Infrastructure Challenges

Workshop

OECD / ITF Study on
Truck Transport Safety, Productivity and Sustainability

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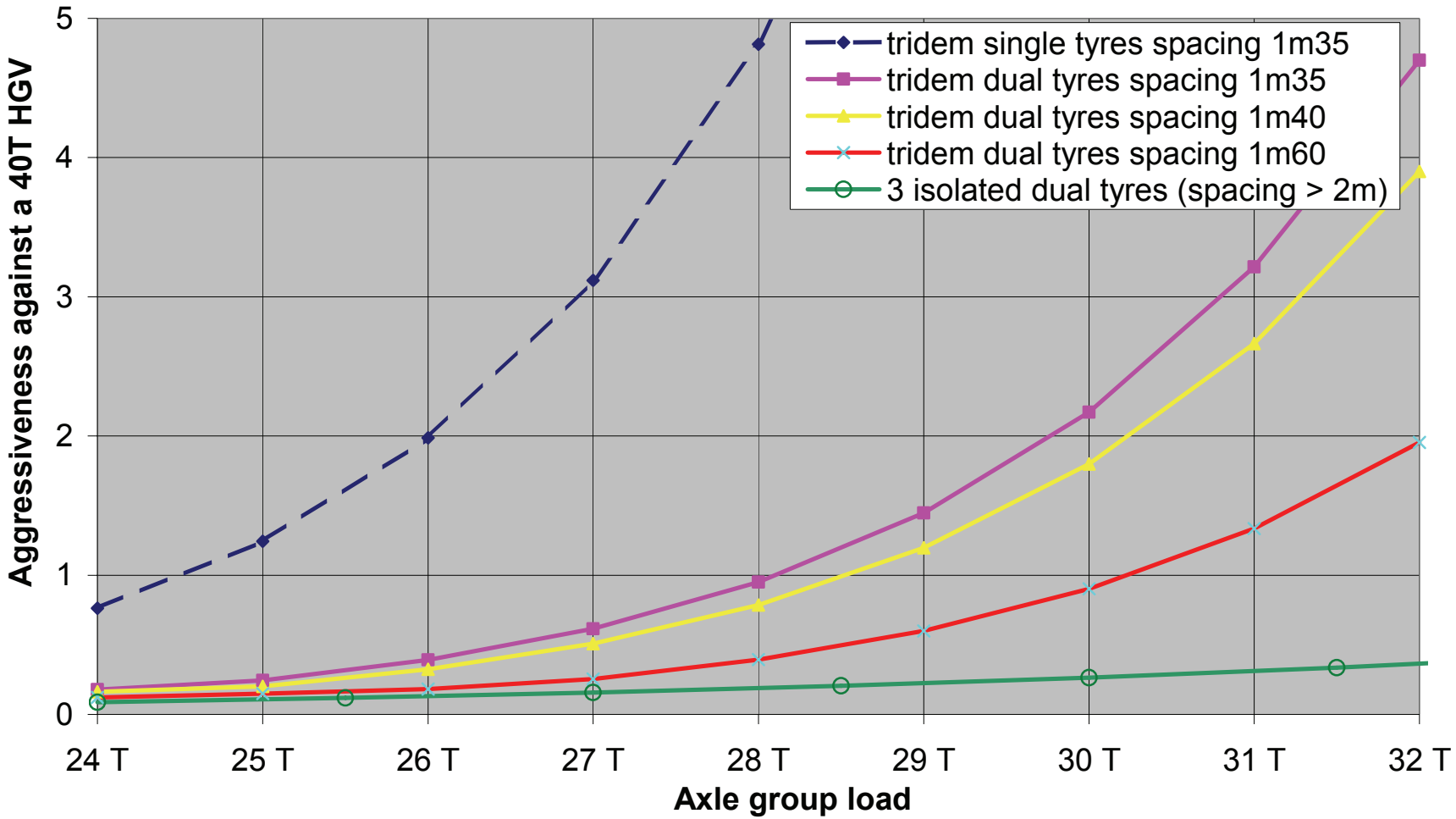
Outline

- Effects on Pavements
  - Pavement issues
  - Effect of axle configuration
  - Methodology
- Effects on Bridges
  - Methodology
  - Extreme loads and load effects
  - Fatigue
- Other Impacts
  - Impacts on safety barriers, bridge piers and tunnels
  - Impacts on road perception and operations
- Conclusions and Recommendation

Pavement issues

- If pavements and trucks are developed together, transport is facilitated while reducing its cost
- It requires to take into account many aspects :
  - Environment
    - Pavements (type, strength, …)
    - Climate
    - Availability of resources (aggregates, soils, …)
  - Truck configurations
    - Axle load
    - Group of axles (number, spacing)
    - Wheel and tyres
    - Load distribution
    - Suspensions and steerable axles

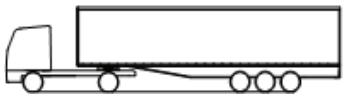
Example : influence of axles and tyres



Method for evaluating truck aggressiveness

- Relative Vehicle Wear Factor: $VWF_{rel}(truck_x) = \frac{VWF(truck_x)}{VWF(truck_{ref})}$

- Reference truck



40 t / 16.5 m

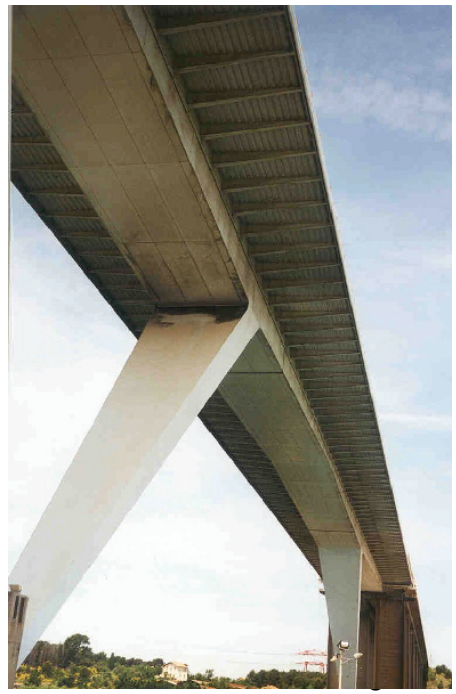
- Wear factor of a group of axles: $WF_{\text{group of axles i}} = k_i \cdot \left(\frac{W_i}{W_{ref}} \right)^{\alpha_i}$

where :

- k_i and α_i are two parameters which depend, for each group of axles i, on the type of pavement and the expected traffic volume;
- W_i is the total weight carried by the group of axle i ;
- W_{ref} is the total weight carried by the equivalent reference group of axles

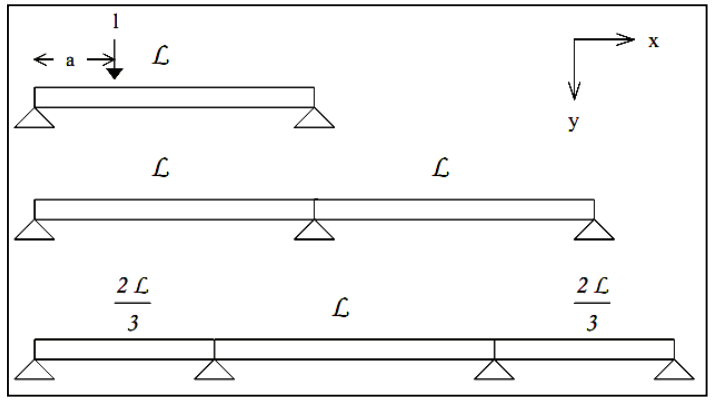
Bridge issues

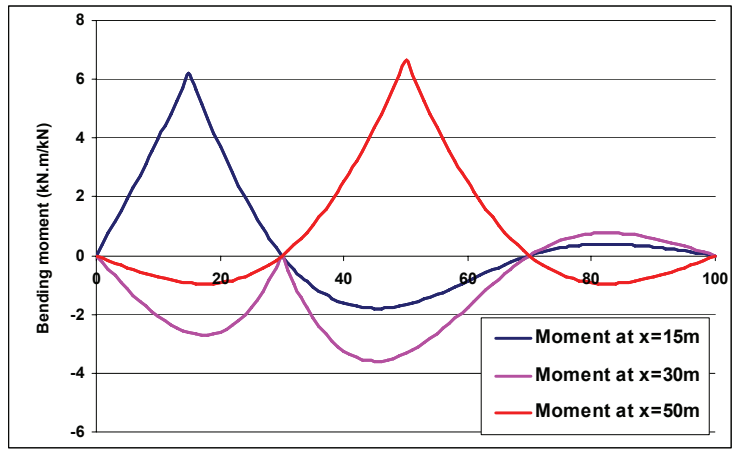
- Bridges are key/critical elements of the road network
- Bridges must be: reliable, safe, durable, and not too costly
- Heterogeneous bridge stock (ages, design, state, etc.)
- Traffic loads evolve with time:
  truck configurations, weights and dimensions
- Comparison/assessment of different truck configurations against aggressiveness
- Extreme load effects
- Fatigue (repeated loading)



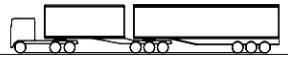
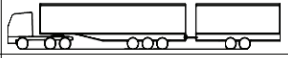
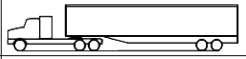
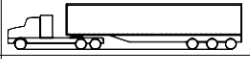
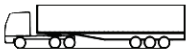
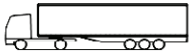
Traffic loads and load effects

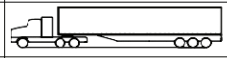
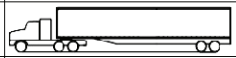
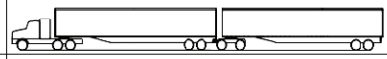
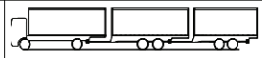
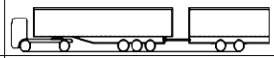
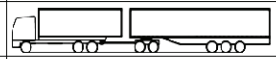
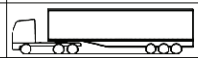
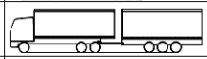
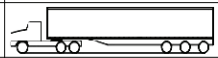
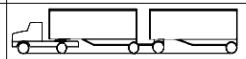
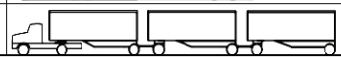
- Modelling bridges as beams : simple supported, continuous (2-3 spans)
- Influence lines : transfer functions
- Bending moments + shear forces
- L = 10, 20, 50 and 100 m
- Calculation done for 39 heavy vehicle configurations (OECD)
- Maximum load effect (1 truck)
- Fatigue: $(\text{Max-min})^{\alpha}$, α = 3, 5
- Comparison to a reference 40 t articulated truck





Heavy vehicle configurations

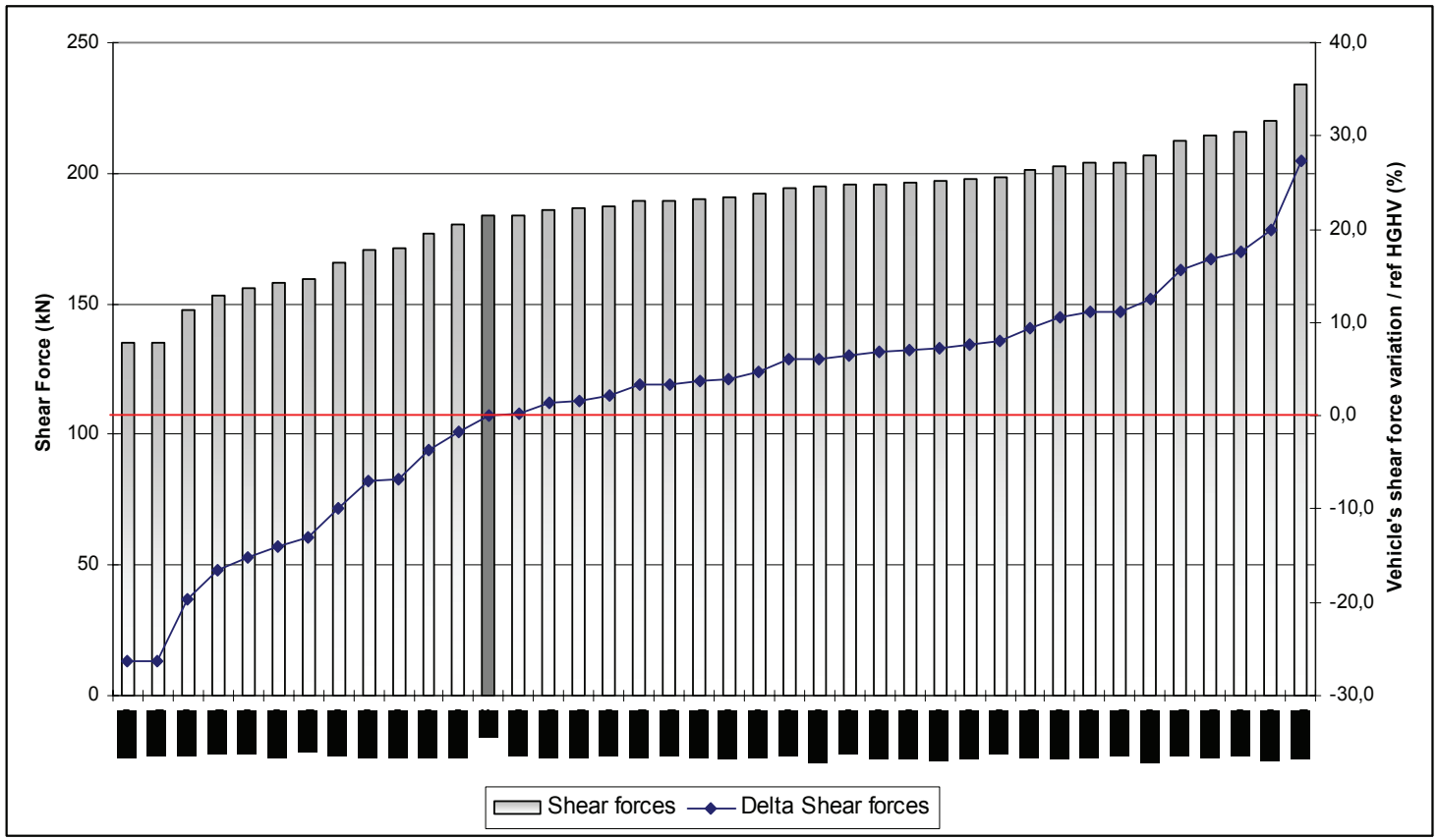
N°	Label	Vehicle configuration	GVW (t)	Payload (t)	Length (m)	Nb axles
0	Ref		40	26	16,5	5
1	AU1-w		45,50	29,00	17,31	6
2	AU2-h		68,00	44,50	25,01	9
3	AU3-v		90,50	60,00	33,31	12
4	BE1-w		39,00	22,80	16,40	4
5	BE2-h		60,00	39,30	25,25	8
6	CA1-w		39,50	25,30	21,55	5
7	CA2-w		46,50	31,30	21,55	6
8	CA3-h		62,50	42,30	20,43	8
9	CA4-v		62,50	37,30	38,33	9
10	DK1-w		44,00	30,00	16,48	5
11	DK2-w		48,00	32,00	18,75	6
12	DK3-w		48,00	32,30	16,50	6
13	DK4-h		60,00	40,70	25,25	8
14	DK5-h		60,00	38,00	25,10	8
15	EU1-w		38,00	24,00	16,50	4
16	EU2-w		40,00	26,00	16,50	5
17	EU3-w		40,00	27,00	16,90	5
18	EU4-w		40,00	21,90	18,75	5

N°	Label	Vehicle configuration	GVW (t)	Payload (t)	Length (m)	Nb axles
19	DE1-h		40,00	20,80	25,24	7
20	MX1-w		44,00	28,65	20,80	5
21	MX2-w		48,50	32,35	20,80	6
22	MX3-w		44,00	28,65	21,57	5
23	MX4-v		66,50	42,85	39,08	9
24	NL1-h		50,00	33,41	24,20	6
25	NL2-h		60,00	37,70	25,20	7
26	NL3-h		60,00	39,72	25,24	8
27	ZA1-w		43,50	28,14	15,31	5
28	ZA2-w		49,30	31,90	17,75	6
29	ZA3-h		56,00	33,80	21,97	8
30	ZA4-h		56,00	34,24	21,98	7
31	UK1-w		44,00	26,13	16,50	6
32	UK2-w		44,00	28,00	18,75	6
33	US1-w		36,35	21,15	19,77	5
34	US2-w		36,35	23,46	21,98	5
35	US3-w		41,90	26,70	19,77	6
36	US4-h		36,35	23,59	22,06	5
37	US5-h		44,10	28,90	25,12	6
38	US6-v		53,80	37,29	31,57	7

Aggressiveness (max load effect)

Coefficient of aggressiveness (truck n) : $K_n = Max(S_n)/Max(S_{ref})$

Ex.: 10 m simple supported beam, shear forces



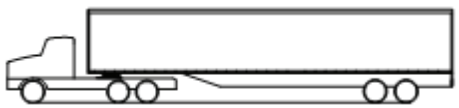
Maximum load effects and US bridge formula

- US bridge formula limits the total mass carried by any series of consecutive axles in a truck or combination :

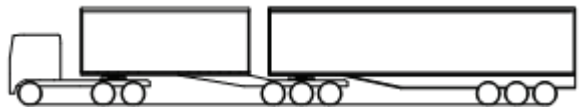
  $W = 500(L\ N/(N-1) + 12N + 36)$ (W in lbs, L in ft)

- Ex: 5-axle articulated 16.5 m = 73730 lbs or 33.5 t max (40 t in EU), $c_{ref} = 40/33.5 = 1.194$

  US-1 : $c_n=0.903$, $C_n=0.756$ AUS-2: $c_n=1.232$, $C_n=1.03$



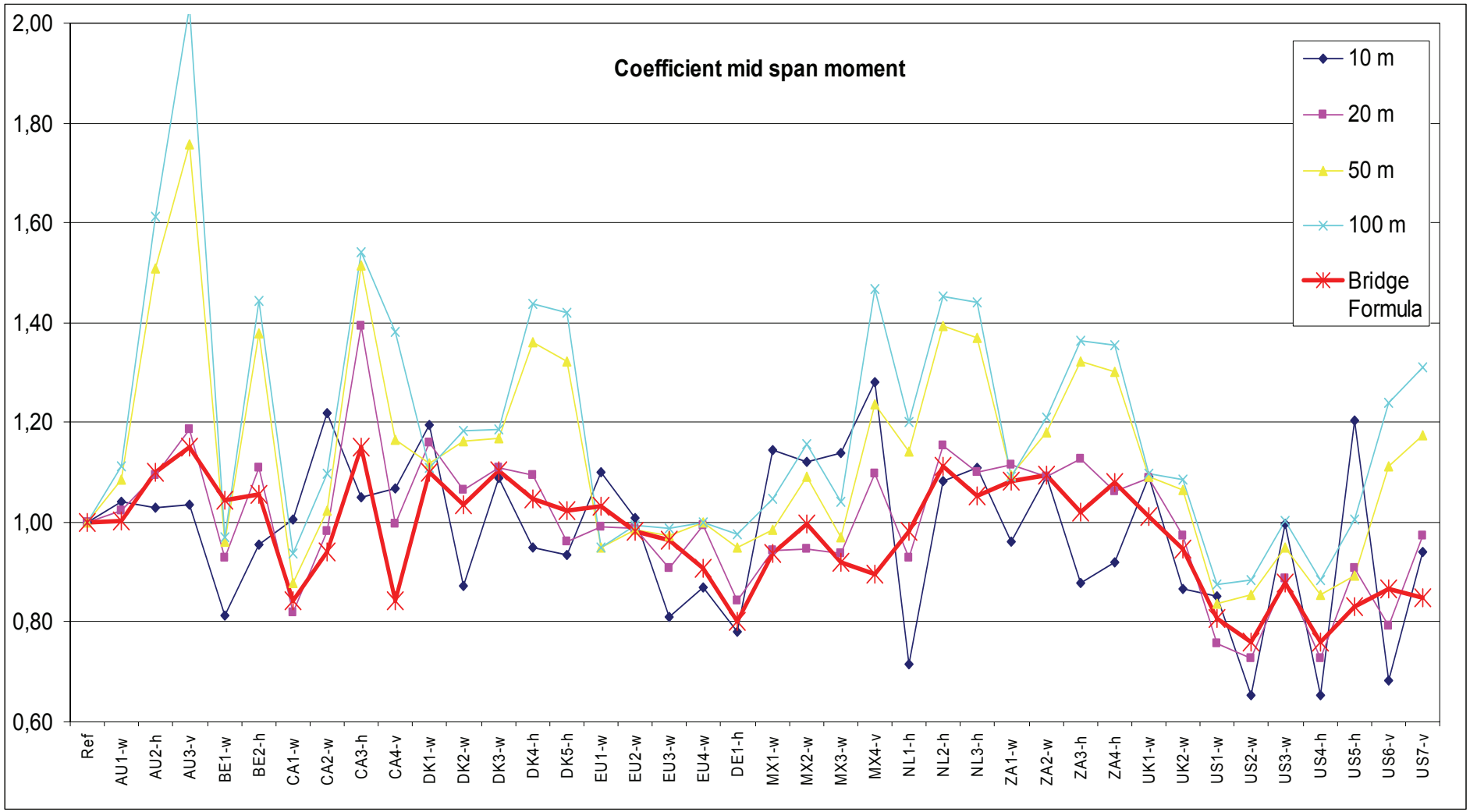
N=5, L=17.33 m, W=36.35 t
W_{bf}=40.25 t



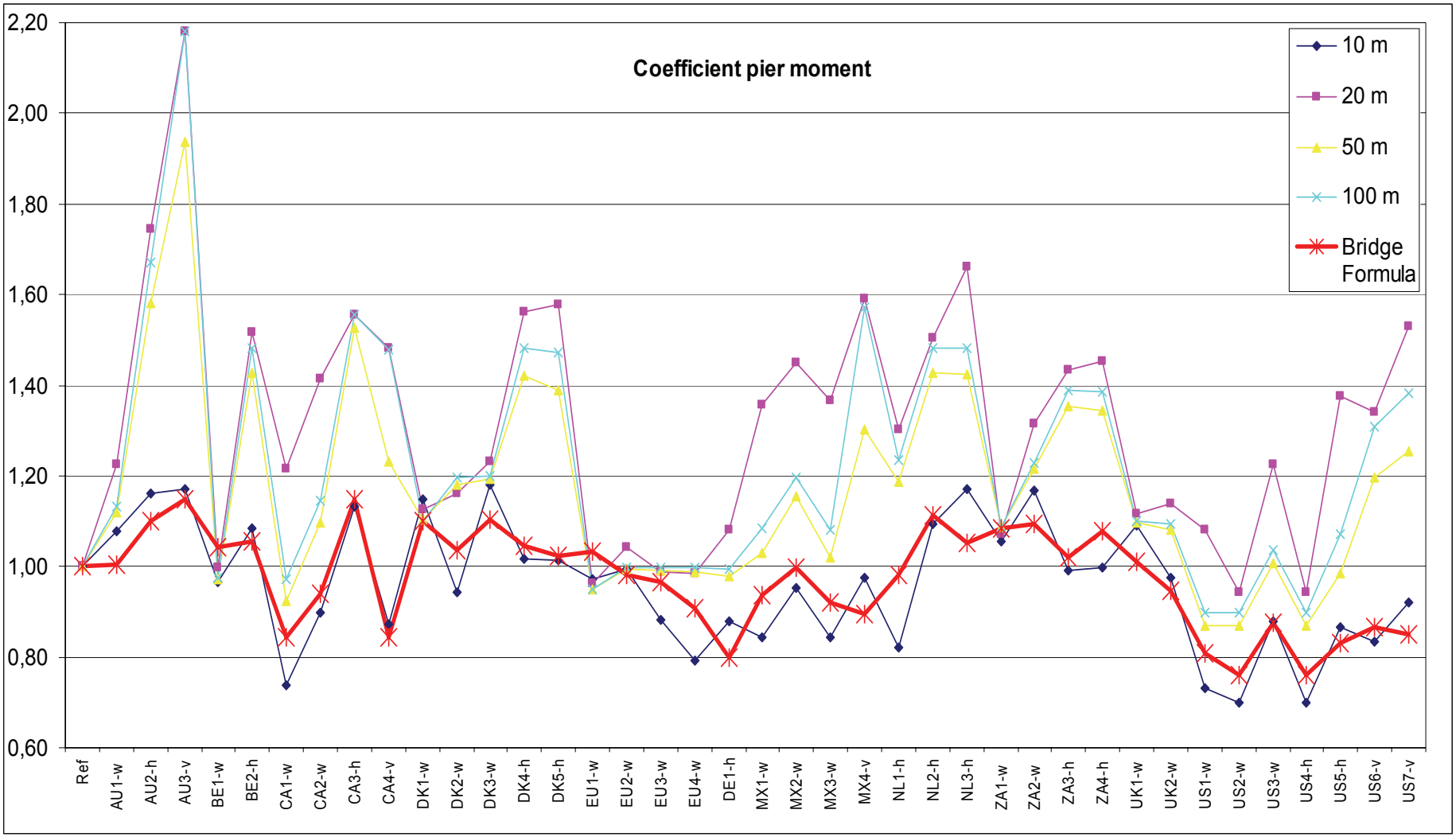
N=9, L=22.75 m, W=68 t
W_{bf}=55.20 t

- For any truck n: $c_n = W_n / W_{bf}$, $C_n = c_n / c_{ref}$ load coefficient
- Comparison of K_n and C_n

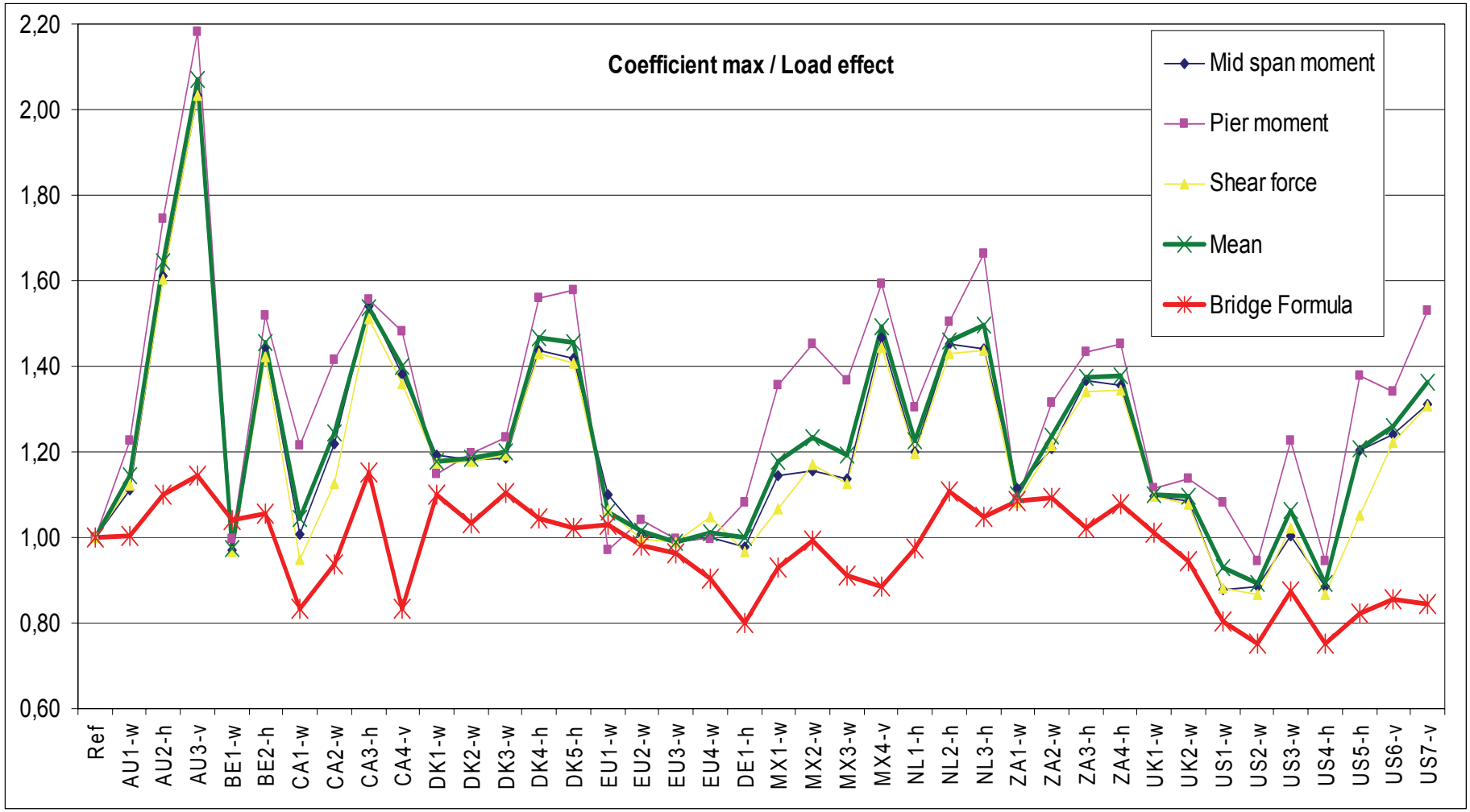
Aggressiveness 1 – max mid-span moment



Aggressiveness 2 – max moment on pier

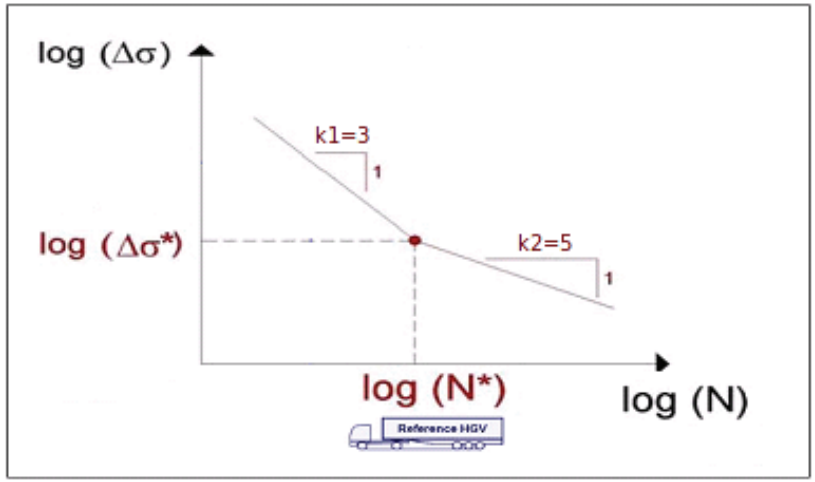


Aggressiveness 3 – all lengths vs max effects



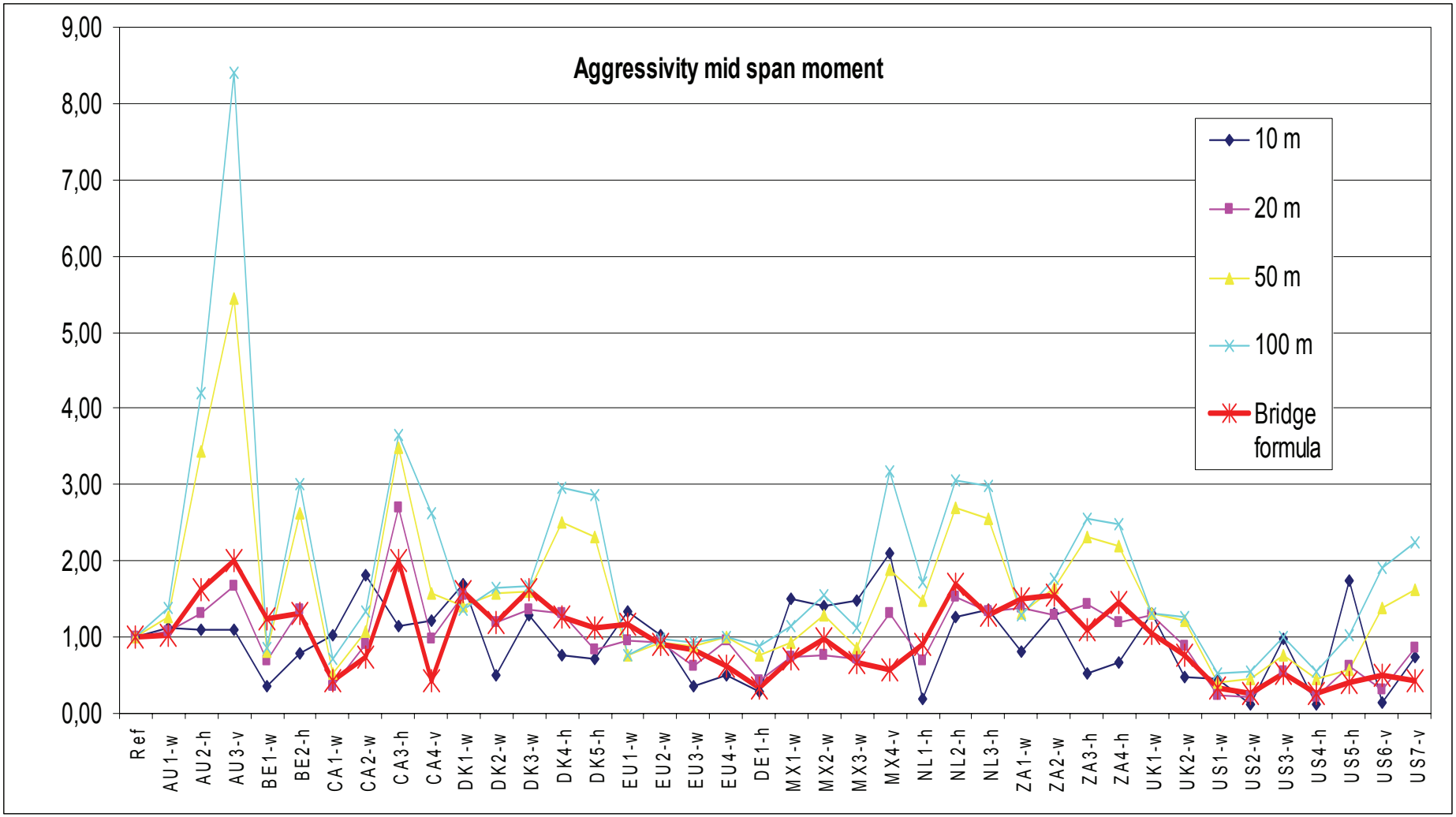
Fatigue aggressiveness

- Miner's law + S-N curve (resistance to fatigue)
- Assumptions (crude !) :
  - one truck run → one stress cycle ΔS (for moment on pier x 2 !)
  - 40 t reference truck → (Max S – min S) ≡ ΔS^* (fatigue limit)
  - coefficient of aggressiveness: $K'_n = (\Delta S/\Delta S^*)^{\alpha}$
- where $\alpha=3$ if $\Delta S>\Delta S^*$ and $\alpha=5$ if $\Delta S<\Delta S^*$
- Bridge formula: $C_n = (c_n/c_{ref})^{\alpha}$
  where $\alpha=3$ if $c_n>c_{ref}$ and
  $\alpha=5$ if $c_n<c_{ref}$

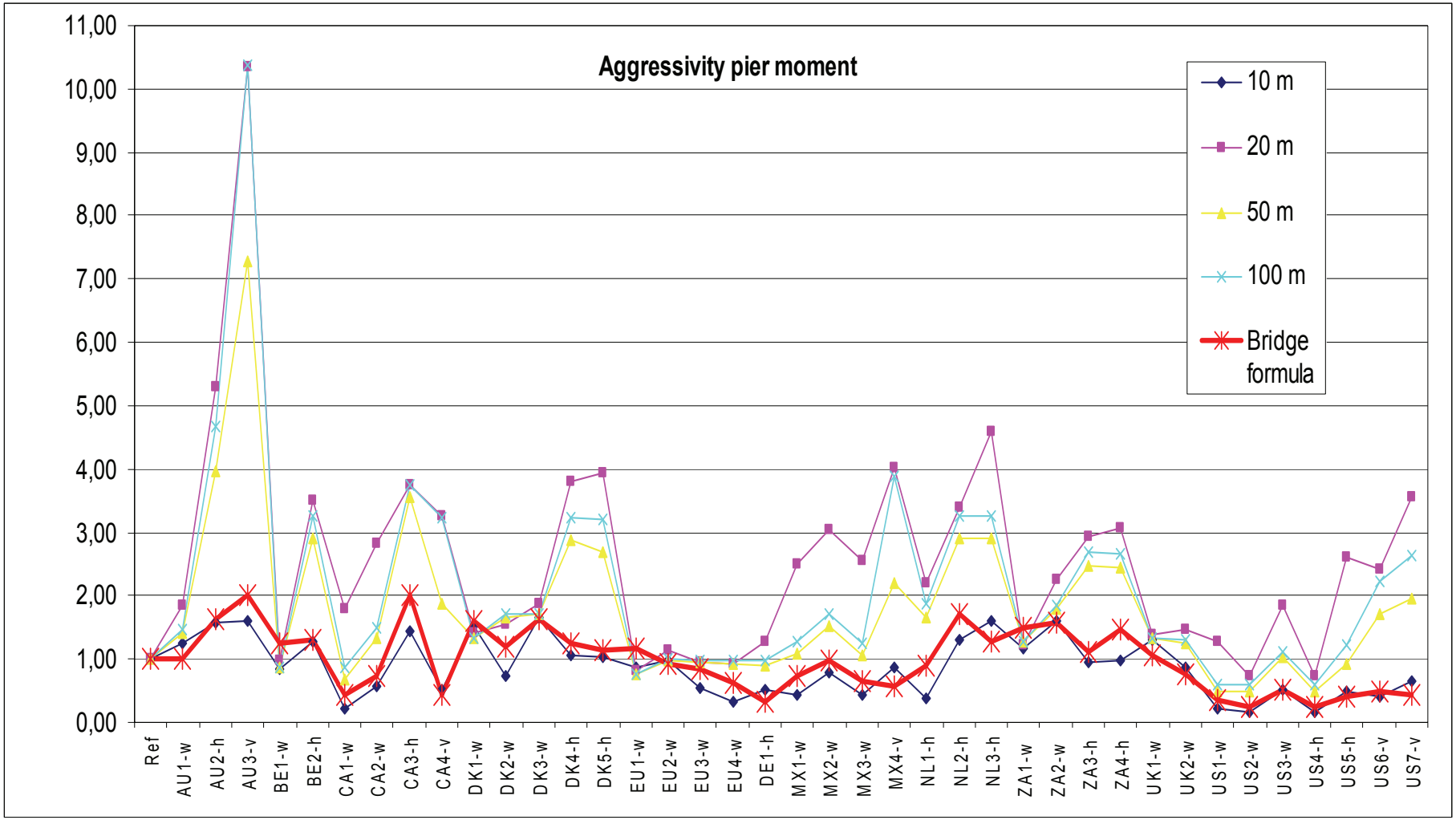


Shape of a S-NEurocode 2 line

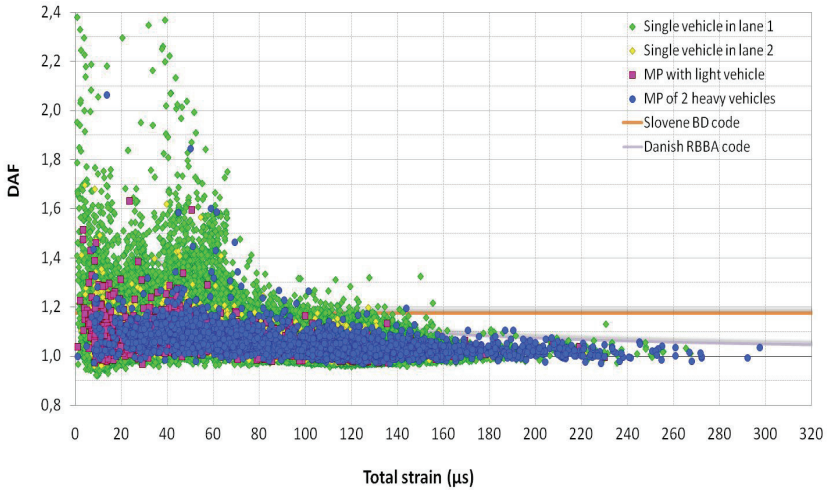
Aggressiveness 1 – fatigue mid-span moment



Aggressiveness 2 – fatigue moment on pier



Dynamic amplification, traffic load and stress monitoring



- DAF rarely exceeds 1.1 to 1.2
  - for heavy loaded vehicles
  - for more than one truck on a bridge
- 1.05 applies to extreme load cases

- B-WIM:
  - mature technology
  - more bridge types
  - more parameters
  - part of bridge monitoring systems

- Bridge (B-)WIM is an appropriate tool: stress + load +…

Impacts on safety barriers, piers and tunnels

- **Safety barriers**: designed for a given vehicle mass, speed and impact angle, e.g. EN 1317 H4b: 38 t, 65 km/h, 20°
- Design depends on: consequences of an accident, traffic volume, type of road, local conditions/geometry, etc.
- **Bridge pier**: design + protection, FE calculations
- Not all trucks contained, decisions to be taken for LHVs…
- **Tunnels**: main issue is fire, up-grade of the EU legislation since the Mt Blanc fire (1999)
  - dangerous goods to be monitored
  - permanent access and inter-distance control
  - maintenance + fire detection/suppression in trucks
  - fire resistant materials, fuel tank protection
  - driver education and training

Impacts on road perception and operation

- Road perception:
  - … and visibility affected, leads to “improper maneuvering”
  - length and distance underestimation ! Overtaking !
  - splash and spray in wet conditions, - night time signaling
- Road traffic operation:
  - to smooth the traffic flow and reduce congestion:
    - speed limit harmonization (between trucks)
    - overtaking limitations/bans
    - to locally allocate dedicated lanes to trucks
  - to improve safety and efficiency:
    - crossings and turns design, LHV’s prohibited in some area/sections
    - adapted speed limitation vs. the infrastructure (roundabout, curves…) and the vehicles (load, height of the gravity center, performances…)
    - extension of parking lots
    - IAP (Int. Access Program) to be developed

Conclusions and recommendation (1)

PAVEMENTS

- Axle loads and configurations are much more important than the gross vehicle mass
- Distributing the load evenly among all the axles substantially reduces the aggressiveness
- Method exists to evaluate these aspects respecting the characteristics of the studied network

Conclusions and recommendation (2)

BRIDGES

- Truck aggressiveness mainly depends on the axle loads and the UDL (kN/m)
  $\rightarrow$ do not increase axle load, increase truck length more than load
- The heaviest trucks govern some bridge effects (medium span, semi-local effects), multiple presence events and long spans, fatigue can be an issue
- The US federal bridge formula is applicable for short/medium span bridges, has been designed for 20 m / 73 200 lbs trucks. To be up-dated and extended.
- Dynamic effect is NOT a major issue, bridge load and stress monitoring can be very effective (e.g. with B-WIM) + IAP and truck routing

Conclusions and recommendation (3)

OTHERS

- Safety barriers and bridge piers to be re-assessed/reinforced (LHVs)
- Better hazard monitoring (truck/driver/infras) in tunnels…
- ITS to be developed for road operation, strategies to be developed for LHVs

Thank you !