This project has received funding from the Shift2Rail Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement no. 826087 (M2O)

Deliverable D5.2
Dissemination, Exploitation and communication report

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Summary

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1. Executive Summary

M2O Shift2Rail project has been developed in close collaboration with S2R FR8RAILII project in charge of the provision of the TUs (with its TCMS and DBCU), of the infrastructure for the demonstrators and of the operations of the demonstrators.
M2O was mainly responsible to analyse general requirements for Long DPS trains running safely on the EU Network with up to 4 TUS and a length of up to 1500m, the TUs being remotely controlled by the Lead TU with GSM-R or LTE, if necessary, as radio communication system, and to preliminarily assess the safety of experimental test campaign with DPS. M2O was responsible of the radio communication solution and the analysis of the global safety of the consist on the basis of LTD simulations made with TrainDy software, recognized as giving results satisfactory close to the experimental measurements.
The project developed in its first phase a strong research on the type of consists, the sensitivity of the LTD simulations results to the various parameters characterizing the braking performances of wagons in order to develop simulations incorporating the variations of these main parameters alone or in conjunction. The main critical operations were also defined.
The midterm event was to be an opportunity to disseminate these first results when the pandemic burst out stopping all physical events expected.
Since the beginning it appeared that the communication had to target the various categories of stakeholders interested in the project:

- Universities interested in the Scientific methodology developed in M2O and for that article, conference and video contacts have taken place
- Rus, IMs interested in improving their asset utilisation and reducing their cost
- Shippers, forwarders, decision makers for transport expecting capacity increase and costs reductions.
- Authorities expecting safety improvements and less investments to face the sustainability of transport when growth come back.

The results of the project enable to give guidelines and to appreciate the possibility to use the DPS trains according to the main characteristics of the main market segments.
From the characteristics of their products and of their flows of traffics (distance, quantity, frequency requested, unique or multiple destinations) a first approach helps to decide if there is a clear possibility to set up such a solution or if it seems clearly impossible or if further investigation is necessary. It gives also certain boundaries where it seems possible and certain examples tested.
In any case, due to the diversity of TUs, Wagons, infrastructures it is always necessary to have a further analysis to see if all the requirements of the safety analysis made in M2O can be fulfilled in a certified way.
The implementation phase indicates a way to introduce progressively such Long DPS trains based on rough cost benefit analysis of the interests of stakeholders.
Finally, a roadmap to progress in the implementation is suggested involving actions of various stakeholders and of authorities to reach the goal.

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2. Abbreviations and acronyms

Abbreviation / Acronyms	Description
TU	Traction Unit
LTD	Longitudinal Train Dynamics
LCF	Longitudinal Compressive Forces
LTF	Longitudinal Tensile Forces
DPS	Distributed Power System
EB	Emergency Braking
T-EB	Full traction followed by an emergency braking
DBV	Driver's brake valve
FTL	Full Train Load
ILU	Intermodal Loading Unit
RU	Railway Undertaking
SWL	Single Wagon Load

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3. Background

The present document constitutes the Deliverable D5.2 Dissemination, communication and Exploitation" report in the framework of the TD5.4, of IP5.

It capitalizes on previous Long Train analysis, coming from D3.1 and D3.3 of M2O and on recent marketing research made in France to relaunch rail freight transport having shown an excellent resilience during the pandemic.

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4. Objective/Aim

The objective of this deliverable is to report on the communication efforts made during the project but also to be a tool for all interested stakeholders to approach easily the DPS Long Train question to see if they can have an interest for their business targets to investigate further with the precise characteristics of their problem.

More generally, it aims to help Authorities to appreciate the interest for their own objectives to support the development of that type of solution because of the extra capacity provided at low cost, of the positive impacts on the transport cost, on its safety and on its sustainability.

Finally, a suggested roadmap tends to give a solution for a progressive implementation in comparison of other solutions where the advantages appear only after a large percentage of deployment.

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5. Market segments that could be interested

5.1. Market trends

The freight transport market is mainly composed of a few main segments:

- The bulk transport (liquid or solid), with very different densities, on short or long distances with unique or multiple destinations, in large volumes on a regular or spot basis.
- The combined transport segment which is a growing segment in its various subsegments classical combined transport of containers and swap bodies but also semi-trailer transport with vertical or horizontal transfer.
- The single wagon load transport which is necessary for certain segments of the industry suffers in certain Countries where RUs have drastically restrained the offers. In some European Countries the clustering of industries has allowed to keep significant offers for which the flexibility brought by DPS trains in terms of length and competitiveness on trunk travels may support the efficiency of the system.

Before the Pandemic rail freight was having a very serious growth specifically in the container field with 12,5% in volume in 2019 followed by around 20% drop in 2020 largely due to shrinking consumption. But it remains as the largest potential segment which should bounce back as soon as the economy restarts.
So, it is an important target segment if rail can prove its reliability. The pandemic period where passenger trains were much less numerous has shown Rail freight capability to be reliable at a very high level. The low previous reliability was partly due to being frequently stopped by works or by passenger trains.

5.2. Stakeholders interest

Taking into account the various segments and the resilience shown during the pandemic the various categories of stakeholders are being interested:

5.2.1. Bulk segment

In the bulk field the shipper has a key role as he has generally large volumes to be handled to unique destinations for certain products (ore, coal, sand, Chemical products, refined oil products, cereals for industries) or for multiple destinations when refined products have to serve one or two storage areas. In this field, the wagon owner is also an important partner as it has to provide the most efficient wagon and to maintain it properly. The RU must find with IM the most efficient path to ensure a quick rotation for the equipment. For the business the efficient improvement should generate added value to be shared between the partners. The wagons, being rented per calendar day, are less interested and they are frequently the property of the industrial partner.
For this field, the cost reduction is the main target and the consists will be (following the

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nomenclature of D3.3[1]): a) LLW as long as possible; b) LWL to reach the maximum mass; c) even LWLW, if light traffics can complete the train length.

5.2.2. Combined transport segment

In this segment and specifically for the general consumption product market road is dominant not only on the last mile distribution but also on medium and sometimes long distance transports. Their progress towards cleaner trucks is effective rapidly and they are also building on a permanent pressure to enlarge their carrying capacity by extending the length of their trucks up to 25m long (Gigaliners) and their authorized weight. Of course, this does not allow them to penetrate at any time inside cities for the final distribution but is for rail a serious competition as Trucks have nearly no access restrictions to motorways most of the time and have the same priorities as passenger cars on the motorways. This is the main handicap of freight which are operationally suffering a lower priority in case of incidents. This point is very important as it impacts the reliability. On the 9 Corridors better priorities for freight transport are organized and the DPS trains, which can be progressively introduced, will prove their efficiency.
The market potential is greater in the field of smaller shipments and complex supply chains are organized for which these DPS trains can participate for long runs only if reliability is insured.
Rail offering a greater sustainability, which is valued by citizens and supported by the EU, M2O results ease greatly future market uptake by defining some safe consists interesting the various segments.

5.2.3. Wagon Load traffics

This segment is essential for certain type of cargo like dangerous chemical products, Basic metal products, fertilizers but it is frequently in limited quantities. In that cases, quantities are frequently less than FTL and using marshalling yards are necessary. But this increasing the costs, many industries have restricted their use of wagon load and frequently closed their private sidings. The potential could increase, if trains with various compositions and various lengths could be sent from one site. This is favoured by clustering industries with logistic centres, like it is done in Italian Interporto or in Germany where industries are clustered and much less in France where industries are scattered, just to give some examples. The potential could be growing if several short trains combining heavy stuff from different industries may be quickly transformed in a first hub in a DPS train for a long distance run and a quick separation in a hub for a short run to their destination. All

- [1] LWL indicates a train consist in which the active TU are at the beginning and at the end. Pictogram is 

for DPS system. For LLW, the two TUs are one after the other.
- LWLW indicates a train consist in which the active TU are at the beginning and in the middle. Pictogram is 

.
- LWLWL indicates a train consist in which the active TUs are at the beginning , end and middle of the train. Pictogram is 

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these operations being done without entering a specific yard could be quick and interest shippers, RUs. The competition with road is fierce with road transport.

5.2.4. Interest of actors in each market segment

5.2.4.1. Bulk segment

Reminding that we are largely in a mature segment where cost reduction is the target the following table will point out the positive aspects and the drawbacks for each actor

Actor	Positive impacts	Drawback
Shippers	More efficiency of assets : transport cost reduction Possible horizontal collaboration	Investment in private siding if any
RUs	More efficient use of staff, market share gain	Investment on TUs
IMs	Gain of capacity	Investment on sidings and on specific points
Terminal operators	Market share gain	Investments on tracks possible

5.2.4.2. The combined transport segments

In this segment, high potential external factors may influence the interest of certain actors. Before the pandemic the economy was growing steadily and the lack of drivers was hindering the road development and favouring combined transport it is difficult to have a clear view for the future. Basing the analysis on the market potential, the following table summarizes the usual positions:

Actors	Positive impacts	Drawback
Combined transport operators	Possible gain of market share with capacity increase on network and specifically corridors	More rigorous capacity management on trains to keep the positive efficiency
Road hauliers with crane-able ILUs	More capacity on classical terminals, staff productivity, gain of market share with semi-trailer investment	Need for small company the organize the collaboration for the end transport, little more investment to be craneable
Road hauliers with non crane-able ILUs	Full use of existing assets, extreme flexibility in case of extra traffics, staff productivity enhanced, market share gain	Need to have a horizontal transfer terminal
Terminals (Ports or Inland)	Flexible and powerful way to connect ports to dry ports, possible collaboration between two regional medium size ports	For inland terminals or hubs need to invest to ensure quick reception and handling of such long consists
Combined transport operators for horizontal and vertical transfer	Ramp up very quick on new routes if price matches road marginal cost, possibility to take any type of semi-trailer, possibility to mix with classical flat wagons for vertical transfer, positive solution	Heavy costs in terminals and in specialized wagons

	if road drivers are not sufficient in numbers, fits to existing road hauliers equipment with no changes	
RUs	Efficiency of TUs, staff productivity	Investment on TUs
IMs	Increased network capacity,	Investments in sidings, terminals and specific points, impacts on other traffics
Ship owners	Enables to decongest port terminals coping with huge number of movements from Giant container carriers	If terminals belong to ship owners' investments may be necessary
Logistics operators	The growing demand of more e-commerce and of green image may mean more rail which a large share of logistics operator cannot accommodate on their platforms totally dedicated to road. If reliability and speed are guaranteed adding some groupage containers or semitrailers on a flexible combined transport DPS train is a progress.	The risk remains if the punctuality of such train is not extremely high. In vesting in groupage semi-trailers directly or indirectly is certainly necessary

5.2.4.3. The wagon load segment

This segment is extremely challenging. One part for dangerous goods must remain operational for safety reasons, the other part faces clearly the frontal road transport competition. Many RUs have decided to reduce drastically the service, but some others have taken up the challenge through X-Rail organisation. Such a service can only progress it the whole network of its participants are capable to balance flows and avoid as much as possible empty runs. At the same time the quality level has to match Road service quality and one of the main challenges is the reliability at the same level of the cost. The various actors' interests are described in the following Table:

Shippers with dangerous goods	Safety,	Reliability, cost reduction
RUs	Flexibility in volumes, increase productivity on trunk travel	Investment on TUs
IMs	Gain in capacity with long trains having the same dynamics	Investment in sidings, some places in signalling, impact on other traffics, on path planning, reviewing priority rules in case of incidents.
Terminal operators	Hope to regain market share	Investments to facilitate service to such new consists
For other shippers with non-dangerous goods	Flexibility of volumes, cost acceptable, sustainability image	For certain reopening of their private siding, some constraints on time schedule

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5.3. The road competition

The road competition is extremely active and develops its competitiveness rapidly with also efforts to improve its green image with a strong CO2 emissions reduction. Figure 1 reports the roadmap for CO2 reduction.

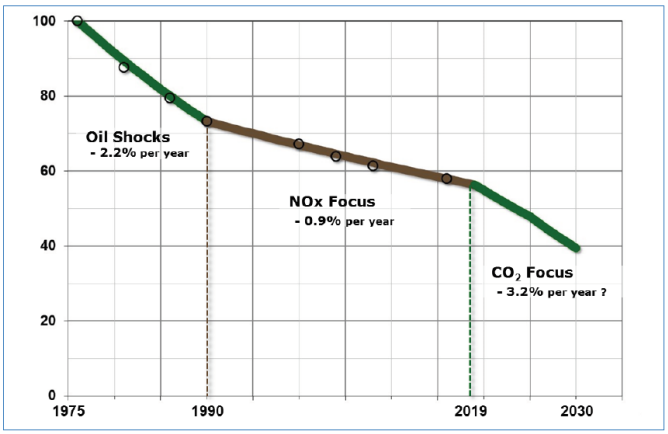

Figure 1 Long duty Freight Transport Roadmap 2019

What is clear is that, to reach the goals EU has fixed in term of rail marked share in 2030, it is absolutely necessary to achieve rapidly a jump in the efficiency of rail freight transport. Long trains even without DPS have demonstrated that on certain routes DPS trains will boost that progress and the motto should be: when GIGALINERS are accepted GIGATRAINS must be accepted. It is however clear that road is necessary for last mile distribution and the impact of clustering around freight villages should help very much. Finally, digitalisation enhancing reliability and supporting filling coefficient of the trains is progressing.

The quick Road evolution showing urgency for Rail to progress.

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SWEDEN
"Sweden has allowed long and heavy vehicles on its roads. The transition from 24m to 25.25 m and 60 t trucks in 1998 was to take advantage of the new EU approach to road transport that was included in Directive 96/53/EC."
"In parallel a new intense discussion started on "follow Finland" since the neighbour country in 2013 decided to increase the total weight to 76 t after dialogue with EU"
Concerning CO_2 e.g. the new goal is to make a reduction at system level of 15% only by a massive implementation of HCT-vehicles (max. 34.5 m and 74 t). By 2030, HCT vehicles should account for 80% of all t-kms transported on the roads in Sweden requiring that almost all prime movers, trailers, links and dollies are approved to be part of a 34.5 m 74 t road train.
FINLAND
"Based on Swedish examples, their own research and small pilots they have decided to extend the total weight from 60 t to 76 t without special restrictions. This new regulation was approved by the European Union and was set in operation from autumn 2013."
The NETHERLANDS
"HCT has been progressively introduced in the Netherlands since 2001. Between 2008 and 2011 a research and pilot project was carried out to test 25.25 m and 60 t within a limited network of the public roads. The results were good and from 2013 these longer and heavier vehicles are permitted on part of the public road network, subject to special permits."
DENMARK
"A long-term pilot program with field tests of 25.25m and 60t has been underway in Denmark since 2008"
GERMANY
"13 among 16 federal states authorised use of 25.25 m vehicles limited to 40 t (44 t for combined transport) from January 2017 in order to protect bridges on a restricted road network. In December 2017, two more federal states followed suit; leaving only the city-state of Berlin outside the system.

Country	Regulation Tons/Metres	Year established
The Netherlands	60 t/25.25 m	2013
Finland	76 t/25.25 m	2013
Denmark	60 t/25.25 m (Long term trial)	2014
Norway	60 t/25.25 m	2014
Sweden	64 t/25.25 m	2015
Spain	60 t/25.25 m (special permits)	2016
Germany	40 t/44t/25.25 m	2017
Sweden	74 t/25.25 m	2018
Finland	76 t/34.50 m	2019

Figure 2 Source International Transport Forum High capacity Transport

6. Marathon2Operation answers

6.1. Possible train consists for each market segment

6.1.1. Bulk segments

6.1.1.1. Heavy Bulk

Depending on the type of commodities, the length of the train is limited by the TU capacity. For

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heavy homogeneous bulk trains, the load per meter is in average 6t/m and up to 7.9 T/m. The trains with one TU (e.g.BB27000 type) at the head on standard infrastructure with gradients less than 10‰ consists up to 2400T have a length of 400m for 6T/m. For heavier and longer trains a second TU (Multiple unit) can be added at the head which enables to reach 3600T limited by the risk of disruption of the train. To go further, it is necessary to put the second TU at the end of the consist with a second driver connected by radio with the front driver and finally with a multiple unit at the head and a second manned TU at the end, 5700T consist has been run on the French network with a length of 967m, just to give an example of existing long and heavy train. The reference trains considered in M2O are actually those running on the German Network but they are likely representing the trains running on the European network when infrastructure allows at speed less 100km/h.
M20 analysed such trains in a wider way with more variable loads in the consists for the lighter ones using train generation according to UIC 421.

		MASS brake regime	virtual reference consists generated according UIC 421 with 1 TU tested in critical conditions				
TU characteristics	LENGTH	0-800T	801-1200T	1200T-1600T	1600T-2500T	2500T-4000T	2500T-5500T
TU BR187	0-740m	P	GP	LL	G	G UNIF LOAD	
BOBO MAX constant traction force 35KN	0-740m		GP	LL	G		

Figure 3 Comparison of BoBo Max TU vs BR187

6.1.1.2. Lighter Bulk

These types of bulk weighs around 4.5T per metre leading to consists of 3330T for 740m. These types of bulks fully use length and exceeds traction weight limits of 1TU at the head of the train, needing to have a second TU at the head of the train. This opens the way for a progress of efficiency in the same way as for heavy bulk, by adding a second TU at the end which would then fully use the weight limit of an 850m Long train with a total weight of 3800T with two TUs at each end of a DPS train. M2O should enable to confirm the safety of such consist.
M2O is offering a more efficient solution with an unmanned TU at the end of the consist. The various possibilities are shown in the table here under.

Trains with 2 Tus, 100Km/h, homogeneous flat wagons with bogies, 6,6T/m average load almost uniform loading ; all wagons with LL shoes; train runing in nominal mode; maximum length of consist 1000m							
For all trains simulated the brake regime is G mode (but for the last one)							
TU	Wagons	Wagons	Wagons	Wagons	Wagons	Wagons	TU
960m 6500T	820m 5500T	720m 4500T	620m 3500T	TU BR187Train Length 0-500m and mass 2501T-4000T running in P brake mode with a radio communication LTE		Direction	"------>"
GSM-R	GSM-R	GSM-R	GSM-R	LTE			

Figure 4 Trains with 2 TUs

6.1.2. The combined transport segments

As explained above these segments are the most dynamic ones. Before the pandemic, the lack of

drivers for road transport was boosting the business.
The pandemic has had two different consequences:

- the lack of road drivers was still strong while tremendous reduction of passenger rail activities has left rail drivers available but at the same time some freight traffics have been reduced due to the slowdown of the economic activity. Rail freight transport during that period has demonstrated its resilience and capacity to serve efficiently the economy specifically for vital activities.
- At the same time with less passenger trains the reliability of rail freight transport has jumped at its highest level. A real new movement in favour of a sustainable rail freight transport pushes forward urgent progress with more support than ever in the last 20 years.

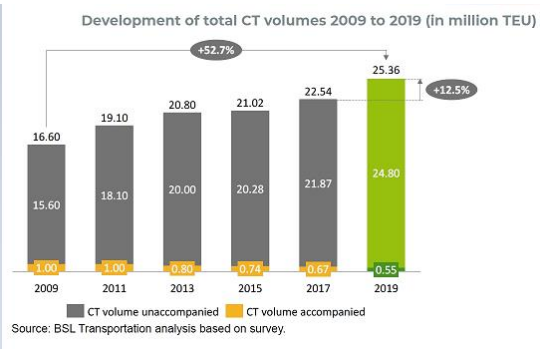

Figure 5 Development of Combined Transport (CT)

The combined transport segment is the best opportunity with a large potential to develop sustainable solutions and to serve all industries and populations even not clustered.

6.1.2.1. Transport of maritime containers in full block trains

This first segment, immediately attractive, is the transport of containers from ports to dry ports to cope with the huge number of containers discharged on the very few ports called by the giant 21000 TEU container carriers which are congesting the port terminals and which have to be out of the port as quickly as possible. They have to leave the ports to reach inland dry ports by the most powerful means of transport: Block trains or barges are the best possible solutions.
Rail has a challenge in terms of volumes carried using the less possible Rail network capacity because everybody knows that, if infrastructure works are absolutely necessary, they take quite a long time to be started and achieved.
Today with an average weight of 2,5T/m trains of 850m driven by one TU (as BB27000 of Alstom) on a route with less than 10‰ gradients and more than 350m curves with high resistance wagons in G regime are already running in France, for instance.
M2O should offer soon possible solutions of the 1TSW type or 2T type according to the specific characteristics of the train and infrastructure. They will be very attractive.

6.1.2.2. Intermodal transport beyond dry ports or hubs

The second segment deals with the second part of the logistics chains and starts from dry ports, from hubs, from industries and from logistics clusters. This part is composed of short, medium and long-distance connections which have to be set up. If the short distance connections or the final distribution links will remain the privileged road transport activity domain, the medium and long-

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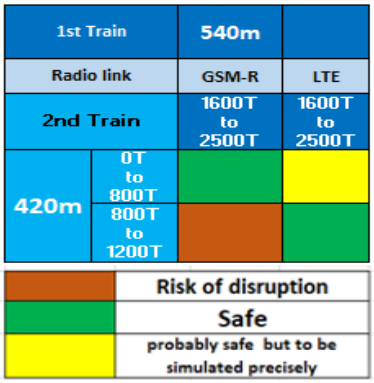
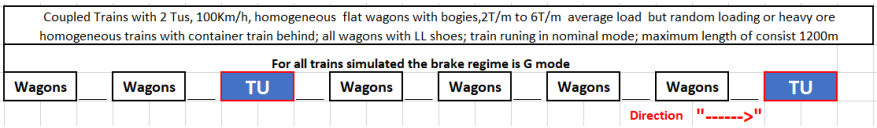
distance connections are a field where competition between road and rail exists.
To face road competition described before, rail freight transport must rapidly react and lengthening combined transport trains is the quickest solution:

- If it is for a unique destination the DPS consists proposed by M2O are identical to those developed in 6.1.2.1.
- If it is for multiple destination rail freight trains are generally composed of two parts that must be decoupled at an intermediate yard to add one locomotive more to drive the two parts separately to their final destinations. This traditional solution is quite costly and generally not competitive on medium distances because of the costs at the intermediate stop with manoeuvres and moreover it is not very robust solution as it implies to leave the main track to go to sidings which sometimes are not electrified implying to coordinate several resources. The M2O solution DPS Train 2T should provide interesting possibilities with a heavier first train (heavy or light bulk) and a lighter intermodal train behind easily decoupled on-line in less than 10 minutes in a station where a second driver takes the rear part of the train towards its final destination.

Some necessary conditions have to be noted for all intermodal cases: adaptation of terminals to the new format of the train consists and some adaptation of the rail network to ensure a safe run of such longer trains.
Setting up a powerful rail link for combined transport for certain secondary ports which are only called by feeders and are not able to feed long trains. In that case, as the volume is not sufficient for a long distance destination (hub or terminal) M2O will offer the possibility to set up quickly (around 10 minutes which were measured during FP7 Marathon) the coupling of two sub-trains arriving in a coordinate way on a siding or in a station to create a M2O DPS consist able to be extremely competitive on the trunk travel and allowing a decoupling in less than ten minutes to let the two sub-trains finalize their journey towards their final destination. M2O will offer the 2T type of DPS consist or even the 2TSW type of DPS consist if the weight is quite heavy.





This is an example of a2T type DPS train of an overall length of 1000m which is a coupling of a first light bulk train of 4,6T/m and a container train from less than 2T/m up to 2,8T/m. This type of train can be a good solution if the consist has to cross some steep gradients which could be difficult with one locomotive hauling 3700T with wagons equipped with 85T UIC couplers.

6.1.3. Wagon load segment

The definition of the wagon load segment refers to less than full train loads. This means that it is not economically possible with the available number of wagons to create a complete train using either the maximum weight which can be hauled by the TU or the maximum Train length authorized on the route of this shipment. This segment encompasses a very small number of

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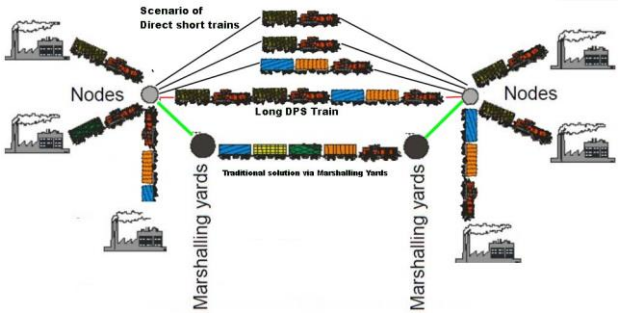
wagons, previously called single wagon load traffics up to part trains which can be as long as half a full train.



The classical transport plan in this segment involves a collection phase from private sidings or small stations, a consolidation phase to reach a marshalling yard where the wagons of the various consolidated consists arriving are sorted to create new consists to run to the next hub where they can be spread to reach their final destination.

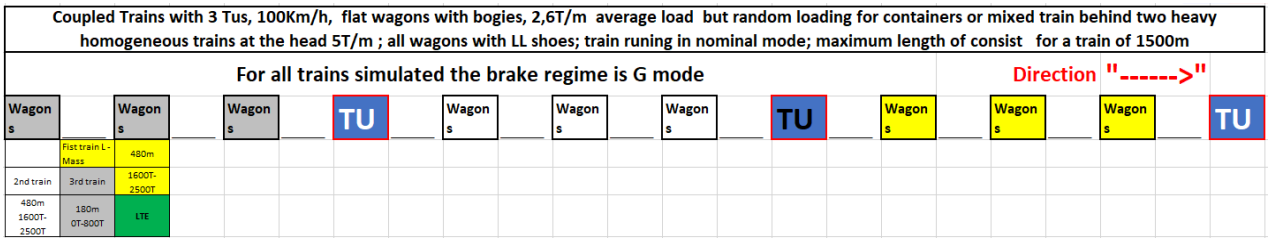


Figure 6 M2O solutions for 3 coupled trains

This segment, facing the road competition has decreased significantly in the last 15 years.

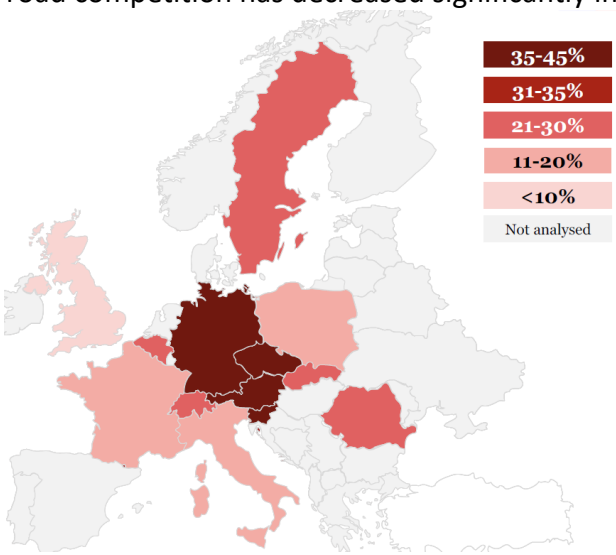


Figure 7 Study on SWL traffic in Europe PWC 2015

However, this segment was still representing 6 years ago around 25% of the rail freight transport as dangerous chemical cargo (for safety reasons), basic metals or fabricated metal products, heavy equipment of industry and agricultural products (cereals from silos) continued to require such type of transport. To face that competition some Countries have nearly abandoned that segment while some others having still powerful industry clusters are still keeping important traffics.

Another evolution through XRail (association of RUs) has developed SWL transports with long distance trunk travels to connect national distribution networks giving a better competitiveness to this traffic.

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M2O can offer a solution to by-pass marshalling yards with a DPS train consolidating 2 to 3 medium size trains of on the long-distance trunk run enhancing the competitiveness of the system.
The global cost distribution of Wagon load transport segment is largely variable, and the following average cost distribution must only be considered as an example.

A DPS train with 3 locomotives is of the type shown in Figure 7 above and is precisely composed of a first DPS part train at the head weighing 2500T (heavy bulk) with a length of 480m, a second DPS part train behind weighing 1600T (light bulk) for 480m length and a last DPS part train at the rear end weighing 350T with 180m length (container or rolling motorway).
Three classical trains, weighing in total 4450T coming from two single wagon load terminals and one from an intermodal terminal could be used two create two trains after sorting in a marshalling yard with a weight of 2225T each and be again sorted to reach their final destination.
The transport plan here-under (Figure 8) represents three basic short trains avoiding going through the marshalling yards but trying to reach directly their final destination and a long DPS train where these three trains are coupled in a node after replacing their diesel TUs by electric TUs and runs to the next node where the three short trains are restored to run with diesel TUs to their final destination.

Figure 8 Transport plan for three basic short trains

The operations shown in this figure enables to compare the costs of the two transport plans.
The basis of the costing is issued from the last study about wagon load of the European Commission (Move/B2/ser/370/SI2.658347).

REFERENCE SCENARIO

3 short trains one of them being heavy has 2 diesel TUs. They are running on 50km to a node where the two diesel TUs are replaced by a powerful electric TU. These 3 trains will by-pass the two marshalling yards on thier route and will reach the next node where the powerful electric TU will be replaced by two coupled diesel TUs to continue the trip to their final destination.

		COLLECTION	50 km	action in node	Level 2 trains	100 Km	action in Marshalling yard	Main leg of the travel	500 km	action in Marshalling yard	Level 2 trains	100 km	action in node	DISTRIBUTION TRAIN	50 KM	
10	1st train	1 diesel TU	10,5x50=525€		1 diesel TU	6,4x100 = 640 €		6,4 x 500=3200€				6,4x100 = 640 €				4480
16	2nd train	1 diesel Tu	10,5x50=525€		1 diesel TU	6,4x100 = 640 €		6,4 x 500=3200€				6,4x100 = 640 €				4480
				change to 1 electric TU									Change to 2 diesel Tus			
30	3rd train	2 Diesel Tus	10,5x50x2=1050€	150 €	1 elec TU	6,4x100 = 640 €		6,4 x 500=3200€			1 elec TU	6,4x100 = 640 €	150 €			4780
	peages/Tolls		2 x50x3=300€			2 x100 X 3=600€		2 x2x 500=2000€				2 x100 X 3=600€				3200
				THIS PART OF THE COST IS TO BE COMPARED TO DPS TRAIN												16940

DPS TRAIN SCENARIO

3 short trains, one of them being heavy has 2 Diesel TUs at the front. They are running on 50km to a node . In the node each of these trains are equipped with an electric TU and are coupled together to create a long DPS train of 4550T,1200m long with 3 Tus. This train will run directly to the next node by-passing the two marshailling yards. In this node the sub-train are decoupled and equipped with the necessary diesel TU to continue their run as standrad trains to their final destination

	action in node	Level 2 trains	100 Km	action in Marshalling yard	Main leg of the travel	500 km	action in Marshalling yard	Level 2 trains	100 km	action in node	TOTAL
	Change diesel TUs into 3 elec Tus	This DPS Train is 1200m long with 3 Tus of which one is including possession, maintenance and driving, the two other have to be counted for possession and maintenance, the infrastructure charges of 1 standard train is to be increased by around 20% (length of train), the energy necessary for a standar heavy train of 4550T will be the energy necessary for two standard trains of 2250T less 5% which in that case will be 3,4€/km								Change diesel TUs into 3 elec Tus	
	450 €									450 €	900 €
possession, maintenance and DRIVING of the lead TU		4,6€/km x 700km									3 220 €
possession, maintenance of the 2 other Tus with no drivers		2,1 x2x 700km									2 940 €
Track access charges (20% more than a standard train		2€/km x 700 x 1,2									1 680 €
Energy for the three Tus		(1,8€/km x 2) x 0,95 x 700km									2 394 €
Assumption of the cost of the DPS equipment per travel 1€/km		1€ x 700km									700
										COST REDUCTION -30%	11 834 €

Figure 9 Reference and DPS scenarios

On this transport plan, M2O 3T proposal for DPS trains should be very attractive compared to the reference scenario.
This is only an example but if we would have to add one marshalling operation in this scenario to create the adequate final trains running to their final destination the comparison will still be in favour of the DPS long train with a smaller percentage because of the overall cost increase. If a rough comparison is made with road transport on its trunk travel taking into account that the net load transported by this DPS train represents only 50% of the gross tonnage of the train which amounts to 2225T and that such a truck would have a net payload of 27T and that the cost of a marginal road km would be 0,65€/km the cost of the road transport would be (2225/27)·0,65·700=37495€ largely above the DPS train cost 11834€.

6.2. Methodology of Analysis of business cases

6.2.1. Parameters of the business case

The important parameters necessary to study an operational problem where a DPS Long train solution would be attractive are summarized hereunder in the Figure 10.
The figure is not designed to drag conclusions but to support the first approach of the business analysis by giving guidelines on the main features of the transport necessary to analyse the problem. This figure leads the Reader to areas where: a) a solution should exist; b) where it is definitely impossible; c) where it is hardly possible; d) where more investigation is needed.
Three main categories of cargo have been analysed as the characteristics of the cargo are quite different and leads to different type of consists adapted to constraints of the activities requiring such transports.

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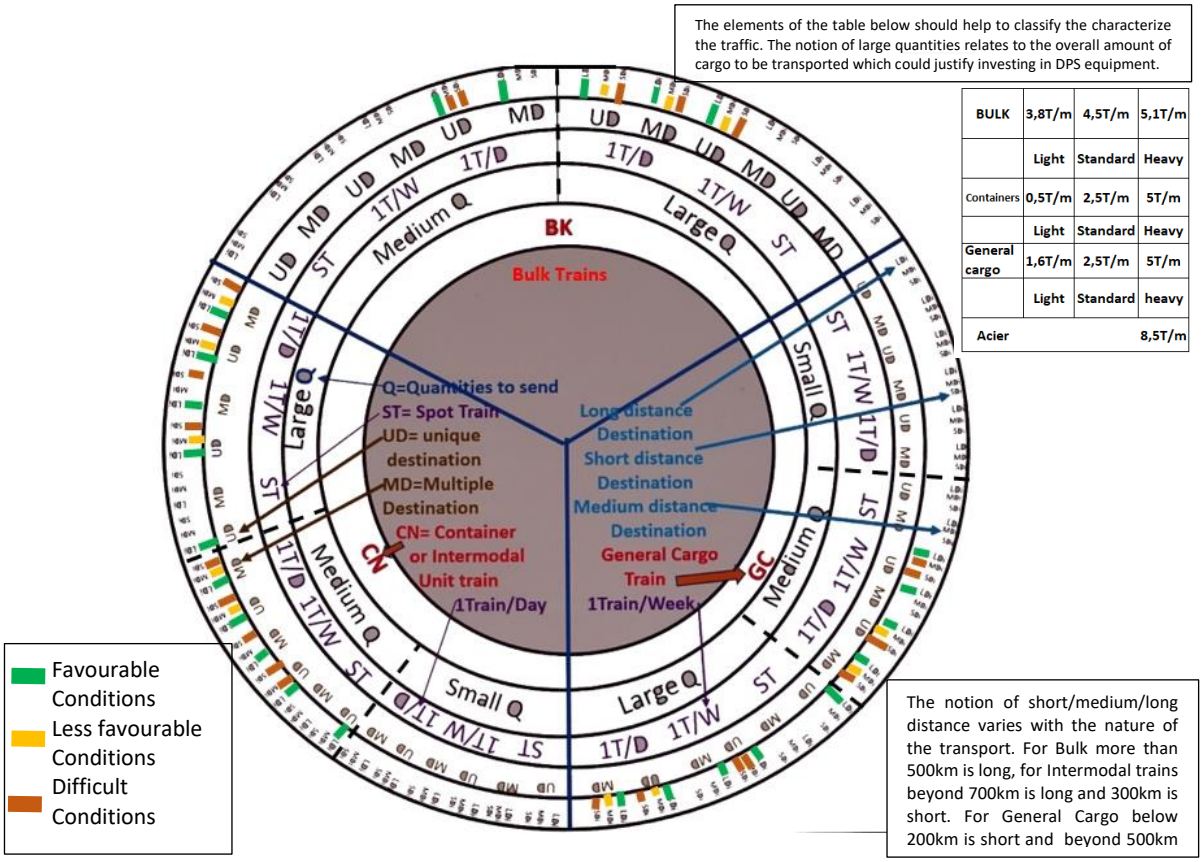

Figure 10 Key parameters for DPS trains

6.2.2. The simulations which have allowed to feed this table

The M2O answers with DPS train to the various business cases summarized in the table are supported by a large number of simulations representing consists which Train dynamics have been simulated with TrainDy and compared to reference trains already authorized to run on the German Network.

6.2.2.1. Standard and reference trains

Existing trains, taken as reference, involve trains with one TU at the head and different consist behind which are in the figure xx running in P, GP, LL and G Brake regime with various tonnage and a length limited to 740m. Simulations with BoBo Max TU having a high power of constant 350KN have also been simulated to see if LTD limits were respected in critical braking situations.

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		MASS brake regime	virtual reference consists generated according UIC 421 with 1 TU tested in critical conditions				
TU characteristics	LENGTH	0-800T	801-1200T	1200T-1600T	1600T-2500T	2500T-4000T	2500T-5500T
TU BR187	0-740m	P	GP	LL	G	G UNIF LOAD	
BoBo MAX constant traction force 35KN	0-740m		GP	LL	G		

Figure 11 Classic trains with BR187 or BoBo Max TU at the train head

6.2.2.2. Consists 1T-SW

Such trains where TUs are at both ends of the consists with 2 drivers exists on the network with standard lengths for heavy consists having to climb steep slopes. These trains are often bulk trains for ore, coal, sand, or steel trains carrying coils on Shimms wagons, or even container trains or rolling motorway trains with heavy trailers or "artics" on board.

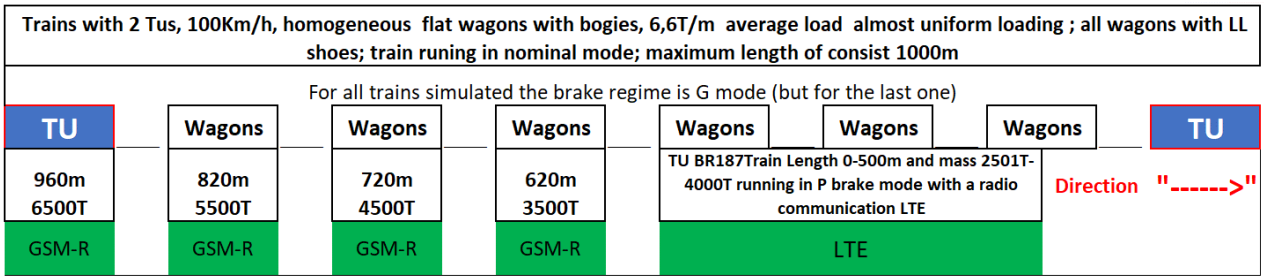

Figure 12 M2O solution for "sandwich" trainsets, i.e., with one TU at each train end

The attractiveness of certain of these DPS train configurations have been shown in 6.1.1.2. above. These sort of trains, if they are quite long, may be composed of two sub-trains one of heavy bulk or heavy stuff and the second one of containers lighter. The DPS train can be split at the final destination of the first part and continue its travel as a standard train with the rear sub-train. This could be easy, as no specific manoeuvre would be needed.

6.2.2.3. Consist 2T

Such DPS trains configuration should be classical in the future. It answers the need of the market not to reduce the frequency of departures from the origin of the trains. This is justified by the fact that very few terminals, even in ports can provide the double of the volume and keep the same frequency of departures. The solution is to depart from two different terminals and to couple the trains in a station on-line in a very short time to constitute the long DPS train to run on the trunk travel delivering an enhanced efficiency. Decoupling the two sub-trains of the DPS Train should be done on-line very quickly in a station and the two standard trains will then run separately to their respective destinations.

A variety of consists have been simulated as shown in Figure 13.

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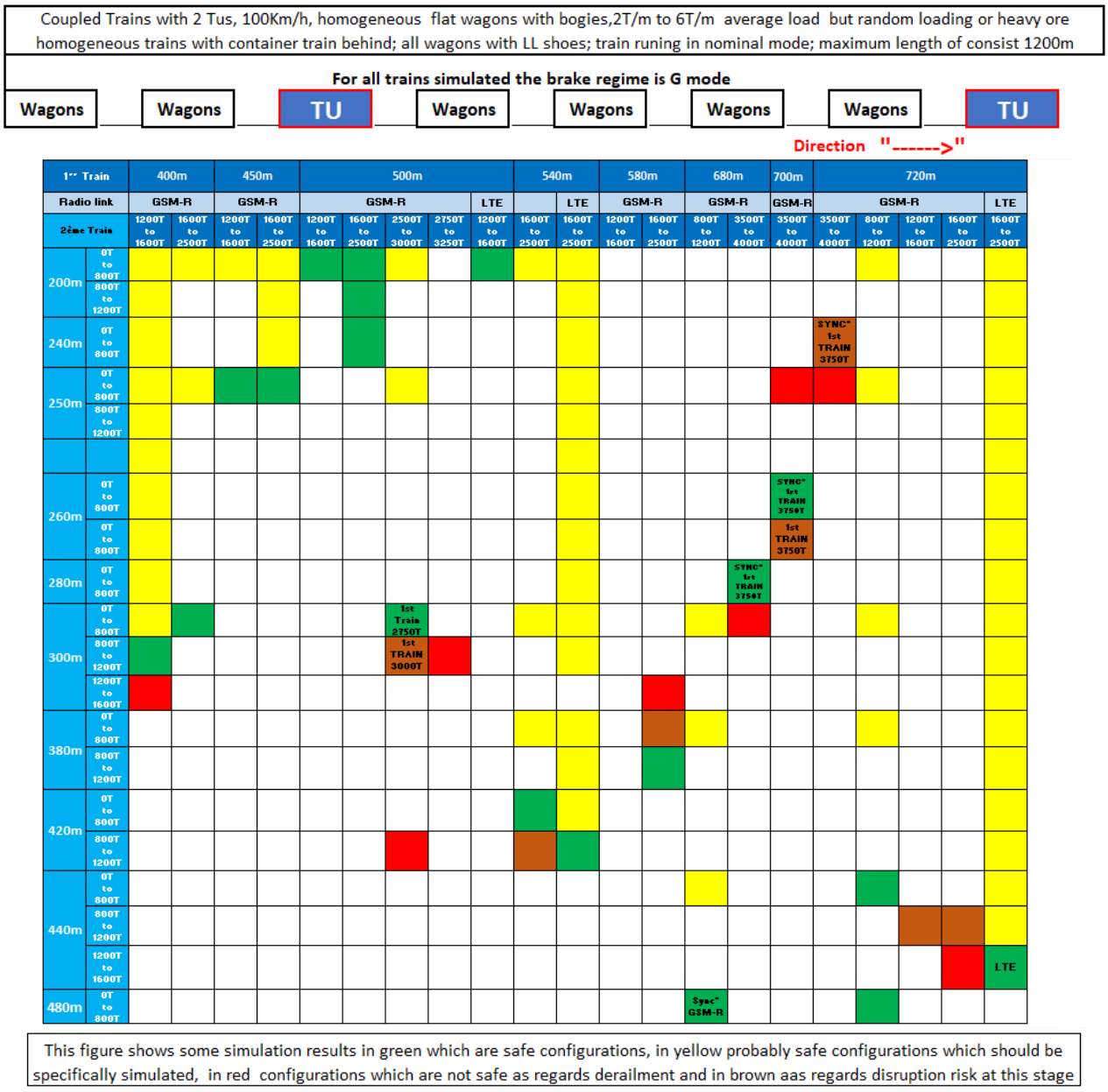

Figure 13 Different M2O solutions with 2 coupled trains.

6.2.2.4. Consist 2T-SW

Such DPS train consist is interesting for two heavy sub-trains coupled that will have to run on steep slopes needing an extra TU to push. The results of the simulations of some consists are in the Figure 14. In these consists, where three TUs are involved, the GSM-R communication solution has to be replaced by LTE and looking forward to the introduction of FRMCS (5G) a virtual new communication solution named Synchronous has been introduced with very short latency and the capability to delay a little the application of the brake on the lead TU to ensure a roughly perfect synchronisation of all TU braking actions. However, some simulations with a virtual use of GSM-R and its classical latency time has been made but indicated as virtual by an **X** in Figure 14.

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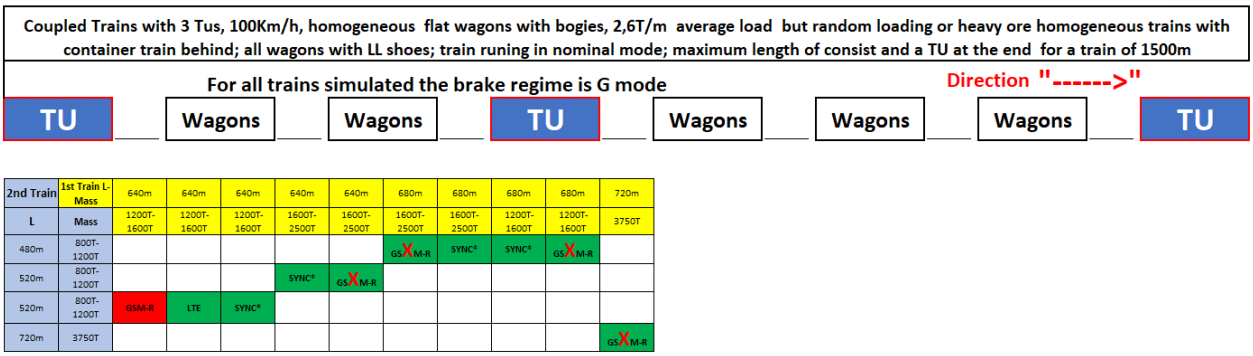
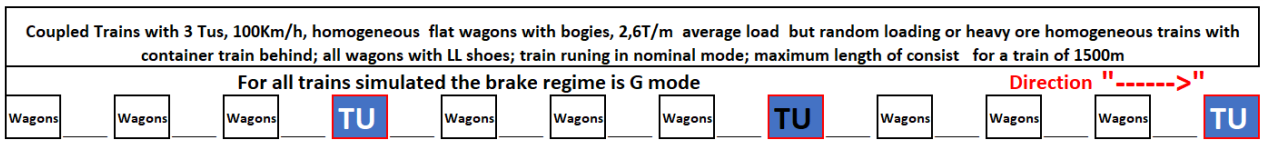


2nd Train	1st Train L-Mass	640m	640m	640m	640m	640m	680m	680m	680m	680m	720m
L	Mass	1200T-1600T	1200T-1600T	1200T-1600T	1600T-2500T	1600T-2500T	1600T-2500T	1600T-2500T	1200T-1600T	1200T-1600T	3750T
480m	800T-1200T						GSM-R	SYNC*	SYNC*	GSM-R	
520m	800T-1200T				SYNC*	GSM-R					
520m	800T-1200T	GSM-R	LTE	SYNC*							
720m	3750T										GSM-R

Figure 14 M2O solution with three TU, one of them placed at train end.

6.2.2.5. Consist 3T

These types of consist may result from 3 short Trains of Wagon load traffics having different destinations, some of them being heavy, which are to be coupled together to create a DPS Train. In certain cases, depending on the destination distance, it may be more efficient, to bypass one or two marshalling yards, where the trains would have been sorted to create only two standard trains. These trains should, in turn, be split again to reach their final destination by creating a long DPS train which could be split in the original three short trains in a node, to reach their final destination.



	1st train L-Mass	313m	313m	313m	380m	380m	480m	480m
2nd train	3rd train	1200T-1600T	1200T-1600T	1600T-2500T	1600T-2500T	1600T-2500T	1600T-2500T	1600T-2500T
313m 800T-1200T	313m 0T-800T	GSM-R						
313m 800T-1200T	313m 0T-800T		SYNC*					
313m 1200T-1600T	313m 800T-1200T			GSM-R	SYNC*			
380m 1600T-2500T	380m 0T-800T				GSM-R			
380m 1600T-2500T	380m 800T-1200T					GSM-R		
480m 1600T-2500T	180m 0T-800T						GSM-R	LTE
480m 1600T-2500T	180m 0T-800T							SYNC*

Figure 15 M2O solutions for three coupled trains.

6.2.2.6. Consist 3T-SW

These type of consist with 4 TUs enables to associate one heavy trains in the front with homogeneous loading and two container lighter trains behind or two heavy homogeneous trains and a final TU at the rear end. This consist may reach 1500m length and 7500T mass. The efficiency of such a train is interesting but two relatively heavy container trains behind a short heavy bulk train in front could be a productive solution. The results of some simulations are in Figure 16 below. In these simulations the Sync virtual solution already described, the future 5G solution with its expected latency, and the theoretical GSM-R (not applicable in this case but interesting because of its global latency) have been simulated to have an assessment of the latency impact on the LTD.

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Certain configurations generate a risk of disruption of the consist and others a risk of derailment.

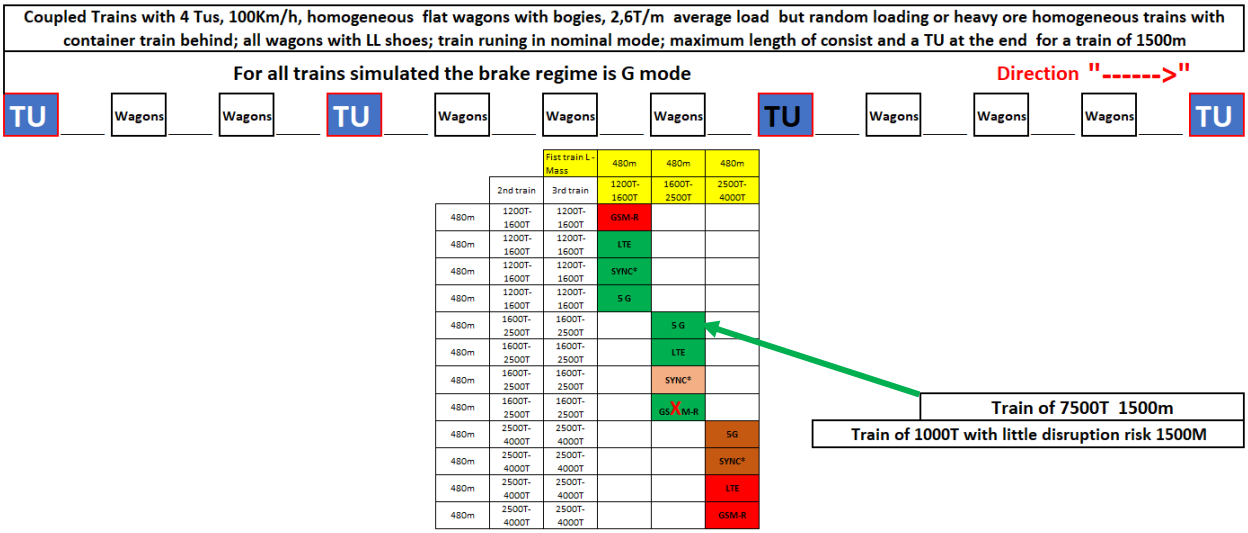

Figure 16 Three coupled trains plus an additional TU at train end.

These configuration gives a powerful transport capacity.

6.2.2.7. Consist 4T

These type of consist associates 4 relatively short trains to create long DPS consists between 1200m and 1500m. The first train is quite heavy, and the weight is decreasing towards the end of the whole consist or all trains are in the same category of weight. The interesting result is to be able to create 1500m consist with 6100T of mass which should be efficient if the economic analysis justifies the 4 TUs. The results of the simulations are in the Figure 17 below.

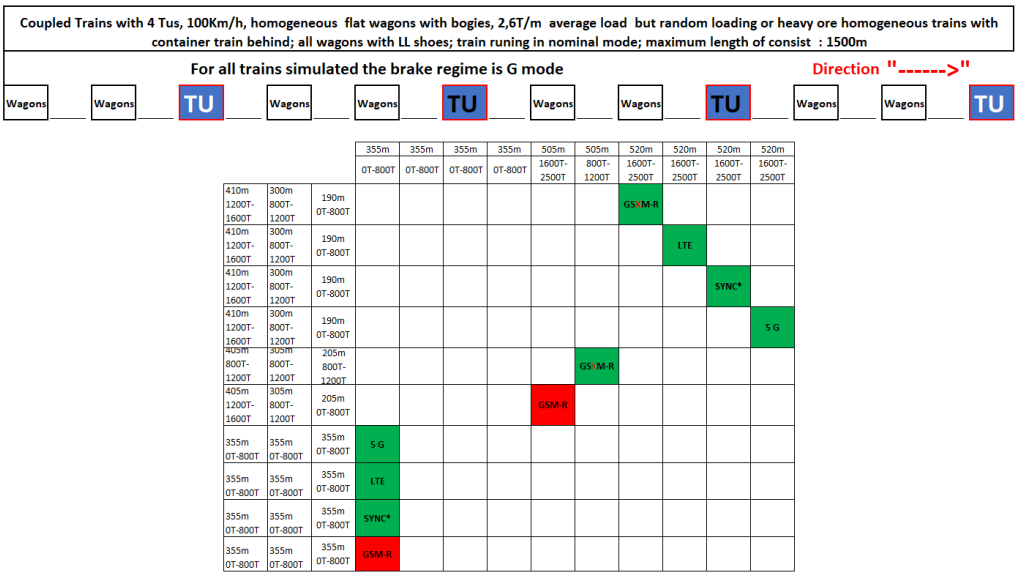

Figure 17 M2O solution for four coupled trains.

6.2.2.8. Final considerations on simulations

All the previous simulations are made on the basis of nominal mode of the DPS Train and on precise

wagons characteristics. Any specific consist must of course be simulated specifically before testing. Some more simulations have been developed to compare reference trains simulated with manned TUs and DPS trains in critical situations where DPS would be in degraded mode. These simulations have been done on trains of the category which should be used for the tests of FR8RAILII. An example of these simulation results is in the Figure 18 below: each dot represents the LCF (or LTF) of a train, with a specific wagon permutation. DPS trains perform better than reference trains (with manned TUs) considering LCF; this is usually true also for LTF, even if some cases in which reference trains perform better than DPS trains exist. The train operation represented is an Emergency Braking after Acceleration of a consists having length and hauled mass roughly equal to 650 m and 1600T, respectively, in degraded mode (radio communication is lost), when the train braking regime is Long Locomotive (LL).
This final analysis confirms the interest of DPS consists as regards the level of safety.

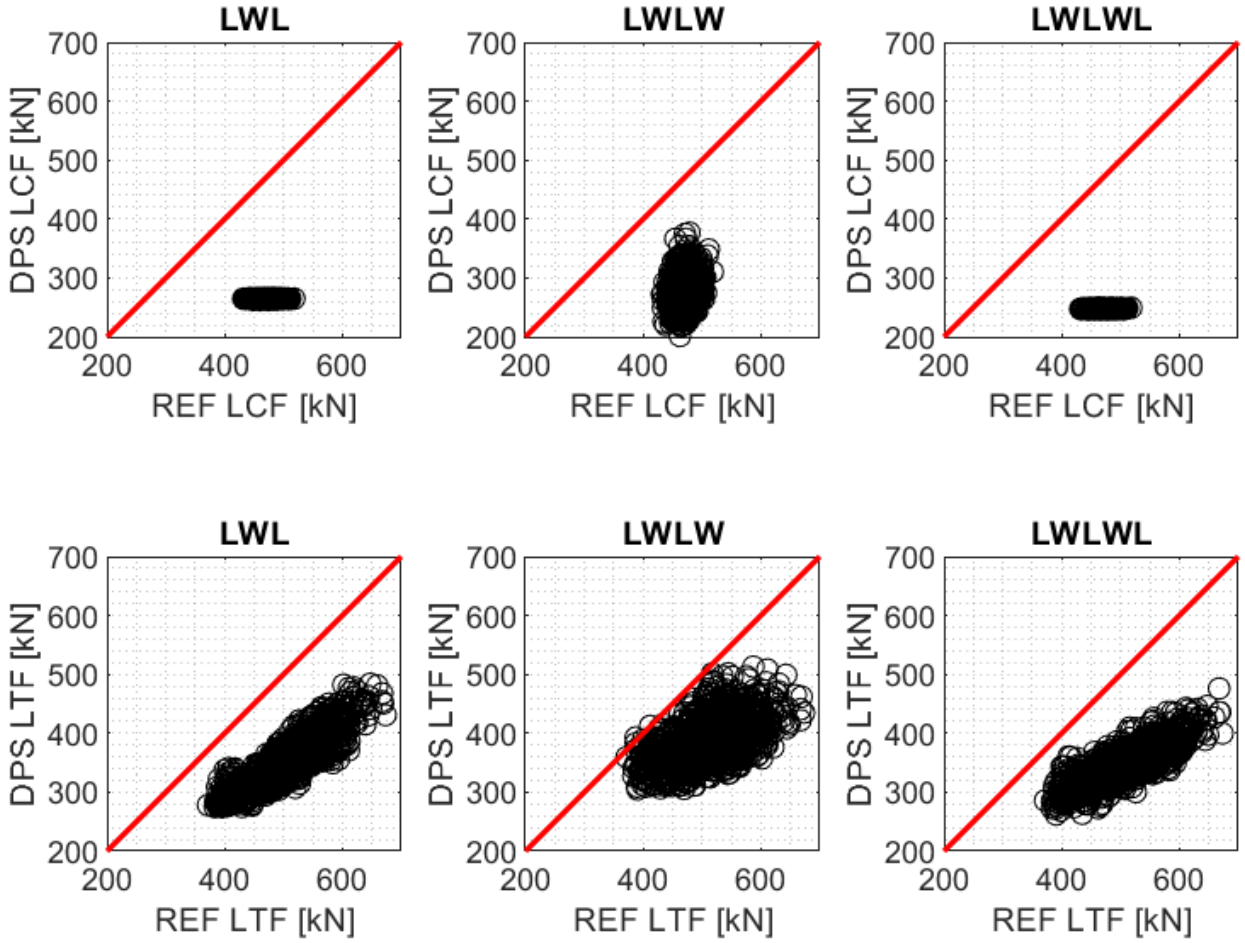

Figure 18 Effect of wagon permutation on Longitudinal Forces. Comparison of Reference and DPS trains.

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7. Implementation of M2O achievements

7.1. Methodology proposed for implementation

M2O has investigated thoroughly the radio communication and the Longitudinal Train Dynamics of a DPS consist. These results integrated with the safety characteristics of the TCMS and DBCU of the Traction Unit will enable to complete case by case the safety case of real consists beyond the test trains running in the first quarter of 2021.
Then the implementation of the DPS system for the train traction will be introduced progressively according to the interest of the decision makers.
The main interest is the cost reduction which can be obtained and the positive impact on the network capacity.
Of course, according to the level of traffics using certain sections of the Railway Network it will be necessary to lengthen some sidings in order to let rapid trains overtake DPS long Freight trains. At the same time, some terminals will have to be adapted to these new long trains.
These investments should not require massive funding and could be achieved in a reasonable time along the Corridors which offer possibility of long runs for trans-European freight trains.

7.1.1. The market segments

It is possible to divide the interested market of DPS trains in three segments:

- The first segment of the market which should be interested is the heavy bulk transport as DPS will enable to increase significantly the tonnage of a standard 750m train, while reducing the transport cost. For these consists no infrastructure modifications will have to be undertaken.
- The second segment where the competition is fierce and where there is a significant development potential is the intermodal segment. For these segments the target of 1000m trains would already boost the efficiency which is threatened by the road gigaliners which are already running in Nordic countries and tested in central Europe. The various categories of operators of intermodal trains carrying containers, swap-bodies, semi-trailers in pocket wagons and of rolling motorway trains are keen to reach this target of 1000m long trains and 2000T of mass. Another opportunity for these traffics to develop rapidly was the lack of road drivers existing before the COVID-19 crisis. In this segment first developments will appear on long routes using Corridors. It is on these corridors that infrastructure works should be undertaken rapidly.
- The third segment that should also be interested is the wagon load activity in desperate search of economies. The possibility to consolidate short trains to create a DPS long train appears positive specifically in Regions where clusters of industries remain very active. Digitization should help these traffics to reach their full efficiency with a booking system to fill as much as possible the long DPS trains.

7.1.2. The support actions

The implementation will have to be supported by a strong communication policy focusing the attention on the quick wins which should appear in the first market segment.
The analysis of the problem for each decision maker is not easy. The figure 8 tends to guide them

towards a preliminary possibility to find a DPS solution which could answer specific transport question. But there is a need of a more advanced support like a tool calculating the LTD of the possible DPS train answering the specific transport case as long as the characteristics of the infrastructure, of the whole consist (TUs and Wagons), of the average speed expected and of the availability of radio communication network are known. This tool could be placed on the website of the project.

7.2. Road Map to reach full development

In this respect the first question to address is where this system should be developed.
The congestion of certain itineraries on main corridors should trigger a quick analysis of the impact of DPS trains on long distance connections. The necessary works mainly composed of extending a certain number of sidings to cope with long trains should start rapidly.
The analysis to be undertaken must involve the feeding of the link on which the DPS train should operate and propose the scheme of the solution involving on or more departure terminal to ensure a good filling coefficient.
At the same time an analysis on the type of track access charges should be launched. Certain structures of track access charges are based partly or totally on the mass transported instead of taking mainly into account the capacity of network utilised. This way of capturing the productivity produced by the DPS system will have a considerable negative impact on the development.
The road map must involve telecommunication authorities to insure the availability of GSM-R, LTE, or FRMCS which are essential for these trains.
It is also necessary to check the electric power available on the route as these consists will need more power to function as the number of such trains will increase during the development.
The roadmap of the development should also involve the shippers and more largely the decision makers to make them aware of the new possibility and put incentives to make them test the solution as soon as it is available.
The fundamental advantage of that solution is that the efficiency gained is incremental and needing reasonable investments. The progress is easy to be measured with the number of the DPS trains-km running on the European rail Network. Other solutions often needs a large number of rolling vehicles to be equipped before getting the first return.
One of the risks is the sharing of the added value created. It will be useful to develop solutions to compensate RUs, IMs in due proportion to their investments and to reduce also the cost for decision makers, thus increasing the competitiveness of the rail freight transport.

7.3. Dissemination and communication

During the last period of the project the contacts with stakeholders have been concentrated on the Mid Term event by Visio conference, the two advisory boards where two major Rus participated, to a visio presentation made to the AUTF with the participation of the European shippers council and in the final events with a flyer distributed to 900 stakeholders generating a registration of 100 participants to this event.
At the same time a Newsletter was issued just before the final event and another one will be issued very soon keeping up the interest of our stakeholders until the final tests for which M2O is finalizing the presentation of the necessary deliverables and on which M2O will report on its

Website.
Moreover, a tool could be put on the website to ease the decision of stakeholders interested to further investigate possible adapted competitive DPS solutions for them.
Already the structure of this Deliverable has been designed to support their interest in the various possibilities to be tested with probability of technical feasibility.

8. Conclusions

M2O project is bringing advanced results on the way to final certified DPS using radio communication between the Leading TU and up to three guide TUs remote controlled. The Radio Communication analysis demonstrated that GSM-R was not able to control more than one remote controlled TU and that LTE and FRMCS in the near future will enhance the efficiency of the radio communication in DPS Trains.
After detecting the most relevant parameters impacting the Longitudinal Dynamics in the train many types of consists have been simulated in the M2O project with TrainDy software to define certain possibilities of safe DPS consists subject to precise analysis of the specific characteristics of the train, of the infrastructure on the route and of the radio network availability.
The analysis of the various market segments that could be interested by the achievements of M2O showed that quick wins would be possible for the bulk transport segment which would gain in efficiency and in cost reduction without impact on the infrastructure as its train lengths would remain inside the standards.
It showed also that a large potential market could be the Intermodal transport with reasonable investments on Traction Units, track infrastructure and terminals. This market uptake could be reached in the short or Medium term.
Finally, a more challenging segment of the rail freight transport, the single wagon load segment, could see its efficiency increased by creating DPS trains with short single wagon load trains where relatively long trunk travels would be needed. This segment, where rail is in fierce competition with direct road services, is however essential for dangerous cargo transports.
To try to face the complexity of rail Freight transport in the elaboration of rail solutions M2O has made a large number of simulations enabling to elaborate some support to guide the interested stakeholders to see the possible DPS solutions for their specific business case are displayed in Figure 10 of this deliverable.
Moreover, a comprehensive safety analysis leading to functional requirements should help interested operators to prepare specific safety cases to set up DPS trains by using deliverables placed on the website.
The significant steps achieved by M2O must be accompanied by a strong dissemination and communication policy and by a support during the launching period by the authorities overlooking a fair sharing of the added value created while developing the reasonable investments needed on infrastructure and terminals to launch first operations as soon as possible.