SEVENTH FRAMEWORK PROGRAMME

THEME 7

Transport including Aeronautics

Project NEAR²

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5	VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS	VGTU	Lithuania
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10	EIRC Consulting Private Limited	EIRC	India
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Abstract:_______________D3.2 includes the description, relevance with Eurasian land bridge, current development situation, as well as the future research directions and priorities on the topic of "Operations and System Performance".

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EXECUTIVE SUMMARY

One of the main goals of the NEAR^2 project is the creation of Concept Documents that map the current situation along the Eurasian railway land bridge in specific fields of expertise (based on the ten poles of excellence of the European rail Research Network of Excellence – EURNEX) and define future research needs based on identified gaps in technology and knowledge.

The current document has been developed within the activities of Work Package 3 ("Investigation of the current situation of research gaps, needs and priorities") and it corresponds to one of the ten Concept Documents that have been created under the NEAR^2 activities, dealing with the field of "Operations and System Performance". Its aim is multiple:

- to define the topics that are related to operations and system performance and affect the efficiency of the Europe-Asia railway corridors;
- to identify the problems, needs, gaps and barriers that exist and degrade the regular rail movement of goods between Europe-Asia, always in regards to the relevant topics;
- to identify future research needs and priorities that will support the formulation of a research agenda for the Eurasian Landbridge.

The current Concept Document will form the basis for discussion, both in the framework of the project and beyond, comprising the cornerstone for bridging the gaps in knowledge and technology in order to improve the efficiency of the railways in the Eurasian Landbridge.

CONTENTS

LIST OF TABLES

ABBREVIATIONS AND TERMINOLOGY

CCS	Control-Command Sub-system
CD	Concept Document
COTIF	Convention de l'organisation intergouvernementale pour les transports internationaux ferroviaires (convention of the intergovernmental organisation for international carriage by rail)
ERA	European Railway Agency
ETCS	European Train Control System
EURNEX	European Rail Research Network of Excellence
GSM-R	Global System for Mobiles-Railway
ICT	Information and Communication Technology
ITS	Intelligent Transport Systems
ITU	Intermodal Transport Unit
OSJD	Organisation for Co-Operation between Railways
OTIF	organisation intergouvernementale pour les transports internationaux ferroviaires (intergovernmental organisation for international carriage by rail)
TSI	Technical Specification for Interoperability
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
WG	Working Group
WP	Work Package

1. INTRODUCTION

1.1. The NEAR^2 Project

The rapid development of Asian economies, particularly China, India and Russia, has dramatically increased the trade volumes between Europe and Asia, with the largest trading partners of Europe actually being located in Asia. Nowadays, the most important trade loads are being transported between the two continents by sea.

Railway transport, using the existing and new land routes for the Trans-Eurasian land bridge presents a viable alternative to the maritime routes, which is gaining significant momentum. Due to the origins and current nature of this rail land bridge, numerous issues need to be resolved to bring the system to a modern state of infrastructure, services and operations. Furthermore, to build the capacity to fully exploit the systems potential adaptation of new technologies, interoperability solutions and optimized operations should be considered. In order to support this objective, NEAR^2 proposes the creation of a Rail Research Network along the Trans-Eurasian land bridge, exploiting the structure and leveraging the achievements of the existing European Rail Research Network of Excellence (EURNEX), engaging this way all the existing research centres in a continuous and fruitful international cooperation.

One of the core activities of NEAR^2 is the formulation of 10 Concept Documents (CDs) that map the main issues that concern the achievement of interoperability along the EU-Asia railway network. The gaps in the existing knowledge in terms of barriers and potential solutions are also being investigated, thus leading to the identification of research needs and priorities. Each Concept Document covers a specific thematic area, based on the 10 EURNEX Poles of excellence, and is supported by a project-partner-membered NEAR^2 Working Group (WG). The 10 WGs of the project are the following:

1. Strategy and Economics
2. Operations and System Performance
3. Rolling Stock
4. Product Qualification Methods
5. Intelligent Mobility
6. Safety and Security
7. Environment and Energy Efficiency
8. Infrastructure and Signalling
9. Human Factors and Societal Aspects
10. Training and Education

1.2. The NEAR^2 Working Group 2

The scope of the 2nd Working Group is to identify the weaknesses and strengths of the Trans-Eurasian railway corridor in regards to the operations and the performance of the overall system. In order however to ensure the efficient and seamless operation of the railway system it is necessary to resolve several other issues having to do with interoperability, rolling stock, intelligent mobility, etc. In this respect, and as depicted in the relevant section 5, the interface of WG2 with other WGs is really important. For this reason, throughout the document it is mentioned that the operations are affected by issues dealt with in other Concept Documents. The goal of the present Document is to examine these issues under the perspective of the operations and system performance.

The leader of Working Group 2 is the University Of Berlin (TUB), while the rest of the members are:

- The Czech Technical University of Prague
- Petersburg State Transport University and
- TRAINOSE

1.3. Scope of the document

The present Concept Document aims at identifying and presenting a framework of actions that will allow the formulation of an appropriate scientific background and partnership that will, in turn, support the creation of a competitive Eurasian railway connection. Thus, the present Concept Document focuses on the following actions:

1. identification and definition of existing alternative railway routes that connect Western/Central Europe to Asia (chapter 2);
2. definition of those topics of operations and system performance that affect the efficiency of the railway transport; statement about the relevance of the topics to the Eurasian Landbridge (chapter 3);
3. analysis of the current situation of the network under study in the field of each topic (chapter 4);
4. identification of the interfaces with other Concept Documents (chapter 5);
5. identification of future research needs and priorities that will support the formulation of a research agenda for the Eurasian Landbridge (chapter 6);

6. identification of common future research projects related to the topics of interest of Working Group 3 (chapter 7).

2. NETWORK APPLICATION FIELD

In order to justify existing problems that are related to the topics of interest of Working Group 2 (chapter 3), thus identifying and analysing research topics and areas of cooperation for the improvement of the Eurasian Landbridge (chapter 6), the Near^2 partners have identified existing alternative railway routes the connect Western/Central Europe to Asia and more specifically:

- Japan (via the sea of Japan)
- China
- India

This action allowed the:

- identification of the crossing countries of the railway routes;
- recognition, in the level of each country, of the segments of the railway network that could be used for the Europe-Asia railway connection;
- justification of existing problems that are related to the topics of interest of Working Group 3.

For the definition of indicative Eurasian railway corridors that would be set under the WG8 examination, important existing land routes have been considered, such as:

- the Trans-Siberian route that connects the Russian Pacific Ports of Vladivostok Nakhodka with Moscow;
- the TRACECA Corridor (TRAnsport Corridor Europe-Caucasus-Asia), which offers a number of itineraries along the once called “Silk Road”;
- the Trans-Asian Railway route (TAR) through Turkey and Iran;
- the railway corridors in Kazakhstan.

Furthermore, existing case studies of Europe-Asia freight transportation by rail have been considered, namely:

- *Container rail service that connects Germany to China, launched by DB Schenker*: a trial run that offers a 23-days freight movement from Germany to north-eastern China via the Trans-Siberian railroad, covering 6,875 miles with transit in Poland and Belarus (source: http://www.joc.com/intermodal-shipping/db-schenker-beginsgermany-china-container-train-service).
- *The “Train Saule” project:* connecting Western Europe with China via Kazakhstan, Russia, Belarus and Lithuania. The Saule train trial (41-container train with

computer-aiced equipment) covered a route of approximately 11,000 km within 13 days (source: http://www.litrail.lt/wps/portal).

- *Beijing-Express reaches Hamburg:* in 2008 a test container train from Beijing arrived at Hamburg (Germany) after a 15-days non-stop journey (10,000 km) through the trans-Mongolian route (a branch of the Trans-Siberian route). DB Bahn is planning a regular freight connection with Asia using one train per day for each direction. (source: http://www.tt-forums.net/viewtopic.php?f=49&t=36000&view=previous).
- *Extension of land bridge to link India, Burma and Thailand:* In 1990 China added a link between its rail system and the Trans-Siberian via Kazakhstan. In addition to Kazakhstan, the railways connect with other countries in Central Asia, including Iran, but do not connect all the way to Europe through south Asia (http://blogs.rediff.com/mkbhadrakumar/2011/07/03/russia-china-ties-poised-for-hugeupswing/).Proposed expansion of the Eurasian Land Bridge includes construction of a railway across Kazakhstan that is the same gauge as Chinese railways, rail links to India, Burma, Thailand and Malaysia and elsewhere in Southeast Asia, construction of a rail tunnel and highway bridge across the Bering Strait to connect the Trans-Siberian to the North American rail system, and construction of a rail tunnel between Korea and Japan. The United Nations has proposed further expansion of the Eurasian Land Bridge, including the Trans-Asian Railway project. (Source: http://en.wikipedia.org/wiki/Eurasian_Land_Bridge).
- *Cargo train from Chongqing, China to Duisburg, Germany*: A cargo train filled with laptops and LCD screens left Chongqing, a mega-city in China's less-developed western regions, starting its 13-day trip (approximately 11,000 km) to Duisburg, Germany, which marked the official launch of the new transcontinental rail freight route across the far western Xinjiang Uygur Autonomous Region, Kazakhstan, Russia, Belarus, Poland, before finally reaching Germany (source: http://english.peopledaily.com.cn/90001/90778/90861/7427278.html).

A: Connection: Western Europe – Russian Far East - Japan

A1: Via main Trans - Siberian railway network:

Poland -Belarus or Ukraine-Russia (Moscow- Novosibirsk – Irkutsk-Vladivostok or Nakhoka) – Japan (Sea of Japan)

Total length Warsaw – Vladivostok : 11,000 km

B: Connection: Western Europe – China via the Trans – Siberian route and its branches

B1: Via branch of the Trans - Siberian railway network and the Manchurian route:

Poland -Belarus or Ukraine -Russia (Moscow- Novosibirsk-Karymskaya-Zabaykalsk) –China (Harbin - Beijing via Manchuria)

Total length Warsaw – Beijing : 11,670 km

B2: Via branch of the Trans - Siberian railway network and the Trans Kazakh route:

Poland -Belarus or Ukraine -Russia (Moscow- Yekaterinburg-Kurgan) – Kazakhstan (Petrovavlosk – Astana - Dostyk) – China (Lanzhou-Zhengzhou-Beijing)

Total length Warsaw – Beijing : 11,670 km

B3: Via branch of the Trans - Siberian railway network and the Mongolian route

Poland -Belarus or Ukraine -Russia (Moscow- Novosibirsk-Ulan-Ude-Naushki) – Mongolia (Zamyn Uud) - China (Beijing)

Total length Warsaw – Beijing : 11,560 km

C: Connection: Western Europe – China via the TRACECA corridor (Silk Road)

C1: Via the TRACECA – Turkmenbashi rail route

C1.1: Western Europe – Slovakia (Bratislava) - Hungary (Budapest) - Romania (Bucharest, Constanta) or Bulgaria (Varna) - Black sea - Georgia (Poti -Gardabani) – Azerbaijan (Boyuk Kasik-Baku) – Caspian Sea - Turkmenistan (Turkmenabad) – Uzbekistan (Khodza Davlet – Keles) -– Kazakhstan (Sary Agash – Almaty - Dostyk) – China (Lanzhou-Zhengzhou-Beijing)

Total length Bratislava – Beijing : 10,090 km + (water route via Black sea =1,270 km)

C1.2: Western Europe - Slovakia (Bratislava) – Hungary (Budapest) - Romania (Bucharest) – Bulgaria – Turkey (Edirne – Istanbul – Sive - Kars) – Armenia (Akhurgan – Ayrum) or Georgia - Azerbaijan (Boyuk Kasik-Baku) – Caspian Sea - Turkmenistan (Turkmenabad) – Uzbekistan (Khodza Davlet –Keles) – Kazakhstan (Sary Agash – Almaty - Dostyk) – China (Lanzhou-Zhengzhou-Beijing)

Total length Bratislava – Beijing : 12,170 km + (water route via Caspian sea =270 km)

C2: Via the TRACECA – Aktau route

C2.1 (land detour of the Black Sea through Ukraine and Russia): Western Europe – Slovakia (Bratislava) – Ukraine (Chop-Fastov-Dnepropetrovsk) – Russia (Rostov -) – Azerbaijan (Yalama - Baku) – Caspian Sea - Turkmenistan (Turkmenabad) – Uzbekistan (Khodza Davlet – Keles) – Kazakhstan (Sary Agash – Almaty - Dostyk) – China (Lanzhou-Zhengzhou-Beijing)

Total length Bratislava – Beijing : 12,885 km

C2.2: In C1.2 the section Caspian Sea - Turkmenistan (Turkmenabad) – Uzbekistan (Khodza Davlet – Keles) – Kazakhstan (Sary Agash – Almaty - Dostyk) is replaced by the section Caspian Sea - Kazakhstan (Aktau-Makat-Kandagash - Sary Agash – Almaty - Dostyk)

Total length Bratislava – Beijing : 12,710 km

D: Connection: Western Europe – China via the Central Corridor in Kazakhstan

Western Europe - Poland -Belarus or Ukraine - Russia (Moscow - Aksaralskaya) - Kazakhstan (Ganushkino –Makat - -Kandagash-Almaty - Dostyk) – China (Lanzhou-Zhengzhou-Beijing)

Total length Warsaw – Beijing : 11,645 km

E: Connection: Western Europe – India via the Trans- Asian railway route

Western Europe - Slovakia (Bratislava) – Hungary - Bulgaria - Turkey –Iran- Pakistan - India (New Delhi)

Total length Bratislava – New delhi : 7,970 km

3. Topics Related to Operations and System Performance

Based on the thematic areas of Working Group 2 "Operations and System Performance", five topics are suggested in this Concept Document:

- Intermodal freight operation as a part of the global logistic chain,
- cause/effect links between maintenance and operations,
- rules/regulations interoperability,
- lines/stations performances evaluation methods and models,
- railway traffic regularity monitoring and dispatching.

In this chapter, the topics will be described briefly, while their relevance to the Eurasian Landbridge will be discussed.

As mentioned above, the topics are based on the thematic areas of WG2. Such thematic areas were defined so as to encompass all relevant issues of operations and system performance. Therefore, their use for this document ensures that such relevant issues are taken into account.

The links between these topics and those described in the other Concept Documents are particularly strong. This is to be expected, since operations are affected significantly by constraints coming from rolling stock and infrastructure in particular, and system performance is the result of the characteristics of rolling stock and infrastructure. Also, important environmental topics affect operations: noise can be a constraint to capacity, extreme weather can cause disruptions. Human factors are particularly important given the broad cultural diversity along the Eurasian Landbridge. Such links are better illustrated in Chapter 5 of this Concept Document. However it will be seen in the following descriptions that the links themselves play an important part in defining the nature of the problem. For this reason, many issues are just mentioned here that are described in more detail in other Concept Documents.

3.1. Description of each topic

3.1.1. Intermodal freight operation as a part of the global logistic chain

A significant part of land freight transport is intermodal: more than one mode of transport is used for the delivery of the goods from the supplier to the customer. In deliveries for which the rail mode constitutes the larger part of the journey, the so-called "first-mile" and "last-mile" are often left to road transport, which allows a greater capillarity.

When this is the case, typically the transport is realised by placing the freight in standardised containers, with the containers being transhipped from road vehicle to rail vehicle, or vice-versa, in dedicated intermodal terminals. The logistic chain may involve sea transport also, with terminals located at the sea-ports for transhipment between ship and road or rail vehicles.

From the perspective of system performance, smooth intermodal freight operation is important for a number of reasons, among which:

- the duration of first-mile and last mile operations often constitutes a relevant part of the total journey time;
- moreover such operations are subject to variability in duration due to their complexity; this affects the predictability of the delivery (ETA expected time of arrival), and requires careful operations management.

The number, location and management of intermodal terminals along a given route are therefore key factors that need to be addressed in order to create a competitive link between origin and destination. Moreover, new technology is being introduced in terminals; with innovative train-to-train container movement solutions being developed that could be useful in the presence of gauge changes.

3.1.2. Cause/effect links between maintenance and operations

Both infrastructure (track, signalling, other installations) and rolling stock (locomotives and wagons) go through time-cycles comprising periods of unavailability due to maintenance. These maintenance periods may have effects on operations, and vice-versa operations are planned taking into account the need for such periods. Such periods have to be managed carefully in order to avoid negative impacts on system performance.

For example, corrective maintenance takes place when a failure is observed, and thus it is, in a sense, not fully planned. This occurrence may be predictable in terms of frequency (e.g. a breakdown every *n* days), but not in terms of its exact instant. Whether the occurrence is for rolling stock or infrastructure, a delay can be created to running trains. Such delays create variability in system performance (journey times), which is closely linked to lack of customer satisfaction and competitiveness.

On the other hand, when planning maintenance operations on both rolling stock and infrastructure, care is taken to avoid impacting train operations. For example, major civil engineering works are planned sufficiently ahead allowing train schedules to be modified accordingly. However, rail freight operations in Europe sometimes have difficulties due to the lack of communication between the different rail administrations. Operators can end up knowing about major track works at short notice, and this affects their competitiveness.

Moreover maintenance operations follow standards that may differ from country to country. In particular, rolling stock maintenance can be critical since it might occur in workshops that are quite distant from the vehicle's place of origin. This can mean that workshop staff is less familiar with the wagon type and maintenance rules, leading for example to longer maintenance times (and consequent effects on system performance).

From the point of view of operations and system performance, it is therefore important that maintenance practices are harmonised as much as possible.

3.1.3. Rules/regulations interoperability

In addition to the maintenance rules mentioned above, railway systems are governed typically by a large set of operational rules regarding issues such as:

- vehicle-infrastructure compatibility: track gauge, maximum axle load, static and dynamic gauge, maximum allowable length for trains,
- braking system,
- train control: ground-to-train communications for signalling,
- power supply,
- other operational variables: running right or left, maximum speed etc.

Historically, the International Union of Railways (UIC) has been involved in setting rules and standards for international transport, particularly of goods. UIC Leaflets cover a large portion of the above-mentioned issues.

Such rules fit into a wider regulatory framework including national laws, inter-governmental agreements (e.g. the COTIF convention), other international agreements (e.g. OSJD) and laws that are valid across different countries (e.g. EU law).

In Europe, much work has been dedicated to harmonising and rationalising the applicable regulatory framework. The main aim is interoperability: trains should be capable of running seamlessly across the different countries of the Union, without unnecessary replication of authorisation procedures. For this reason, an Interoperability Directive (Dir. EC 2008/57) was introduced. This directive requires an alignment of rail legislation of member states on aspects that could reduce interoperability between networks. Most importantly, it introduces Technical Specifications for Interoperability (TSI), one for each sub-system into which the railway system is ideally divided. For example, the CCS TSI (Control-Command System TSI) is connected with the introduction of the ERTMS/ETCS train control system. It is clear that the direction taken in Europe to favour interoperability, and in turn the competitiveness of the rail system, is to develop common technical specifications that overcome the structural and cultural differences between countries.

3.1.4. Lines/stations performances evaluation methods and models

The topic of evaluation of line and station performance is the one that brings together all the other four topics identified in this section (3.1.1, 3.1.2, 3.13 and 3.1.5). The rest, in fact, aim at quantifying detailed impacts on system performance. This is where these detailed impacts are seen together in a system perspective to allow quantification of overall system performance indicators on the basis of the characteristics of rolling stock, infrastructure, operational rules and environment.

Up to this point, the main system performance indicators that have been mentioned are the overall journey time (period of time between departure and delivery, planned and actual values) and its variability. These indicators, along with some others (e.g. indicators of damage to goods), are the ones most closely related to customer satisfaction, and therefore to the competitiveness required to bring Eurasian rail services to life and maintain them.

When modelling operations on a computer, the overall journey time is typically broken up into a sequence of elementary time-periods, each associated with a single operation (e.g. time taken to unload containers of trucks and complete a train, time needed between completion of loading and departure of train, partial journey times, time spent by a train in intermediate terminals etc.). The level of detail into which the problem is addressed can address a whole route (level of detail given in the examples above) or parts of a route (e.g. the time needed in intermediate terminals can be broken up further into waiting time on entry to the terminal, time for paperwork for customs and rail operations, etc.).

Up till this point, the calculation has been considered to involve, ideally, a single train. However, an important indicator of rail system performance is the number of trains (or even single loading units/consignments) that can be processed by the system in a given time-period (e.g. per hour, per day) - i.e. the capacity of the system. High capacity means the capability of meeting increasing demand without saturating the system, considering that systems close to capacity tend to have problems with journey times and its variability (delays).

The calculation of figures for system capacity needs to take into account the interactions between trains (or loading units, or consignments), i.e. the fact that the system can only process a certain number of items at the same time.

Typically, the calculation goes hand in hand with the calculation of journey times. Conceptually it is addressed by looking separately at line capacity and terminal capacity (freight stations, intermodal terminals etc.), even though nowadays computer simulation allows the problems to be coupled.

With repeated calculations, it is possible to vary the characteristics of the system and observe the effects on system performance. This in turn makes it possible to optimise the system according to the desired objectives.

3.1.5. Railway traffic regularity monitoring and dispatching

Railway systems have a variety of ways of dealing with train dispatching (i.e. defining and realising the succession of trains on a given line) and the monitoring of traffic regularity (i.e. planned versus actual, delays, tracking and tracing of trains and consignments). Ideally, train traffic should be monitored in a number of control centres, eventually dealing also with the signalling (safety) aspects, so that traffic data can be collected, stored and analysed with the main purpose of continuous improvement of the service.

For freight traffic this is particularly important, since the information on where a certain train (or better, consignment) is located is valuable to the customer and is a part of customer satisfaction and overall competitiveness with other modes.

An efficient dispatching system is also connected with the possibility to exploit route capacity fully, by minimising delays particularly in case of traffic perturbations or disruptions.

This is an area of strong development in recent years, in which Information and Communication Technology (ICT) represents an opportunity for rapid improvement with respect to current practices. Various technologies are available for train localisation - through the signalling system (e.g. by means of track circuits), or by means of satellite detection (this imposes fewer requirements on the signalling system and vouches for lower costs).

3.2. Relevance with the Eurasian land bridge

3.2.1. Inter-modal freight operation as a part of the global logistic chain

In the context of the Eurasian Landbridge, intermodal operations are relevant for the following aspects:

- when first-mile and last-mile are performed through road transport; such operations need to be managed carefully in order to streamline total journey time and avoid introducing delays;
- intermodal terminals may be designed to allow transhipping between two different rail vehicles, for example between two trains suited for two different track gauges; this is a potential solution to be considered for cross-border operations in case of gauge change;
- in a sense, other gauge changing operations (bogie or axle changing, variable gauge bogie operation) can be likened, in terms of their effects on system performance, to intermodal operations, and studied/managed in a similar way.

3.2.2. Cause/effect links between maintenance and operations

The relevance of this topic for the development of the Eurasian Landbridge lies in the fact that, over such long routes involving several different rail administrations, effective and predictable maintenance periods could be more difficult to achieve than in regions where maintenance rules and practices are more uniform.

3.2.3. Rules/regulations interoperability

This aspect may be considered as one of the most relevant for the achievement of high system performance across the Eurasian Landbridge.

In addition to the difficulties existing across EU countries, it is expected that other difficulties will arise due to the integration between countries, or blocks of countries, that have not shown such strong railway ties in the past. Main problem areas could be:

- different infrastructure characteristics,
- different rolling stock characteristics,
- technological fragmentation,
- different languages,
- cultural boundaries/political interests.

Such factors will very likely impact operations and system performance (particularly journey time and its variability) by affecting:

- train completing,
- brake tests,
- paperwork,
- train managing,
- traction changing,
- switching of wagons,
- switching of load at the stops between two gauges.

3.2.4. Lines/stations performances evaluation methods and models

The mathematical models of lines and stations across the Eurasian Landbridge promise to be quite complex due to the geographical dimension of the problem. Such models need to be developed in order to understand how well the current infrastructure and rolling stock characteristics are able to meet the envisaged increase in supply and demand of freight transport across the Landbridge, and what modifications are necessary to cope with future demand.

The challenge is twofold:

- the increase of rail transport supply ("more trains") could saturate current system capacity limits, negatively affecting customer satisfaction,
- in contrast, to increase demand requires customers to be satisfied, and this calls for predictable delivery times.

It is likely that an increase of system capacity will be necessary. Current and future limitations to capacity include essentially:

- maximum length of trains: along any given route, the section allowing the shortest trains is the one that dictates the length of the train along the whole route, unless wagons are removed or added conveniently (quite difficult);
- maximum speed of trains: sections with low maximum speed typically have a lower line capacity; if this occurs far from terminals (which usually have lower capacity with respect to lines) it can represent a constraint to the capacity of a whole route;
- maximum axle load: similarly to the length of trains, any section allowing an axle-load that is significantly lower than that allowed on adjacent sections can constitute a bottleneck for a whole route;
- signalling system: the type of signalling system strongly affects line capacity;
- terminal capacity: freight stations and intermodal terminals can easily represent bottlenecks;
- rules and regulations: procedures and paperwork can take longer than rail operations, particularly if language/cultural barriers are involved (e.g. customs formalities);
- political priorities: issues like priority of passenger trains over freight trains, importance of freight transport to a particular country, track access charging, are all factors that hamper increases of rail service supply;
- environmental capacity constraints: an important example is noise, whose emission is regulated in different ways according to country/culture and which can represent a problem to capacity when rail traffic is increased on particularly sensitive routes (usually those passing through cities where noise exposure is higher); also, the actions taken in case of extreme weather can have important effects on capacity.

3.2.5. Railway traffic regularity monitoring and dispatching

Although probably not the highest priority, traffic regularity monitoring and dispatching is an area offering good opportunities, due to the rapid evolution of technology in recent years.

The Eurasian Landbridge could be a good testing field particularly for innovative ICT-based dispatching across borders; with systems capable of taking into account infrastructure maintenance constraints automatically (this is an aim of European FP7 research). The use of fully automated systems would be a strong opportunity in overcoming language barriers, which are inevitable if paperwork remains the only support for dispatching.

Centralised automated traffic regularity monitoring is of great value for customer satisfaction, since the information could be used not only for continuous improvement of the service, but also to keep the customer informed of consignment progress across the different rail administrations.

3.2.6. Importance and priorities

In the following table, the five topics introduced above are assigned a level of importance and priority. The criteria for the attribution of the degree of importance and priority are:

- importance - indicates relevance for the Eurasian Landbridge, considering the crucial need for competitiveness;
- priority - indicates an order of priority of the topics should there be constraints such as budget limitations in their study.

Table 1: Evaluation of the importance and priority of the topics

Topics	Importance and priority
Inter-modal freight operation as a part of the global logistic chain	+++
Cause/effect links between maintenance and operations	++
Rules/regulations interoperability	+++
Lines/stations performances evaluation methods and models	+++
Railway traffic regularity monitoring and dispatching	++

(very important and high priority:+++; important but without high priority:++; low priority:+)

None of the topics identified are of low priority. However, three topics emerge as very important and of high priority. The rationale behind the assigned levels can be summarised as follows.

- It is crucial to strive for competitiveness of the Eurasian Landbridge with respect to other modes of transport, particularly by sea.

- From a railway operations point of view, it is important for competitiveness to ensure that capacity is sufficient to meet growing demands with high levels of service regularity and customer satisfaction.
- In order to do this, it is necessary to develop methods and models specific for the routes of the Eurasian Landbridge. In this way it will be possible to understand pros and cons of each route, bottlenecks and opportunities for improvement. Therefore "lines/stations performances evaluation methods and models" are assigned both high importance and high priority
- Even in such an early phase of study of the possibilities for the Eurasian Landbridge, it is clear that interoperability will be difficult due mainly to language/cultural barriers and infrastructural issues. Therefore "rules and regulations interoperability" is assigned high importance and high priority. Also, the existing changes look difficult to remove, thus solutions for gauge change or for switching containers between wagons need to be explored. For this reason "inter-modal freight operation as a part of the global logistic chain" is assigned high importance and high priority.
- While the points mentioned above are critical for the removal of bottlenecks/limitations and to ensure a smooth start-up of the initiative, the other two topics offer rather opportunities for a highly efficient system, appealing to customers and therefore competitive. For this reason they are considered as "important" but not "priorities".

4. CURRENT SITUATION AND POSSIBLE FUTURE TARGETS

All in all, the current situation can be summarised in the following key points.

A number of different railway connections exist between Europe and Asia that could be exploited to create a competitive Eurasian Landbridge (see §2).

In order to achieve competitiveness, railway system performance in terms of operations (essentially journey times and capacity) has to reach high levels. To this end, today there are both threats and opportunities.

The main threats are represented by constraints, limitations, bottlenecks present along the connections. Target values can be guessed for some of them even at this early stage. These are, essentially:

infrastructural constraints:

- differing axle loads (22,5 tons max. in Europe, 25 tons max. in Russia); a target value for the future could be 25 tons/axle along the whole connection;
- differing line gradients (up to 20 ‰); a target value could be no more than 12 ‰;
- differing maximum train speeds due to infrastructure characteristics (ranging from 60 km/h to 120 km/h); a target value could be 120 km/h everywhere;
- differing maximum train lengths due to infrastructure characteristics (ranging from 750 m to 1300 m); a target value could be 1500 m (adequate length of sidings is required);
- differing line capacity (ranging from 15 trains/day to 210 trains/day) due to track layout (single-double track) and traffic characteristics (mixed traffic passenger and freight); the target value depends on precise demand forecasts which are not currently available;
- the presence of track gauge changes (1435 mm in Europe and China, 1520 mm in the former USSR, 1676 mm in India) - at least one gauge change is necessary for trains running along any East-West connections; ideally, no gauge changes should be necessary, but this seems to be a solution requiring excessive investment; a target could be set on the time required for a gauge change;
- clearance between infrastructure and rolling stock, leading to limitations on sizes of containers, swap bodies etc.; the current minimum height of 3.50 m could be unified to 4.00 m;

rolling stock constraints:

- different braking systems; it is not reasonable to set a target at this stage;
- different wagon coupling (automatic, manual); in the long term, automatic coupling could be a target;

- different train control systems; a single interoperable train control system along an entire connection seems to be a reasonable target;
- different power supplies; the use of universal multi-voltage locomotives and diesel locomotives seems reasonable to be able to overcome this barrier;

rules and regulations:

- different standards and operational practices, causing delays mainly for: troubleshooting during maintenance, paperwork when crossing borders; it does not seem reasonable to aim at entirely common standards for rolling stock/infrastructure (including maintenance), signalling, power supply, rather the exploitation of existing commonalities (COTIF, OSJD, UIC) and guideline documents to overcome the differences (including linguistic/cultural);
- operations in general; customs, train cancellations, waiting for other delayed trains/containers, are important factors that currently lead to variability in the journey times in the order of days; strategic and tactical operational measures are needed to overcome such problems (e.g. precise strategies for dealing with delays, such as abandoning First-In First-Out when necessary, not delaying priority trains etc.).

environment:

- potentially: noise and extreme weather operations.

Major opportunities arise for the following issues.

intermodal operations:

- emerging technologies for transshipment of containers, swap bodies etc. could alleviate the problem of dealing with track gauge changes;

rules and regulations for operational practices:

- information and communication technologies: the barriers regarding operations mentioned above could benefit from recent developments in ICT (language barriers, paperless automated train dispatching, paperless customs, support systems in case of different applicable standards, train/consignment tracking and tracing);
- existing regulatory framework: most countries potentially interested by the Landbridge have railway administrations that are members of UIC (except Afghanistan, Kyrgyzstan, Tajikistan, Uzbekistan), so that UIC Leaflets can constitute a basis for common operations/maintenance; blocks of countries are members of COTIF and OSJD or both (Afghanistan, Pakistan and India are involved in neither); the European experience of interoperability (TSIs, ERTMS/ETCS) can be exploited.

5. INTERFACES WITH OTHER CONCEPT DOCUMENTS

This document sections helps the avoidance of overlaps with other Concept Documents on the one hand and, on the other, supports the identification of common future research projects (chapter 7).

Table 3 presents the interfaces of the WG2 topics with other WGs. When an interface occurs, it signifies that the specific issue of operations and system performance is strongly linked with the corresponding issue identified in the table. For example, for the top-left cell of the table, a strong logical link can be observed between the operational issue of how intermodal terminals operate within a Eurasian railway connection and the strategic/economical issue of cross-border relationships (political will to foster rail transport, priorities, membership in different international organisations etc.).

From the point of view of research to be developed (see following sections of this document), the existence of an interface means that the study of the operational topic mentioned requires input from (or, less often, provides input to) the corresponding topic identified in the table.

It can be observed that all topics have an interface with the training&education issue addressed in Near^2 WG 10. In fact, the future development of the operational/system performance topics dealt with here will certainly require skilled researchers and railway staff.

Rolling stock (WG3), Intelligent Transport Systems (WG5) and infrastructure (WG8) stand out from the rest in terms of interfaces with WG2 (this document). This is because rolling stock and infrastructure are, of course, the crucial "hardware" for railway operations. The use of ICT implied in Intelligent Transport Systems is more "software-related". The fact that this issue stands out together with the previously mentioned two is due to the strong potential impact on international operations that can derive from these emerging technologies.

Although presenting a strong interface only to the "rules and regulations" topic, the human factors issue is of great relevance given the vastly differing cultures involved in the Eurasian Landbridge. Important inputs are expected on this issue to solve the operational issues.

The other interfaces, although important, are of lesser conceptual importance than the ones mentioned above. They are not discussed in detail here.

Table 2: Interfaces of WG2 topics with other Working Groups

		WG1	WG3	WG4	WG5	WG6	WG7	WG8	WG9	WG10
N	***WG2 topic (and thematic area)***	**strategy and economics**	**rolling stock**	**product qualification methods**	**ITS**	**safety and security**	**environment**	**infrastructure**	**human factors**	**education**
1	**Inter-modal freight operation as a part of the global logistic chain**	cross-border issue development	lift-off lift on the containers, changing the bogies, changing the loco and drivers or not	intermodality issues						for the specific WG2 theme
2	**Cause/effect links between maintenance and operations**					common technical inspection and maintenance procedures		civil engineering works		for the specific WG2 theme
3	**Rules/regulations interoperability**	regulation and organisation	gauge, power supply, traction system, motive power	operational rules and constraints, interoperability by UIC leaflets	interoperability, human factors, knowledge sharing, knowledge exchange			maximum train length, track gauge, maximum speed, traction system, maximum axle load, static and dynamic gauge, signalling,*drive right or left, ETCS in sight or not*	length and distance, technological fragmentation, cultural boundaries/political interests, soft factors	for the specific WG2 theme
4	**Lines/stations performances evaluation methods and models**		heavy load bogies, vehicle dynamics, braking system, freight wagons, automatic coupling, next generation of train control		telematics ERTMS/ETCS		N&V extreme weather, energy efficiency	track capacity, track installations, operational installations, signalling *border capacity*		for the specific WG2 theme
5+6	**Railway traffic regularity monitoring and dispatching**		train communication network and control, on-board navigation		telematics ERTMS/ETCS					for the specific WG2 theme

6. Future Research Needs and Directions

On the basis of the analysis described in §4 it is possible to formulate specific research needs and directions with the aim of fostering the development of competitive Eurasian railway connections. High performance levels in terms of journey times and capacity have to be achieved. In order to do so, both the threats and opportunities described in §4 have to be addressed.

The following points summarise the required scope of research needs. The scope should be intended to comprise only the aspects related to operations and system performance. It is clear that inputs are required from other sectors of railway engineering and that outputs to other fields of research are envisaged. Guidance on the areas in which interfaces with other fields are required is given in §5. It is also important to include impact assessment and particularly life-cycle cost considerations within the scope, given the large project scale and the potentially huge consequences on Society.

Identification and mitigation of operational constraints, limitations, bottlenecks present along the Eurasian connections

understanding of the effects on operations and system performance of :

- infrastructural constraints
- rolling stock constraints
- rules and regulations
- environmental constraints (noise, energy efficiency)

Exploiting the potential of new technology

understanding of the effects on operations and system performance of :

- emerging technologies for operations in terminals/stations
- information and communication technology

Impacts

- Social impacts
- Economic impacts (including life-cycle cost considerations)
- Environmental impacts

7. IDENTIFICATION OF COMMON FUTURE RESEARCH PROJECTS

Future research projects should address the main needs identified in §6. In this section §7, a structure is proposed for this purpose. It includes high-level objectives to be addressed by future projects and builds on the topics identified and prioritised in section 3.

The main high-level objectives/outputs of operations and system performance research can be formulated as follows:

- to define and quantify target values for the Key Performance Indicators (KPIs) related to customer satisfaction and competitiveness (journey times, delays) and infrastructure performance (capacity) along the Eurasian railway corridors;
- to identify operational constraints, limitations, bottlenecks, proposals for mitigation and effects on KPIs;
- to propose layouts, concepts, technology for terminals/dispatching/monitoring, and operations-management procedures for the selected Eurasian corridors, as input to more detailed studies for development of suitably tailored rolling stock, infrastructure, strategic/political agreements;
- to refine the layouts and concepts on the basis of the results of these detailed studies, arriving at optimal layouts/concepts in terms of KPIs;
- to draft text proposals for standards and regulatory documents dealing with operations and maintenance, with the aim to foster harmonisation and interoperability.

These objectives follow roughly a chronological order: first KPIs and constraints need to be determined, then optimal layouts/concepts and proposals for standardisation/regulation can be put forward.

The following research activities are relevant to the achievement of these objectives. They are categorised according to the topics defined and prioritised in section 3.

Inter-modal freight operation as a part of the global logistic chain

- current availability in terms of number, location and management of intermodal terminals along the identified Eurasian railway routes, including gauge-change sites;
- definition of future requirements in terms of number, location and management of intermodal terminals and gauge-change sites;
- redesign/upgrade of existing intermodal terminals/gauge-change sites;
- design of new terminals (considering the use of innovative transhipment technology - e.g. switching containers from train to train rather than changing the gauge of wagons);
- definition of operations management (possibly common) of intermodal terminals/gauge-change sites.

Cause/effect links between maintenance and operations

- analysis and description of existing maintenance standards;
- analysis and description of existing operational practices (i.e. how does maintenance affect operations in actual service);
- identification of common aspects and cause-effect links considering the enhanced international nature;
- development of guidelines applicable to entire corridors, aimed at harmonisation of practices whilst complying with the existing standards.

Rules/regulations interoperability

- comparative formal logical analysis of the regulatory frameworks existing across the Eurasian Landbridge (embracing COTIF and OSJD), identification of a common structure;
- identification of key aspects critical to interoperability across Eurasian corridors;
- proposal of rationalisation of regulatory framework and guideline document for harmonisation (including draft texts for standards and regulatory documents).

Lines/stations performances evaluation methods and models

- development of computer models of lines and stations/terminals along the identified Eurasian corridors;
- figures for current system performance indicators (journey times, delays, capacity);
- identification of bottlenecks to operations (infrastructure, environment - noise, rules/regulations - paperwork, cultural issues etc.);
- validation of computer models for selected case studies;
- development of scenarios based on demand/supply requirements and modelling of scenarios - optimisation, choice of best operational concepts.

Railway traffic regularity monitoring and dispatching

- analysis of the effects on operations of innovative dispatching technology;
- analysis of the potential of state-of-the-art traffic regularity monitoring in terms of attractiveness to customers/demand;
- harmonised information exchange on matters such as customs and security, real time data and traffic between rail operators across borders;
- analysis of the effectiveness of the use of GPS technology;

- harmonised interfaces for container and load tracing and tracking;
- defining and harmonising data exchange required for cross border train planning and operation.

Transversal topics

- life-cycle cost analysis;
- impact assessment.

OVERALL CONCLUDING REMARKS

In this document, key operations-related topics for the realisation of competitive Eurasian rail services are identified. The interactions with other aspects of railway systems (rolling stock, infrastructure etc.) are explored. On this basis, research needs are identified and correspondingly a common future research project satisfying these needs is outlined.

A number of aspects emerged from the analysis described in this document that are crucial for the success of Eurasian rail corridors and of the research proposal presented:

- competitiveness - from a system-performance point of view this means that the rail system implementing a specific corridor has to ensure target values of customer-satisfaction indicators such as to attract the demand required for economic-financial viability; correspondingly the system has to ensure the target values of supply-related indicators (capacity) sufficient to meet the required demand; evolution over time of these indicators (e.g. network development plans, strategy and politics etc.) needs to be taken into account in the research regarding system performance;
- interoperability - as it has been for Europe, this concept is key for Eurasian corridors and implies, more or less, tackling the same problems (e.g. harmonisation of standards/legislation, technical compatibility etc.);
- cultural issues - cultural/political/strategic issues potentially influence strongly operations and system performance given the broadness of the context (Europe and Asia); this is true also for the management of any future collaborative research project.

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