Optimizing Rail Transportation Safety Improvement

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RAILTEC

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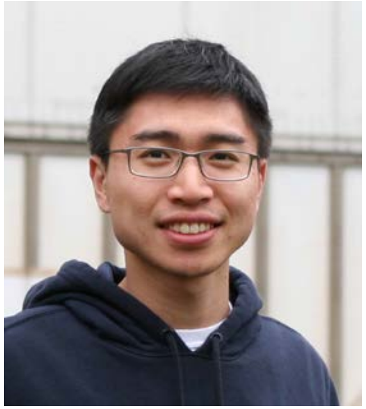


Efficient risk reduction is a common goal

- In all parties' interest – both private and public sector - to invest safety resources as wisely and efficiently as possible
- In the context of improving hazardous materials transportation safety this means identifying the most efficient means of achieving this
- Challenge to industry and government is discerning the correct solution for any given context or question
- Constraints to achieving this are of two broad types:
  - **Knowledge:** analytical tools, data availability, physical and relational uncertainties
  - **Institutional:** regulatory constraints, operational practicalities, litigation concerns, ability to apply knowledge in general
- Basically we need to understand, *what do we need to do*, and *how do we do it most effectively?*

Rail transport factors affecting hazardous materials risk

Infrastructure Design and Condition

Operating Practices

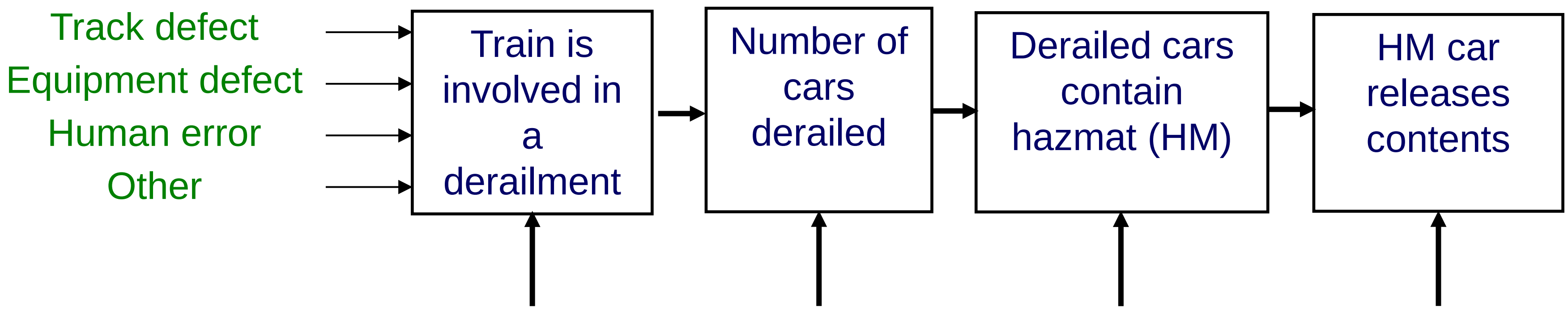
Tank Car Safety Design

Traffic Routing

Modifications to any of these, alone or in combination, may offer the best safety return on investment in a particular context

Events leading to a railroad hazardous materials release

Accident Cause



Influencing Factors

- track quality
- method of operation
- track type
- human factors
- equipment design
- railroad type
- traffic exposure

- speed
- accident cause
- train length

- number of HM cars in the train
- train length
- placement of HM cars in the train

- HM car safety design
- operating speed
- accident characteristics

Basic railway hazardous materials transportation risk analysis model

$$R = Z \times M \times P \times C$$

R: HM release risk

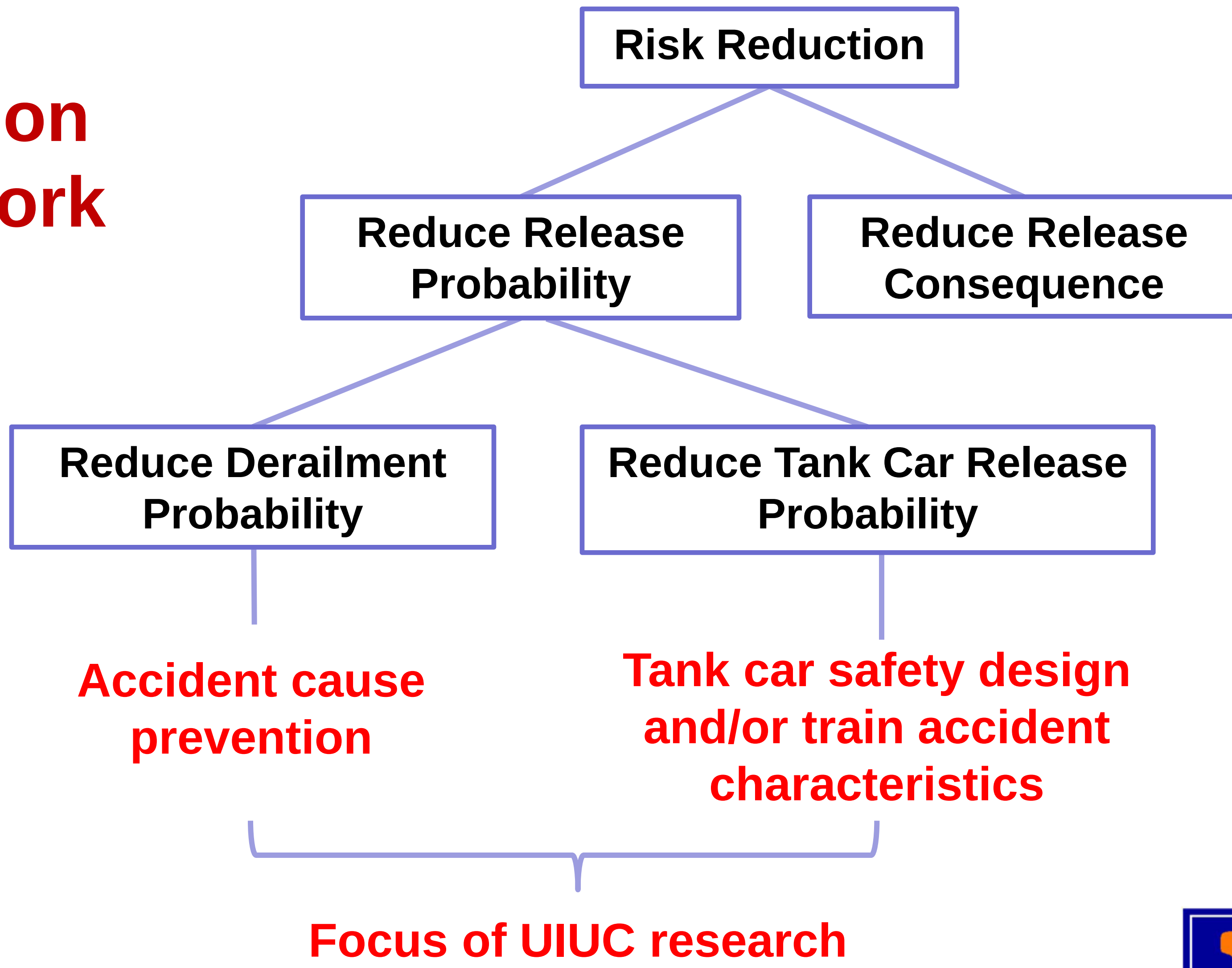
Z: HM car derailment rate per billion HM car miles

M: Billion HM car miles

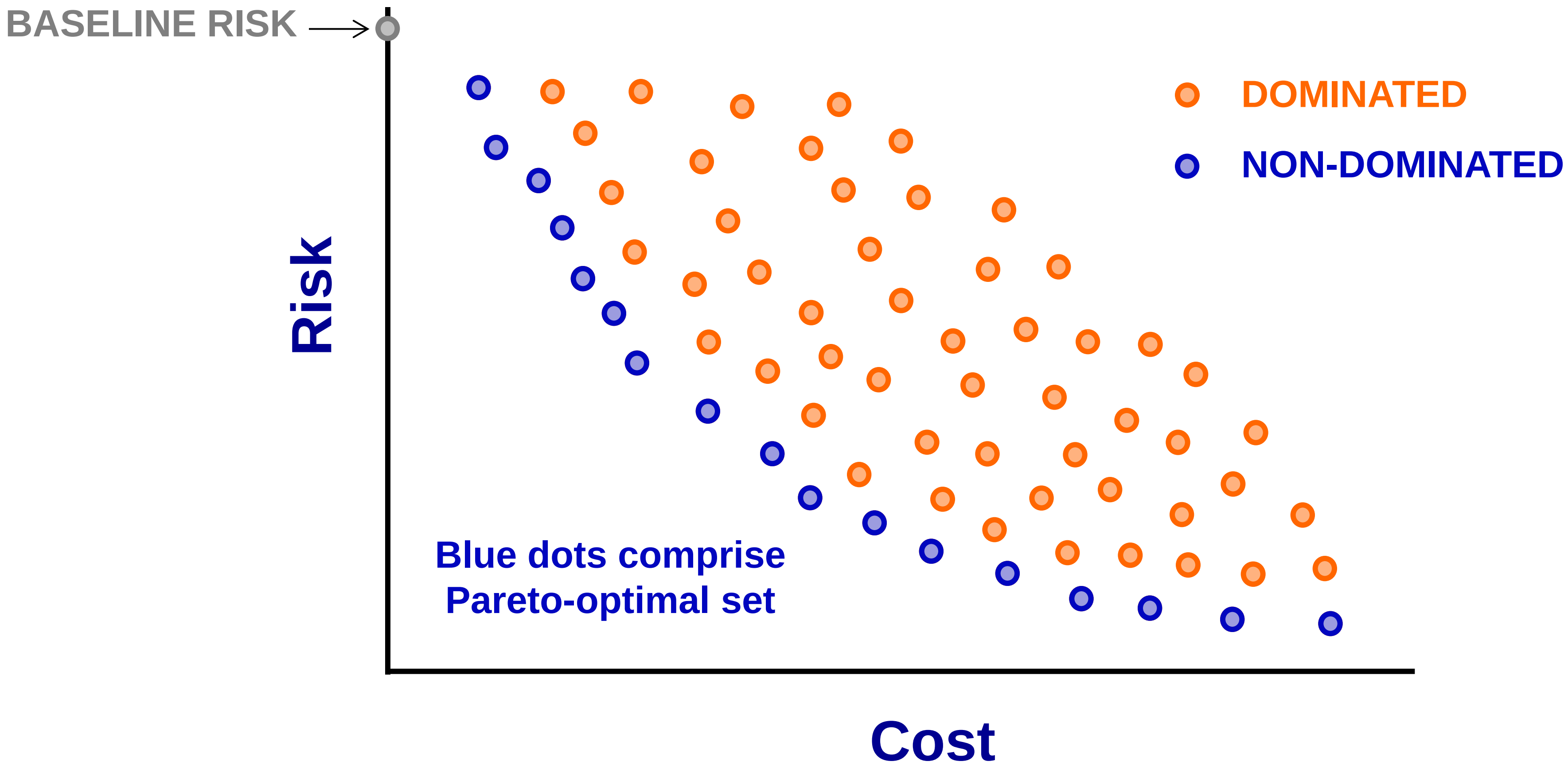
P: Conditional probability of release (CPR) of a derailed HM car

C: Release consequence (e.g., number of persons in the affected area)

Risk Reduction Framework

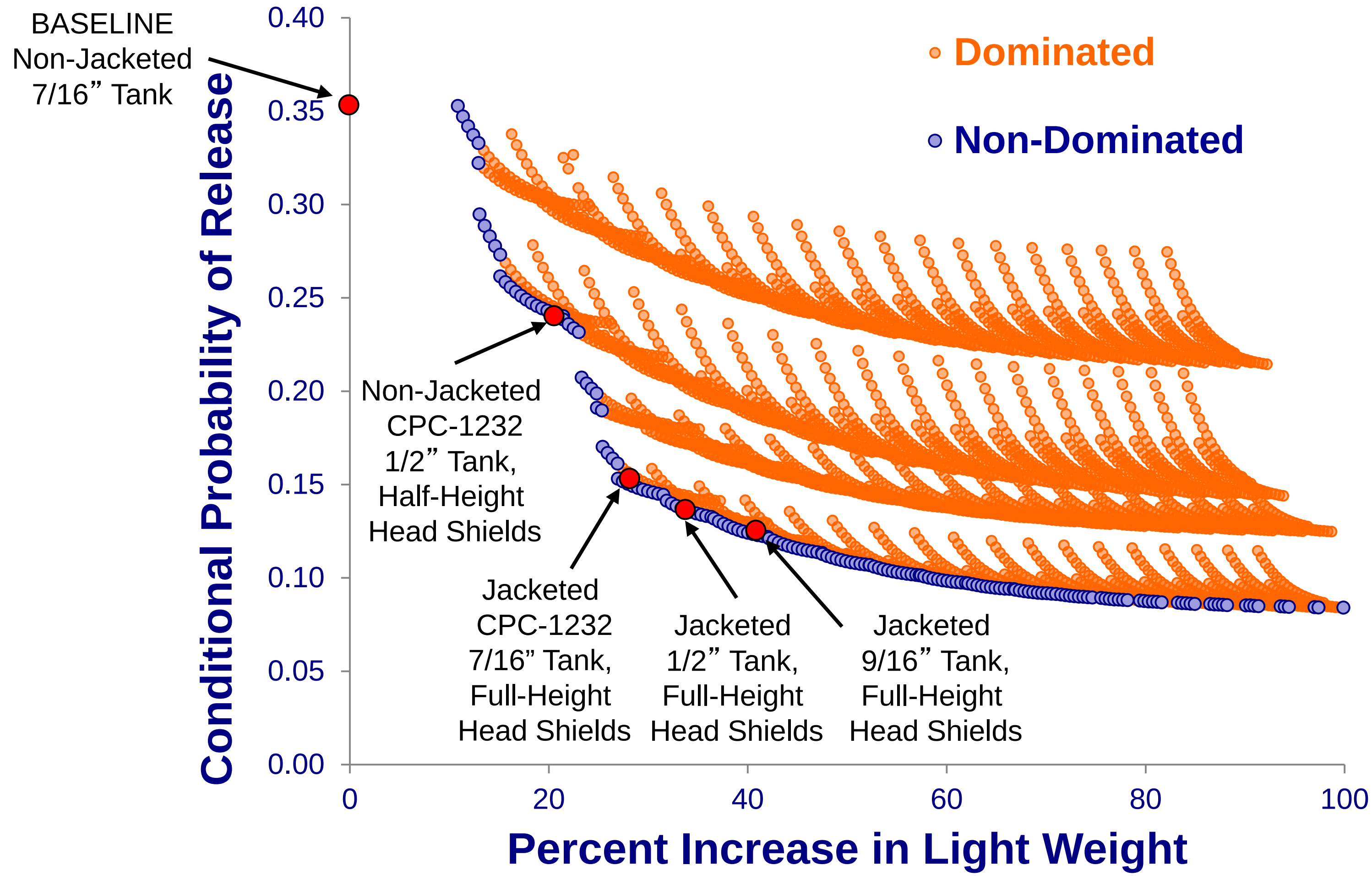


Multi-attribute decision problem

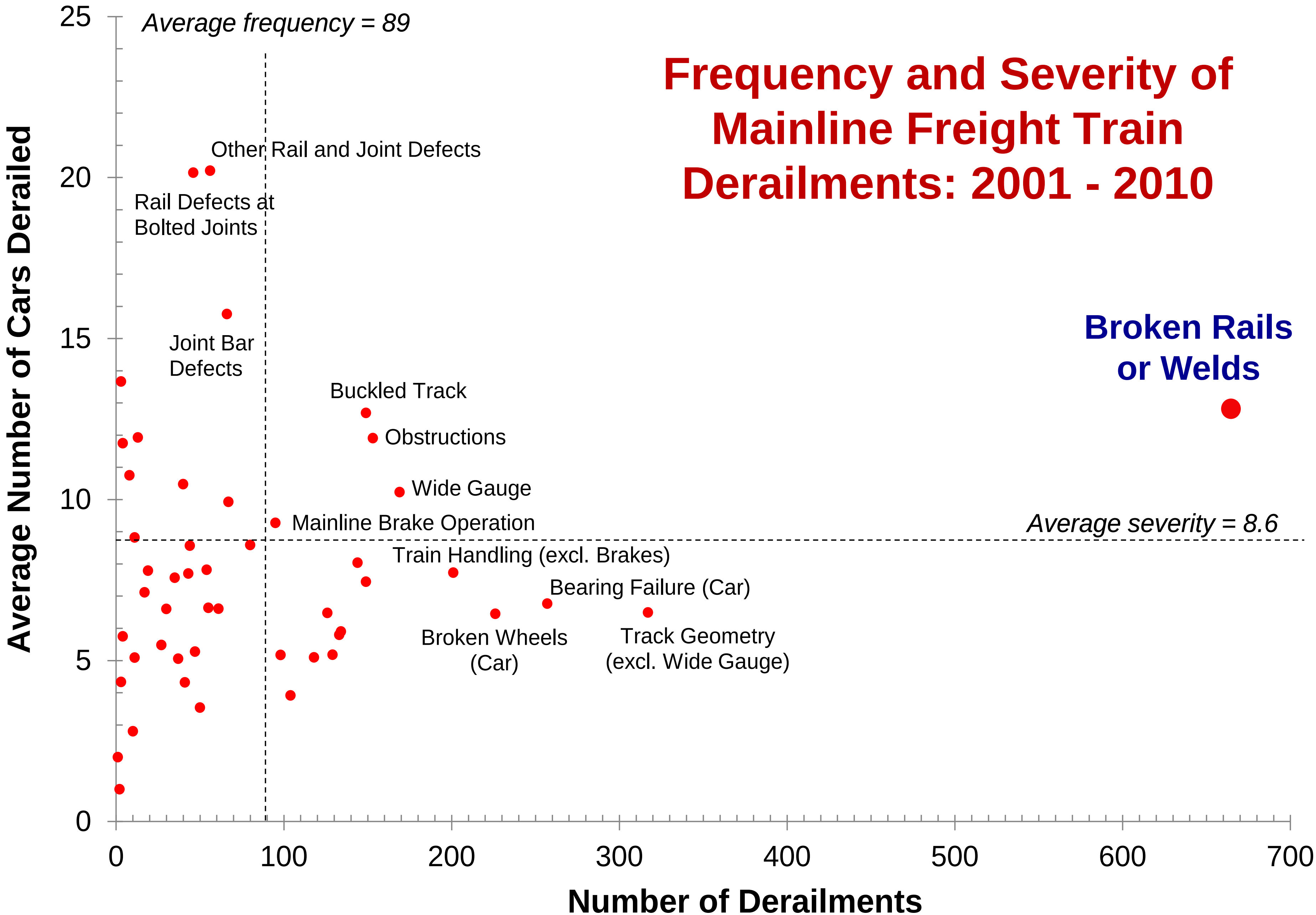


- The Pareto-optimal set represents the best possible solutions for any given level of investment

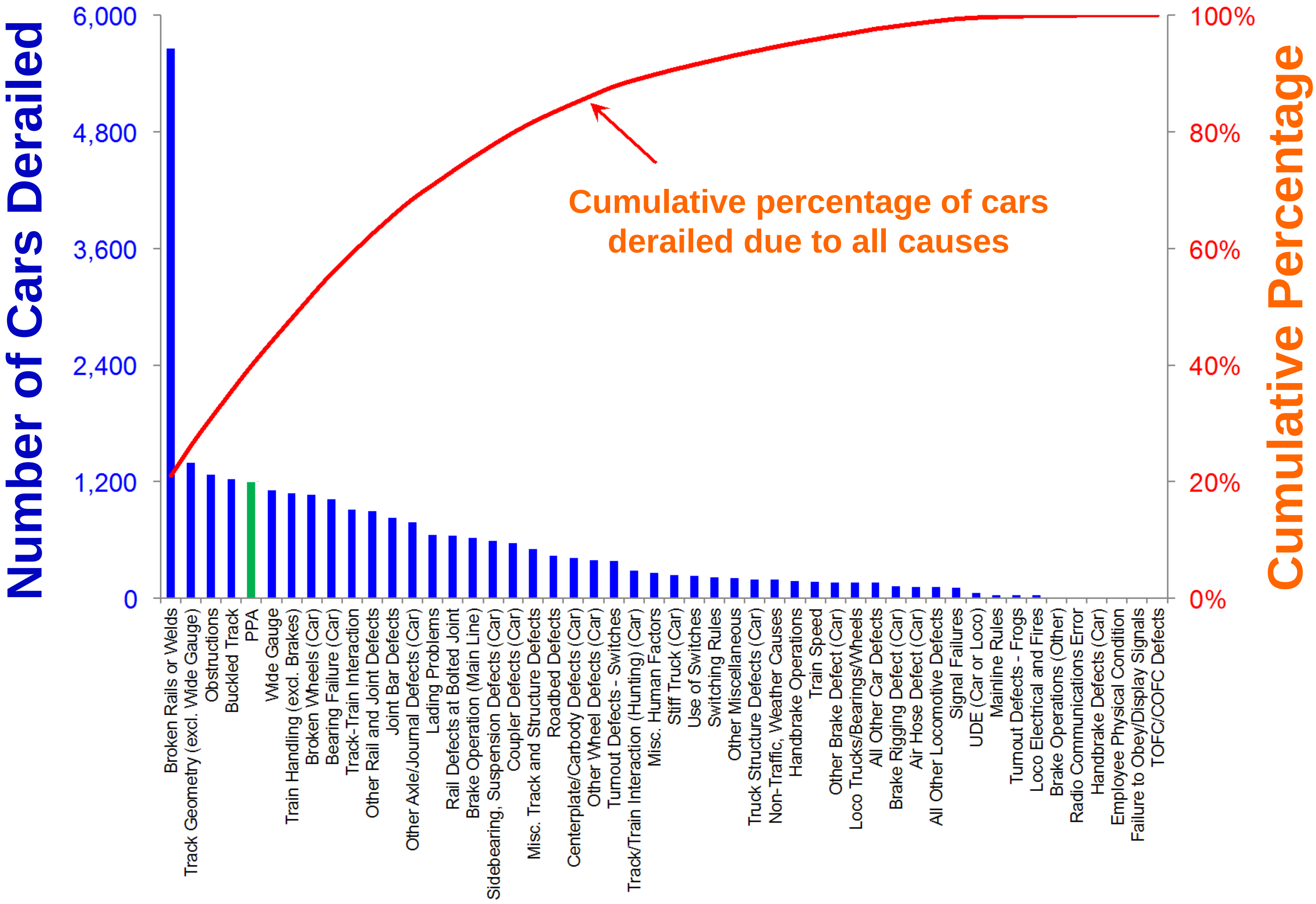
Pareto optimal set of flammable liquid tank car design options



Frequency and Severity of Mainline Freight Train Derailments: 2001 - 2010



Number of cars derailed by accident cause



Factors affecting broken rail occurrence

Defect Prevention

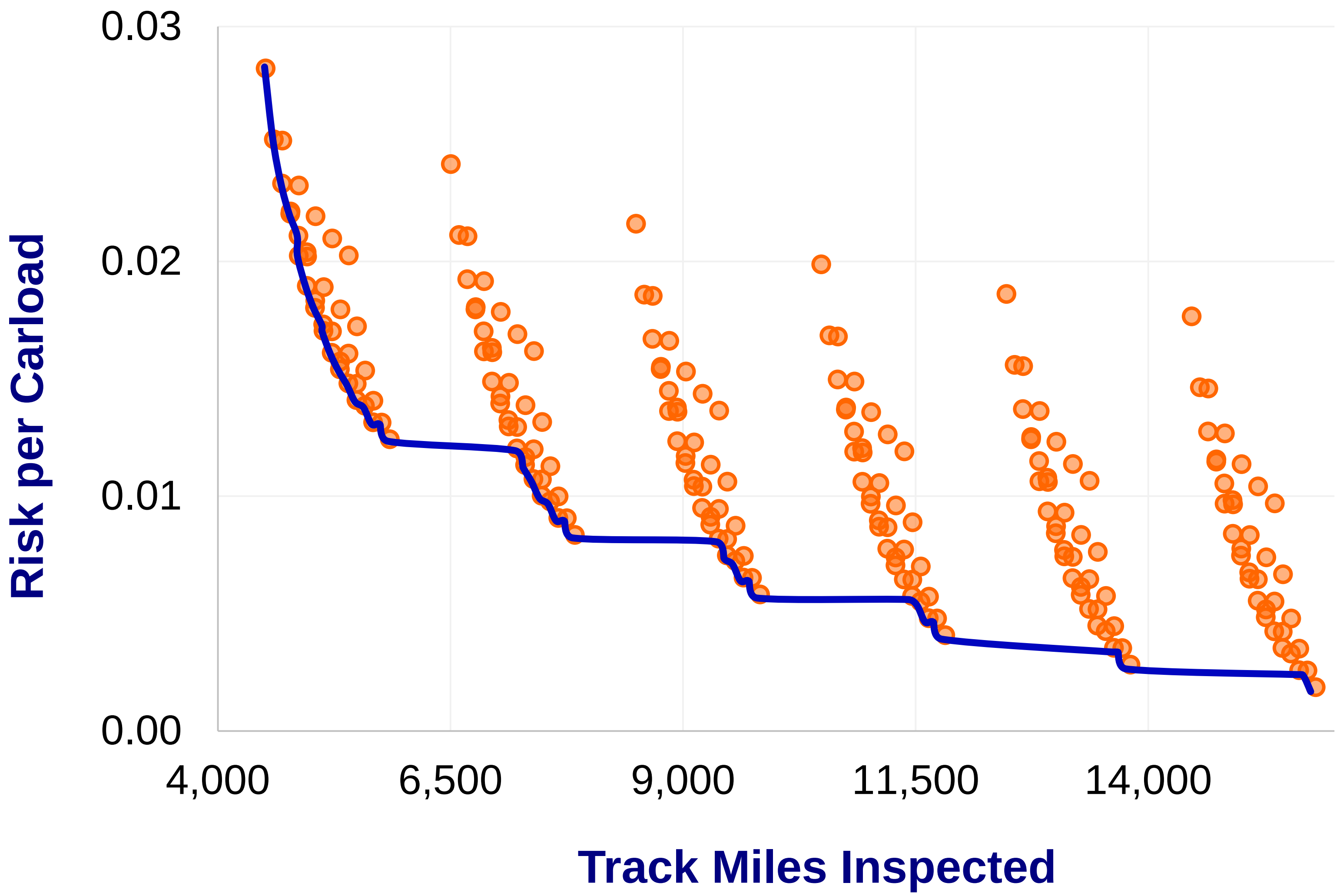
- **Rail steel quality**
  Cleaner steel has fewer incipient flaws
- **Rail management**
  Remove nascent defects
- **Reduce load frequency & severity**
  Rolling stock and track maintenance

Defect Detection

- **Inspection technology**
  Improve detection ability
- **Inspection frequency**
  More frequent testing
- **Inspection scheduling**
  Optimize use of inspection technology

Reduced broken rail occurrence

Example of optimized rail defect inspection scheduling



Risk reduction by integrated strategies

$$R = \sum_{i=1}^{N} \left[(Z_{0i} - \Delta Z_i) \times (A_b(1-\beta) + A_u \beta) \times V_i (1-\mu_i) \times C_i \right] L_i$$

where:

R = risk after implementation of integrated risk reduction strategies

Δz_i = reduction of broken-rail-caused tank car derailment rate

A_b = rate of CPR change in response to 1mph speed change for baseline tank car

A_u = rate of CPR change in response to 1mph speed change for enhanced tank car

β = percent baseline tank cars to upgrade

V_i = train speed (mph)

μ_i = percent speed reduction on the i^{th} segment

C_i = release consequence (e.g., number of persons in the affected area)

L_i = segment length (miles)

N = total number of track segments on the route

Risk-based approach to tank car safety design, retrofit and replacement

- Agreement needed on tank car specification for flammable liquids, especially petroleum crude and alcohol
  - Risk-based approach can help decide on suitable level of tank car safety design accounting for differing levels of product hazard
- Substantial portion of current fleet may need to be retrofitted or replaced
  - Risk-based approach can be used to prioritize car retrofit or replacement
  - Accounting for tank car safety performance, product hazards and shop capacity, will reduce risk in the most rapid manner feasible

Conclusions

- Quantitative analytical tools such as risk analysis and operations research techniques can help maximize efficient use of resources to improve safety in the most effective manner
- Can be applied at various levels ranging from macro to micro
- Long-range goal is complete integration, but tools can and have been used on various sub-elements of total system risk
- Tank car safety design process has benefited from use of optimization methods because of extensive data availability
- Opportunity to reduce broken rail occurrence – but technical and institutional barriers must be overcome
  - Need substantial investment in research to develop new and improved technologies to detect defects
  - Regulatory philosophy should encourage technology development to support continuous testing