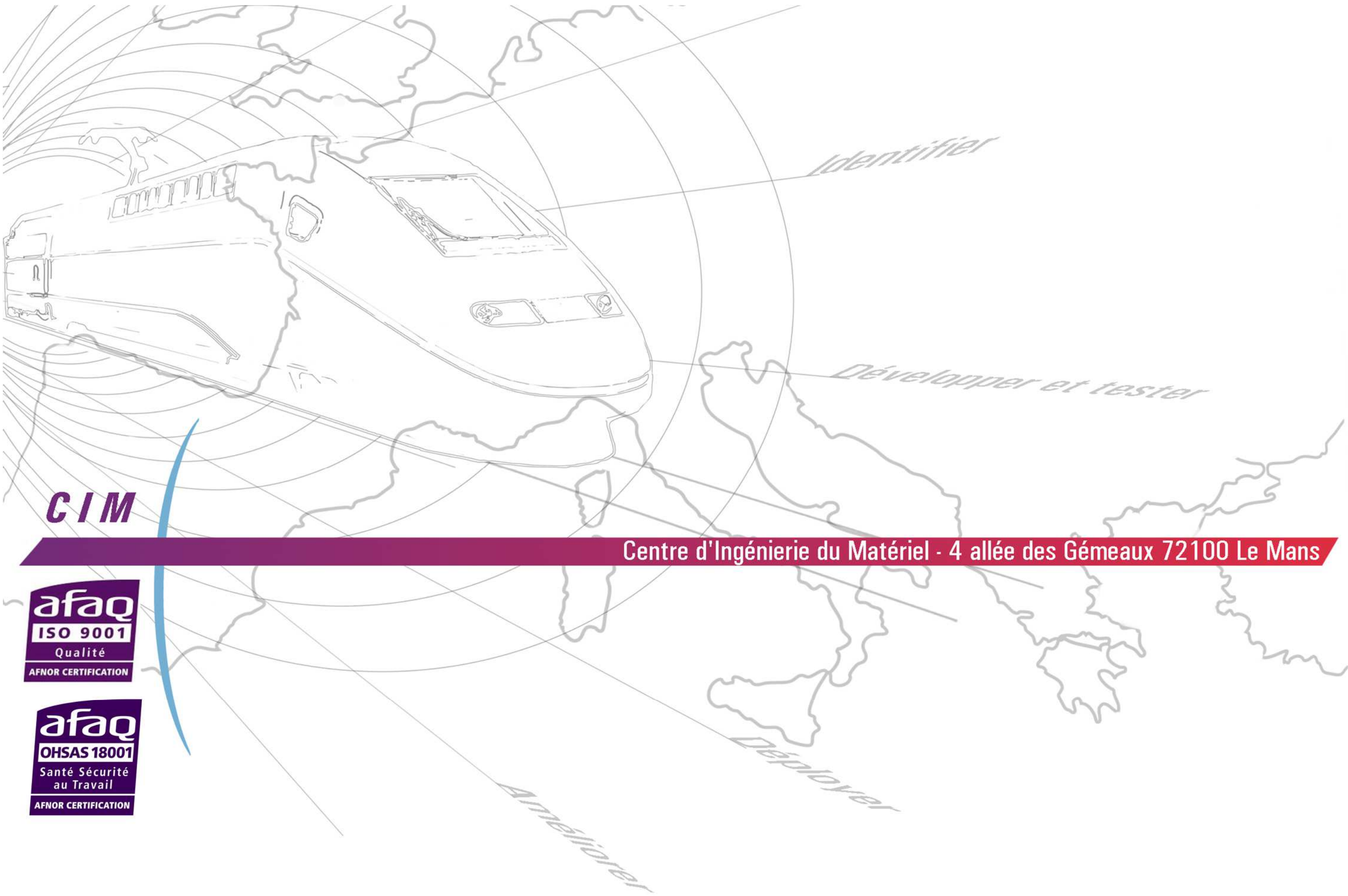

SNCF report on the TrainDy study proposals for UIC

CEF-PSA UBS Action

Référence affaire : 20-1356

Référence : **P/CIM CAB2/2020-1536**

Version 3 du 13/09/2021

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Suivi des modifications

Version et date	Motivation de la modification	Page(s) concernée(s)
Version 1 du 09/07/2020	Creation	Toutes
Version 2 du 01/09/2021	Paragraph added about the impact of Regime P on the energy undergone by the wheel	Toutes
Version 3 du 13/09/2021	Editorial modifications	Toutes

Diffusion

Nom	Société / service	Observations
Alain Scherrer – Giulia Russo	UIC	

SOMMAIRE

1. OBJECT

A technical study has been requested from UIC to SNCF mobility in the framework of the CEF PSA UBS to verify that the proposal for harmonised European braking rules is acceptable from the point of view of longitudinal dynamics.

2. REMINDER OF THE NEED

Hereafter are the scenarios to be analysed:

Scenarios	
1.	G braked trains are proposed to be allowed to have up to 12 (for the test consecutive) axels in a train P-position is allowed. Every other vehicle without G brake position must be isolated. The hauled mass must not exceed 4000t. A check needed whether this can be regarded sufficiently safe.
2.	A check needed how many consecutive non-braked wagons can be allowed in P- trains of up to 4 000 t in hauled mass but by applying the following minimum weight limits: o In the range of 1601...2500 t hauled mass no wagon may be lighter than 32 t. o In the range of 2501...4000 t hauled mass no wagon may be lighter than 40 t.
3.	A check needed how many consecutive non-braked wagons can be allowed in G-trains of up to 4 000 t in hauled mass.

UIC transferred the request to CIM.

3. METHODOLOGY : MONITORING REFERENCE

The present study is about the risk of derailment due to the LCF (Longitudinal Compression Forces) of freight trains compositions according to rules of tonnage and length of wagons.

SNCF thus follows the methodology of Appendix B in UIC-421 "Composition and braking rules for freight trains in international traffic".

This last document, modified during the UIC421 project which took place between 2017 and 2020, is in the process of being approved. The tools developed, the associated assumptions and the results obtained in our present study are based on this modified repository.

4. DESCRIPTION OF THE REFERENCE OFFERS

2.959 trains with a length between 650m and 750m and a linear mass between 2.2 t/m and 3 t/m were operated between January 2012 and June 2014 by SNCF under G regime. They were used to constitute the reference offer. The trains belonging to this transport offer are heterogeneous and consist of various wagons from different holders.

This offer was accepted as a reference (i.e. having an acceptable probability of derailment) by EPSF, French NSA.

In order to analyse these trains in our study, the Tor Vergata "Statistic Tool", developed during the UIC421 project, was used to generate 1000 trains corresponding to the tonnage and length distributions of the 2959 trains in our reference offer. The calculations of LCF shown in this report were carried out with TrainDy software V1.3.3, last version of this UIC software which was validated by the TrainDy consortium.

In order to answer to the need for trains in G regime (scenarios 1 and 3), it is on the basis of this first reference offer that 3 reference offers were established, each having different tonnage ranges of trains. Thus the comparisons are made with iso-tonnage.

The first, quoted above, concerns trains actually from 1500t and 2000t. The second has trains with a tonnage limit of 1600 to 2500 tons, and the third has trains from 2500t to 4000 tons.

It is from the first offer, described above, that the other two were created.

In order to obtain trains between 1600 and 4000 tons, the wagon loading masses were artificially modified. Verifications were carried out in order to verify compliance with the tonnage limits of the wagons and the rules set out above:

In trains from 1600 to 2500t:

- Total mass of a wagon >= 32t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of a bogie wagon = 90t

In trains from 2500 to 4000t:

- Total mass of a wagon >= 40t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of a bogie wagon = 90t

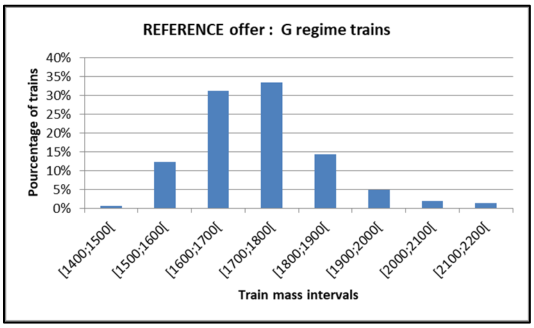
We chose to keep the restriction on the limitation of the wagon's tonnage to 32t and 40t for trains operating in G regime even if this restriction is normally applied only to LL mode trains. We consider that this has very little impact on the LCF generated and makes it possible to answer the main questions asked: the impact of wagons in P regime or unbraked on trains.

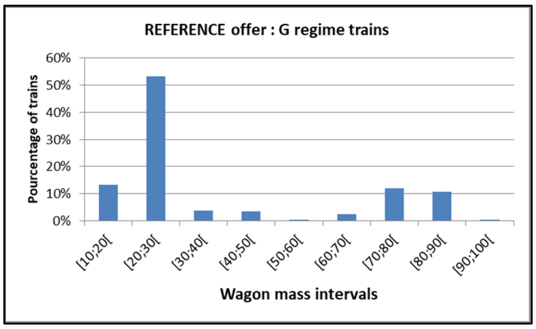
It is not necessary to take into account the admissible LCFs because the comparisons carried out in §6.1 are made on trains having wagons with identical admissible LCFs (cf. §6.2 for the definition of admissible LCF).

We checked that trains and wagons masses over all the projects and scenarios were fulfilled. To illustrate this, below are the three reference offers, each with different tonnage limitations as presented in Chapter 2.2:

Trains masses: Wagons masses:

1.





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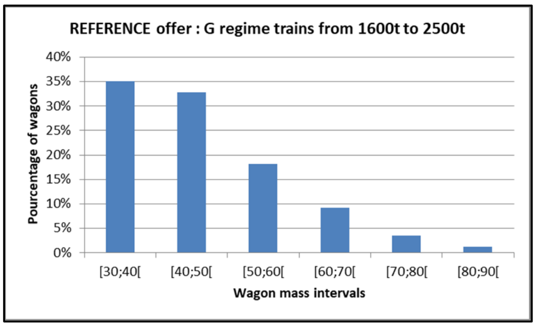
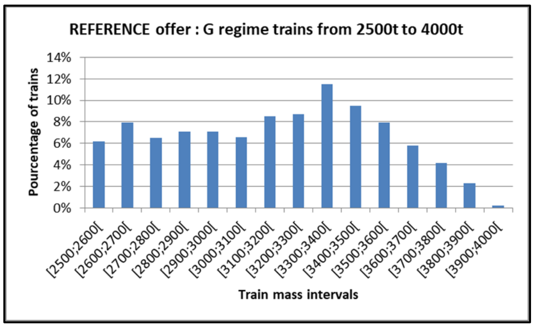
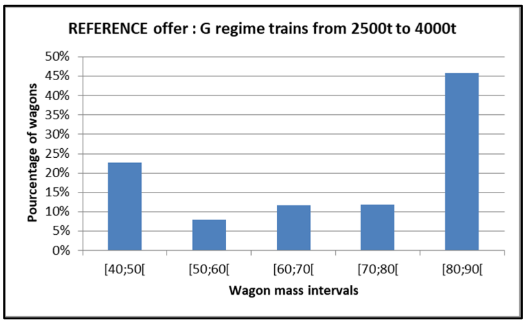


3.





In addition, on LL trains (scenario 2), we selected three reference offers based on train tonnage:

Trains from 1200 to 1600t (format of the trains listed in UIC421 leaflet):

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of a bogie wagon = 90t

Trains from 1600 to 2500t:

- Total mass of a wagon >=32t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of a bogie wagon = 90t

Trains from 2500 to 4000t:

- Total mass of a wagon >=40t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of a bogie wagon = 90t

The following table summarizes all the offers selected as a reference for the study.

1.	*Offre REFERENCE trains G (REFERENCE du projet UIC421 régime G)*
2.	*Offre REFERENCE trains G de 1600t à 2500t (32t/wagon mini)*
3.	*Offre REFERENCE trains G de 2500t à 4000t (40t/wagon mini)*
4.	*Offre REFERENCE trains LL de 1200t à 1600t*
5.	*Offre REFERENCE trains LL de 1600t à 2500t (32t/wagon mini)*
6.	*Offre REFERENCE trains LL de 2500t à 4000t (40t/wagon mini)*

5. DESCRIPTION OF TARGET OFFERS

Three TARGET scenarios are proposed to us according to §2. In order to satisfy the need for study, several offers were defined for each of the scenarios below:

5.1 Scenario 1:

It is proposed that trains braked in G regime can have up to 12 consecutive axles in a P position of the train. Any other vehicle without braking position in G must be isolated. The mass transported shall not exceed 4000 tons.

In order to study the risks associated with this scenario, the following projects were selected:

Project n°1 scenario 1:
Randomly in the train, wagons taken in consecutive ways up to 12 axles max circulate with a P braking mode. If the vehicle is a bogie wagon the number of axles is 4. It is 2 for an axle wagon. This project n°1 is built and compared on the basis of the reference offer n°1 in the table in §4.

Project n°2 scenario 1:
Randomly in the train, wagons taken in consecutive ways up to 200 tons of total mass (loading mass + tare of the car) circulate with a P braking mode. This rule is accepted in France by the document RC AB 7a n°1 of the EPSF. This project n°2 is built and compared on the basis of the reference offer n°1 in the table in §4.

Project n°3 scenario 1:
Randomly in the train, wagons taken in consecutive ways up to 12 axles max circulate with a P braking mode. The loading masses of the wagons are randomly modified to reach a train tonnage limit of between 1600t and 2500t. This project n°3 is built and compared on the basis of the reference offer n°2 in the table in §4.

Project n°4 scenario 1:
Randomly in the train, wagons taken in consecutive ways up to 12 axles max circulate with a P braking mode. The loading masses of the wagons are randomly modified to reach a train tonnage limit of between 2500t and 4000t. This project n°4 is built and compared on the basis of the reference offer n°3 in the table in §4.

5.2 Scenario 2:

The aim here is to verify the number of consecutive unbraked wagons that can be authorized in P trains up to 4000t of transported mass, but with the following minimum weight limits:

- In the range from 1200 to 1600t of transported mass: LL trains (Long Locomotive)
- In the range from 1601 to 2500t of transported mass: LL trains and no wagon can be lighter than 32t
- In the range from 2501 to 4000t of transported mass: LL trains and no wagon can be lighter than 40t

In order to study the risks associated with this scenario, the following projects were selected:

Project n°1 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 1 wagon is not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1200t and 1600t.
Limit :

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°1 is built and compared on the basis of the reference offer n°4 in the table in §4.

Project n°2 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 1 wagon is not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1600 and 2500t.
Limit :

- Total mass of a wagon >=32t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°2 is built and compared on the basis of the reference offer n°5 in the table in §4.

Project n°3 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 1 wagon is not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 2500t and 4000t.
Limit :

- Total mass of a wagon >=40t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°3 is built and compared on the basis of the reference offer n°6 in the table in §4.

Project n°4 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 3 wagons are not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1200t and 1600t.
Limit :

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°4 is built and compared on the basis of the reference offer n°4 in the table in §4.

Project n°5 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 3 wagons are not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1600t and 2500t.
Limit :

- Total mass of a wagon >=32t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°5 is built and compared on the basis of the reference offer n°5 in the table in §4.

Project n°6 scenario 2:
All the wagons have a P braking regime, except the first 5 vehicles after the locomotive (configuration of an LL train). Randomly in the train, 3 wagons are not braked. The loading masses of the wagons are randomly modified to reach a train tonnage limit between 2500t and 4000t.
Limit :

- Total mass of a wagon >=40t
- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°6 is built and compared on the basis of the reference offer n°6 in the table in §4.

5.3 Scenario 3:

The aim here is to verify how many consecutive unbraked wagons can be authorised in G regime trains up to 4000t in mass transported.

In order to study the risks associated with this scenario, the following projects were selected:

Project n°1 scenario 3:
Randomly in the train, 1 wagon is not braked.
This project n°1 is built and compared on the basis of the reference offer n°1 in the table in §4.

Project n°2 scenario 3:
Randomly in the train, 1 wagon is not braked.
The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1600t and 2500t.
Limit :

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°2 is built and compared on the basis of the reference offer n°2 in the table in §4.

Project n°3 scenario 3:
Randomly in the train, 1 wagon is not braked.
The loading masses of the wagons are randomly modified to reach a train tonnage limit between 2500t and 4000t
Limit :

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°3 is built and compared on the basis of the reference offer n°3 in the table in §4.

Project n°4 scenario 3:
Randomly in the train, 3 consecutive wagons are not braked.

This project n°4 is built and compared on the basis of the reference offer n°1 in the table in §4.

Project n°5 scenario 3:
Randomly in the train, 3 consecutive wagons are not braked.
The loading masses of the wagons are randomly modified to reach a train tonnage limit between 1600t and 2500t.
Limit:

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°5 is built and compared on the basis of the reference offer n°2 in the table in §4.

Project n°6 scenario 3:
Randomly in the train, 3 consecutive wagons are not braked.
The loading masses of the wagons are randomly modified to reach a train tonnage limit between 2500t and 4000t.
Limit:

- Maximum total mass of an axle wagon = 45t
- Maximum total mass of an bogie wagon = 90t

This project n°6 is built and compared on the basis of the reference offer n°3 in the table in §4.

6. ANALYSIS OF THE RESULTS

6.1 Analysis of results by comparison of generated LCF

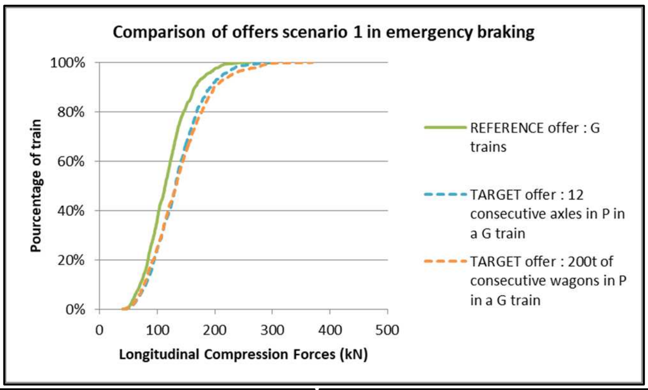
We therefore first compared the LCF10m generated between reference and target offers for a single driving mode (emergency braking at 30 km/h without initial traction or compression force).

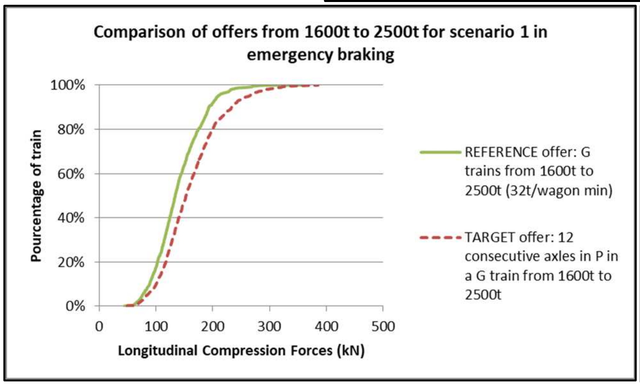
For scenario n°2, as trains are in LL braking mode, and thus having higher LCF10m, the "1 bar service braking" driving mode was also studied to show the difference in relative risk.

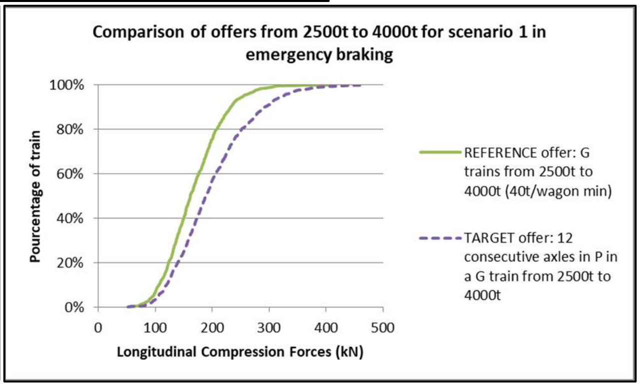
The following comparisons are carried out with a Longitudinal Compression Force distribution function measured over 10 metres per train (LCF10m) (according to the criterion in §B3.5.1 of UIC-421) by comparing the train distributions of the reference offer and target offer.

In order to ease the comparison, the distribution functions to compare for the different scenarios are plotted in order to perform a visual analysis. The distribution function on the left describes a less risky situation than the right one.

Scenario 1:



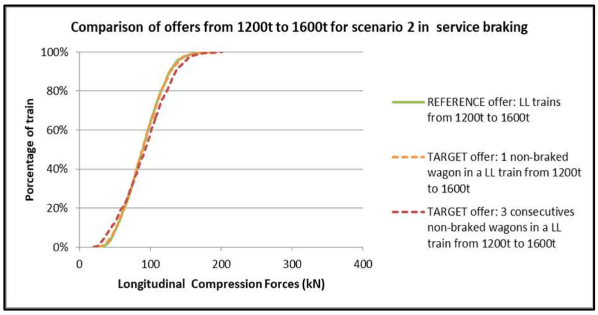


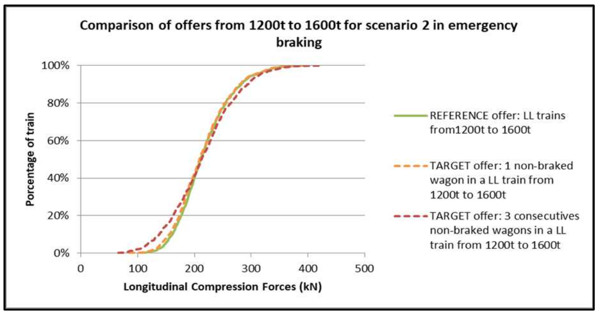


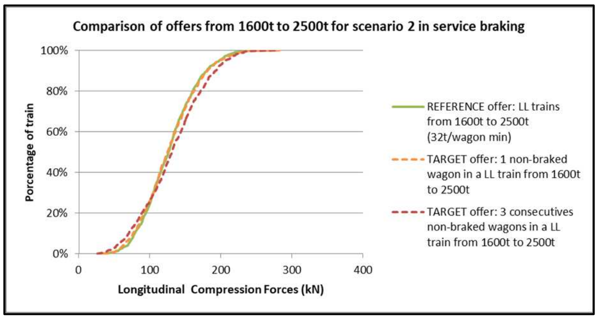
According to the first graph, we can affirm that the french rule (having 200 tons of wagon in P in a G train, looks almost similar to the German rule (12 consecutive axles in P in a G train).

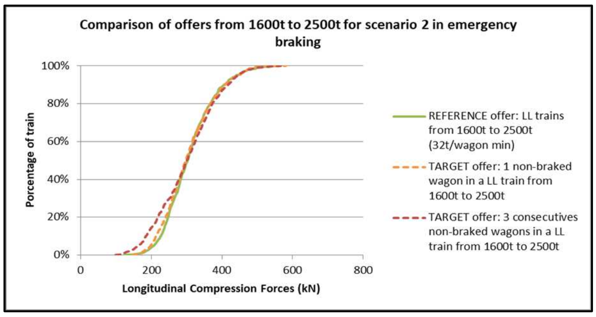
In all cases, the reference offer appears less risky than the target offer but the increase remains low. The target offers are accepted and authorized in the national rules of many European countries.

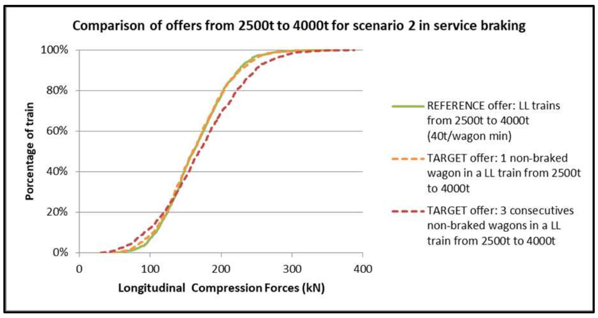
Scenario 2:

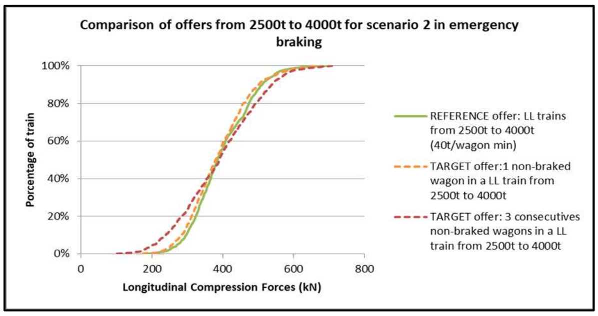










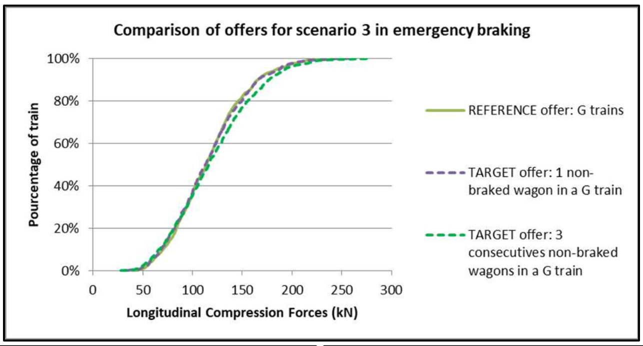


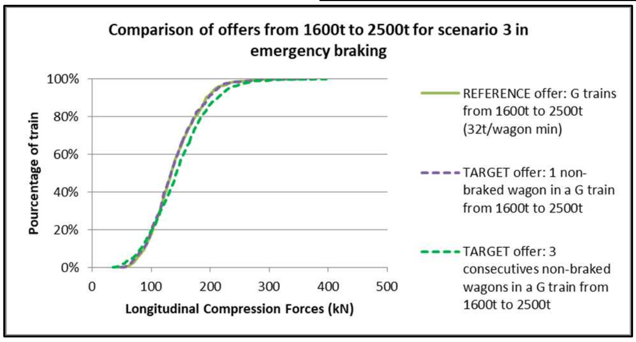
For the two maneuver cases studied above ("service braking" and "emergency braking") and for all tonnage ranges, the reference offer (green curve) presents a result almost identical to the first target offer (orange curve) where 1 unbraked wagon is present in the train.

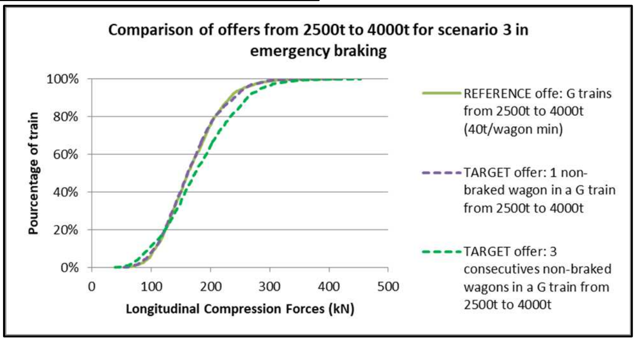
This modification practically does not affect the longitudinal forces, but this is not the case when we move to 3 consecutive unbraked wagons (red curve).

Indeed, the second target offer (3 consecutive unbraked wagons in the train) is presented globally as the most risky with regard to the longitudinal forces generated in the trains, even the LCF decreases also for many trains.

Scenario 3:







As in the previous scenario, having 1 unbraked wagon in the train practically does not affect longitudinal compression forces.

For the 3 projects with different tonnage limits, going from 1 to 3 consecutive unbraked wagons in a G train (which applies emergency braking) does not generate much more longitudinal compression forces (+5% on average).

In a train configuration from 1600 to 2500 tons, this gap increases to +7% difference from 1 to 3 wagons.

The same is true for the configuration of G trains from 2500 to 4000 tons. The impact on the risk of derailment remains very low.

6.2 Analysis of results according to UIC-421 method

This method is presented in Appendix B of UIC421 leaflet as the analytical method to calculate the probability of derailment.
The direct derailment probability calculation was performed by comparing the admissible LCF determined according to the method described below to the LCF maintained over 10 meters (LCF10m) on each wagon; the train was considered to be derailed when at least one wagon on the train had its admissible LCF exceeded.

We have used this method only on the trains that are compared with offer 1 referred in §4. Indeed for offer 1 the construction of trains is directly derived from real French trains while our construction method on other trains (1600t-2500t and 2500t-4000t) allowed to perform the relative analysis presented in §6.1 but does not allow to obtain a representative probability.

Chapter n°B.3.4.2 of UIC-421 leaflet is used to define the admissible LCF for each wagon.

The 240 kN value is used as the characteristic value of the eligible LCF from the reference offer. This LCF is the minimum allowable LCF for a two-axle wagon on a 190m radius curve and a reverse curve. In the same configurations, and for a four-axle wagon, this characteristic admissible LCF value is estimated at 320 kN according to the extrapolation rules defined in UIC-421.

Thus, for each wagon's admissible LCF on a 190 m curve and a reverse curve, the criteria used are as follows:

- *Admissible LCF for an empty axle wagon: 240 kN*
- *Admissible LCF for an empty bogie wagon: 320 kN*

In addition, depending on the wagon load (available on built trains), the extrapolation used is to add 8 kN of admissible LCF per tonne of load.

Whatever the mass of the wagon, the admissible LCF is limited to:

- *400 kN for an axle wagon*
- *600 kN for a bogie wagon*

These criteria will be implemented in the future version of UIC 421.

The following table provides derailment probability estimations according to this methodology (the probability that the vehicle is in the critical lane configuration and that the braking was initiated by the driver is not taken into account but would obviously greatly reduce the figures presented).
In order not to achieve this comparison of derailment probabilities (relative method described in the UIC-421 leaflet and adopted by the European rules on Common Safety Methods (CSM): Commission Implementing Regulation (EU) 2015/1136 of 13 July 2015), we artificially reduced the admissible LCF by 50 kN.

We present the analysis on emergency braking cases only as this driving strategy allows us to evaluate the risk. Indeed, service braking calculations have been carried out and lead to a risk of derailment which is null.

Scenario 1	adm LCF - 50
Emergency braking	**Probability of derailment estimated**
REFERENCE offer : G trains (REFERENCE of the UIC421 project)	**0,027**
Target offer : 200 tons of consecutive wagons in P randomly in a G train	0,081
Target offer : 12 consecutive axles in P randomly in a G train	0,057
Target offer : 1% of French trains have wagons in P mode in a G train	0,028
Target offer : 1% of German trains have wagons in P mode in a G train	0,027
Scenario 3	adm LCF - 50
Target offer : 1 unbraked wagon randomly in a G train	0,015
Target offer : 3 constive unbraked wagons randomly in a G train	0,028

We have chosen not to use the '200t' and '12 axles 'offers as a reference to answer the question. Nevertheless, they correspond to existing situations that we estimated by hypothesis at 1% of the cases.

We have seen above that the two target offers on the two French and German rules generate almost identical LCF; however the French rule appears almost two times more risky according to the probabilities of derailments.

Thus this analysis by the probabilities of derailment confirms the analysis of §6.2 on the limited impact of the recommended measures on the risk of derailment: we consider that the risk is not altered by the adoption of the measures.

7. IMPACT OF THE POTENTIAL NEW RULES ON THE ENERGY BORNE BY THE WHEEL

When a wagon in Regime P is added in a G train, the maximum brake force is reached before the other wagons. During the time of a braking, the brakes of the P wagon bear more energy than the other wagons of the G train. According to leaflet UIC 510-5 and TSI Wag table C.4, the amount of energy for which a diameter 920 wheel is dimensioned is 50 kW, maintained during 45 minutes at 60km/h.

It is important to check if the new rules derived from this study can have an impact on the risk to damage a wheel on the basis of this parameter or on the basis of a comparison between former operational conditions and new operational conditions.

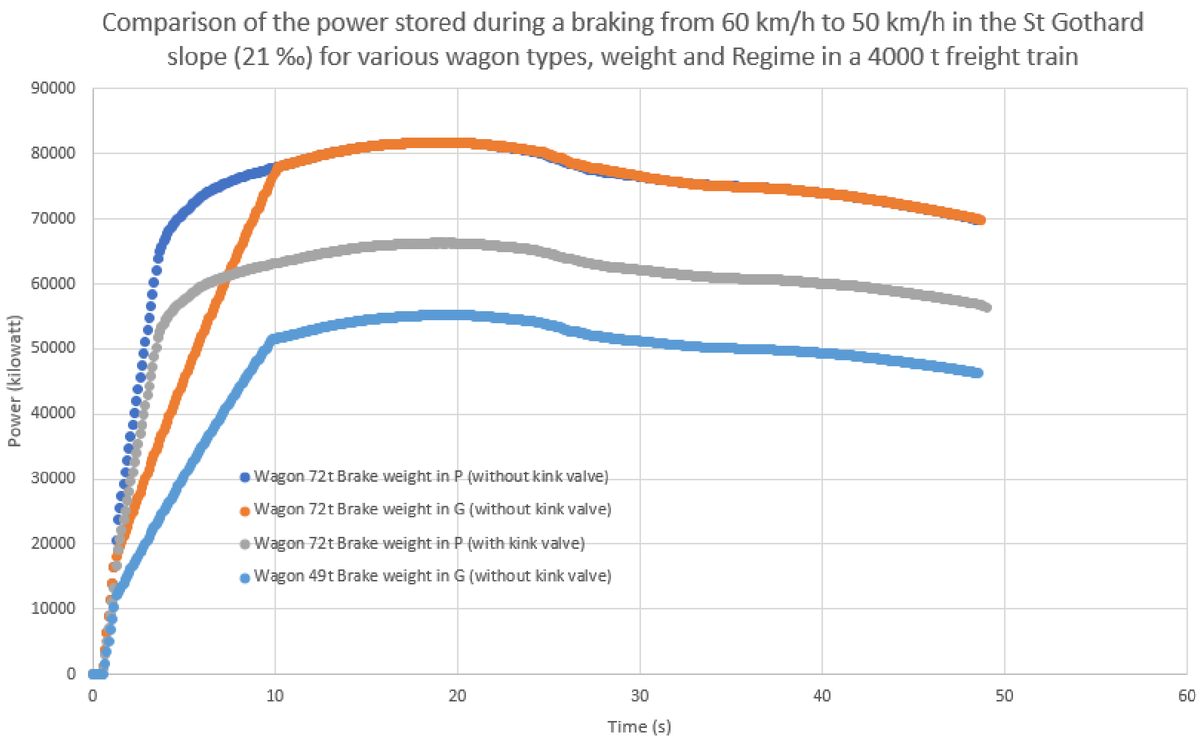
To do so, the worst conditions that could be encountered were determined:

- The worst train is the one of a long heavy train (700 m - 4000 t) braked in G, with the lowest admissible brake weight percentage (55% allowed by current UIC 421) , where a wagon with the maximum braking force possible, braked in P regime, is inserted in front of this train.
- The worst operating conditions in Europe seem to be the slope of St Gothard where a train has to go down a 21 ‰ slope during 40 km. To do so, the driver has to maintain the velocity and can proceed with 2 types of manoeuvre : a reduced automatic braking (e.g. 0.5 bar depression in the main brake pipe) or successive nominal service braking (~1 bar depression) to reduce the velocity from 60 to 50 km/h and release the brake to reach again 60 km/h until the end of the slope.

The successive driving manoeuvres of service brake with 1 bar depression in the main brake pipe were chosen to perform the analysis of the worst case. As TrainDy software is unable to carry out a release of the braking, it was decided to make the following assumption: the train is braked from 60 to 50 km/h and then the release is sudden, and the train freely accelerates from 50 to 60 km/h. This acceleration lasts approximately 12 s.
With these condition the calculation was done with TrainDy, considering 3 different configurations to compare :

1. The wagon in P (15 m – 2 bogies) is not equipped with a kink valve that lowers the brake force in service braking for brake weights over 59t.
2. The train is entirely braked in G (same train as case 1 but with wagon in G instead of P)
3. The wagon in P is equipped with a kink valve

The following graphic shows, for each of the previous configurations, the variation of the power borne by a wheel on the first wagon of the train during the service brake from 60 to 50 km/h in the slope. The evolution of the power of the other wagons is also represented.



The global amount of energy borne by a wheel of the wagon well braked on the entire St Gothard slope is shown in the following table and is derived from the previous graphic:

Configuration	Average of power during the entire St Gothard slope (40 mn)
1 - 72 t BW in P without kink valve	59 kW
2 - 72 t BW in G without kink valve	57 kW
3 - 72 t BW in P with kink valve	48.5 kW
49 t BW in G	38 kW

This shows that the maximum energy value allowed by the wheel during the entire descent of the St-Gothard is exceeded with these assumptions when a well braked wagon is inserted inside a train with the lowest braking conditions acceptable. The fact to turn a P wagon in a G train increases the global amount of energy by 3.5 % which is very low and seems acceptable with respect to the influence of the global heterogeneity which is much higher as explained above. Moreover it does not take into consideration the successive releasing which are faster on P wagons and the fact that some countries favours an invariable velocity in the slope : in this case the influence of the braking in P lasts no more than 10 s which is very low in comparison with the 40 minutes spent in the slope.
The obligation to equip future wagon in P with kink valve is very efficient because it decreases the global amount of energy by 15.6 % with respect to a wagon in G not equipped with kink valve.

Therefore, the new rules aiming at generalising the possibility to have wagons in P in a G train are acceptable with respect to the amount of energy that can be borne by the wheels of the wagon during a braking under the condition that this wagon is equipped with kink valve. For information, this obligation should become mandatory in the revision of the TSI wagon for all wagons with a braked weight per axle above 15,25 tons.

8. CONCLUSION

In all scenarios, train configurations limited between 1200 tons and 2500 tons, regardless of the number of unbraked wagons in the train, are less risky in terms of the risk of derailments and LCF, than the heavier trains limited between 2500 and 4000t.

In scenarios 2 and 3, 1 to 3 consecutive unbraked wagons in the train were analysed. It seemed unnecessary to go beyond 3 consecutive wagons with the results obtained in this last configuration.

New rules aiming at generalising the possibility to have wagons in P in a G train are acceptable with respect to the amount of energy that can be borne by the wheels of the wagon during a braking under the condition that these wagons are equipped with kink valves to limit significantly this amount of energy and make it secure in any configurations.

This study cannot conclude to a null risk as it is based on a relative approach according to Common Safety Methods accepted by Europe. Nevertheless with regard to the studies carried out on the risks of derailments due to LCF:

Scenario 1:

- The offer "**G regime trains of any tonnage with 200 tons maximum of consecutive wagons in P"** is considered operational.
- The offer "**G regime trains of any train tonnage with 12 consecutive axles maximum in P"** is considered operational.

Scenario 2:

- The offer "**LL regime trains between 1200 and 1600 tons with a maximum of 3 unbraked wagons**" is considered operational.
- The offer "**LL regime trains between 1600 and 2500 tons (minimum 32t/wagon) with a maximum of 3 unbraked wagons**" is considered operational.
- The offer "**LL regime train between 2500 and 4000 tons (minimum 40t/wagon) with a maximum of 3 unbraked wagons**" is considered operational.

Scenario 3:

- The offer "**G regime trains of any tonnage below 4000 t with a maximum of 3 consecutive unbraked wagons**" is considered operational.