

Modelling hydrogen vehicles road tunnel accidents using a Bayesian Network

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Publication date: 2020

Document Version Publisher's PDF, also known as Version of record

Link back to DTU Orbit

Citation (APA): Markert, F. (Author). (2020). Modelling hydrogen vehicles road tunnel accidents using a Bayesian Network. Sound/Visual production (digital)

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Digital Stakeholders Workshop HyTunnel-CS project 4-5 May 2020

Modelling hydrogen vehicles road tunnel accidents using a Bayesian Network

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Introduction BBN model

The objective is to develop a probabilistic model to assess the probability of accidents leading to release of the on-board stored hydrogen.

- Bayesian Believe Network (BBN) probabilistic road tunnel model
- BBN is used to model potential accident scenarios of hydrogen vehicles in road tunnels.
- Scenarios leading to pressure vessel destruction
- The assessment of the endpoints of these accidents are chosen to be:
 - Scenarios leading to jet fires immediate ignition
 - Flash fires and explosions delayed ignition
- Decision support: modelling safety measures:
 - Preventive measures to reduce the number of events
 - Mitigative measures to reduce the potential harm



The Risk Scenario Tunnel layout

- The specific characteristics of road tunnels are defined by:
 - > Materials of the tunnel walls
 - Geometry and size of the tunnel
 - Slope of tunnel , e.g.
 - flat –casted sub-sea tunnels (only ends have a slope)
 - "circular" drilled sub-sea tunnels (continuous slope deepest point in the middle)
 - ➢ increasing slope − e.g. mountains
 - ➤ etc.
- A road tunnel tube may be utilized as:
 - ➤ one-way directional traffic 1 or 2 lanes
 - two-way directional traffic 2 lanes
 - other (more complex situations (crossings, etc.)



The Risk Scenario

Traffic regulation & tunnel safety

- Built-in prevention and mitigation systems,
 - > Traffic regulations (number of cars in tube)
 - Distance between vehicles
 - Speed limits
 - Radio communication
 - Traffic control by police
 - ➤ etc.
- Evacuation plans and rescue
 - Egress paths
 - Lightening and signs supporting egress
 - Ventilation strategy
 - Shelters
 - Extinguishing materials
 - Emergency calls
 - Emergency service
 - ➢ other



The Risk Scenario

Traffic

Type of traffic expected in the tunnel:

- Vehicle types
 - Small , medium, large cars,
 - Professional vehicles: Vans, heavy truck (long distance)
 - Busses
 - Hazardous goods transport.
- Number of vehicles in tunnel
- Fraction of vehicle types

The vehicle types may be driven by traditional fuels, batteries electric vehicles or hydrogen & fuel cell electrical vehicles

Assumption: vehicle crashes into a hydrogen fueled car



Tunnel accidents Collision scenarios

Many collision scenarios are possible

- Damage level of the vehicles after collision is dependent on:
 - The velocity differences between the crashing vehicles
 - The respective total mass of the vehicles crashing
 - The orientation of the crash
- Statistically are accidents most frequent close to tunnel entrance / exit
 - This part of a tunnel is still influenced by weather condition
 - The lightning is changing quickly



tunnel

Tunnel accidents

Tunnel vehicle crash scenarios

- The tunnel layout is one directional traffic in the tunnel tube. Two lanes.
- Front rear crashes
- Front side crashes
- Single driver accidents





Tunnel accidents

Tunnel vehicle crash scenarios

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Tunnel accidnts

Tunnel vehicle crash scenarios

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BBN model Node view



This first approach takes the following keyitems into account to predict the conditional probabilities within the BBN

Vehicle types

Accident types

Hydrogen storage size

Consequence types depend on:

Ignition time

H2 release & amount

Severity of hydrogen scenarios depend on:

consequence type

H2 amount released



BBN hybrid model Collision severity – alternative approach

The probability of collision severity may be predicted by the momentum at the moment of the collision. The parameters recognized in this model are :

- Vehicle type distribution
 - fraction of vehicles in tunnel
 - vehicles weight
- Impact: Vehicle speed
- Severity classification by collision momentum = velocity*mass





BBN model Prior data input



- Base case
- Data not validated yet!!
- This example just shows how the BBN works! It does not yet provide a valid quantitative result!!





BBN analysis

Instantiating – accident severity





BBN analysis

Instantiating – accident severity





BBN analysis **Instantiating -Consequence**



- The consequence state "Jet flame" is set to 100%
- BBN automatically sets the ignition time state "immediate" to 100%

- **BBN** updates vehicle types "trucks" to 59% and "accident severity" to "major" 69%conditional causes for jet flame state
- BBN automatically sets the ignition time state "immediate" to 100%

BBN analysis

Instantiating – severity H2 scenario





BBN analysis

Instantiating – severity of scenario





Summary

BBN of road tunnel accidents

- A BBN for road tunnel accidents involving hydrogen cars is developed based on assumed data
- Based on traffic data and the severity of collision accidents hydrogen release scenarios can be assessed
- Alternative: the severity of collision may be modelled using hybrid models
 - Opens for application of physical parameters e.g. crash data to predict hydrogen storage damages

Analysis of scenarios:

- BBN model allows updating of the probabilities due to new knowledge for the hole network.
- Instantiating allows valuable sceanrio and cause consequence assessments.

Next steps:

- Implementing real traffic and accident data
- Development of BBN model to include e.g. egress scenarios



Building the BBN Software used

 GeNIe BayesFusion, LLC; Academic version 2.4.4601.0 -<u>https://www.bayesfusion.com/</u>





Acknowledgements

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (JU) under grant agreement No 826193. The JU receives support from the European Union's Horizon 2020 research and innovation programme and United Kingdom, Germany, Greece, Denmark, Spain, Italy, Netherlands, Belgium, France, Norway, Switzerland.

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HORIZON 2020