The 2° TrainDy study

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Study requirements

Scenario	Minimum weight limit in tons (for trains > 1600/2500 t respectively)	Wagons forbidden (in trains > 1600 t)	Sequence rules (for trains > 1600/2500 t respectively)
Reference	32/40	Articulated / permanently coupled wagons	None
3	32/40	None	None
2	None	Articulated / permanently coupled* wagons	Wagons below 32/40 t at the end of the train
1	None	None	Wagons below 32/40 t at the end of the train

- Hauled mass between 1600 and 2500 t (minimum 32 t/wagon) in regime LL with a maximum of 3 consecutive unbraked wagons, without articulated wagons. These trains are labelled as REF1.
- Hauled mass between 2500 and 4000 t (minimum 40 t/wagon) in regime LL with a maximum of 3 consecutive unbraked wagons, without articulated wagons. These trains are labelled as REF2.

Study requirements

Task No.	Tasks to be performed
1	A check is needed to identify how much the current [1600 t -2500 t] wagon rake weight limit, from which wagons may not weigh less than 32 t, could be increased in case the Long Locomotive contained 6 or 7 wagons instead of 5 (in brake position G), so that the abovementioned restrictions in the scenarios' table are still not necessary.
2	A check is needed to identify how much the current [2500 t-4000 t] wagon rake weight limit, from which wagons may not weigh less than 40 t, could be increased in case the Long Locomotive contained 6 or 7 wagons instead of 5 (in brake position G).
3	A check is needed to identify how much the [1600 t -2500 t] wagon rake weight limit (from which wagons must weigh at least 32 t) can be increased if the minimum allowed curve radius is also increased (as a function of dependency)
4	A check is needed to identify how much the [2500 t-4000 t] wagon rake weight limit (from which wagons must weigh at least 40 t) can be increased if the minimum allowed curve radius is also increased (as a function of dependency)

- Hauled mass between 1600 and 2500 t (minimum 32 t/wagon) in regime LL with a maximum of 3 consecutive unbraked wagons, without articulated wagons. These trains are labelled as **REF1**, in this report.
- Hauled mass between 2500 and 4000 t (minimum 40 t/wagon) in regime LL with a maximum of 3 consecutive unbraked wagons, without articulated wagons. These trains are labelled as **REF2**, in this report.

Study requirements

Special analysis is requested to be done about the influence of articulated wagons in the train in terms of risk for derailment compared to other wagon types, the aim being to identify whether it is justified to apply special restrictions about allowance of articulated wagons in P-trains >1600 t.
Thereby articulated wagons can be:

i. Loaded
ii. Empty
iii. Partly loaded (load/container on one side of the wagon only, uneven loading)

The following assumptions will be used in the analysis:

- Trains can be up to 740 m long
- Simulations are based on cast iron brake pads as reference
- Analysis considers LCF as well as LTF (Longitudinal Tensile Forces)
- One type of locomotive is used in the simulations – as a relative approach is used, this can be regarded sufficient
- The simulations consider articulated wagons in the trains. These are treated as bogie wagons with longer lengths - corresponding to the actual length of articulated wagons.

Methodology

- ✓ The trainsets are generated in agreement with the IRS 40421 flowchart
  - ➢ Full acceleration (i.e., with full power) from zero speed to 30 km/h followed by an emergency braking
  - ➢ Emergency braking from 30 km/ h and train in coasting conditions. The label EB is used
- ✓ The Permissible Longitudinal Compressive Forces (PLCF) are computed in agreement with the extrapolation rules set in IRS 40421. The PLCF is a function of wagon type, **payload**, track radius, buffer type.
  - ➢ For the Longitudinal Tensile Forces (LTF), the IRS 40421 does not provide indications and the value of 550 kN is used for the PLTF. This values does not cause any train disruption (by itself), but it is capable to start a mechanical fatigue process, which can bring to train disruption, after several applications.
- ✓ This study computes the in-train forces considering that the train moves on a straight track, then (in a post processing) the permissible forces are computed considering the minimum track radius. The ratios between LCF and PLCF are computed assuming that the highest LCF (in module) force is experienced between two consecutive wagons running on a curve of minimum curvature radius. This approach is conservative, since it is not likely that the highest LCF of the train is experienced when the wagons are negotiating a curve with the minimum curvature radius.

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- ✓ The Permissible Longitudinal Compressive Forces (PLCF) are computed in agreement with the extrapolation rules set in IRS 40421. The PLCF is a function of wagon type, **payload**, track radius, buffer type.

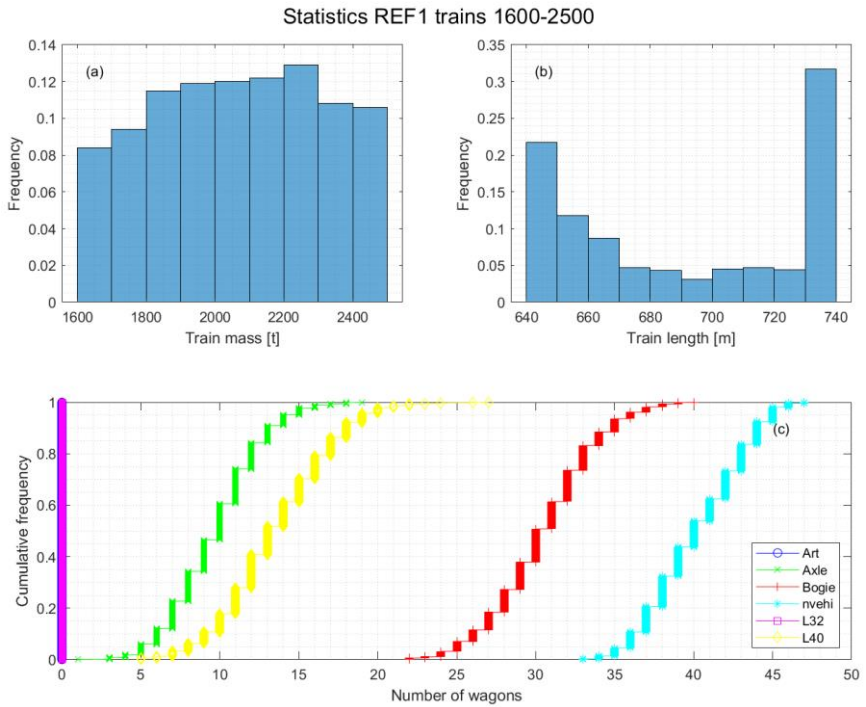
The PLCF of articulated wagons is computed on the basis of IRS 40421 extrapolation for bogie wagons and this following conservative assumption: the payload is divided between the two parts, loading at maximum possible (according to a maximum mass per axle of 22.5 t) one of the two parts and considering as payload, for the IRS 40421 extrapolation, the remaining payload. In formulas:

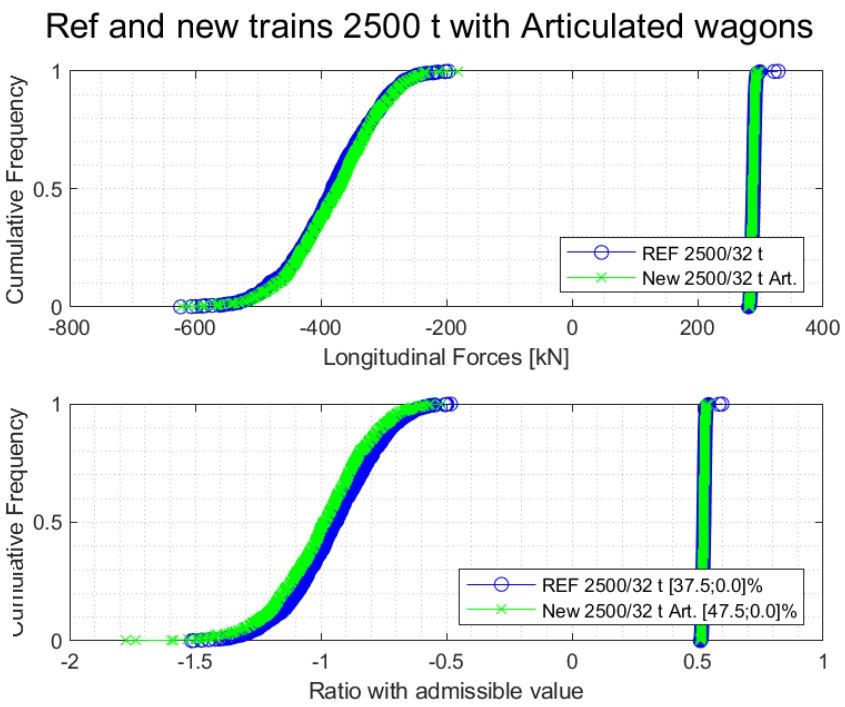
- ❖ $m_{pa} = 22.5$; n_a is the number of axles of the wagon
- ❖ $L = L_H + L_L$, the total wagon **payload** (L) is divided among the load of the heavy part (L_H) and the load of the light part (L_L).
- ❖ T is the tare of the wagon (wagon mass is $M = L + T$, of course)

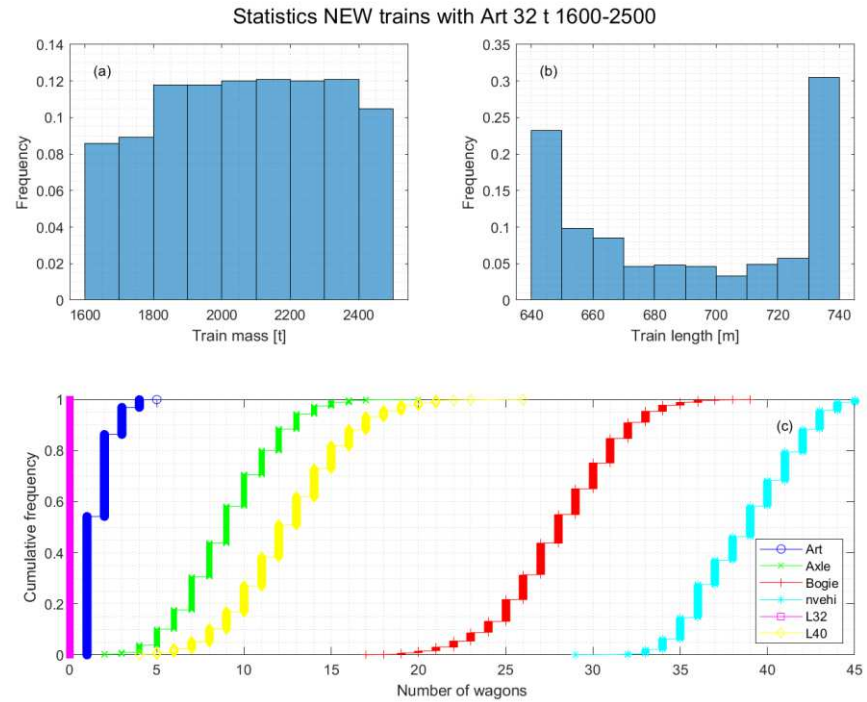
$$L_H = \min\left(L, \quad \frac{m_{pa} \cdot n_a - T}{2}\right); \; L_L = L - L_H$$

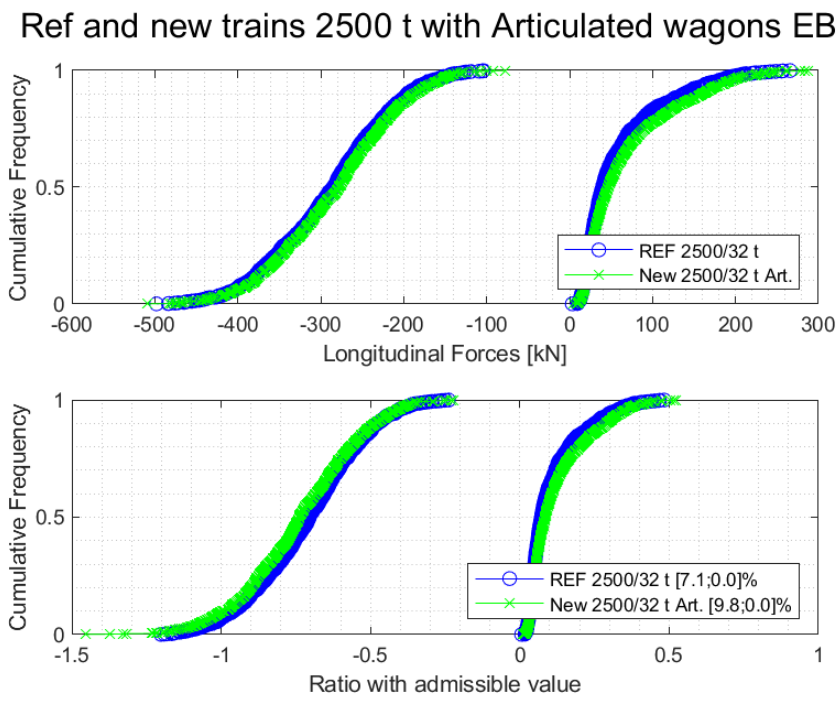
L_L is used as wagon payload for the extrapolation rules of IRS 40421.

Effect of articulated wagons









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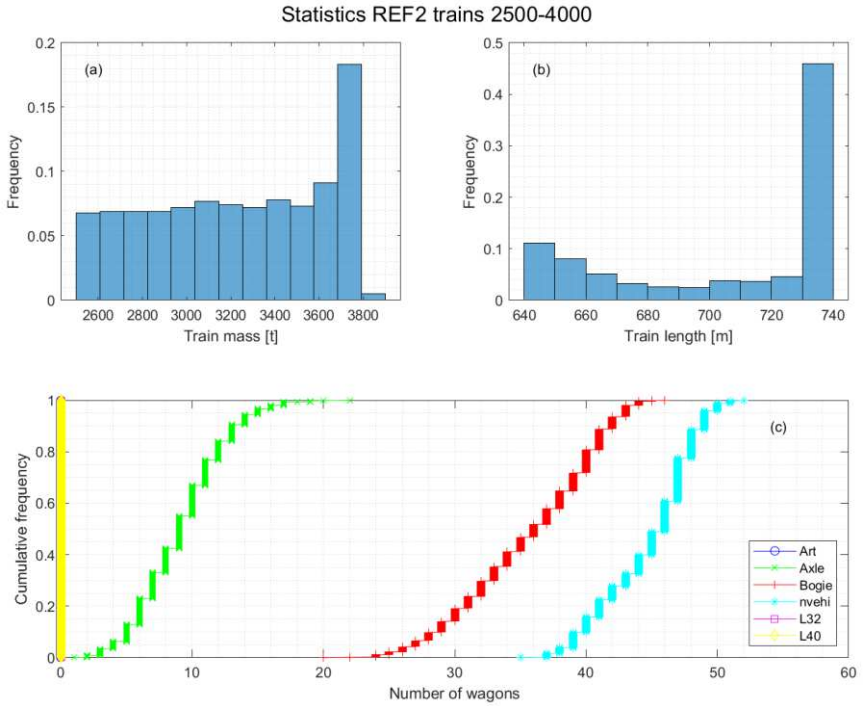
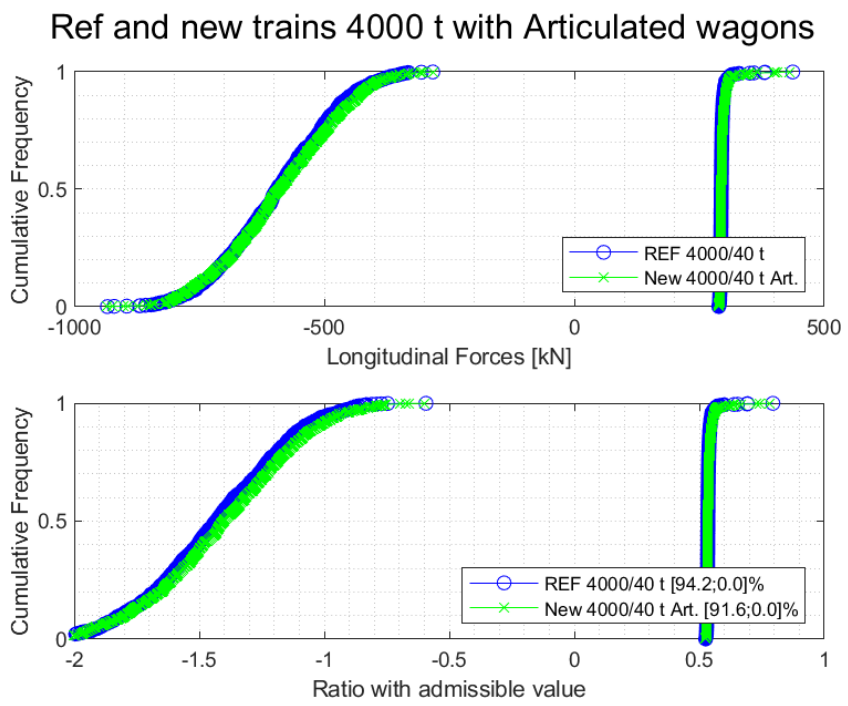
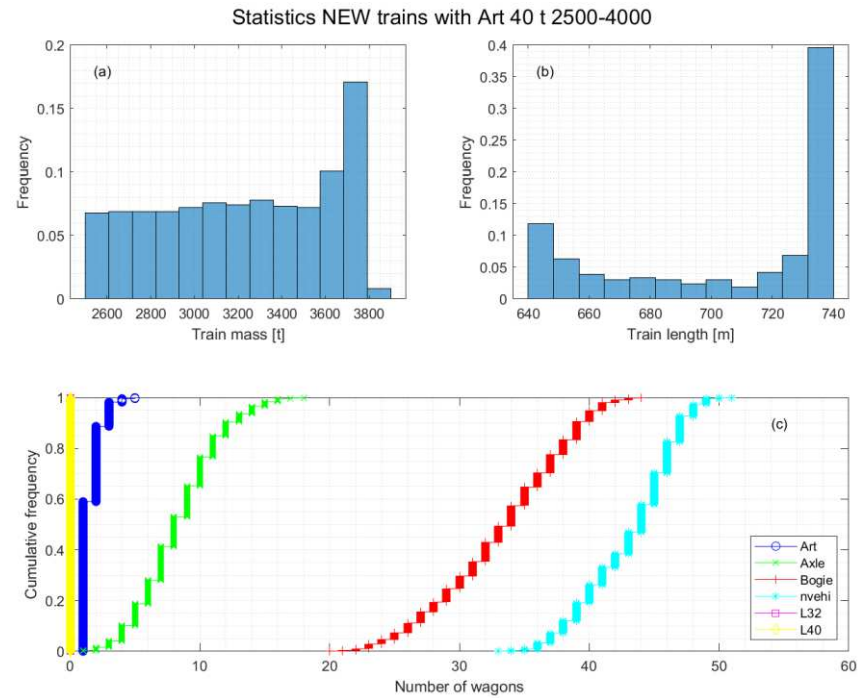
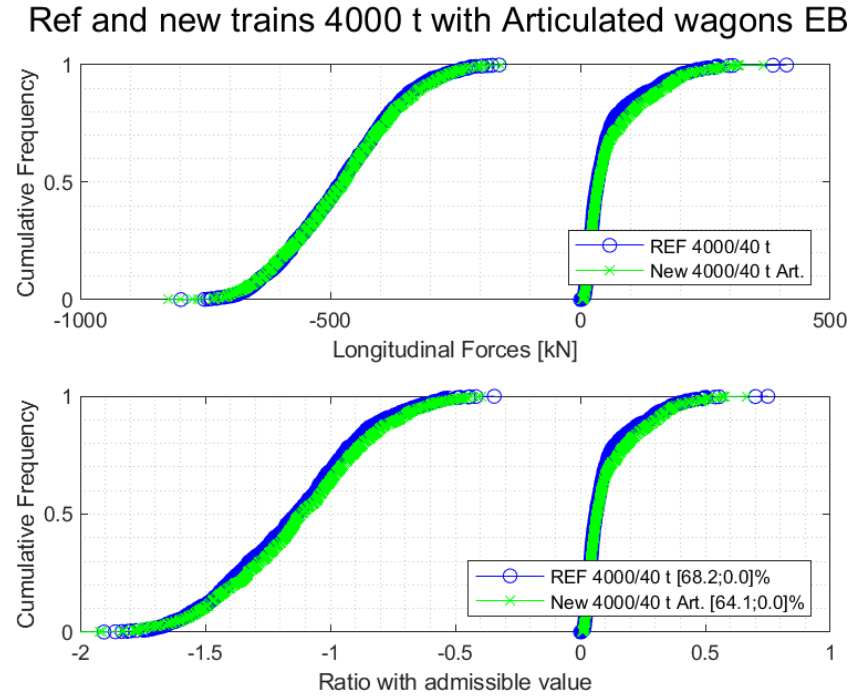
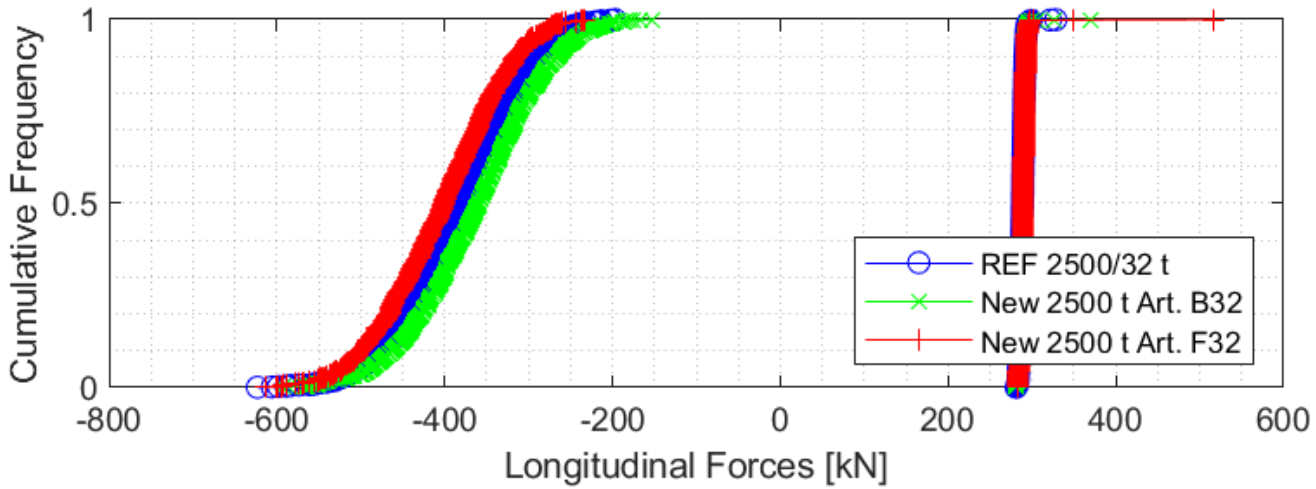


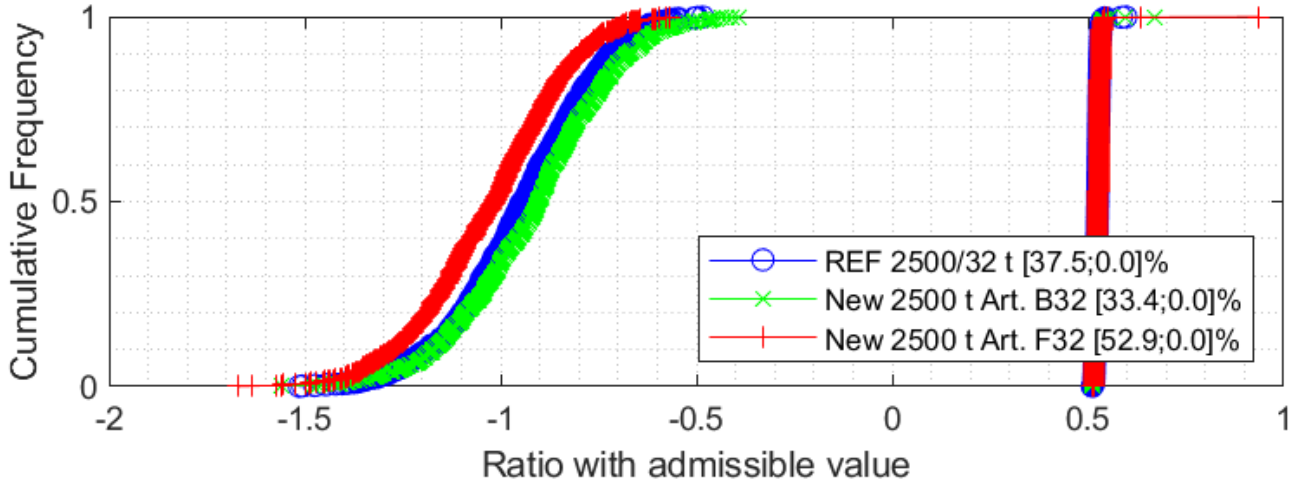




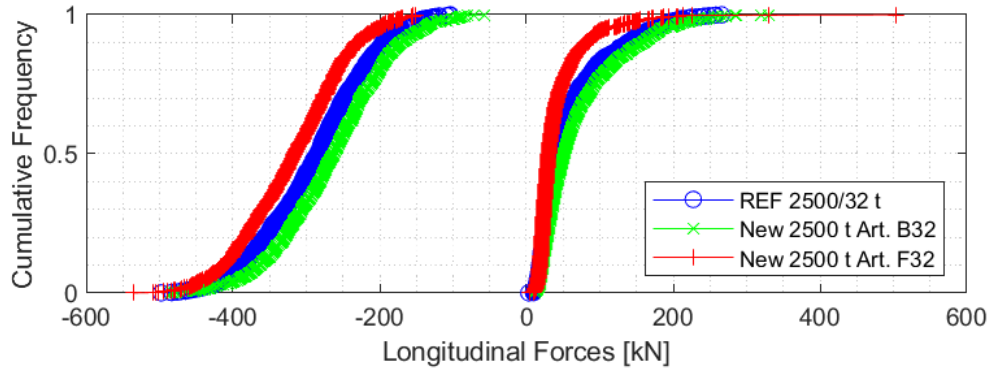


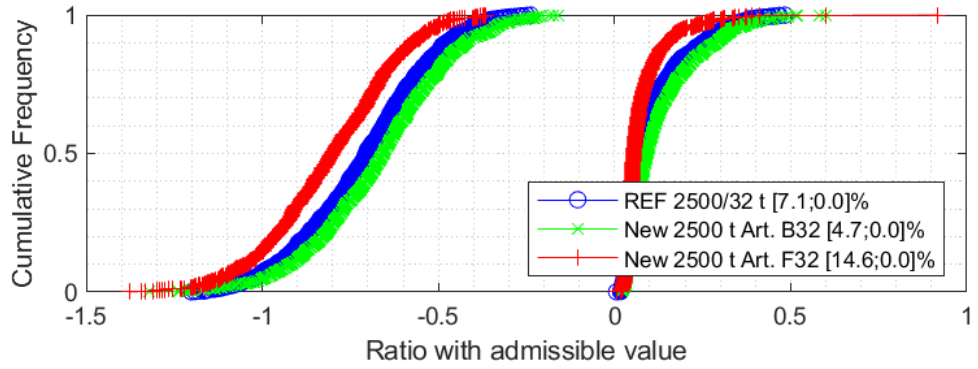
Ref & new 2500 t no mass limits with Art below 32t moved





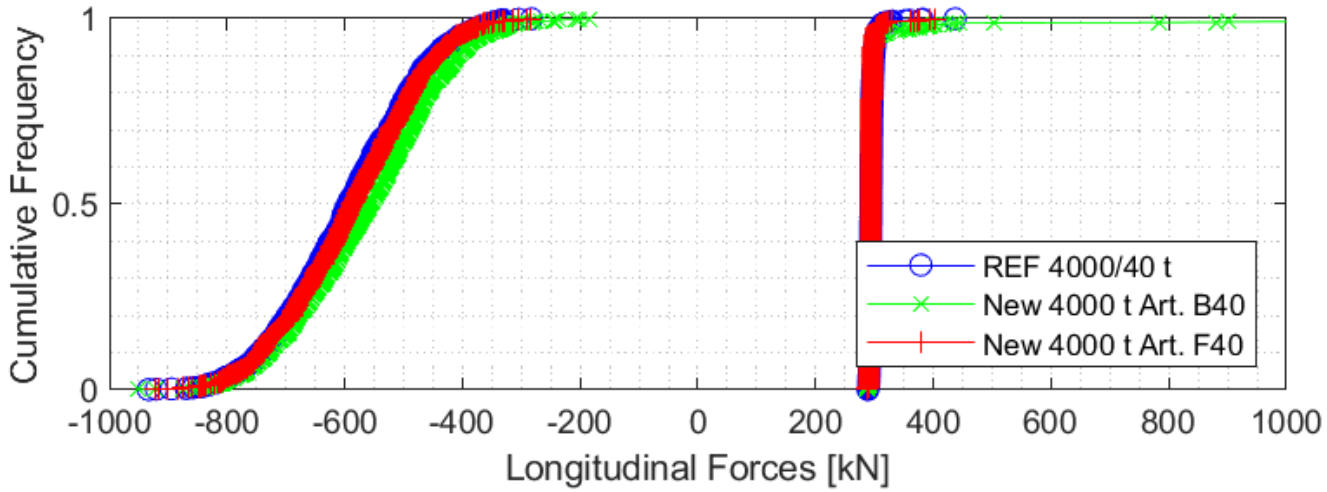
Ref & new 2500 t no mass limits with Art below 32t moved EB

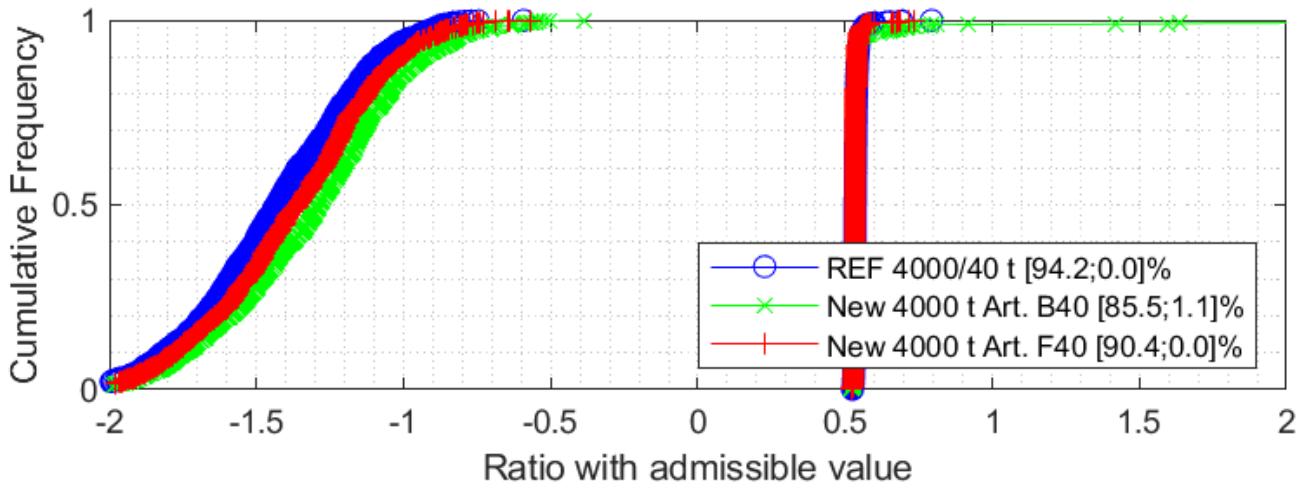




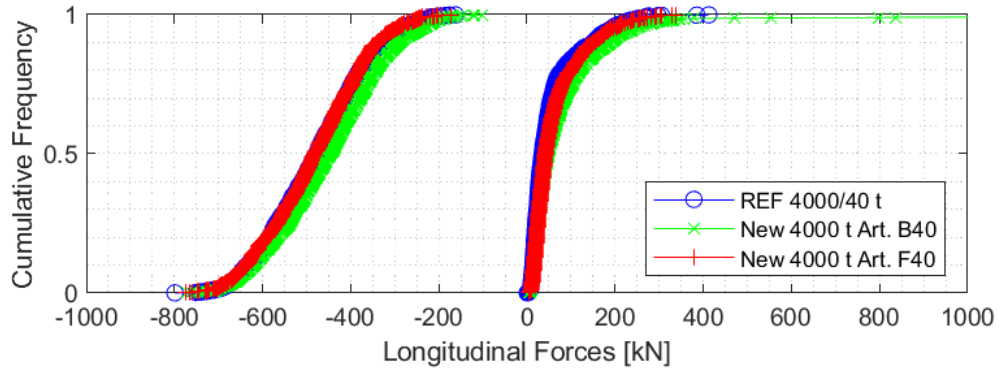
Effect of the light wagons' location

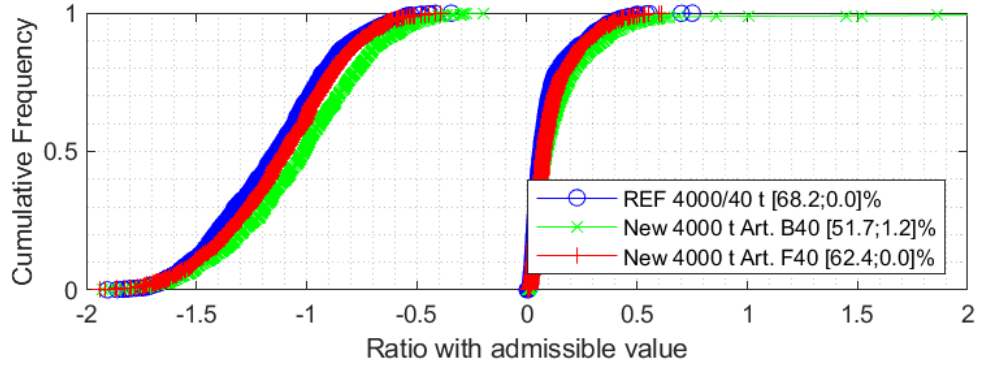
Ref & new 4000 t no mass limits with Art below 40t moved



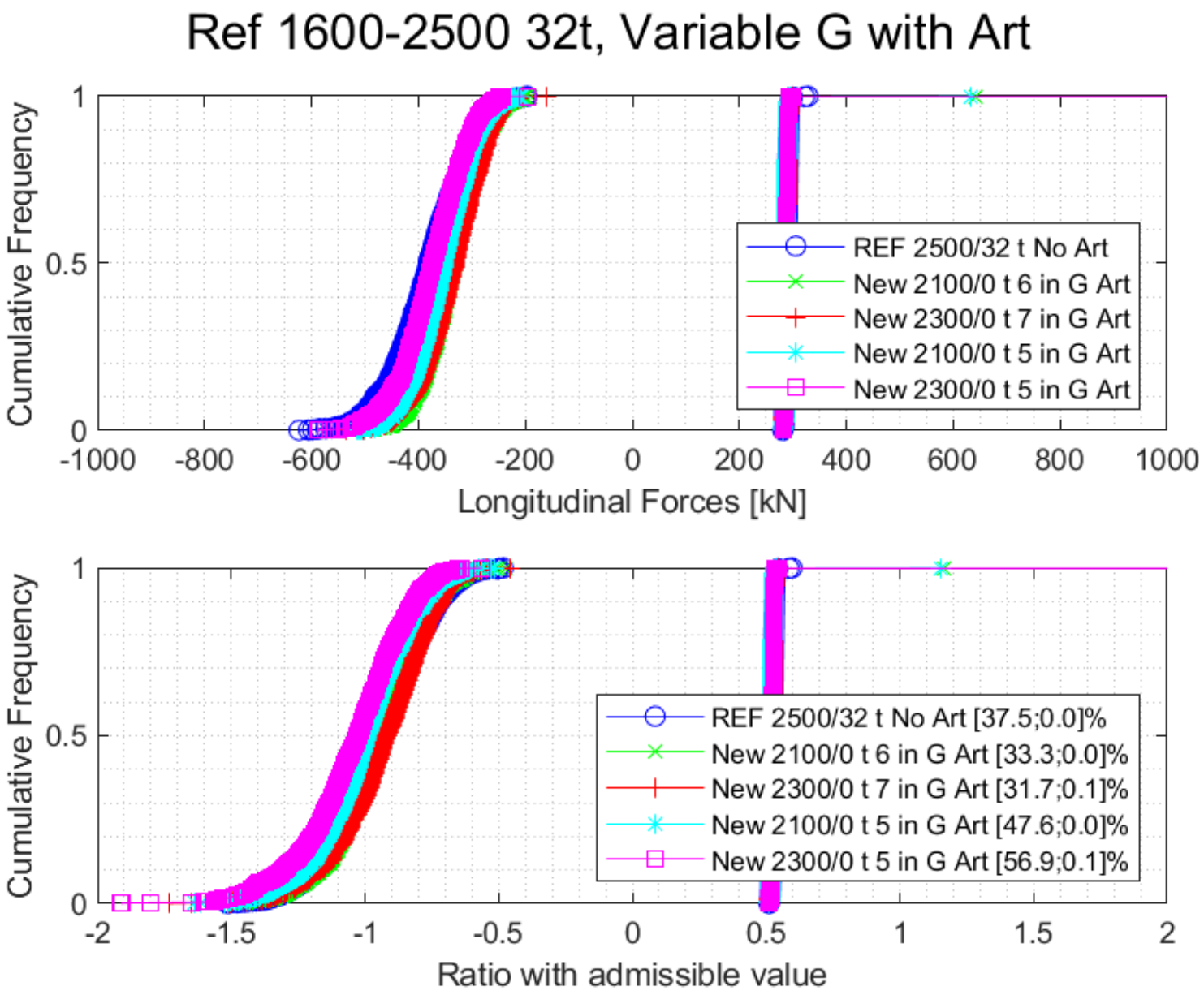


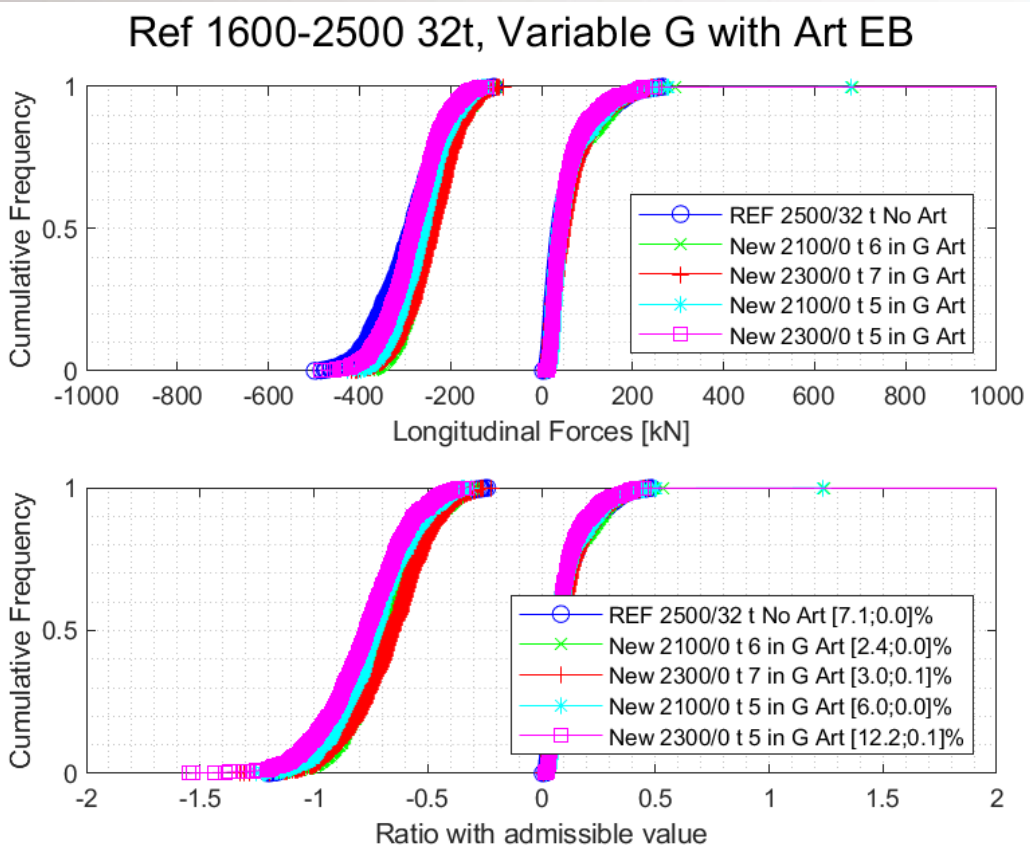
Ref & new 4000 t no mass limits with Art below 40t moved EB



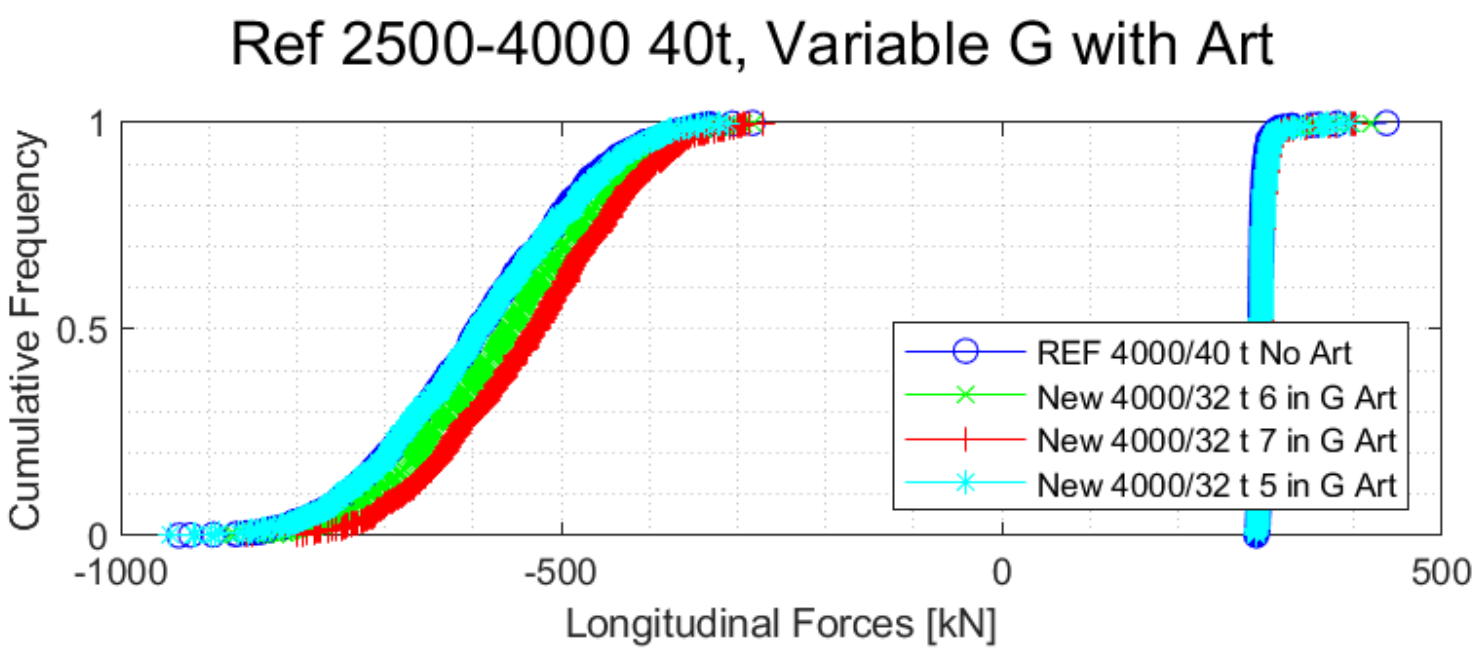


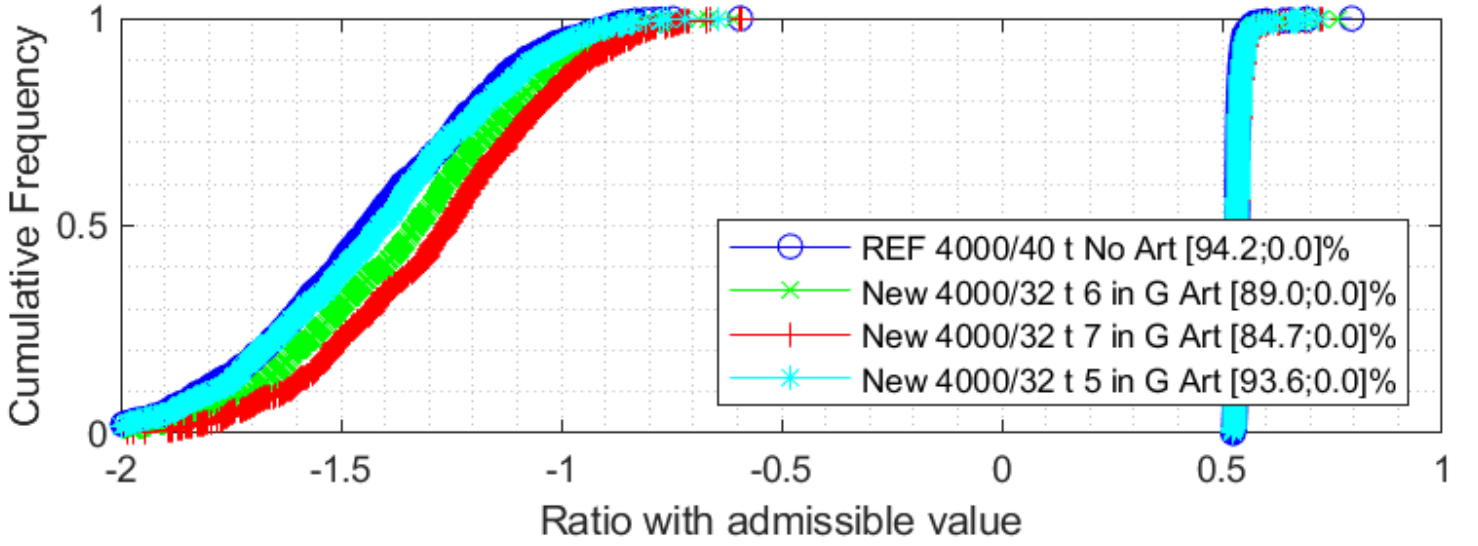
Effect of the light wagons' location

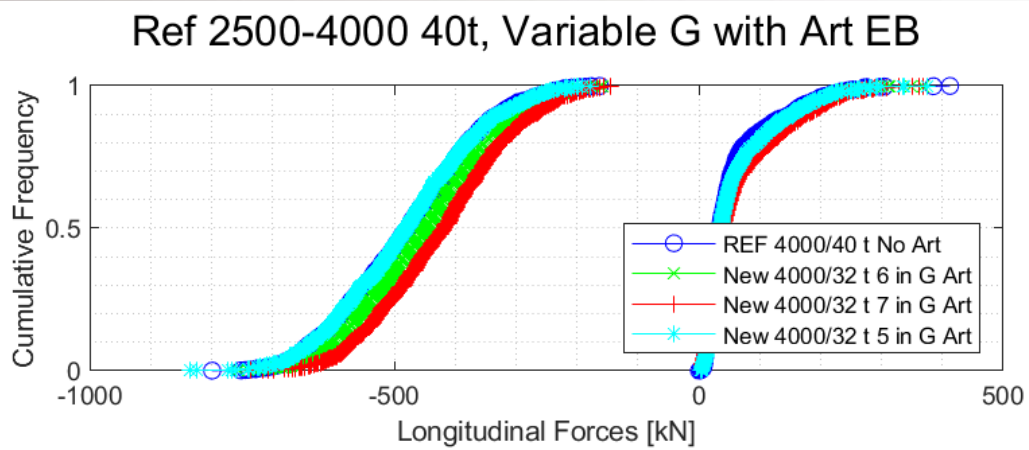


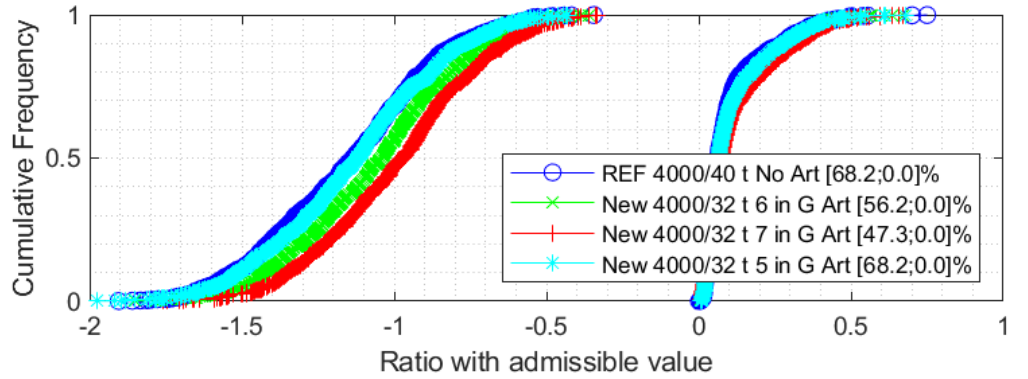


Extended Long Locomotive









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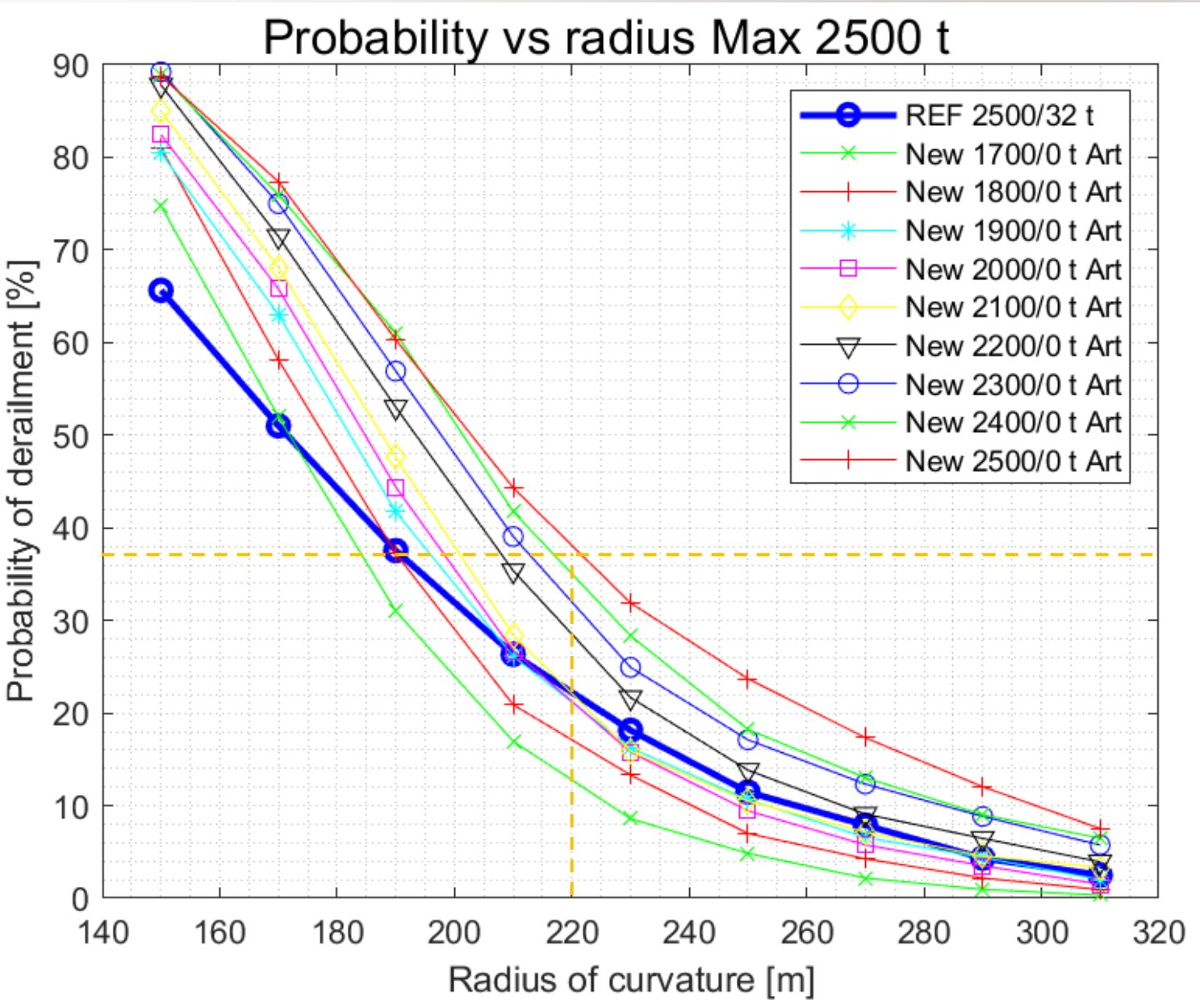

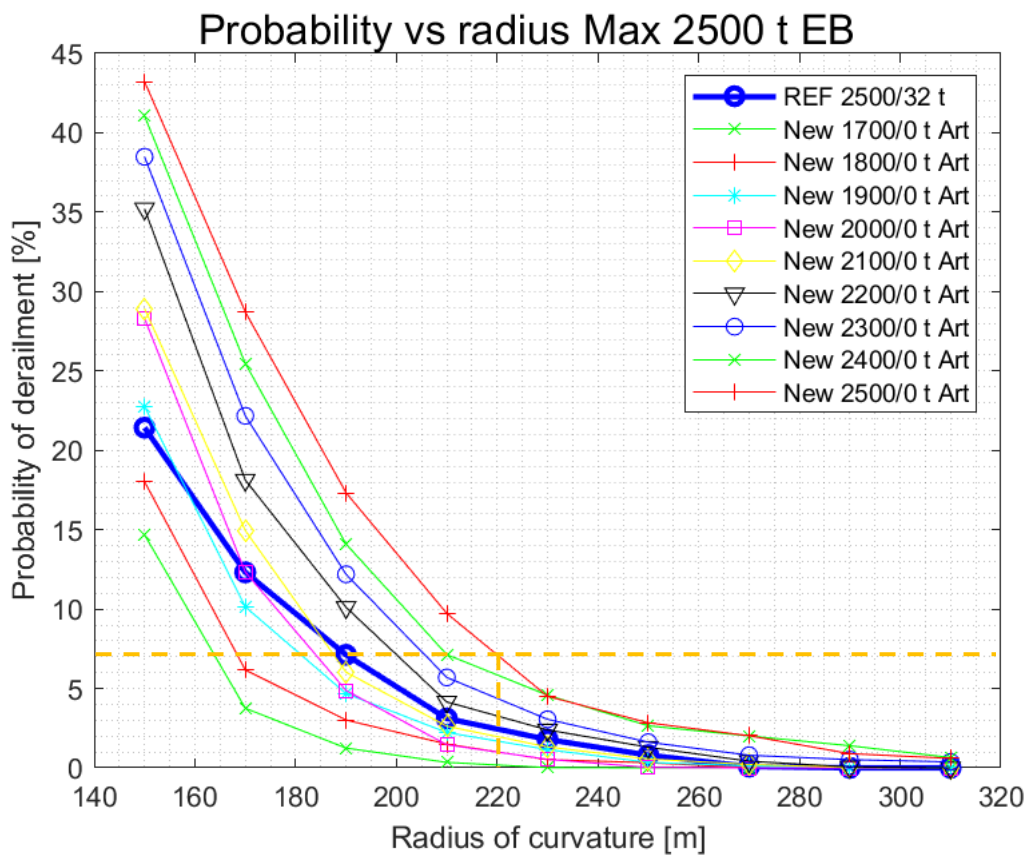

Effect of radius of curvature

Conclusions

- ✓ Trains with only articulated wagons, without any mass limitation, in the mass range 1600-2200t (see Appendix B)
- ✓ Trains in the 1600-2500 t mass range with mixed articulated, bogie and axle wagons, without any mass limitation, but with the wagons lighter than 32 t moved at the end of the train (§4.2.1)
- ✓ Trains in the 1600-2100 t mass range with mixed articulated, bogie and axle wagons, without any mass limitation or wagon ordering, but with the first six wagons after the traction unit(s) in "G" (freight) position (§4.3.1)
- ✓ Trains in the 1600-2300 t mass range with mixed articulated, bogie and axle wagons, without any mass limitation or wagon ordering, but with the first seven wagons after the traction unit(s) in "G" (freight) position (§4.3.1)
- ✓ Trains in the 1600-2500 t mass range with mixed articulated, bogie and axle wagons, without any mass limitation or wagon ordering, if the track radius is bigger than 220m (§4.4.1)
- ✓ Trains in the 2500-4000 t mass range with mixed articulated, bogie and axle wagons, with minimum mass of 40 t and any wagon ordering (§4.1.2).
  - If the wagons lighter than 40 t are moved at the end of the train, the level of safety is higher (§4.2.2)
- ✓ Trains in the 2500-4000 t mass range with mixed articulated, bogie and axle wagons, without any mass limitation or wagon ordering, but with the first six wagons after the traction unit(s) in "G" (freight) position (§4.3.2)
- ✓ Trains in the 2500-4000 t mass range with mixed articulated, bogie and axle wagons, with minimum mass of 32 t and any wagon ordering on every type of infrastructure (§4.3.2).
- ✓ In the 1600-2500 t mass range, with minimum mass of 32 t, the use of articulated wagons cannot be validated (see slides … and …).
- ✓ Trains currently admitted by IRS 40421 (1200-1600t/0t, all wagons accepted) are safer than REF1 (1600-2500t/32t no Articulated) trains
- ✓ REF1 (1600-2500t/32t no Articulated) trains are safer than REF2 (2500-4000t/40t no Articulated) trains

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Thanks for participating

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