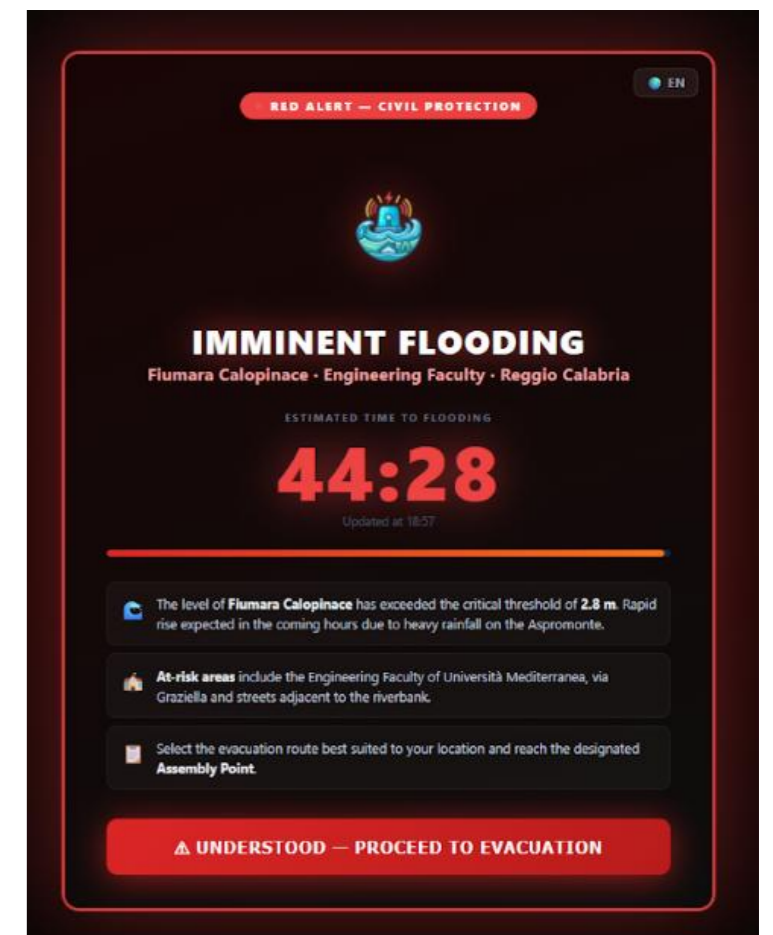
- The natural disasters that occurred in 2023 at the global level caused 86,473 deaths and affected 93.1 million people (CRED, 2024). The United Nations set out Sustainable Development Goals (SDG), related targets and indicators (United Nation. UN, 2018), particularly Indicator 1.5 “By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters”
- Understanding the disaster risk cycle and its components is essential for identifying actions that contribute to risk reduction. One of the main actions for reducing exposure is related to enhancing efficiency and effectiveness of evacuation procedures, consisting in improving mobility of people in an emergency condition.
- Exercises represent one of the main preparedness activities; exercises and training activities play a relevant role in raising awareness of people and managers about evacuation procedures, before their implementation after a disastrous event.
- Emerging ICTs play a relevant role for performing exercises (e.g. Digital Twin)
- The scientific literature highlights a limited number of studies on improving preparedness through outdoor exercises, due to the greater difficulty in replicating them
- Discussion-based game is identified as an option to improve preparedness in condition where it's difficult to reproduce real condition (FEMA, 2020)
- This study proposes a Serious Game (SG) for improving preparedness through exercises, replicating an emergency situation for an outdoor simulation



Elements of a Serious Game (Source: Laamarti et al. 2014)

RESULTS & DISCUSSION

- Case study: Reggio Calabria, a city of about 180,000 inhabitants in southern Italy. Located in an area historically at high seismic and flood risk; it was recently hit hard by the passing of Cyclone Harry
- Serious Game (SG, a_{ki}^s) designed for studying the preparedness level about evacuation procedures in a flood event with the support of a Digital Twin. The focused procedure regards road connections between the university campus and the safe zone in the historic center, proposing different road closure scenarios
- Two scenarios: scenario 0, considering available the entire road network; scenario 1, assuming the closure on the main motorway
- For each scenario and session, people are informed with network of road available. No quantitative information is available other than length of road links
- The SG is designed primarily for people loosely familiar with study area. Players can consult an interactive map with road images to help them make decisions

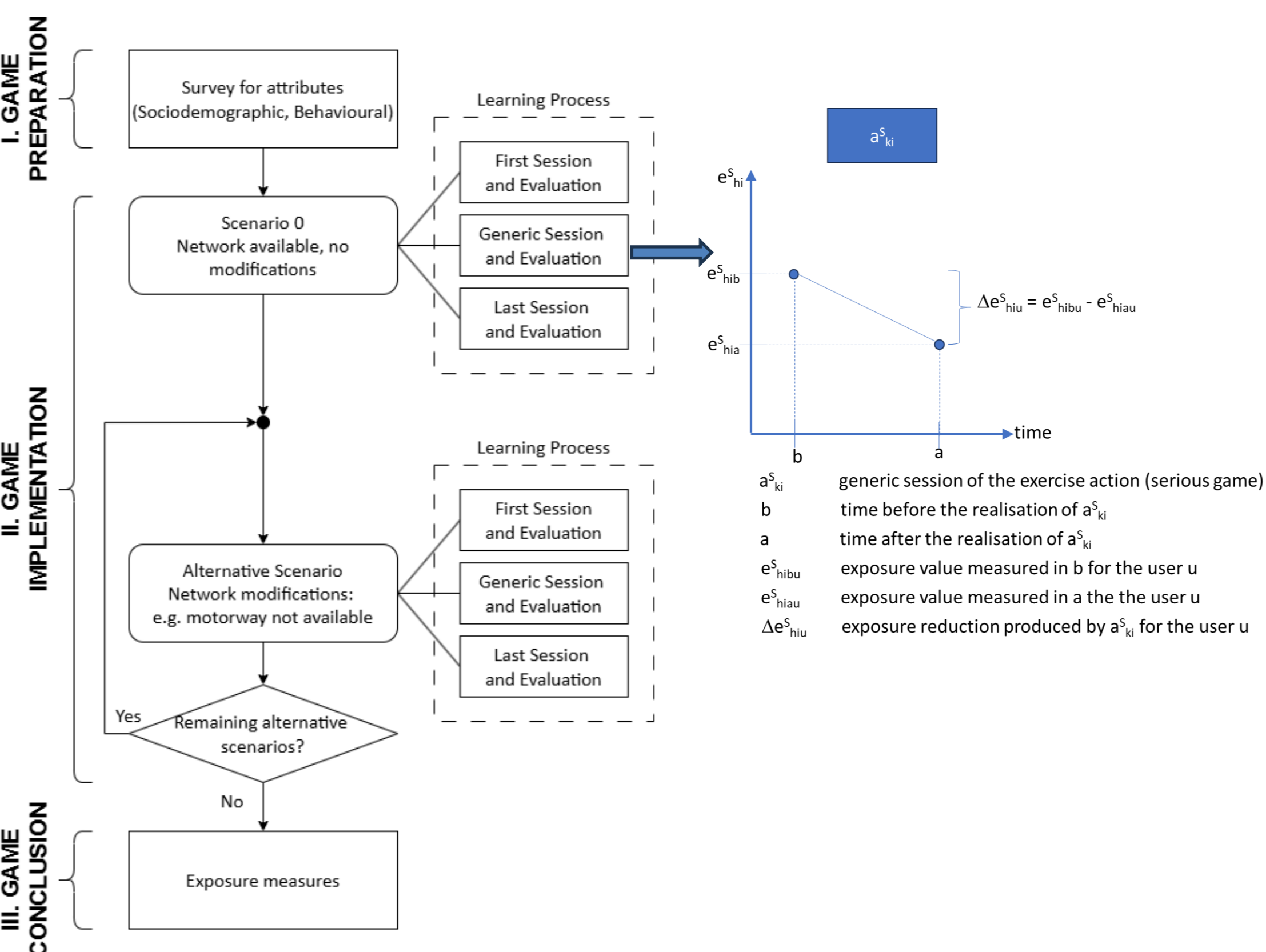


Main results

- Testing evacuation planned procedures by road network in a flood event
- Application in a pilot test, experimenting a prototype of a Digital Twin
- 11 involved users (u)
- 10 game sessions (i)
- Decrement of time taken to find the solution (e_{hi}^s , orientation time)
- Increase in preparedness level at the end of the sessions (Δe_{hi}^s , exposure reduction)

METHOD

- Main Goal: study of behaviour and orientation time of people in a certain area, in condition of interdependence of choices (Travel time are functions of flow)
- User Goal: minimize total travel time in different scenarios
- Understanding of both learning effect and preparedness in varying scenarios



CONCLUSION

This work proposes a framework for designing and implementing a Serious Game. The results of the prototype trial demonstrate the potential for measuring the effects of a training exercise to increase the preparedness of the users involved in the event of an evacuation via the road network. Conducting multiple game sessions shows a progressive reduction in orientation time and therefore exposure. The main limitation of this work is the limited sample size.

FUTURE WORK / REFERENCES

- Future research will be developed using emerging ICT tools that allow for a larger sample size and a more realistic simulated scenario.
- US Federal Emergency Management Agency. FEMA. (2020). Homeland Security Exercise and Evaluation Program (HSEEP). <https://www.fema.gov/sites/default/files/2020-04/Homeland-Security-Exercise-and-Evaluation-Program-Doctrine-2020-Revision-2-2-25.pdf>
 - United Nation. UN. (2018). SDG Indicators. Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. <https://unstats.un.org/sdgs/indicators/indicators-list/>
 - CRED. (2024). 2023, Disasters in number. <https://reliefweb.int/report/world/2023-disasters-numbers>
 - Rindone, C., & Russo, A. (2025). Disaster Risk Reduction in a Manhattan-Type Road Network: A Framework for Serious Game Activities for Evacuation. *Sustainability*, 17(14), 6326.
 - Laamarti, F., Eid, M., & El Saddik, A. (2014). An overview of serious games. *International Journal of Computer Games Technology*, 2014(1), 358152.

This class of SGs combines Transport Risk Analysis (TRA), Transport System Models (TSMs), and emerging Information and Communication Technology (e-ICT) to reproduce, in a virtual environment, a transport system under evacuation conditions. There is the need to verify whether the learning effect, under the conditions studied, determines a progressive improvement in a quantitative measure, e.g. orientation time, or the time to individuate an evacuation path on a road network. The reduction of this time produce benefits in terms of exposure reduction.