Advanced Risk Analysis for Transportation Infrastructure Systems using SCRAM++

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Introduction

- **Probabilistic Risk Analysis (PRA)** is a methodology to estimate the likelihood and consequences of potential events or failures in a system. Figure 1 shows the components of PRA

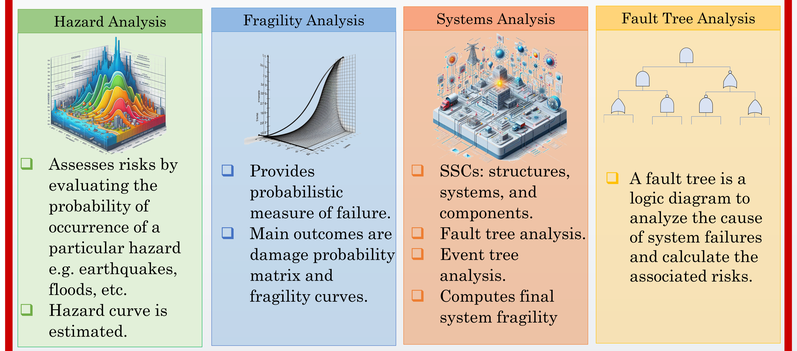


Figure 1. Components of PRA

Fault Tree Analysis (FTA)

- FTA is a top-down, deductive failure analysis method used to identify the root causes of system failures.
- In FTA, a fault tree visually maps out the logical relationships between system component failures and their combined impact on the overall system.

FTA Algorithms

MOCUS (Method of Obtaining Cut Sets)

ZBDD (Zero-Suppressed Binary Decision Diagrams)

BDD (Binary Decision Diagrams)

CTT (Compressed Truth Table)

FTA in Transportation Infrastructure

- Transportation systems, including railways, highways, and intermodal networks, are complex and rely on numerous interdependent components.
- Failures in any part of the system—bridges, tracks, traffic management systems, or signaling equipment—can lead to significant disruptions or accidents
- By modeling these transportation systems using fault trees, engineers can predict how component failures impact the overall infrastructure, allowing for proactive mitigation

SCRAM++ Software Framework

SCRAM++ is a powerful, unified platform designed to improve PRA by integrating multiple FTA algorithms into a modular framework. Figure 2 shows the SCRAM++ software framework

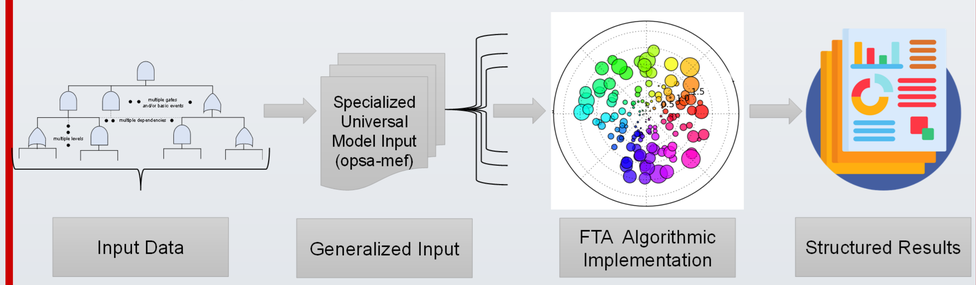
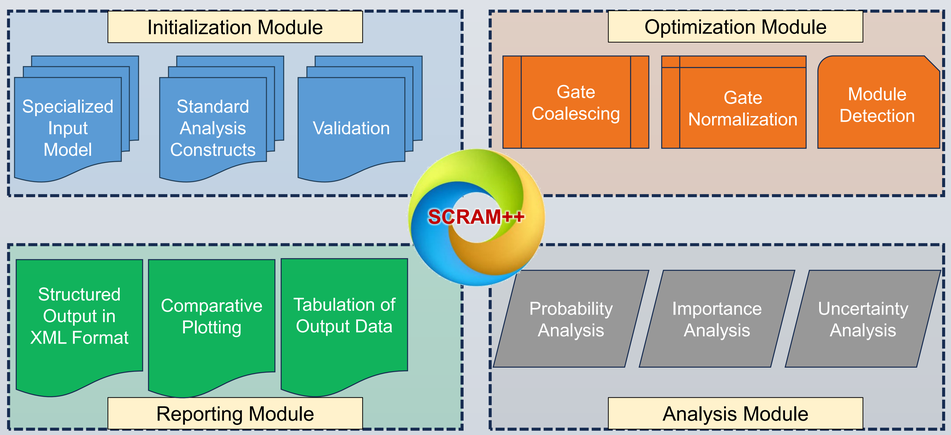


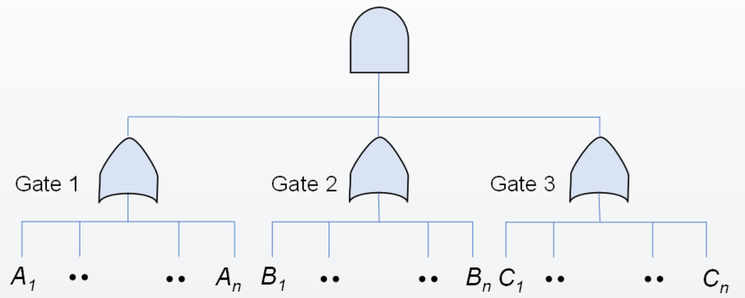
Figure 2. Overview of SCRAM++ software framework

Components of SCRAM++



Analysis and Results

- Figure 3 shows the results for the below fault tree for varying complexity



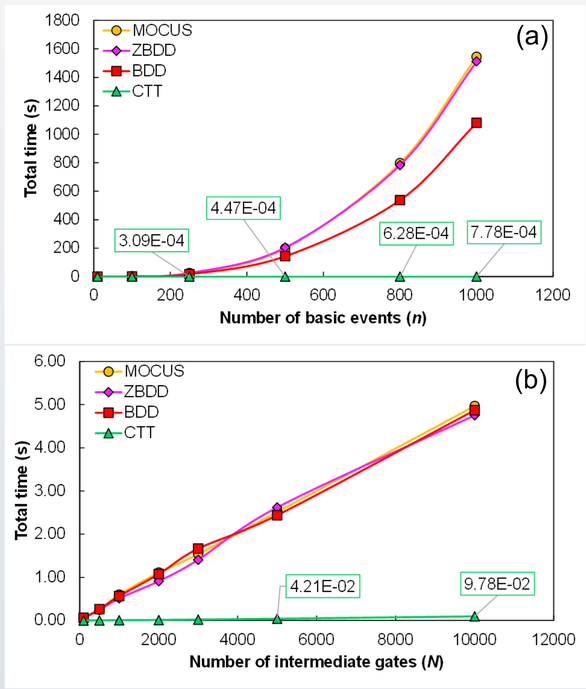


Figure 3. Varying (a) basic and (b) intermediate events

Summary and Future Work

- SCRAM++ offers an advanced risk analysis tool for the evaluation of transportation system vulnerabilities, enabling proactive risk management and enhanced decision-making for safety and reliability
- SCRAM++ can be used to assess transportation system risk under climate change & extreme events