



# Transporting hazardous materials: Transboundary and multi modal aspects

Nils Rosmuller (TNO)



Safera meeting (Athens), 12-13 april 2016



# Hazardous materials transportation in EU by ROAD in milion tons (EU stats, 2015)

???  
Miljon  
tons

???  
Miljon  
tons

Group	NST 2007	Thousand tonnes					Tonne-kilometres				
		2011	2012	2013	2014	Change 2013-2014	2013	2014	Change 2013-2014		
01	Products of agriculture, hunting, and forestry; fish and other fishing products	1 225 334	1 224 461	1 231 559	1 290 398	4.8%	182 117	183 393	185 407	188 920	1.9%
02	Coal and lignite; crude petroleum and natural gas	178 160	167 578	184 455	109 093	-40.9%	11 132	10 161	11 015	10 363	-5.9%
03	Metal ores and other mining and quarrying products; peat; uranium and thorium	4 269 655	3 621 346	3 515 161	3 629 088	3.2%	140 417	128 120	126 026	129 022	2.4%
04	Food products, beverages and tobacco	1 616 887	1 639 575	1 647 432	1 626 498	-1.3%	284 544	290 215	294 435	289 910	-1.5%
05	Textiles and textile products; leather and leather products	66 504	67 652	71 238	63 782	-10.5%	18 198	17 170	18 969	16 809	-11.4%
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	594 906	552 833	564 975	563 722	-0.2%	123 387	116 182	117 958	113 733	-3.6%
07	Coke and refined petroleum products	514 429	510 642	473 715	470 489	-0.7%	52 080	52 437	48 710	48 037	-1.4%
08	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	585 177	573 134	535 794	561 425	4.8%	129 753	127 571	120 973	122 894	1.6%
09	Other non metallic mineral products	2 072 062	1 865 269	1 777 052	1 770 000	-0.4%	155 869	140 031	136 999	136 424	-0.4%
10	Basic metals; fabricated metal products, except machinery and equipment	581 341	554 223	544 150	540 000	-0.5%	58 718	123 216	121 791	121 229	-0.5%
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks	297 236	274 404	262 201	260 000	-2.9%	57 690	55 261	53 669	53 669	-2.9%
12	Transport equipment	240 326	233 202	235 281	235 000	4.6%	61 536	62 928	65 853	65 853	4.6%
13	Furniture; other manufactured goods n.e.c.	105 592	96 531	95 518	100 000	5.1%	28 379	28 915	30 399	30 399	5.1%
14	Secondary raw materials; municipal wastes and other wastes	1 098 067	1 105 930	1 099 720	1 135 387	5.9%	66 454	63 047	63 464	67 220	5.9%
15	Mail, parcels	177 831	174 791	173 104	170 614	-1.7%	37 284	35 666	36 736	36 116	-1.7%
16	Equipment and material utilized in the transport of goods	253 247	263 228	255 648	279 023	9.1%	37 048	39 245	38 118	38 463	0.9%
17	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non market goods n.e.c.	120 225	128 084	139 135	148 026	7.0%	10 973	12 219	13 365	14 303	7.0%
18	Grouped goods: a mixture of types of goods which are transported together	657 355	700 912	818 687	810 655	1.9%	148 386	151 929	175 487	178 765	1.9%
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	170 184	125 753	158 665	161 665	3.0%	23 651	20 025	26 482	25 692	-3.0%
20	Other goods n.e.c.	193 444	162 426	167 822	176 021	4.9%	36 773	32 410	35 331	36 071	2.1%



# Hazardous materials transportation in EU by ROAD

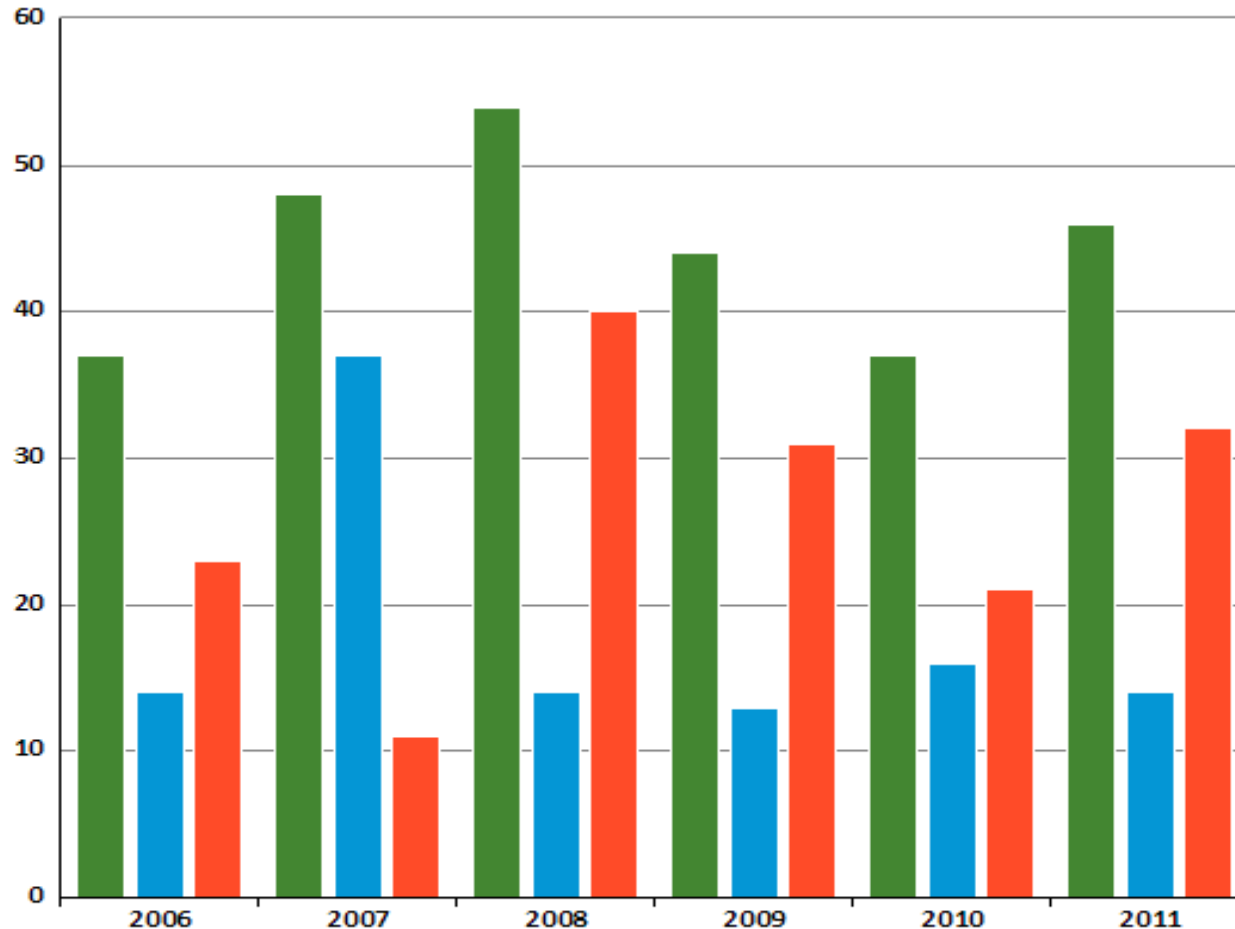
109

561

Group	NST 2007	Thousand tonnes					Tonne-kilometres				
		2011	2012	2013	2014	Change 2013-2014	2011	2012	2013	2014	Change 2013-2014
01	Products of agriculture, hunting, and forestry; fish and other fishing products	1 225 334	1 224 461	1 231 559	1 290 398	4.8%	182 117	183 393	185 407	188 920	1.9%
02	Coal and lignite; crude petroleum and natural gas	178 160	167 578	184 455	109 093	-40.9%	11 132	10 161	11 015	10 363	-5.9%
03	Metal ores and other mining and quarrying products; peat; uranium and thorium	4 269 655	3 621 346	3 515 161	3 629 088	3.2%	140 417	128 120	126 026	129 022	2.4%
04	Food products, beverages and tobacco	1 616 887	1 639 575	1 647 432	1 626 498	-1.3%	284 544	290 215	294 435	289 910	-1.5%
05	Textiles and textile products; leather and leather products	66 504	67 652	71 238	63 782	-10.5%	18 198	17 170	18 969	16 809	-11.4%
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	594 906	552 833	564 975	563 722	-0.2%	123 387	116 182	117 958	113 733	-3.6%
07	Coke and refined petroleum products	514 429	510 642	473 715	470 489	-0.7%	52 080	52 437	48 710	48 037	-1.4%
08	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel	585 177	573 134	535 794	561 425	4.8%	129 753	127 571	120 973	122 894	1.6%
09	Other non metallic mineral products	2 072 062	1 865 269	1 777 052	1 770 000	-0.4%	155 869	140 031	136 999	136 424	-0.4%
10	Basic metals; fabricated metal products, except machinery and equipment	581 341	554 223	544 150	540 000	-0.5%	38 718	123 216	121 791	121 229	-0.5%
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks	297 236	274 404	262 201	260 000	-2.9%	57 690	57 690	55 261	53 669	-2.9%
12	Transport equipment	240 326	233 202	235 281	230 000	4.6%	61 536	61 536	62 928	65 853	4.6%
13	Furniture; other manufactured goods n.e.c.	105 592	96 531	95 518	100 000	5.1%	28 379	28 379	28 915	30 399	5.1%
14	Secondary raw materials; municipal wastes and other wastes	1 098 067	1 105 930	1 099 720	1 135 387	5.9%	66 454	63 047	63 464	67 220	5.9%
15	Mail, parcels	177 831	174 791	173 104	170 614	-1.7%	37 284	35 666	36 736	36 116	-1.7%
16	Equipment and material utilized in the transport of goods	253 247	263 228	255 648	279 023	9.1%	37 048	39 245	38 118	38 463	0.9%
17	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non market goods n.e.c.	120 225	128 084	139 135	148 026	7.0%	10 973	12 219	13 365	14 303	7.0%
18	Grouped goods: a mixture of types of goods which are transported together	657 355	700 912	818 687	810 655	1.9%	148 386	151 929	175 487	178 765	1.9%
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.	170 184	125 753	158 665	161 665	3.0%	23 651	20 025	26 482	25 692	-3.0%
20	Other goods n.e.c.	193 444	162 426	167 822	176 021	4.9%	36 773	32 410	35 331	36 071	2.1%



# EU haz.mats. transportation accidents



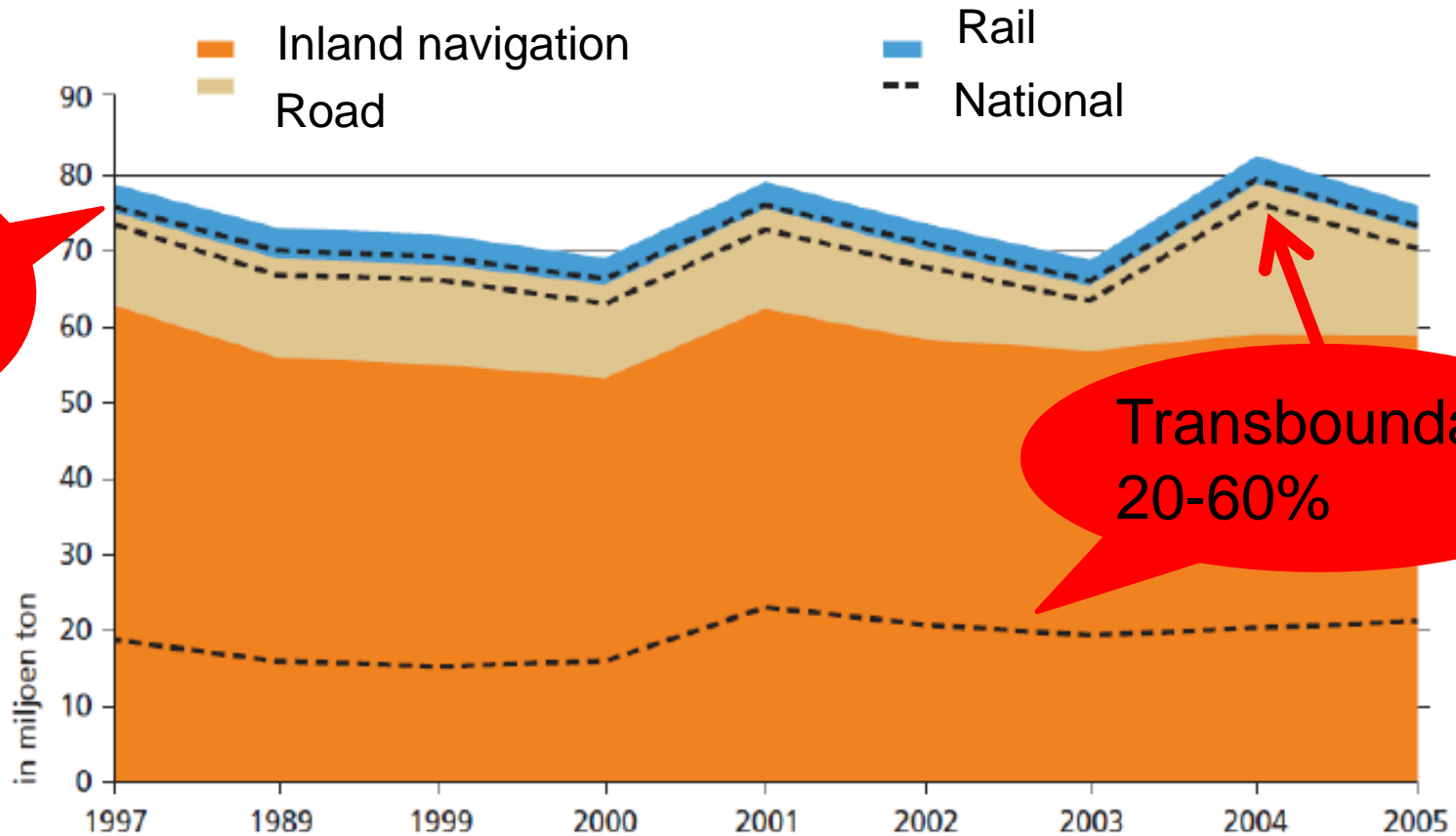
(Eurostat, 2013)

- Accidents involving transport of dangerous goods
- Accidents in which dangerous goods are not released
- Accidents in which dangerous goods are released



# Hazardous materials transportation

EG: the Netherlands: road, railway, inland navigation



75

Transboundary:  
20-60%



# Freight transportation: trends

Sustainability goals: more environmental friendly modes of transportation (inland waterway and rail instead of road transport).

Modal shift goals: eg Port of Rotterdam (in container transport)

	In 2005	In 2035
Road	47%	35%
Inland navigation	40%	45%
Rail	13%	20%



# Freight transportation: trends

Synchro-modality: use the mode of transportation that matches the urgency/need for (fast) transport needs

Clean fuels, such as LNG instead of gasoline



## Research question

*What safety assessment concept facilitates the decision-making of international and multi-modal hazardous materials transportation by shippers?*







# Consortium: BAM, TUDelft and TNO

2nd Safera call



master thesis (TUDelft)  
to make an inventory  
of the problem  
(Dimitra Tasoula)



Safety Assessment of Trans-boundary  
and Multi-modal Hazardous  
Materials Transportation

Concept Development

The LPG and LNG Cases

Dimitra Tasoula - 4329597





## Research approach

- literature study
  - Identify decisions
  - the role of the regulations
  - the risk assessment practices that are currently used
- empirical case study
  - liquefied gases shipping companies
  - Liquefied Petroleum Gas and Liquefied Natural Gas in the Netherlands and Belgium



## Actors

Stakeholders of the Hazardous Materials Transportation System (TRB, 2013)

### Public Sector

National Governments  
Regional Governments  
Global Government Regulators  
Emergency Respondents  
Inspectors

### Private Sector

Logistics Service Providers  
Shippers  
Carriers  
Safety Professionals  
Security Professionals  
Insurers



## Strategic decisions: facility location and routing

<b>Commodity related data</b>	Characteristics of hazardous materials
	Quantity of dangerous good
	Mode of transport characteristics (size, capacity, container type)
<b>Route-related data</b>	Presence of sensitive receptors
	Number of transshipment nodes
	Distance traveled
<b>Population-related data</b>	Population density
<b>Other data</b>	Meteorological data
	Travel time
	Time of day of the trip
	Time of year of the trip
	Facility characteristics (capacity, opening costs)



## Tactical decisions: routing

### Route-related data

Travel speeds

Length of routes

Type of route (urban, rural etc.)

Route characteristics (e.g. intersections)

### Population-related data

Population Distribution

Time-dependent population distribution

### Other data

Meteorological Conditions (yearly, daily)

Statistics on accident frequencies



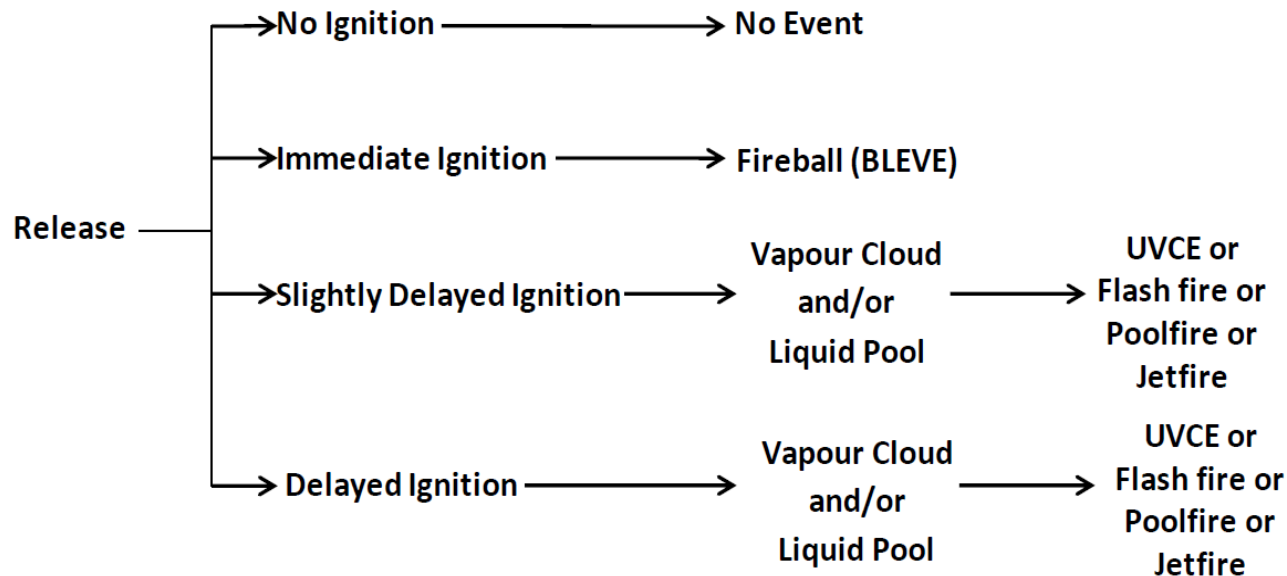
## **Operational decisions: daily trip planning**

Only risk assessments in case of an extra ordinary event such as incident, road construction activities, ...



## Empirical studies: LPG

**LPG:** combustible gas, at normal temperature and pressure is gaseous, compressed and liquid form, in cylinders or bulk tank, using almost all modes of transport (sea or inland vessels, rail, road, pipeline) except for air.

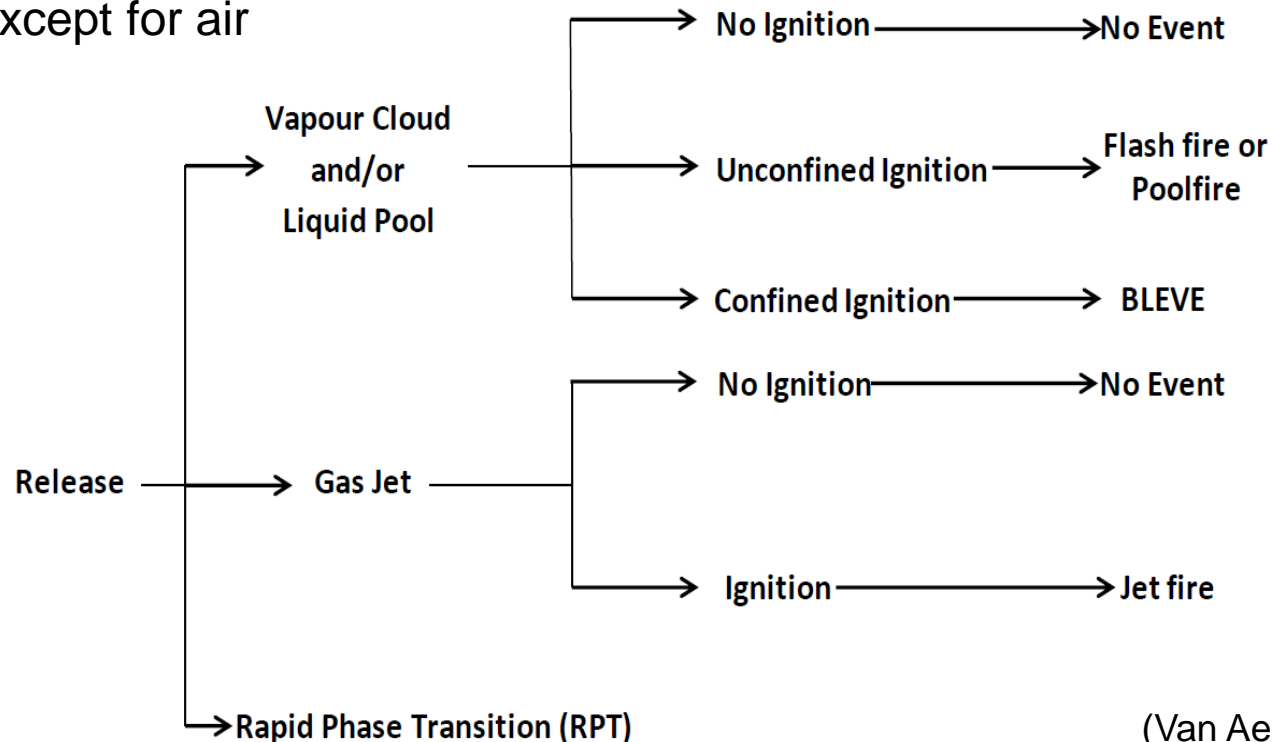




## Empirical studies: LNG

**LNG:** LNG is derived by the cooling of natural gas to below  $-162^{\circ}\text{C}$ , the volume of LNG is 600 times less than the same amount of natural gas at room temperature: *rather clean fuel*

all modes of transport (sea and inland vessels, road, rail, pipeline), except for air







## Conclusion

Multi-modal transportation of hazardous materials (ic LPG and LNG) is not preferred by transport companies:

→ Cost ineffective, increase in operations, more regulations

→ Difficult to monitor whole logistic chain: many, many actors

→ LNG safety concerns related to the international transportation of haz.mats are taken care by the regulations (in EU: ADR, RID, AND).

→ **Baseline: to comply with regulations**

**However:**



## Conclusion

# However:

- There are international differences in regulations:
  - Several countries accept LNG as *fuel* for haz.mat. road transportation (such as NI), others do not (such as Germany)
  - LPG is not LNG: cold, condensation (sight reduction) and emergency response ( do not use water)
  - Research into the consequences of an LNG release
  - Country specific rules for infra objects such as tunnels



## Next activities

Focus on LNG transportation, and more specific on accidental releases in tunnels



BAM: PhD student → Mohammad Rezay



TNO: medior scientists → Andreas Mack and Hans Boot



TU Delft: Genserik Reniers will monitor



## Next activities



BAM: model consequences of released LNG vapor from fuel tank

Scenario 1: released LNG due to safety valves in fuel system

Scenario 2: Fire of the vehicle combined with LNG release

→ Numerical and experimental investigation



## 7. Next activities

TNO: accidental release of LNG from a road truck fuel tank inside a road tunnel

Scenario 3: (semi-)continuous release from fuel feed pipe (10mm diameter)

Scenario 4: Instantaneous release

→ Modeling study