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TRANSPORT & MOBILITY LEUVEN

LNEC
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APOLLO VEHICLE SAFETY

Overweight vehicles impacts on road infrastructure and safety

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Project Results

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All India Permit
GOODS CARRIER
HR55 L-2150
VALID ALL OVER INDIA
SPEED 40 KM
TATA

Mission & methodology

*The purpose of this project is to offer to **road administrations and decision makers** a clear image of the **impact of overweight vehicles** on the **road infrastructure** (material and economic impacts) and **road safety**, and to propose some **mitigation or enforcement tools and policy** to ensure better compliance between the heavy vehicles and the regulations.*

Overloading=

- **Overweight at vehicle level (gross combination weight, GCW)**
- **Overloaded axle(s)**

Methods:

- Desk research
- Online survey with follow-up

Structure of the research

1. Current weight limits around the world
2. Categorization of overweight vehicles
3. Impact analysis
    1. Infrastructure: Pavement & bridges
    2. Road safety
    3. Economic effects: Infrastructure managers & road operators
4. Best practices for mitigation

Current weight limits around the world

- Gross vehicle weights (GV): range 36-130 tonnes
- Axle weights: typically higher in developed, densely populated countries with higher infrastructure management budgets
  - Europe: 10/11.5t (non-driven/driven)
  - South America: 6t (non-driven)
  - Canada/USA: +-9t (non-driven)
  - Africa: 8t
  - Australia/NZ: 7 to 7.6t

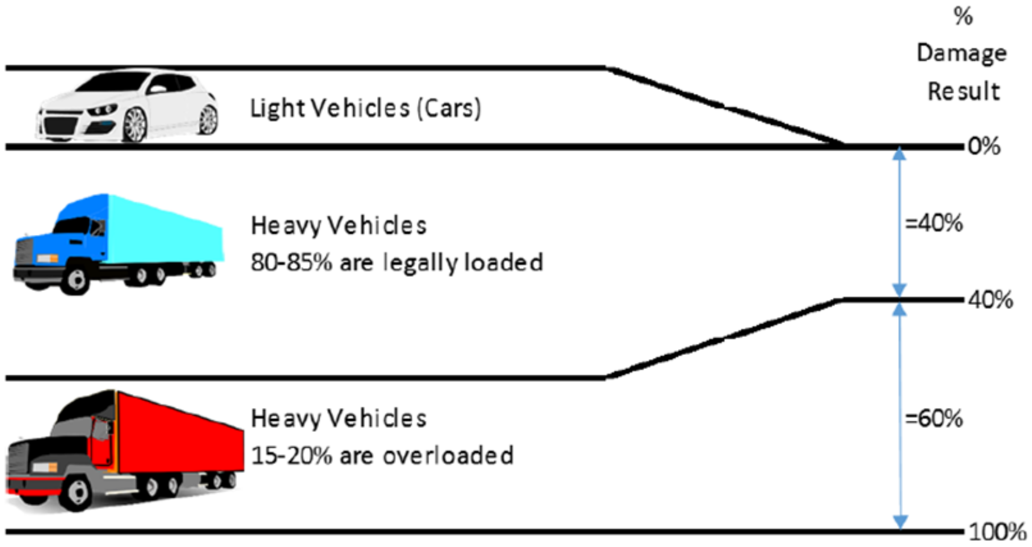
Overweight vehicles around the world

- Based on national data
- Not necessarily consistent
- Difference between primary and secondary road network
- Low % (<1%) of overloads in most HIC
- LMIC clearly higher range from 15-40%
- Some countries almost no weight compliance

- Most important driver = cost saving (facilitated by lack of enforcement)

Infrastructure - Pavements

- Effects on pavements
- Main types of pavements
- Road network composition by type of pavement (input from survey)
  - **flexible (thin) and unpaved roads** are the most common types of pavements in **LMIC**.
- Pavement distresses induced by overweight
  - **traffic load** is the most important distress factor, for all types of pavements (main and additional failure mechanisms)

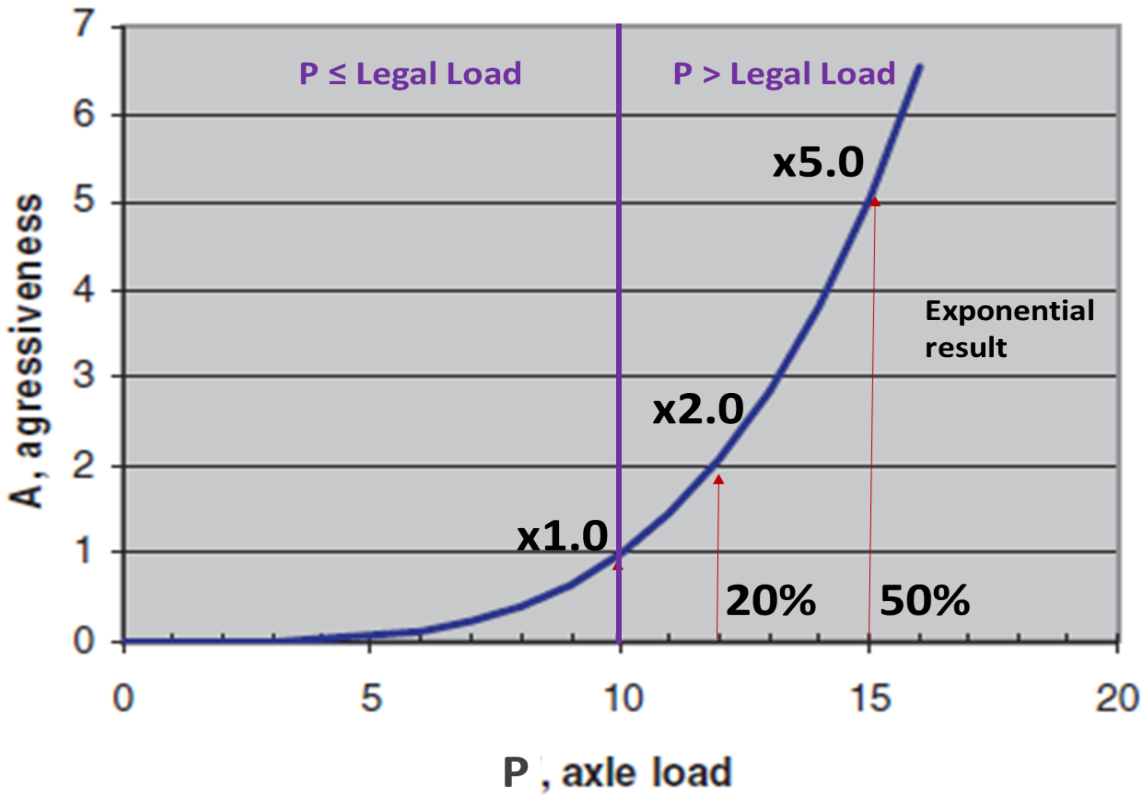


Overloaded vehicle damage impact on flexible pavements (CSIR, Roads and Transport Technology, 1997

Infrastructure - Pavements

- Considerations of truck aggressiveness on pavement structure

- The influence of vehicles configuration
  - Axle load
  - Groups of axles
  - Wheels and tyres
  - Load distribution
  - Suspension

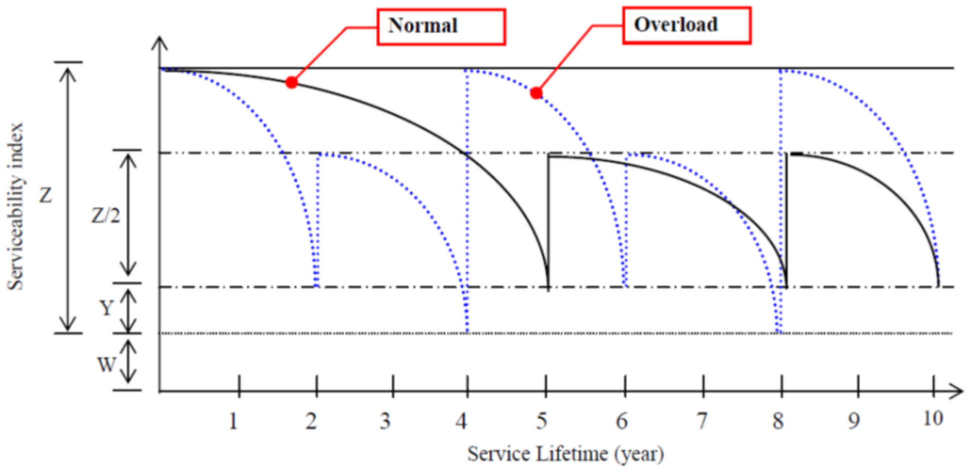


Aggressiveness against a 10 t reference axle according with the 4th power law, adapted from (OECD ITF, 2011)

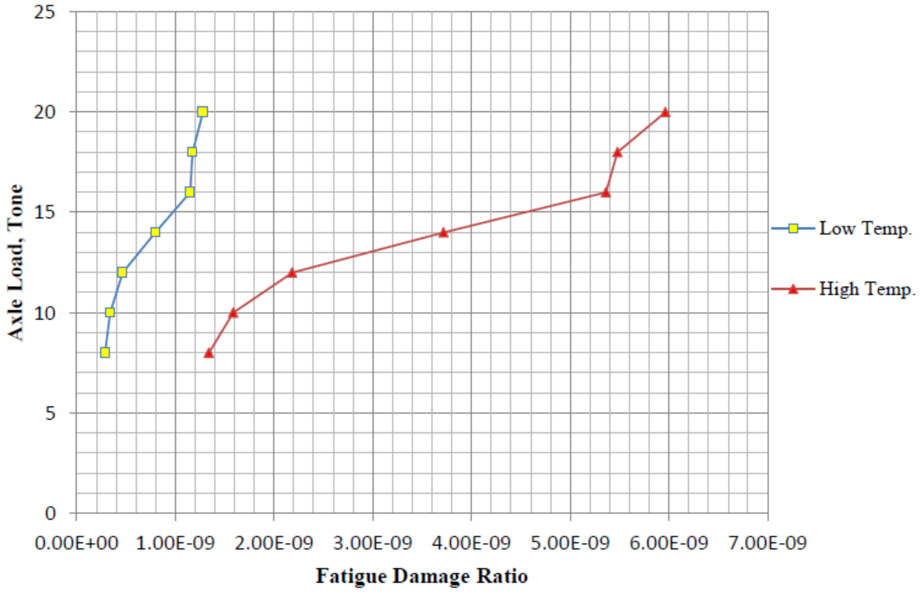
Infrastructure - Pavements

- The influence of pavement characteristics
  - Type of pavement
    - Flexible pavements
    - Rigid and semirigid pavements
    - Unpaved roads
  - Unevenness and dynamic effect
  - Maintenance
- The influence of environmental factors
  - Temperature
  - Drainage and water presence

Distresses of unbound pavements: corrugation
(Skorseth & Selim, 2000)



Scenario of road serviceability decrease due to overloading vehicle (Musbah, 2017)



The relationship between axle load and fatigue damage ratio with temperature (Musbah, 2017)

Infrastructure - Pavements

In summary,

The effect of overloading on pavement residual life depends on different factors **type of pavement**, **type of traffic**, **vehicle wheel and suspension, tire pressure**. The most affected pavements are:

- **unpaved roads** (LMIC) because overloading will result in **permanent deformation** and longitudinal **unevenness**
- **thin flexible pavements** with weak subgrade (LMIC), will suffer exponentially with increasing overload
- **unmaintained pavements** and with cracking initiation will be more affected by overloading

Influence of different factors on pavement service life

	Influence on pavement service life*			
	Type of pavement			
	Unpaved	***Flexible***	***Semi-rigid***	***Rigid***
Vehicles configuration				
Axle load	H	H	H	H
Group of axles	M	M	L	L
Wheels and tyres	M	M	L	L
Load distribution	H	H	M	M
Suspension	M	M	L	L
Pavement characteristics				
Type of pavement	H	H	Only above over design load	Only above over design load
Unevenness	M	M	L	L
Environmental factors				
Temperature	L	H	L	L
Drainage and water presence	H	H	L	L

* H – high; M – medium; L – low

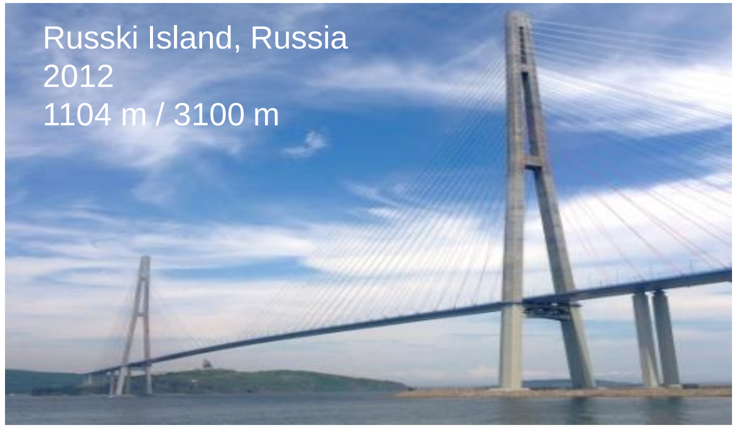
Fatigue damage mechanism:

1) Overloading axles results in a **disproportionate level of damage.** (mitigate through: better vehicle practice & road design)
2) Pavement **design and maintenance good practices** will reduce the extent of damage
   - **Vehicles (**encouraging good distribution of load among the axles & use of ‘road friendly’ suspension and twin tyres)
   - **Pavements (m**inimising pavement roughness & designing correctly for the temperature conditions)

Infrastructure Impact: Actions on Bridges

- Dead loads
- Natural and climatic actions
- Live loads: **Traffic loads**
- Accidental loads (incl. **highly overloaded trucks**)

- Modern bridges: higher performant materials, more accurate computation and modelling economy of material and energy ⇒ **live load/dead load increases**
- Accumulation of (heavy) vehicles on long pan bridges
- Live loads: **Traffic loads**
- Accidental loads (incl. **highly overloaded trucks**)



Infrastructure Impact: Overload Phenomenon on Bridges

- Continuous increase of heavy traffic
- Average rate of overloads: 5 to 10% of the lorries, mostly by less than 10%, but higher overloads on secondary roads
- Lack of gross vehicle weight limit harmonization in the EU (max. 40 to 75 t)
- Use of routing apps (e.g. Waze) ⇒ large and heavy vehicles on secondary roads + under designed/ maintained bridges
- Short gaps between trucks, illegal spacing (< 50 m) and "twinning", congestions, plans for platooning…
- Lighter procedures and permanent permits for abnormal loads (up to 120 t)

Collapse of the Mirepoix, France, suspension bridge because of an overloaded truck (2019)

Annone, Italy (2016), 110 t truck

Infrastructure Impact: Impact of Loads and Overloads on Bridges

- Aging structures $\Rightarrow$ fatigue, wear…
- Fatigue of steel and composite bridges, increased by corrosion, cables (suspended and cable stayed bridges), prestressing cables in cracked structures
- Uncertain safety margin and load capacity of aged bridges
- Combination of actions: traffic loads + temperature + corrosion

- Short spans: **individual wheel and single axle loads govern local load effects**, (influence lines of 1 to 5 m), with dynamic amplification (up to 40 or 50%)
- Medium spans: **gross vehicle weight and group of axle loads govern semi-local effects**, (influence lines of 5 to 30 m), with moderate dynamic amplification (up to 15 to 25%). Crossing and overpassing of heavy vehicles
- Long span bridges: **series of heavy loaded vehicles at short gaps**, no dynamic amplification
- Horizontal forces: braking, centrifugal and transverse effects (curves)

Infrastructure Impact: Mitigation measures for Bridges

1. to identify the most sensitive bridges and sub-structures
2. to limit the permitted load on aged, partially damaged or with loss of load capacity bridges
3. to carefully monitor loads and overloads on bridges affected by disorders
4. to monitor the total load on long span bridges (congested traffic), and to prevent crossing or multiple presence (overtaking) of overloaded trucks on short and medium span bridges
5. to install WIM or bridge-WIM system before or on sensitive bridges, with ANPR, to identify the overloaded vehicles crossing them, and to issue warnings to the truck owners (at least), or fines (if the WIM system are type approved by the legal metrology).
6. to report suspected identified overloads to the bridge owners and the road authorities, and to take preventive measures by the truck operators.

Safety: What is affected by Overloading?

- Overloading => vehicle performance => collision risk
  - (Steering & handling, braking, structural failures, load movement, collision severity, speed differentials (slow trucks up hill), lower effectiveness of roadside restraints etc.)
- Effects not always adverse
- Vehicles are designed for more weight than regulations allow – modest overloading may not be obvious to driver
- Careful messaging to drivers is required: Advice needs to match their experience

Safety: Vehicle specification & condition

- High income countries
  - Good fitment of vehicle safety systems (e.g. ABS/ESC)
  - High standards of new vehicle condition/specification
  - Good in-use condition with regular periodic technical inspection (except USA)
- LMIC
  - Most also report good fitment of ABS/ESC
  - New vehicle condition noted as average to good.
  - Where PTI mentioned, problems with compliance or correct implementation noted
  - 3 of 5 report “average” in use vehicle condition, 1 poor to average, 1 poor
- Safety implications of overloading likely to be greater where vehicle specification/condition is worse – limited evidence suggests worse in LMIC

Safety: How does performance influence collision and injury?

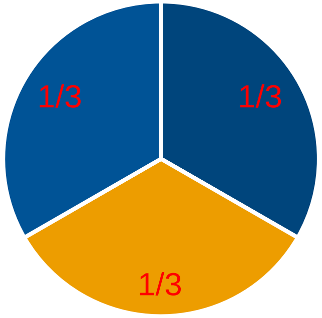
- Overloading is frequent, even in HIC
- Individual vehicle performance effect can be large: catastrophic examples easily found but….
- Overall frequency of collisions as a direct consequence of overload appears low.
- Beware…..
  - Data limitations, under-reporting etc
  - Indirect effects: e.g. overloading prematurely polishes road surface, reduces skid resistance and contributes to single vehicle car collision
  - Analyses mainly exist in high income countries with good infrastructure, vehicles and enforcement
  - Situation may be substantially worse in other countries, particularly LMIC
- Survey unable to improve availability of data

- Proportion of injury collisions involving an HGV where overloading
  - Contributory GB 1.0%
  - Contributory Scotland 1.3%
  - Present Portugal 0.3%
- Proportion of Fatalities from collisions involving HGVs where overloading present/contributory
  - Contributory GB 0.3%
  - Contributory Scotland 0.0%
  - Present Portugal 1.2%
- Note fatality numbers subject to errors from very small sample size.
- Meaningful analyses not possible with remaining countries – impossible to compare by country income level

Economic impact: Road transport operators

- Revenue: more weight ~= more revenue

- Total cost = variable cost (fuel, road charge)
  + semi-fixed cost (labour)
  + fixed cost (equipment, insurance,…)



Impact of overweighting

Incentive to maximise cargo load

- Cost of fines: risk of getting caught x level of the fine
  Bribes…

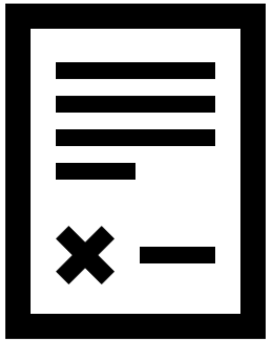
Economic impact: Road infrastructure managers

- Costs of overloading: determined by how many vehicles (prevalence) & amount of overweight (intensity)

- Other considerations:
  - Design axle load is often lower than maximum legal load
  - Overloading may be a result of economic need (e.g. lack of capacity of road transport)

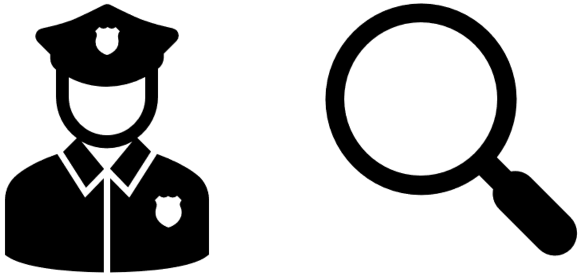
- Economic countermeasure: fines (more than) proportional to overload

Best practices for mitigation



Legislation

Prevention and education



Detection and enforcement

Penalties

Best practices for mitigation

1. Elements of legislation
   - Vehicle
   - Axles/axle sets
   - Network
   - Weight limits
   - Derogations
   - Detection methods
   - Penalties
2. Prevention and education
   - About legislation
   - Other consequences of overloading: road conditions, safety, vehicle damage,…
   - Government and road transport sector

Best practices for mitigation

3. Detection and enforcement
    - Methods: static: fixed/mobile, LS-WIM on dedicated area, or in motion (WIM)
    - On-Road and Bridge WIM
    - On board WIM
    - Applications of detection/WIM based on survey input
    - Used for preselection or direct enforcement
4. Penalties
    - Liability (driver-vehicle owner-cargo owner)
    - Financial/operational/institutional
    - Rewarding good behaviour

Conclusions

- Damage from overloaded vehicles is disproportionate (axle weight – “4^{th} power law”)
- System perspective: cover all aspects
  - Economic need is driver
  - Strong enforcement: detection + penalties/incentives
  - High quality infrastructure can better withstand overloads
  - High quality vehicles reduce safety risks
- LMIC:
  - higher frequency over overloading (10-100%)
  - Secondary roads
  - Unpaved/thin flexible pavement roads most sensitive

Recommendations

- System approach
- Progressive fines
- Enforcement sites at critical points in the network
- Use of WIM
- Maintenance of pavements and bridges

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