



Iran University of  
Science and Technology

# How to Measure and Compare Safety Performance of Railways?

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# Contents

- A bit about me and the railway education
- Some statistics on railway safety
- Why measuring is important?
- How to measure safety performance?
- Introduction to DEA and its applications
- Potential models
- Conclusions

# Educational Background

- Got my PhD from University of Southampton (UK) in 2012
- Master in Systems Eng. , Iran 2008
- Bachelor in Railway Eng. , Iran 2002
- An absolute railway fan!

# Human Resource Challenges of Railways

- “Ensuring that knowledge is passed on to the generation
- Developing workforce skills/capabilities
- Retaining valued talent”

(SIAFI and UIC, 2014)

- 5.6 million people directly work in railway companies that are members of UIC

(UIC, 2018)

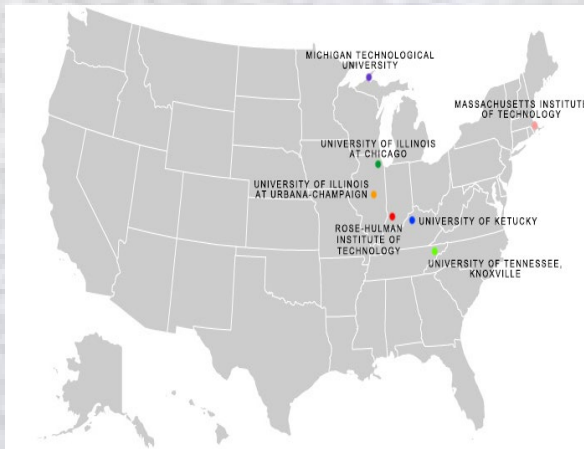
# Spectrum of Railway Education

- National Initiatives
- Railway focused Universities
- Railway Departments/Schools
- Railway Related Majors
- Railway courses/research at other departments

# National University Rail Center in the USA

# UKRRIN

(UK Rail Research and Innovation Network)



- Centre of Excellence in Digital Systems
- Centre of Excellence in Rolling Stock
- Centre of Excellence in Infrastructure

Consortium of seven partner colleges and in North America.

<http://www.nurailcenter.org/>

<https://www.ukrrin.org.uk/>

# China

- Beijing Jiatong University
- Changsha Railway University

# Russia

- Moscow State University of Transport
- Petersburg State Transport University
- Ural State university of Railway Transport

# Ukraine

- Kharkov State Academy of Railway Transport

- 
- Railway Technical Research Institute (Japan)
  - Korea Railroad Research Institute
  - ...



- Department of Rail Vehicles and Transport Systems-  
RWTH Aachen University (Germany)



- School of Railway Engineering (Iran)
- ...

- Master's course in Infrastructure Engineering and Railway Systems

UNIVERSITY MASTER'S  
COURSE IN  
INFRASTRUCTURE  
ENGINEERING AND  
RAILWAY SYSTEMS  
Innovation for  
integrated mobility

 SAPIENZA  
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17:00 OF 23 NOVEMBER 2017

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 FERROVIE  
DELLO STATO  
ITALIANE

- Railroad Engineering Program

- 
- Railway Systems Engineering and Integration (Master)
  - Railway Safety and Control (Master)
  
  - Railway Engineering (Turkey)

# School of Railway Engineering

- Established in 1997 at Iran University of Science and Technology (IUST).
- Financial support for establishment from Iranian Railways



## Majors at the School of Railway Engineering

Major	Bachelor	Master	PhD
Track and structure Eng.	✓	✓	✓
Rolling stock Eng.	✓	✓	✓
Railway transportation Eng.	✓	✓	
Electrical Railway Eng		✓	
Control and Signaling Eng.		✓	✓
Railway safety Eng.		✓	

# Number of Graduates

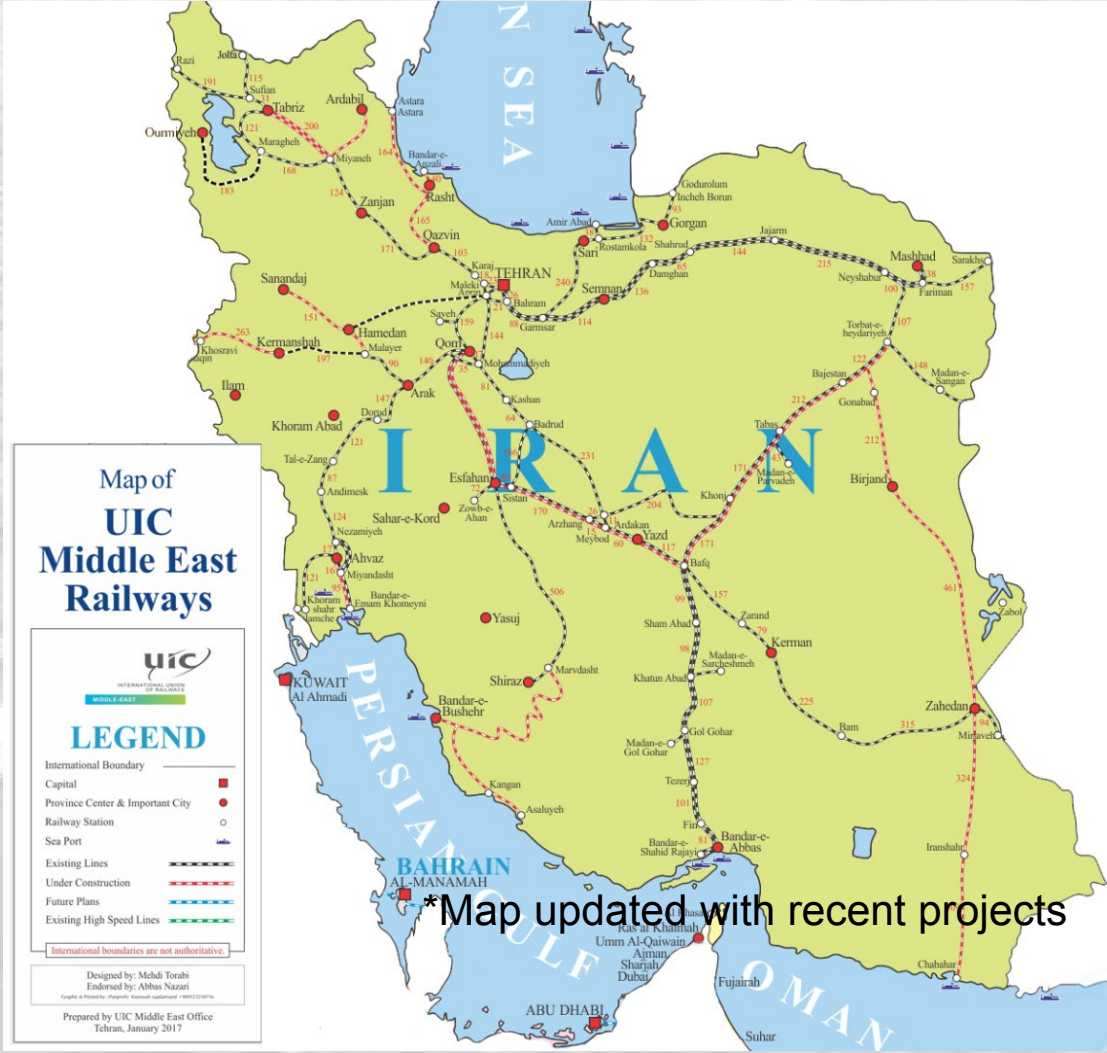
Major	Bachelor	Master	PhD	Total
Track and structure Eng.	450	140	3	621
Rolling stock Eng.	395	105	5	524
Railway transportation Eng.	392	81	-	473
Electrical Railway Eng.	-	94	-	94
Control and Signaling Eng.	-	25	-	25
Railway safety Eng.	-	107	-	107
<b>Total</b>	<b>1237</b>	<b>467</b>	<b>8</b>	

(School of Railway Engineering, 2018)



# Railways in Iran

- Population: 80.5 million (18th in the world)
- Area: 1,648 thousand Sq m (17th in the world)
- GDP (nominal 2016): 425 Billion \$ (25th in the world)
- Railways (According to UIC synopsis 2016)
  - Length of lines: 8576 km; Double tracks: 1900 km; Electrified lines: 181 km
  - Railway lines under construction: 4700 km
  - Tonne-km: 27 billion
  - Passenger-km: 12 billion



The 3<sup>rd</sup> Workshop on Railway Operation for Safety and Reliability

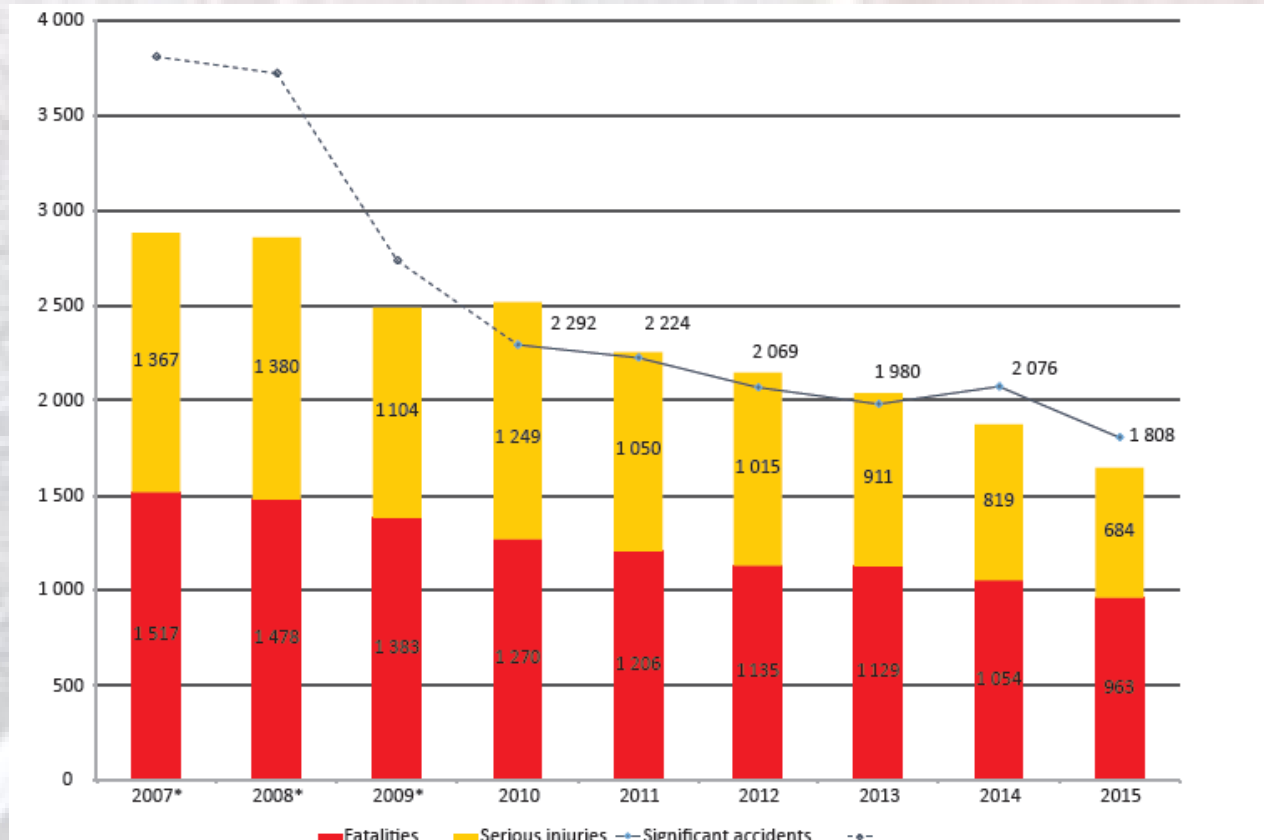
# Railways are safe but...

Transport mode used by user	Fatalities per billion passenger-kilometres
Airline passenger (on EU territory)	0.06
Railway passenger	0.10
<i>Bus/coach occupant (note: figures relate to the 2010-2014 period not 2011-2015)</i>	<i>0.19</i>
Maritime vessel passenger	0.27
Car occupant	2.67
Car driver	1.82
Car passenger	0.85
Powered two-wheelers	37.80

(European Commission, 2016)

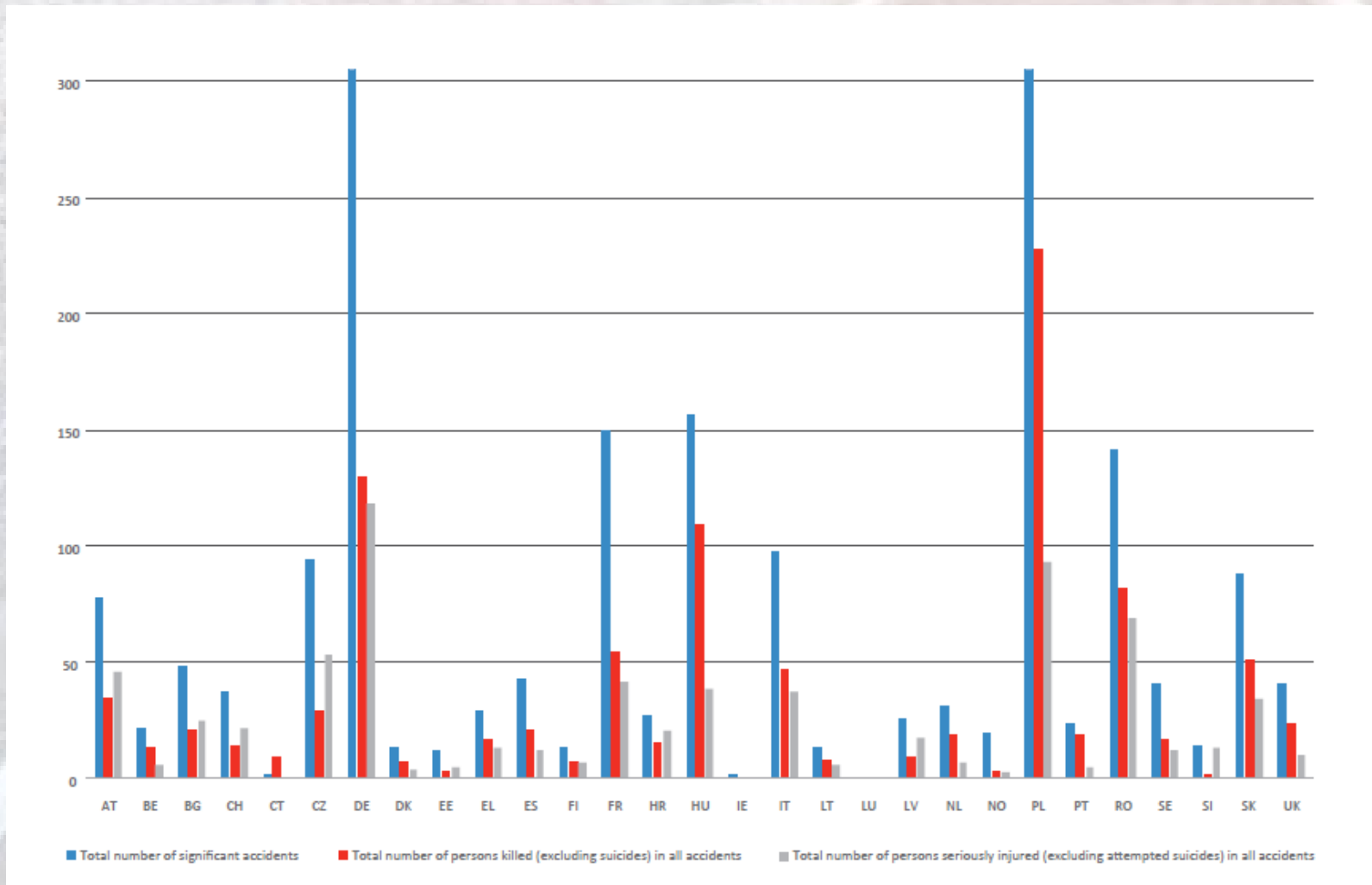


# Railways are safe but...



Significant Accidents and Fatalities in the EU (UIC, 2018)

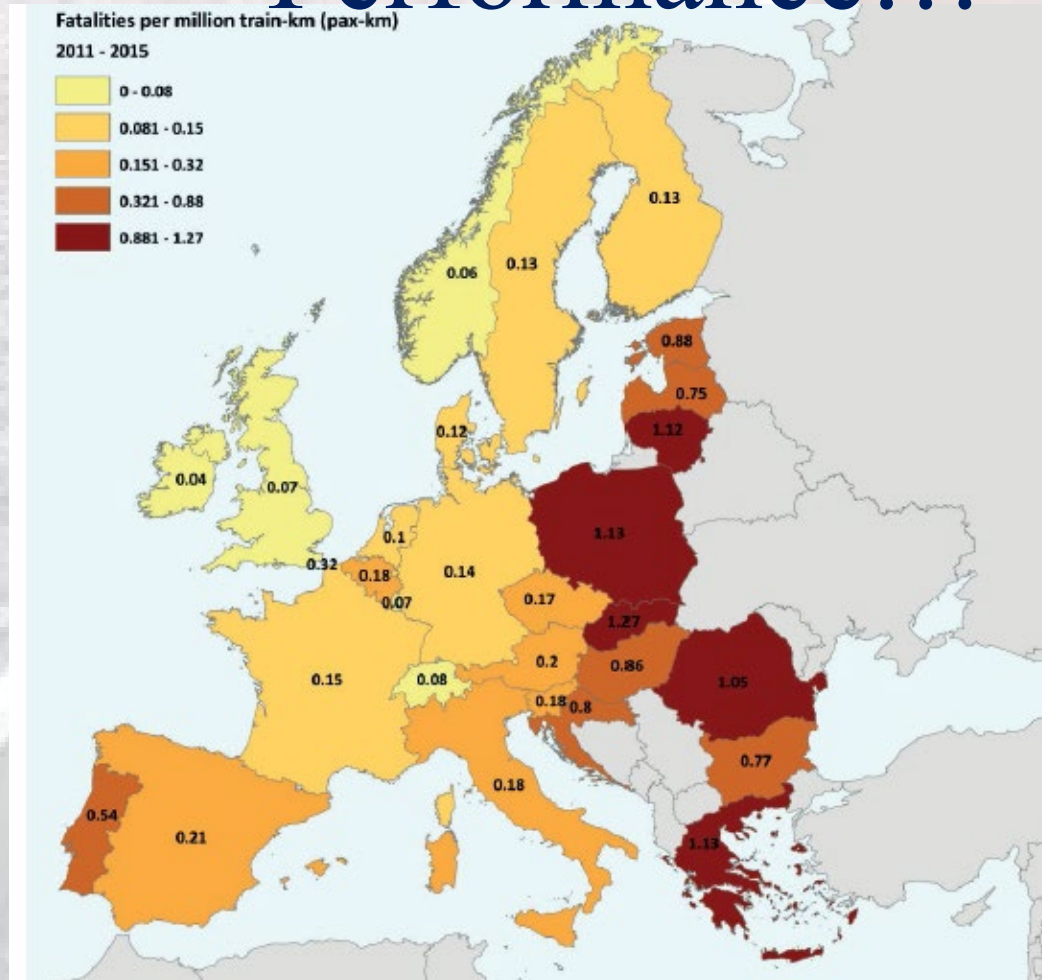
# Safety Performance of Railways in the EU





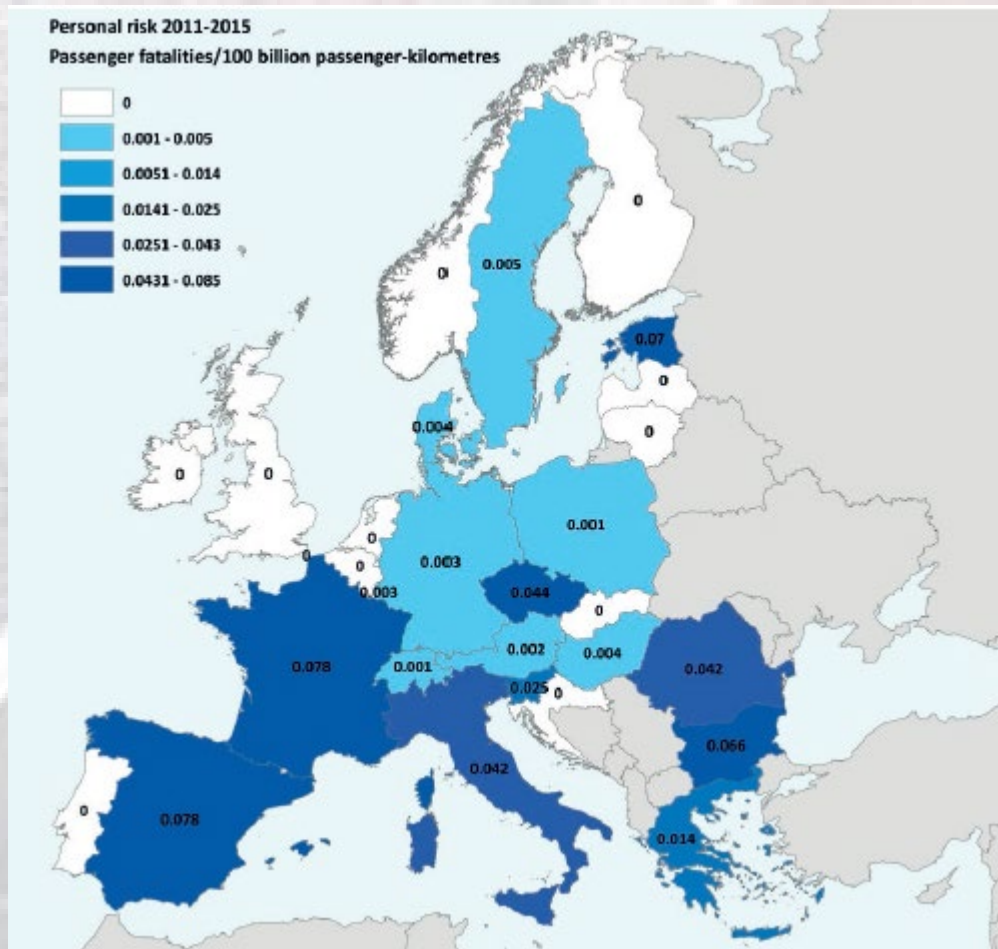
**What is the safest railway in the world?  
How to compare the safety performance  
of railways?**

# Different Levels of Safety Performance...



(UIC, 2018)

# Different Levels of Safety Performance...



(UIC, 2018)

# Different Levels of Safety Performance...

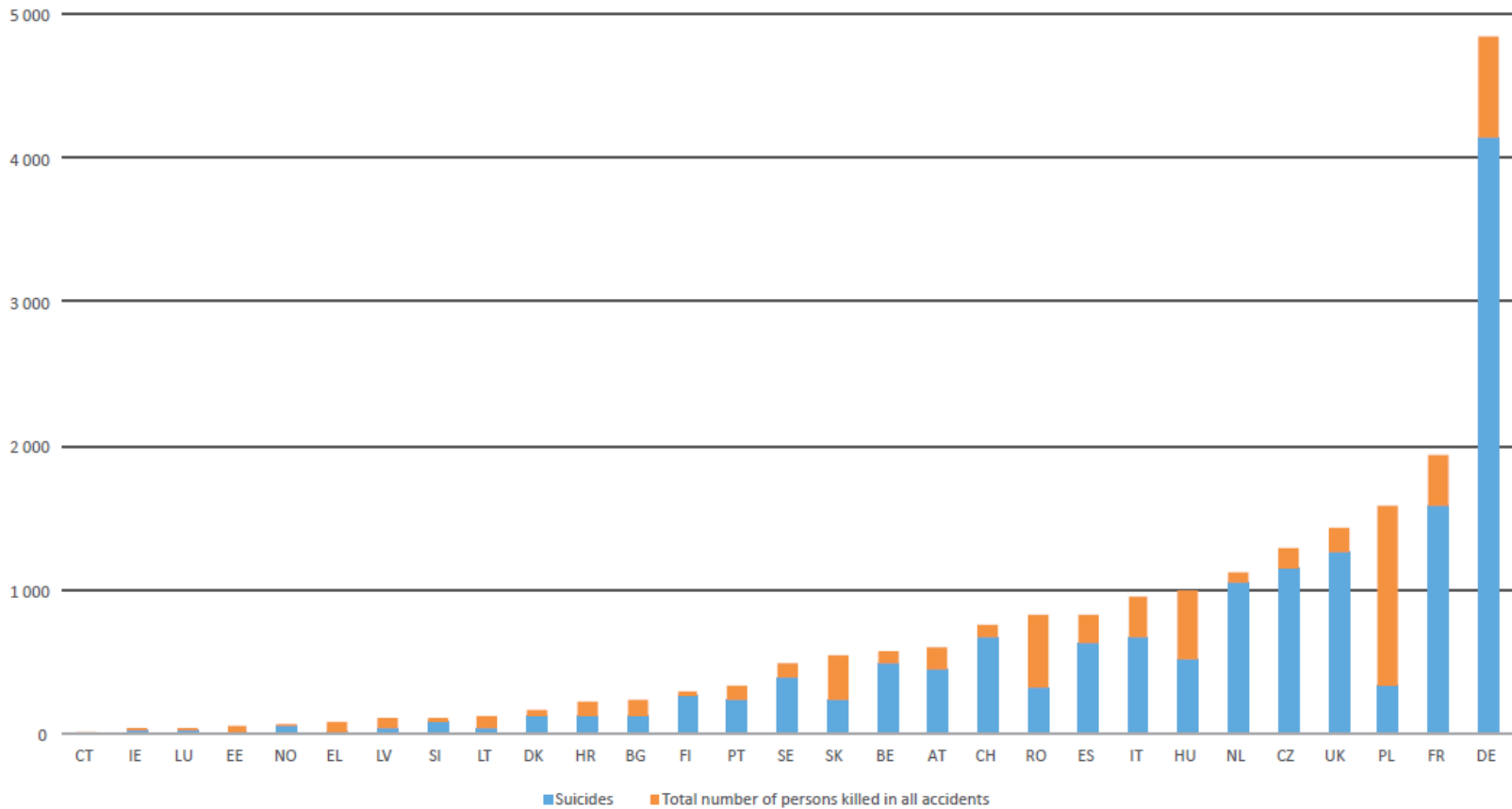
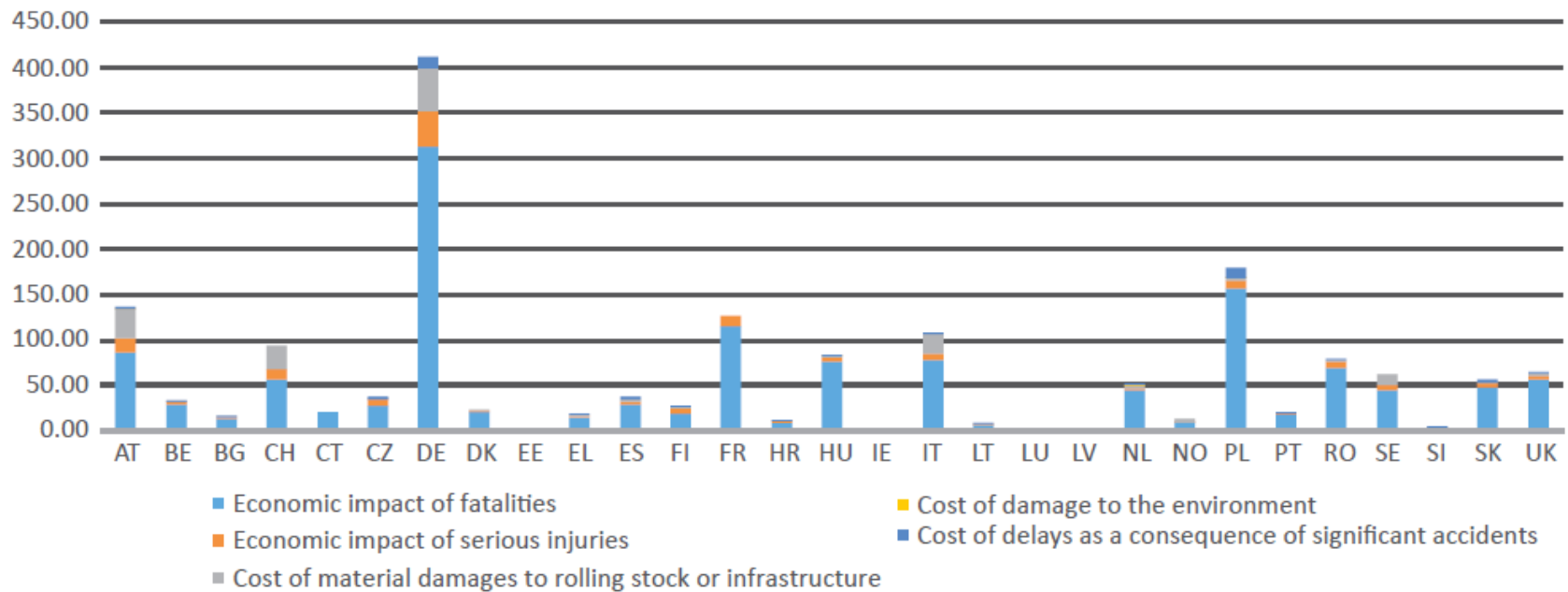


Figure 12a: All railway fatalities and suicide fatalities on railways (EU-28, Norway and Switzerland; 2011-2015)

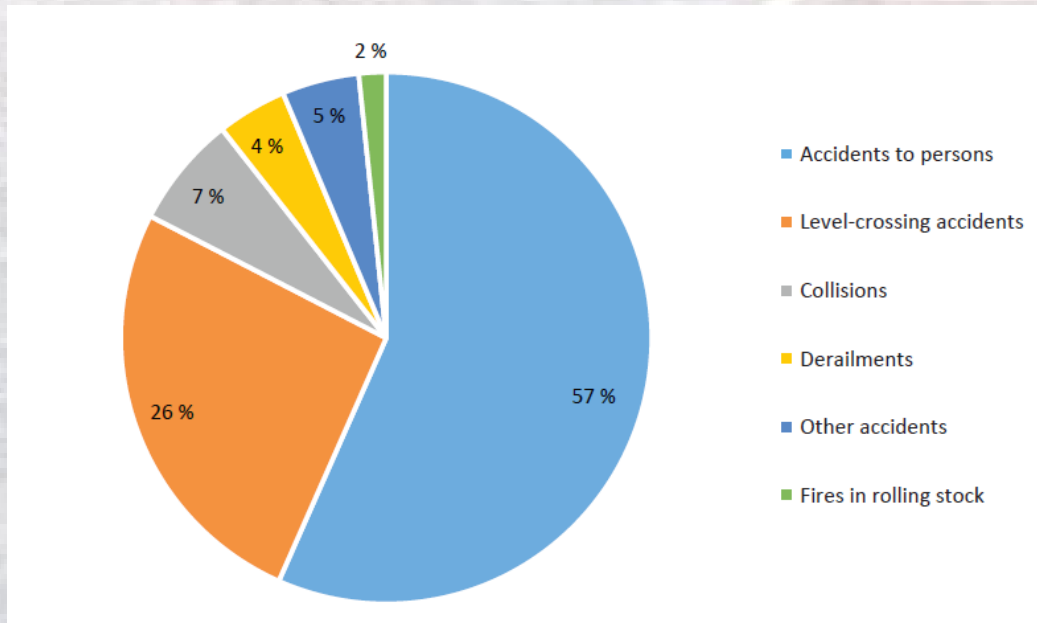
(UIC, 2018)

# Economic Impacts of Railway Accidents



(UIC, 2018)

# Different Types of Railway Accidents

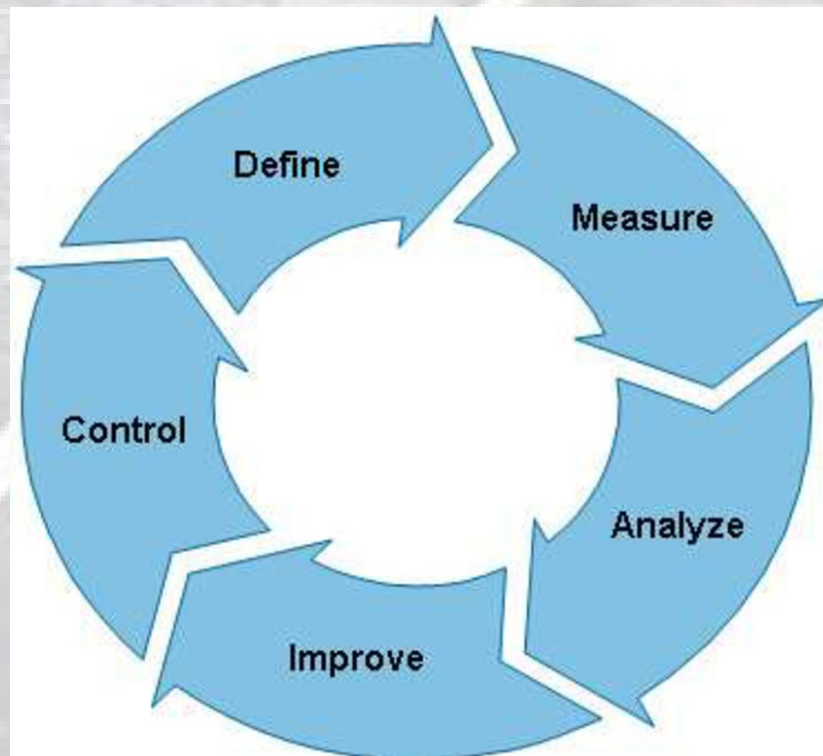


(UIC, 2018)



# Why Measure?

– Part of Improvement Cycle

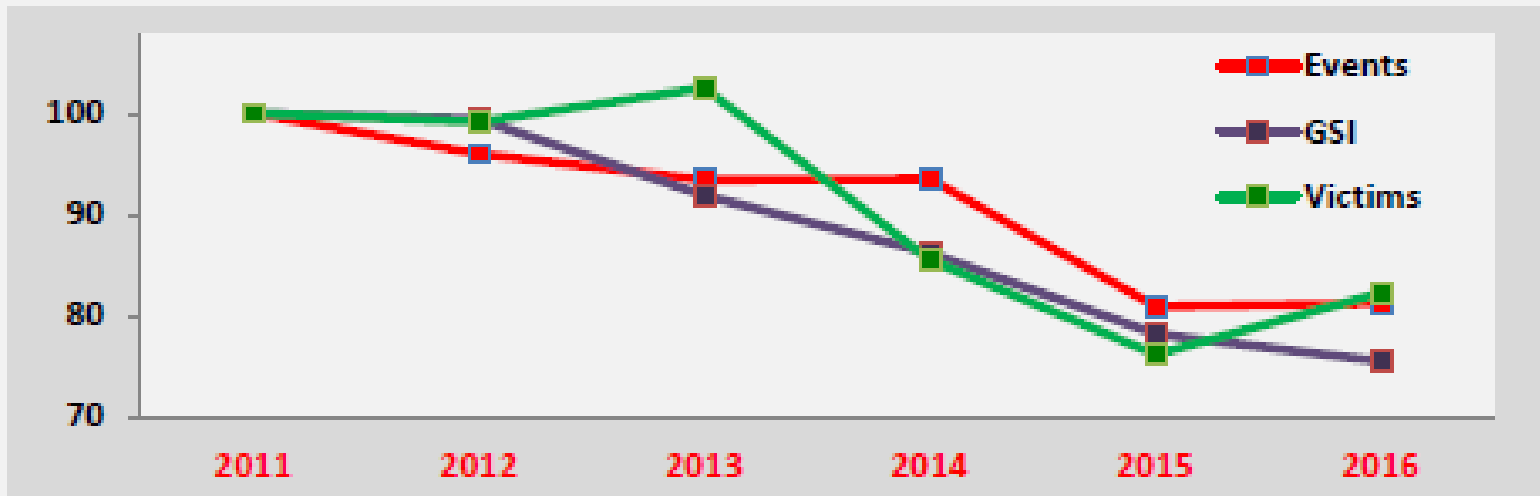


(Pyzdek, 2003).

# UIC Global Safety Index

- Weighted number of accidents
- Created in 2015

2016.



(UIC, 2017)

# UIC Global Safety Index

$$\text{GSI} = 1/1000 \times \Sigma (((C_v \times C_n) + C_a) \times C_r)$$

where:

- $C_v$  is the coefficient for the category of victim, from 1 (a serious trespasser injury) to 8 (a passenger fatality);
- $C_n$  is the coefficient for the number of victims, from 0 (no victim) to 5 (more than 5 victims);
- $C_a$  is the coefficient for the type of accident, from 1 (a person hit by a train) to 7 (a derailment or a collision between trains);
- $C_r$  is the coefficient for the cause, from 1 (external causes) to 2 (internal causes).

(UIC, 2017)

# Index Number Problem

“complex that is made up of individual measurements for which no common physical unit exists” (Frisch, 1936)

- Derailment per million train-km??
- Fatalities per million passenger-km??
- Total number of accidents per million train-km??
- ...??

# Data Envelopment Analysis Model (DEA)

$$\max h_o = \frac{\sum_{r=1}^s u_r y_{ro}}{\sum_{i=1}^m v_i x_{io}}$$

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1 \quad j = 1, \dots, n$$

$$u_r, v_i \geq \varepsilon \quad r = 1, \dots, s \quad i = 1, \dots, m$$

(Charnes et al., 1978)

# DEA Model

$h_o$  = efficiency of the unit under assessment

$u_r$  = weight given to output r

$y_{ro}$  = amount of output r for unit under assessment

$v_i$  = weight given to input i

$x_{io}$  = amount of input i for unit under assessment

$g_o$  = efficiency of the unit under assessment

$\omega_i$  = weight given to input i in the linear model

$\mu_r$  = weight given to output r in the linear model

(Charnes et al., 1978)

# My Previous DEA works

Khadem Sameni, M., & Preston, J. (2012). Value for railway capacity: assessing efficiency of operators in Great Britain. *Transportation Research Record: Journal of the Transportation Research Board*, (2289), 134-144.

Khadem Sameni, Melody, and Alex Landex. "Capacity Utilization in European Railways: Who is the fairest of them all?." *Transportation Research Board (TRB) 92nd Annual Meeting Transportation Research Board. Washington, DC. 2013.*

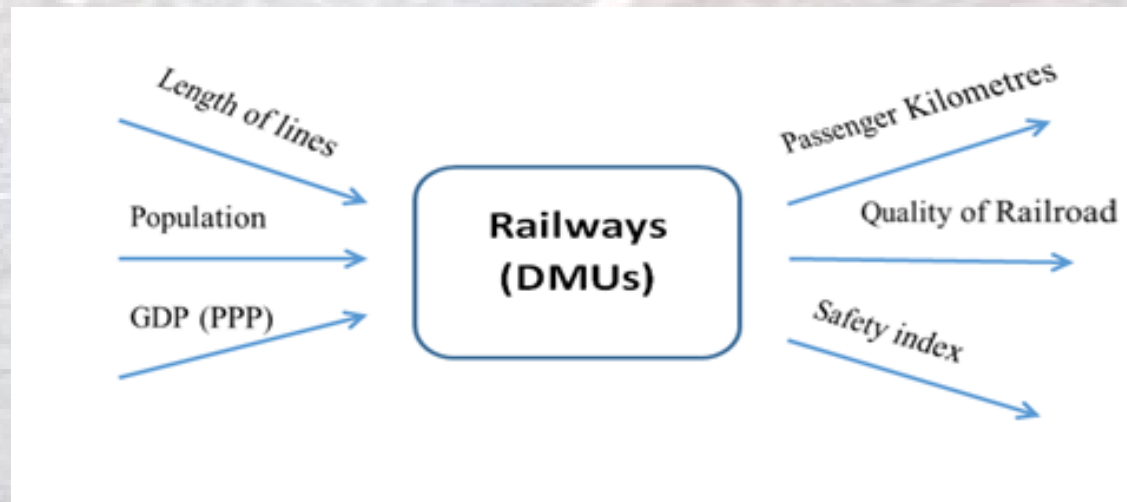
Khadem Sameni, Melody, John Preston, and Mona Khadem Sameni. "Evaluating efficiency of passenger railway stations: A DEA approach." *Research in Transportation Business & Management* 20 (2016): 33-38.

# Some of DEA applications in Safety

Authors	Topic	DMU	Inputs	Outputs
(Odeck, 2006)	Road	19 Norwegian Regions	No input (Constants)	Usage control, safety belt control, technical control
(Hermans et al., 2009)	Road	21 EU countries	Motorway density, seatbelt wearing rate, percentage of cars below 6 years old, percentage of GDP spent on health, percentage of drivers below speed limit, percentage of users with blood alcohol content below limit	Road traffic fatalities per million inhabitants, fatal injury crashes per 100,000 inhabitants
(Shen et al., 2011)	Road	19 EU countries	Mean speed on (Urban roads/rural roads and motorways), speed limit violation, seatbelt usage, child restraint usage, helmet usage, fatalities caused by alcohol	(Fatalities/ serious injuries/ slight injuries) per million inhabitants, No. of crashes per million inhabitants
(Ahmadvand et al., 2011)	Road	30 Iranian Provinces	3 principal components (PC): PC 1 (road safety policies and facilities), PC 2 ("safety reformation"), PC 3 ("safety instruction")	1 PC (no. of crashes and no. of casualties)
(Shen et al., 2012)	Road	27 EU countries	Population, passenger-km, passenger cars	Fatalities
(Noroozadeh and Sadjadi, 2013)	Railway	25 EU countries	No. of employees, No. of rolling stock, length of lines	Total number of accidents, No. of victims, passenger-km
(Egilmez and McAvoy, 2013)	Road	50 US states	"safety expenditures, the number of registered vehicles, the number of registered	No of fatal crashes



# A Sample of Railway Safety DEA Model



(Khadem Sameni and Kashi Mansouri, 2017))

Khadem Sameni M, Kashi Mansouri M R. Analyzing Efficiency of Railway Transportation by Considering Quality of Services: New Data Envelopment Analysis Models. IJRARE. 2017; 4 (1) :47-55

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**VRS Model**

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<b>Country</b>	<b>State</b>	<b>Score</b>
<b>Austria</b>	<b>Efficient</b>	<b>1</b>
<b>Czech Republic</b>		
<b>Estonia</b>		
<b>Finland</b>		
<b>France</b>		
<b>Hungry</b>		
<b>Latvia</b>		
<b>Luxembourg</b>		
<b>Netherlands</b>		
<b>Slovakia</b>		
<b>UK</b>		
<b>.</b>	<b>.</b>	<b>.</b>
<b>.</b>	<b>.</b>	<b>.</b>
<b>.</b>	<b>.</b>	<b>.</b>
<b>Croatia</b>	<b>Inefficient</b>	<b>0.631</b>
<b>Poland</b>	<b>Inefficient</b>	<b>0.578</b>
<b>Greece</b>	<b>Inefficient</b>	<b>0.525</b>

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# Conclusions

- There are challenges to use index numbers to compare safety performance of railways
- Data Envelopment Analysis can be promising for comparing safety performance
- More research is underway



Thank you  
for your kind attention

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