

B.Sc - Road & Railway Design I.

DESIGN, CONSTRUCTION & MAINTENANCE OF ROADS

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University of Pécs – Faculty of Engineering and Information
Technology - Department of Civil Engineering

Pécs, 2019



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Lecture 1.



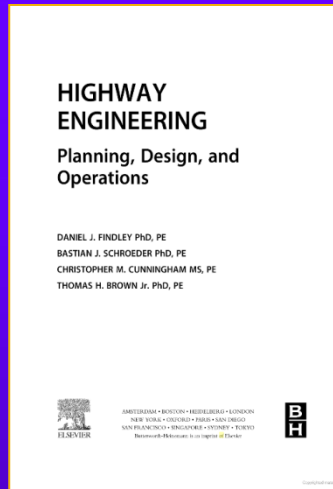
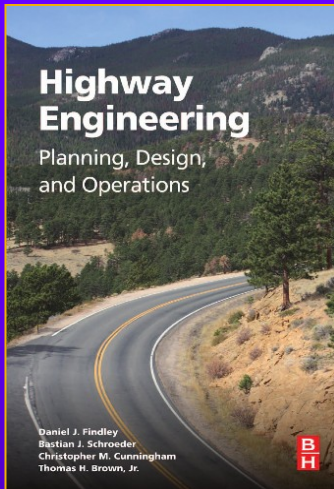
HISTORY OF ROADS & ROAD TRANSPORT

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RECOMMENDED READINGS



Daniel J Findley, Bastian Schroeder,
Christopher Cunningham, Tom Brown:
*Highway Engineering: Planning, Design
and Operations*. Elsevier Inc. (2016)

[https://www.amazon.com/Highway-Engineering-
Planning-Design-Operations/dp/012801248X](https://www.amazon.com/Highway-Engineering-Planning-Design-Operations/dp/012801248X)

Design Manual for Roads and Bridges (UK)

<http://www.standardsforhighways.co.uk/ha/standards/dmrb/index.htm>

Highways England: Guidance - Standards for Highways online resources

<https://www.gov.uk/guidance/standards-for-highways-online-resources>

New York State Department of Transportation (USA): Highway Design Manual

<https://www.dot.ny.gov/divisions/engineering/design/dqab/hdm>

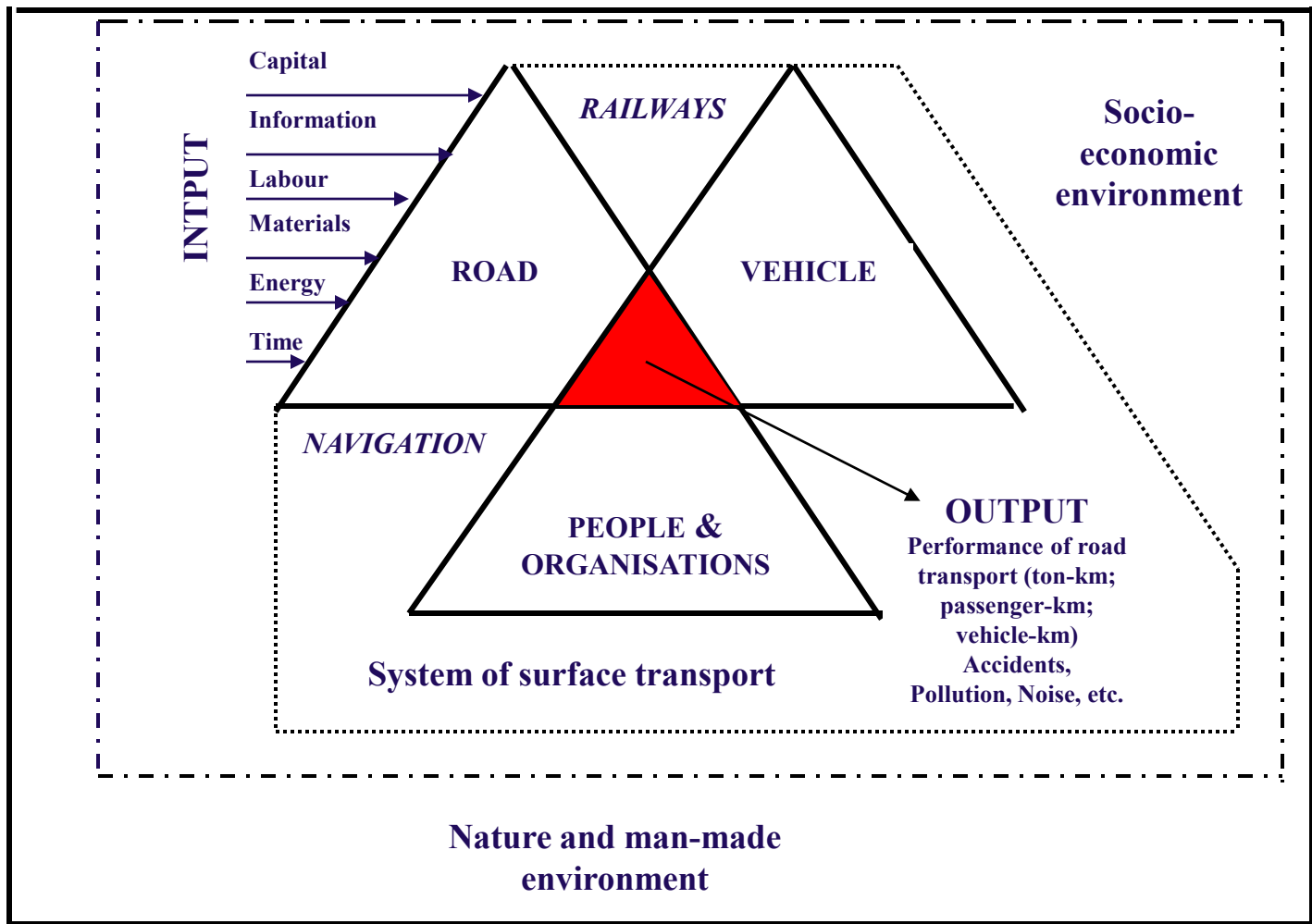
Transportation Research Board (TRB): Highway Capacity Manual

(Online Edition – HCM 2010) <http://hcm.trb.org/?qr=1>

HISTORY OF ROAD TRANSPORT

1

- ❖ *Transport* is the organised or regular movement of people, animals and goods from one location to another, using natural or artificially produced means (vehicles and paths)
- ❖ Transport is a *precondition* of all social and economic (human) activities
- ❖ Constituting elements of the *transport system*: infrastructure + vehicles + people and professional organisations



Sub-system of *road transport* within the system of surface transport, that of socio-economic as well as nature & man-made environment

HISTORY OF ROAD TRANSPORT

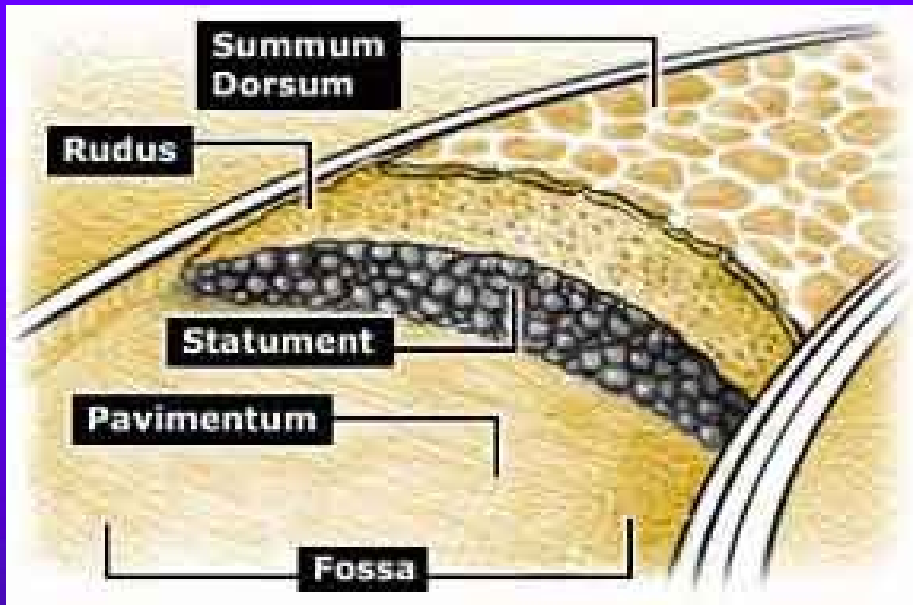
2

- ❖ The first *paved* (permanent) *roads* in Europe were built by legionaries in the ancient time of the Roman Empire, for military purpose (the army could march from one part of the Empire to the other quickly)
- ❖ Remains of *Roman roads* can be found even today in former Roman provinces (Iberia, Gallia, Britannia, Pannonia, Dacia) as well
- ❖ In the *Middle Ages* main trade routes (Amber-Road, Silk-Road) weren't paved, so became unsuitable under wet weather conditions (heavy rain, melting snow); roads were paved only in cities

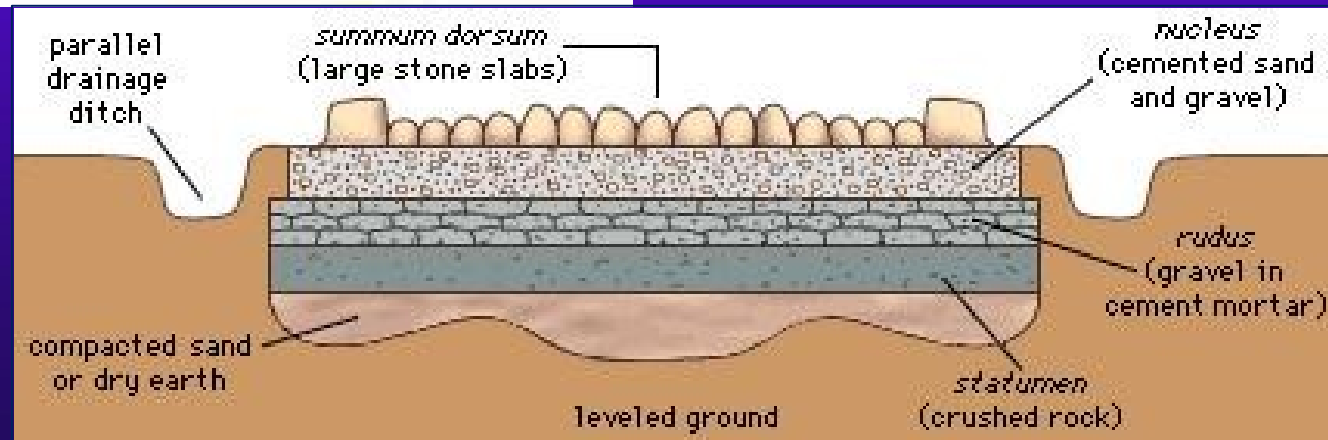
ROADS OF THE ROMAN EMPIRE



PAVEMENT OF A ROMAN ROAD

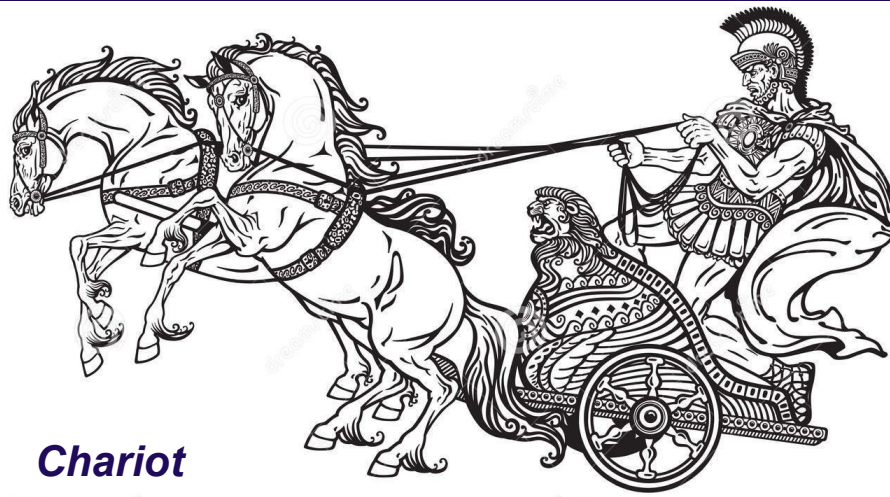


Sand and small size gravel on the bottom, carved large stone slabs laid on the top

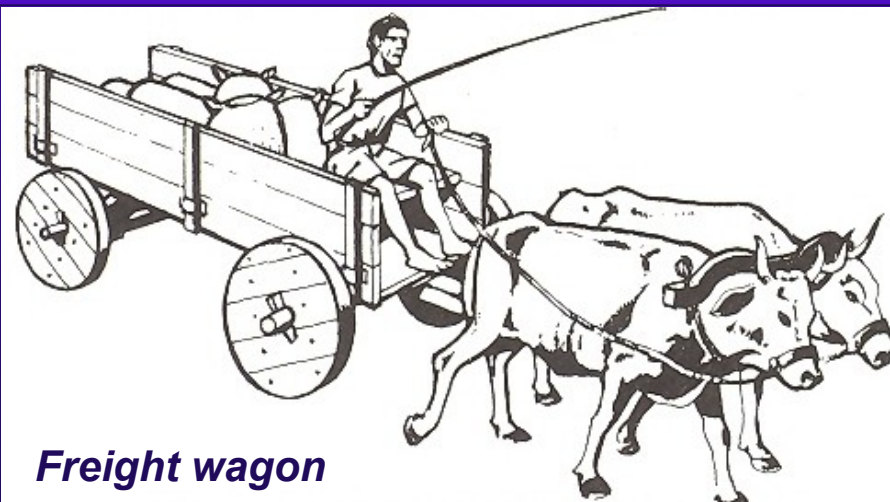


ROMAN ROAD IN POMPEI

WITH PAVEMENT RUTS AND PEDESTRIAN CROSSING



Chariot



Freight wagon



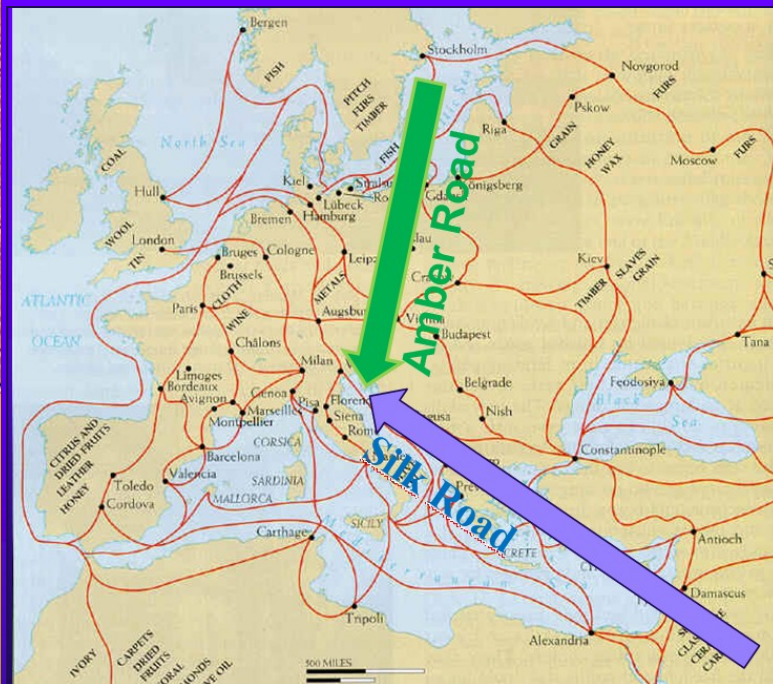
ROMAN ROAD IN SAEPINUM

(CATANIA, SICILY)



Construction of a Roman road

TRADE ROUTES IN THE MIDDLE AGES



DEVELOPMENT OF TECHNOLOGY

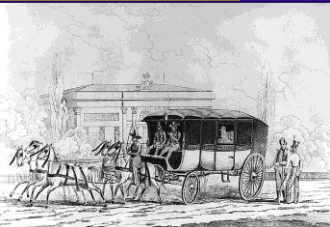
1

- ❖ The first *highway engineering* school in Europe: School of Bridges & Highways (*École des Ponts et Chaussées*) was founded in *Paris* in 1747
- ❖ *P. M-J. Trézaguet* in France developed a new type of relatively light road surface, based on the theory that underlying natural formation, rather than pavement should support the traffic load
- ❖ In Scotland *T. Telford* placed great emphasis on two features:
 - ❖ maintaining a level roadway with a maximum gradient of 1 in 30; and
 - ❖ building a stone surface capable of carrying the heaviest anticipated loads

DEVELOPMENT OF TECHNOLOGY

2

- ❖ To meet demand raised by regular mail-services and transport of agricultural products, roads from crushed stone and gravel, compacted by the traffic were built in the early 18th century
- ❖ Scottish civil engineer *J. L. McAdam* developed a method of levelling roads and paving them with gravel in 1824
- ❖ Road material consisting of a solid mass of stones of nearly uniform size was laid down in layers into the road bed; the use of binding materials or rollers started later



STRUCTURE OF PAVEMENTS INVENTED IN THE 18TH CENTURY

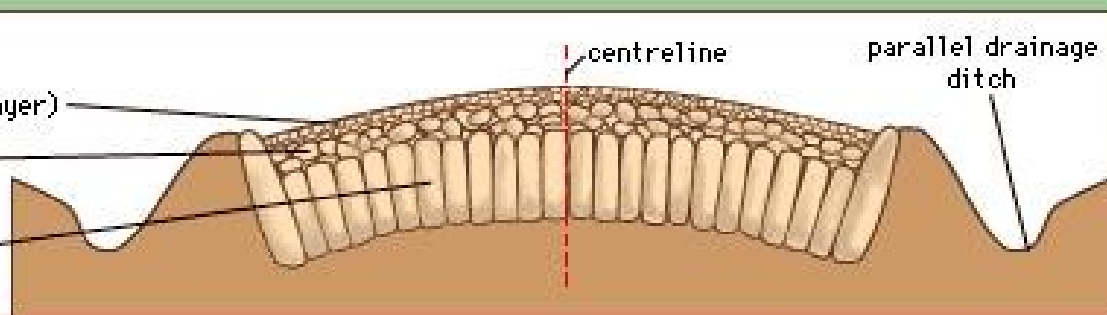


Trésaguet

gravel or broken stone (1-inch layer)

broken stone (2-inch layer)

foundation layer (8 inches)

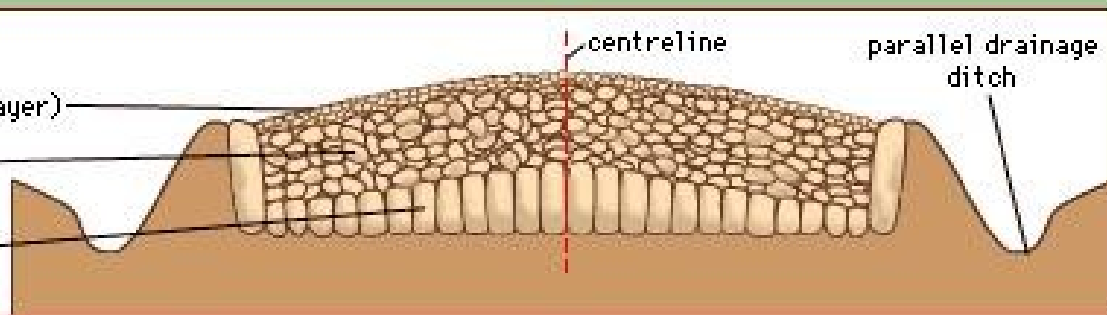


Telford

gravel or broken stone (1-inch layer)

broken stone (7-inch layer)

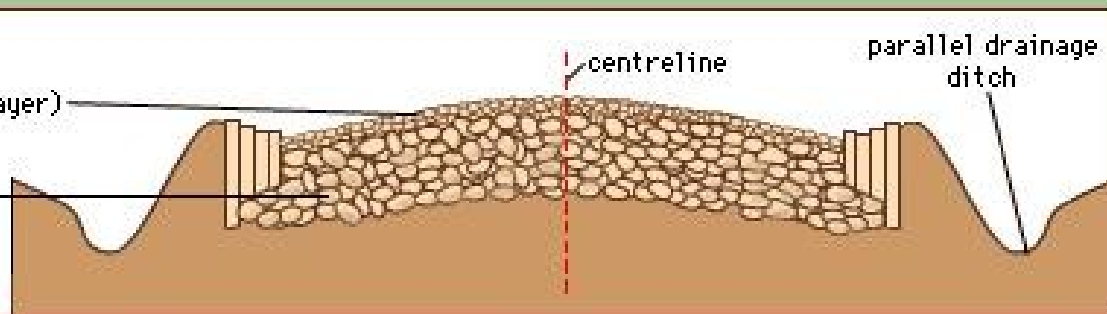
foundation layer (7 inches)



McAdam

gravel or broken stone (1-inch layer)

broken stone (8-inch layer)



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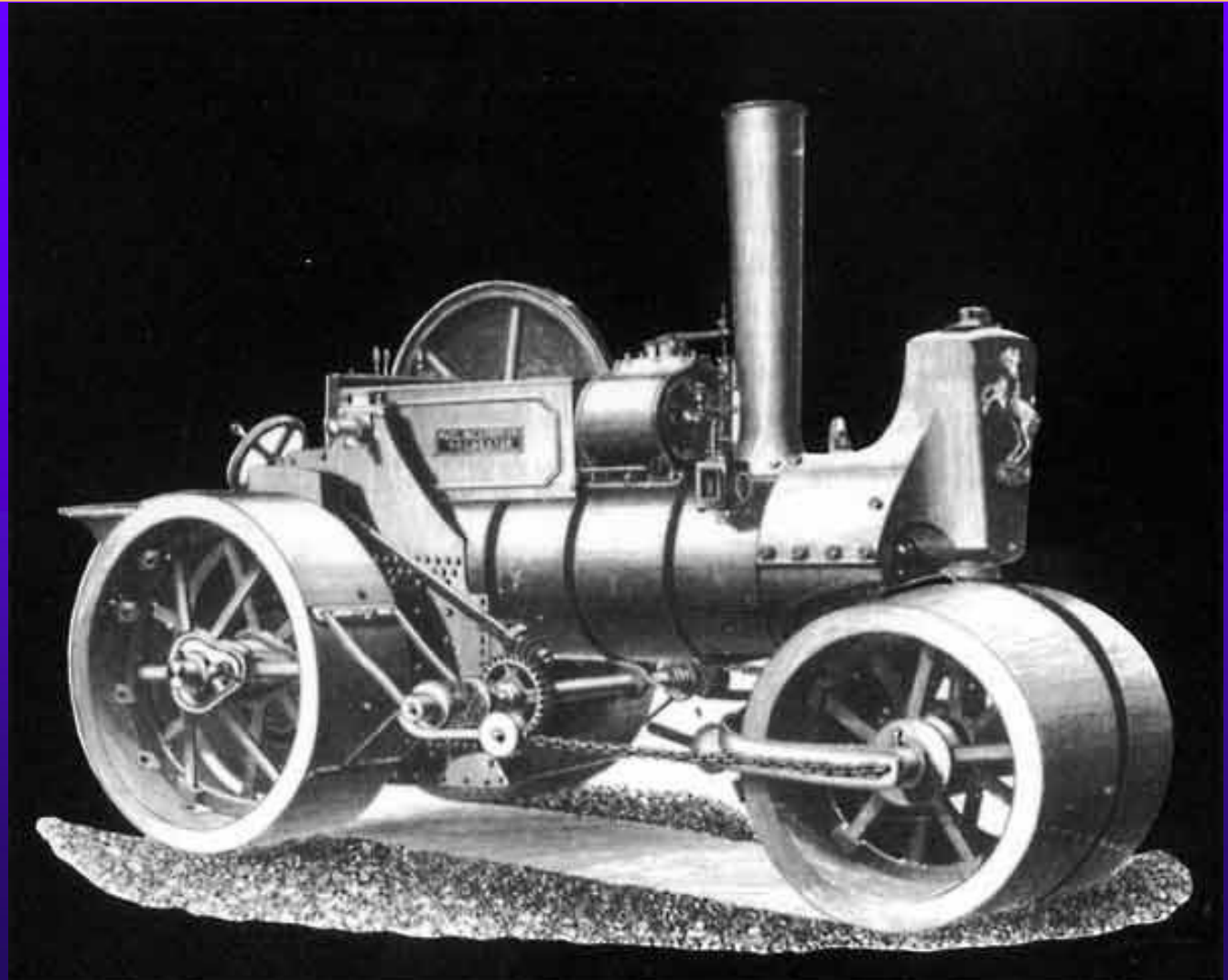
CONSTRUCTION OF A MACADAM PAVEMENT

(USA, 1823)



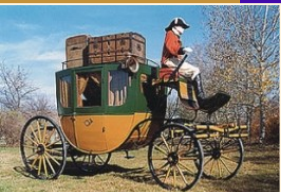
STEAM ROLLER

(19. CENTURY)



McADAM'S HERITAGE

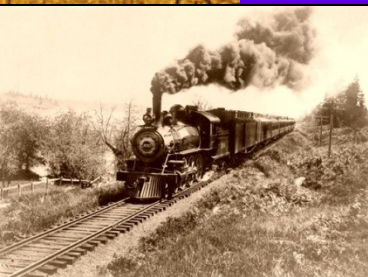
- ❖ Drainage was essential to McAdam's method and he required the pavement to be elevated above the surrounding surface
- ❖ McAdam's total structural reliance on *broken stone* represented the largest paradigm shift in the history of road pavements - principles of the "*macadam*" road are still used today
- ❖ McAdam's success was also due to his *efficient administration* and his strong view that road managers needed skill and motivation
- ❖ *Macadam roads* were adequate for use by horses and carriages or coaches, but dust in summer, subject to erosion with heavy rain, mud in winter



HISTORY OF ROAD TRANSPORT

3

- ❖ Beginning in the 1840s, the rapid development of railroads brought the construction of lightweight *McAdam* roads to a virtual halt
- ❖ For the next 60 years, road improvements were essentially confined to city streets or to feeder roads to railheads, other rural roads remain impassable in wet weather or snowy winter
- ❖ The initial stimulus for a renewal of road building came not from the automobile, whose impact was scarcely felt before 1900, but from the bicycle



HISTORY OF ROAD TRANSPORT

4

- ❖ While the requirements of the lightweight, low-speed bicycle were satisfied by the old “*macadamized*” surfaces, the automobile began to raise its own seemingly insatiable demands as the world entered the 20th century
- ❖ Roads at the turn of the 20th century were largely inadequate (dust in summer, mud in winter), for the demands about to be placed on them by the *automobiles* and *trucks*



EARLY AUTOMOBILES

Karl Benz and Gottlieb Daimler made the first cars in 1885 and 1886



The Ford T-Model





NEW PAVING MATERIALS

- ❖ As vehicle speeds increased rapidly, the available friction between road and tire became critical for accelerating, braking, and cornering and dust raised by traffic represented a nuisance and safety hazard
- ❖ Numerous pavement failures also made it obvious that much stronger and tougher materials were required
- ❖ The result was an ongoing search for a better pavement - *asphalt* (a mixture of bitumen and stone) and *concrete* (a mixture of cement and stone) both offered promise

NATURAL BITUMEN PONDS

- ❖ The Pitch Lake (La Brea) in Trinidad is the largest in the World (41 ha), and 76 meters deep; the liquid asphalt is black and viscous, but the surface is semisolid and can be walked on
- ❖ It was created thousands of years ago, when the Caribbean continental plate was forced under another plate, opening fault lines that allowed oil from deep underground deposits to rise to the surface, where it collected in a volcanic crater; the air caused lighter elements of the oil to evaporate, leaving behind mucky ponds of asphalt, colloquially called pitch or tar, and technically referred to as bitumen
- ❖ Mining started in 1867 and 10 million tons of asphalt has been extracted since, used to build high grade road surfaces in over 50 countries



DEVELOPMENT OF TECHNOLOGY

3

- ❖ The first road use of asphalt occurred in 1824, when asphalt blocks were placed on the *Champs Élysées* in Paris, but the first successful major application was made in 1858 on the nearby *rue Saint-Honoré*
- ❖ The first successful concrete pavement was built in *Inverness, Scotland*, in 1865
- ❖ Neither technology, however, advanced far without the pressures of the car, and they both required the availability of powerful stone-crushing, mixing and spreading equipment

DEVELOPMENT OF TECHNOLOGY

4

- ❖ The impetus for the development of modern road asphalt came from the *United States*, which had few deposits of natural bitumen to draw upon and where engineers (*De Smedt* and *C. Richardson*) were therefore forced to study the principles behind the behaviour of this material
- ❖ The automobile ran on *gasoline*, which at that time was simply a by-product of the distillation of kerosene from petroleum; another by-product was *bitumen*
- ❖ Two forms of asphalt were developed: *asphaltic concrete*, (strong and stiff and thus providing structural strength); and *hot-rolled asphalt*, (containing more bitumen and thus producing a far smoother and better surface)



DEVELOPMENT OF TECHNOLOGY

5

- ❖ Like asphalt technology, concrete road building was largely developed by the turn of the 20th century and was restricted more by the available machinery than by the supply of materials
- ❖ Problems were encountered in producing a surface that could match the performance of the surface produced almost accidentally by hot-rolled asphalt
- ❖ For the following century the two materials remained in intense competition, both offering a similar product at a similar cost, and there was little evidence that one would move far ahead of the other as they continued on their paths of gradual improvement



THE RULE OF THE ROAD

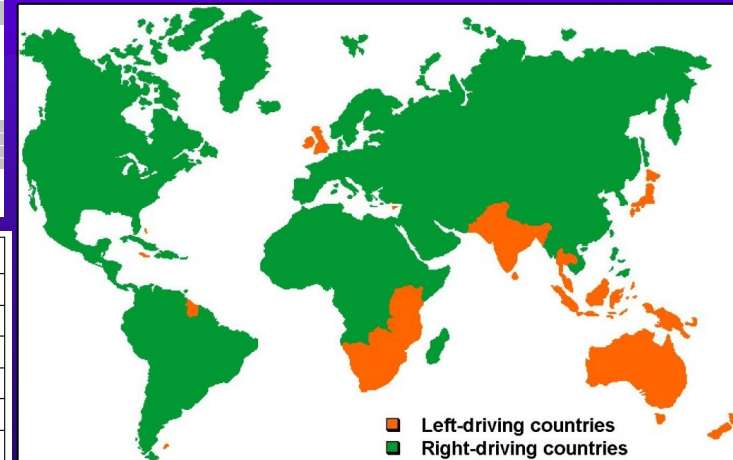
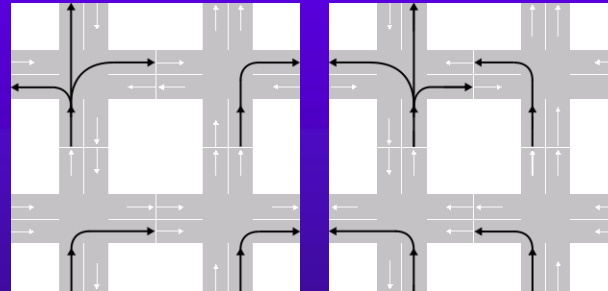
1

- ❖ The terms right-hand traffic (RHT) and left-hand traffic (LHT) refer to regulations requiring all bidirectional traffic unless otherwise directed, to keep to the right or to the left side of the road
- ❖ About two thirds of the world's population (163 countries and territories) are RHT, with the remaining (76 countries and territories) LHT
- ❖ Some historians believe, since most people were right handed, swordsmen preferred to keep to the left in order to have their right arm nearer to an opponent and their scabbard (worn on the left) further from him; moreover, it reduced the chance of the scabbard hitting other people

THE RULE OF THE ROAD

2

- ❖ During the 1900s many countries changed from LHT (maintained in British territories and islands) to RHT (disseminated by the French after the 1789 Revolution), mostly to conform with regional custom (in Europe the last switch: Sweden 1967)



MANOEUVRE	LHT	RHT
Unless overtaking stay on the	<i>left</i>	<i>right</i>
On roundabouts traffic rotates	<i>clockwise</i>	<i>counterclockwise</i>
Driver sits on the	<i>right</i>	<i>left</i>
Oncoming traffic is seen coming from the	<i>right</i>	<i>left</i>
Traffic must cross oncoming traffic when turning	<i>right</i>	<i>left</i>
Most traffic signs are on the	<i>left</i>	<i>right</i>
Pedestrians crossing a two-way road look first for traffic from their	<i>right</i>	<i>left</i>
Dual carriageway ramps are on the	<i>left</i>	<i>right</i>
After stopping at a red light it may be legal to turn	<i>left</i>	<i>right</i>

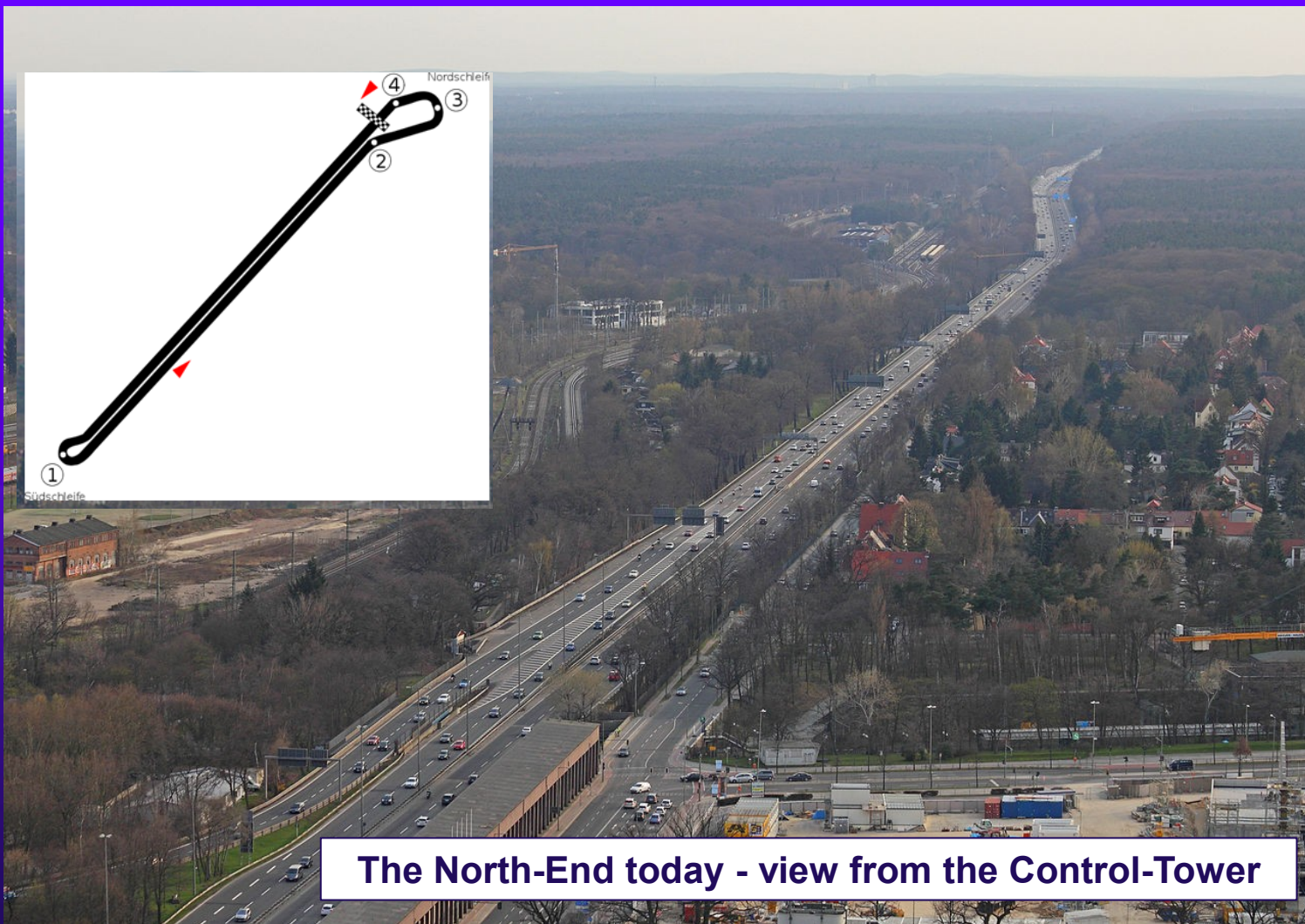


BIRTH OF MOTORWAYS

- ❖ Increased speed of road traffic and appearing accidents made necessary to rethink alignment geometry and dimensions of roads
- ❖ The longitudinal division of the road surface, improved alignment and regulation of access from adjoining properties (eliminating conflicting traffic movements) lead to increased safety even at high average speed
- ❖ Between 1913 and 1921 a group called *Automobil-Verkehrs und Übungsstrasse* (Automobile traffic and training road, better known as *AVUS*) had built 10 kilometres of such road (precursor of *Autobahn* or *motorway*) as a motor racing circuit in *Berlin* (Germany)

AVUS RACING CIRCUIT (1921)

(Germany)



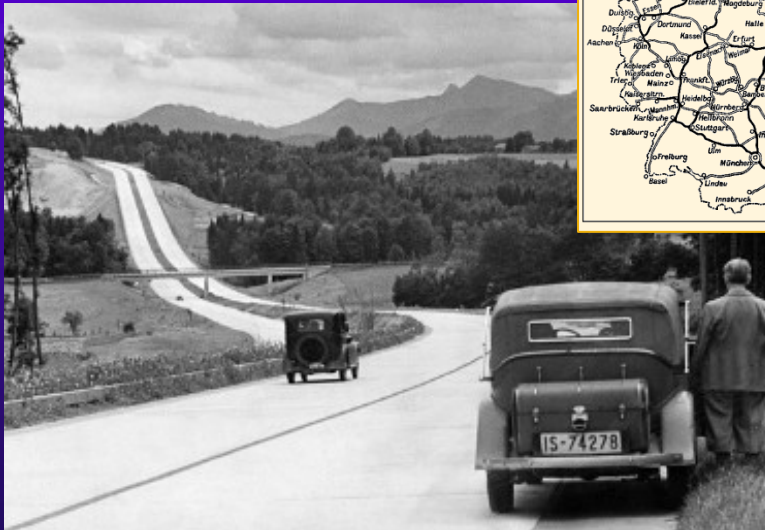
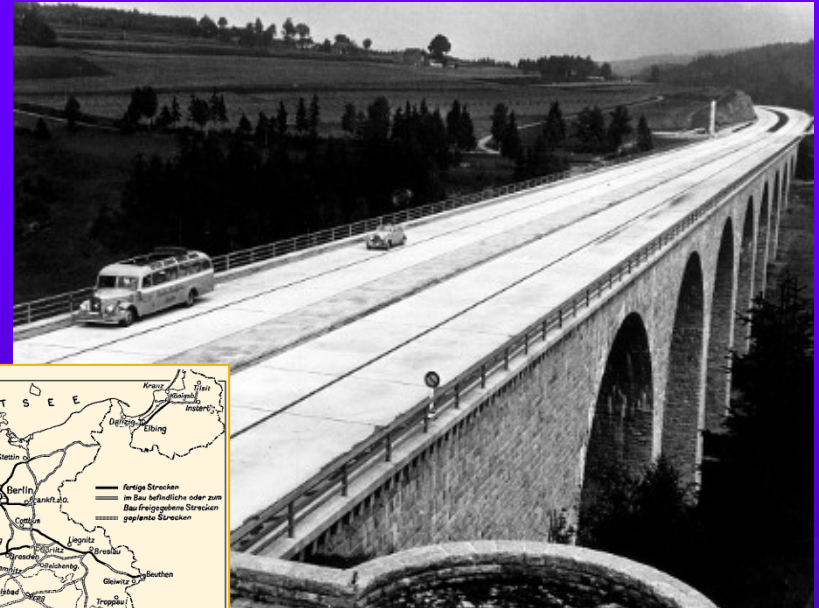
GERMAN *AUTOBAHNEN*

1

- ❖ Successful experience led to the world's first motorway being built from *Cologne* to *Bonn* between 1929 and 1932
- ❖ In 1933 *Hitler* ordered construction of the concrete paved *Reichs-autobahnnetz* or “national motor road network” aiming to alleviate unemployment, using forced labour (for military purpose)
- ❖ *Autobahn* was designed for large traffic volumes and speeds (>150 km/h), provided 7.5 m carriage-ways divided by a median strip of 5 m metres, bypassing cities and providing limited access
- ❖ About 6500 km of German motorways were in use in 1942 when construction ceased during WW II

GERMAN AUTOBAHNEN

2





AUTOSTRADA

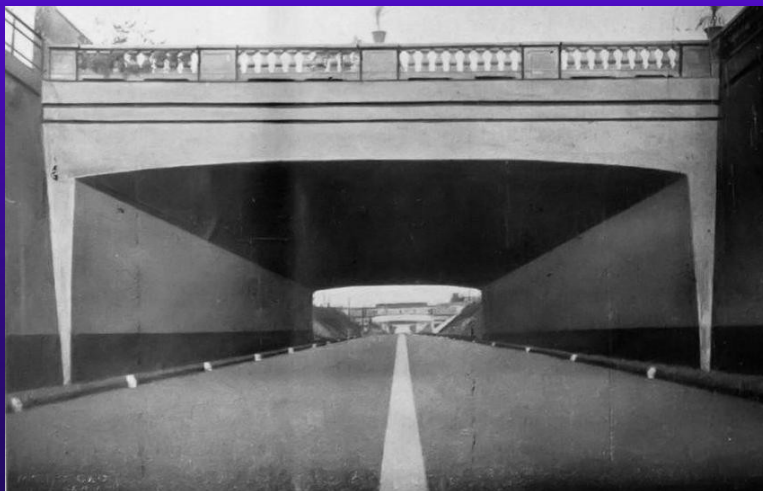
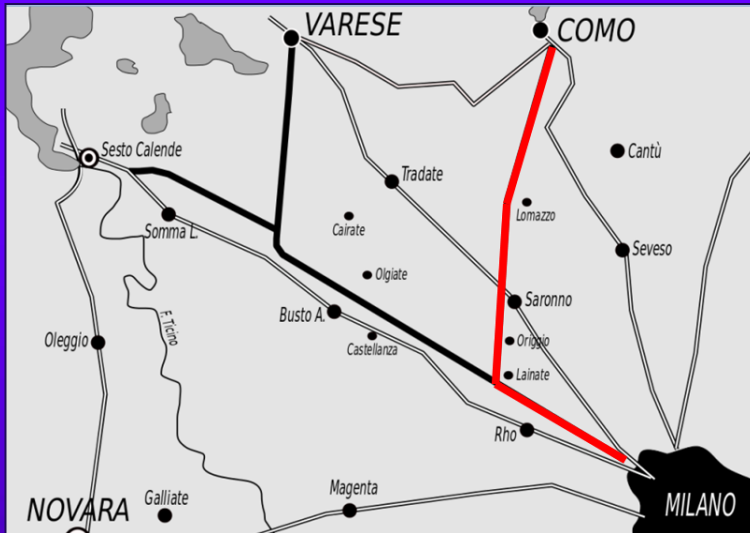
MILANO-LAGHI

1

- ❖ A 12 km long part of a motorway connecting *Milano* to the *Lakes* (*Autostrada Milano-Laghi*) was opened near *Lainate* (Italy) in 1924 as the 2nd motorway in the World after AVUS
- ❖ It was a toll road: the collected money intended to cover the costs of road construction and operation – the idea has been idealistic, since only 85 000 automobiles circulated on Italian roads in 1923
- ❖ A 24 km long second stretch (*Lainate-Como*) has been opened in 1925

AUTOSTRADE MILANO-LAGHI

2





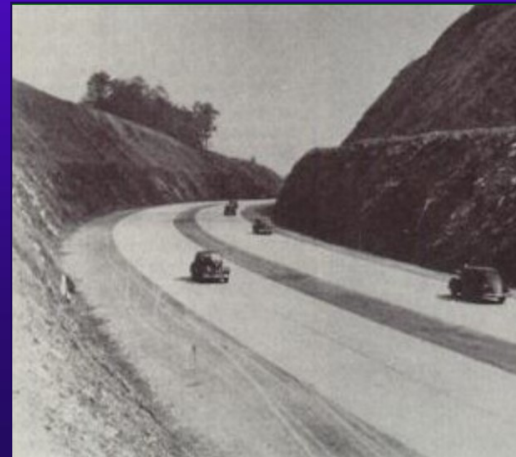
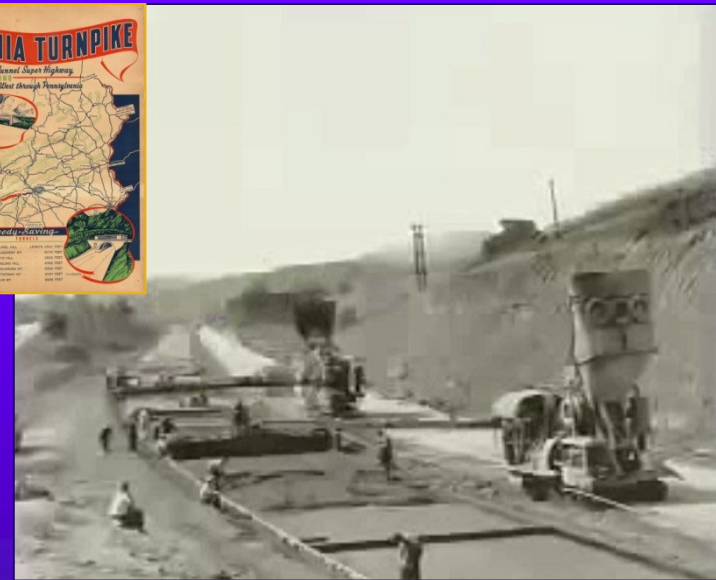
PENNSYLVANIA *TURNPIKE* (USA)

1

- ❖ The first North American *freeways* (known as *parkways*) opened in the New York city area in the 1920s
- ❖ The *Pennsylvania Turnpike*, a toll road across the *Appalachian Mountains* from *Pittsburgh* to *Harrisburg* (256 km), following the alignment of an abandoned railroad, completed in 1940, with concrete pavement
- ❖ The turnpike provided two 7.2 m carriage-ways and a 3.0 m median, 7 two-lane tunnels, with no cross traffic at grade and with control of access and egress at 11 interchanges

PENNSYLVANIA TURNPIKE (USA)

2

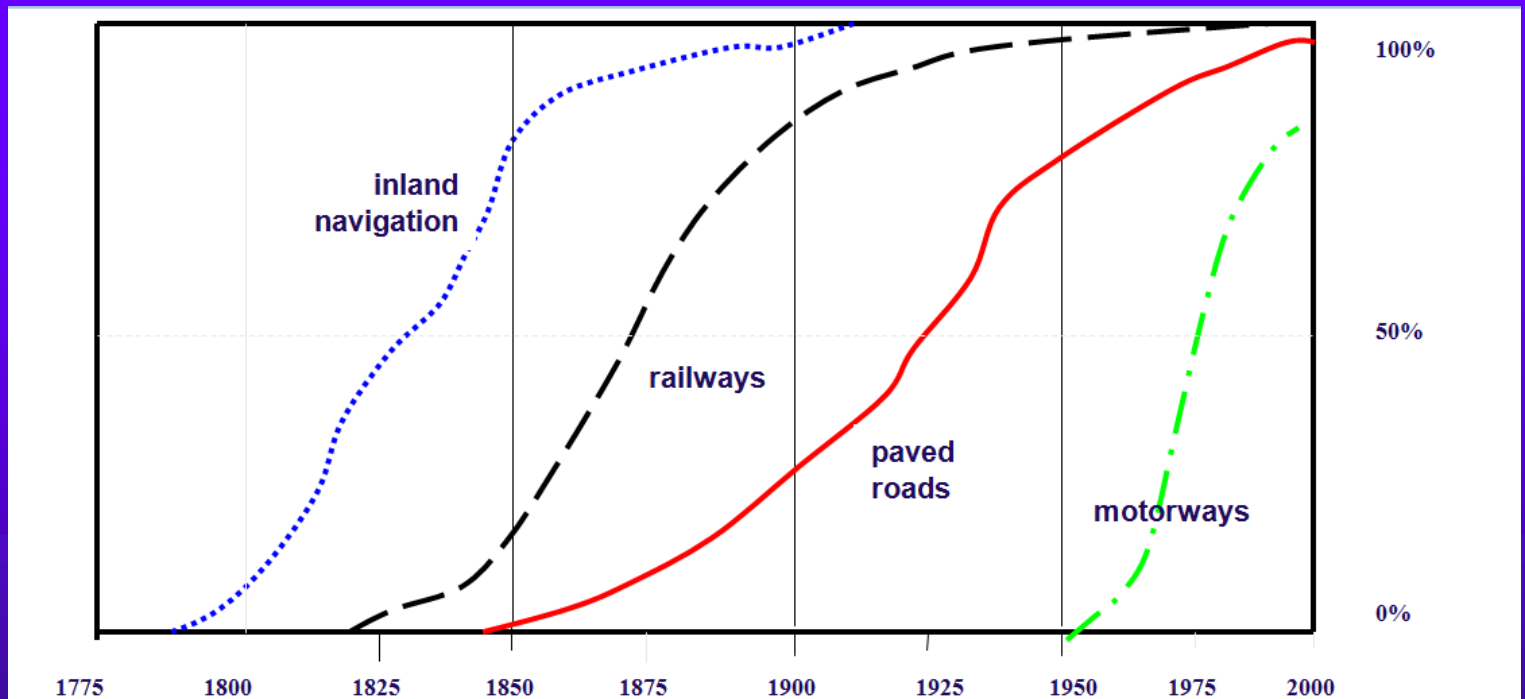




CONSTRUCTION OF MOTORWAY NETWORKS

- ❖ The favourable public reaction to this new type of highway provided the impetus for the post-World War II motorway construction boom in the USA and Europe
- ❖ The United States launched the „*National System of Interstate and Defense Highways*” program, and built more than 70 000 km of new motorways between 1954-1970
- ❖ Member States of the European Economic Communities followed suit between 1960-1990
- ❖ Britain, heavily influenced by the railways, did not build its first *motorway*, the Preston By-pass (M6) until 1958

TRANSPORT INFRASTRUCTURE AS A COMMODITY



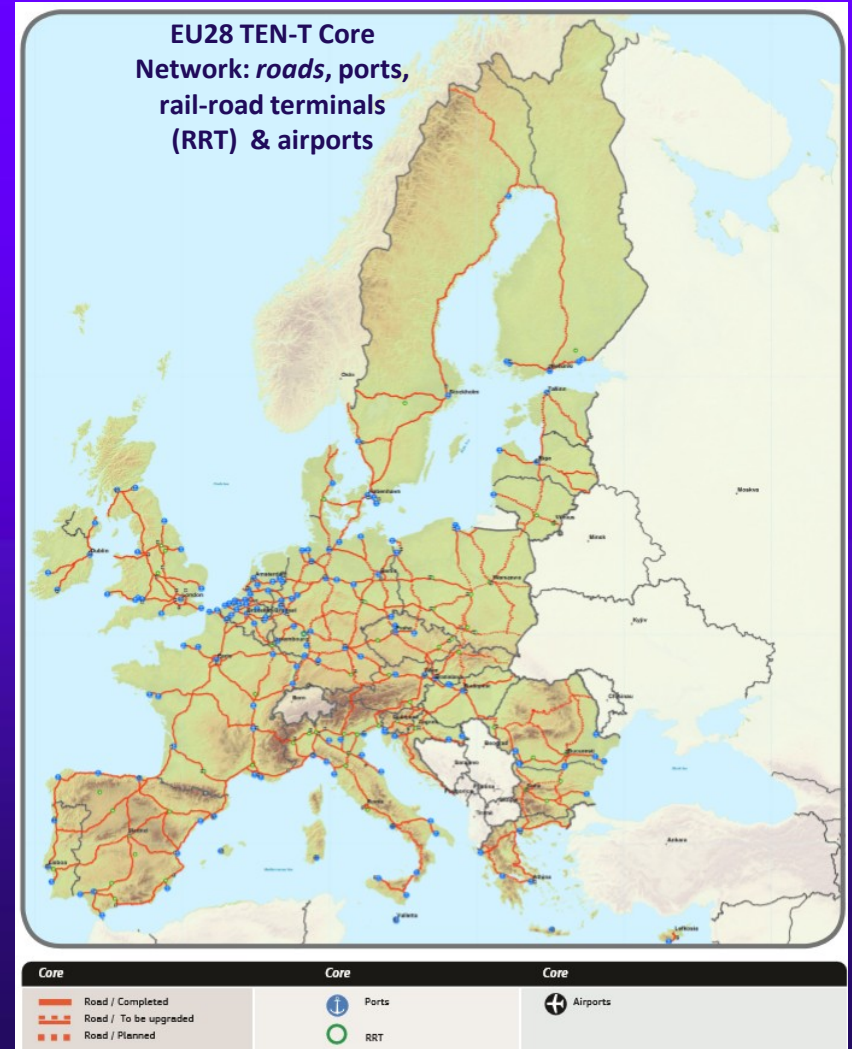
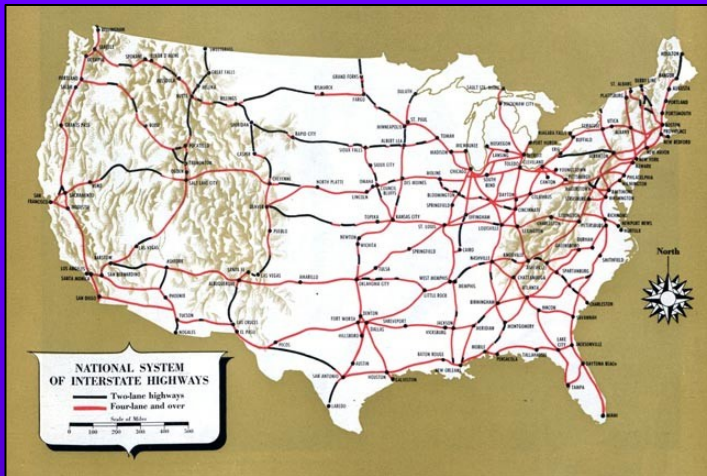
**Development of transport infrastructure (networks)
in Great Britain**



NATIONAL ROAD NETWORKS/SYSTEMS

- ❖ In the modern era, the nations of Europe (lead by France) first introduced the concept of road systems then underpinned it by relevant legislation (*Road Acts*)
- ❖ A national road network/system is generally divided into classes:
 - ❖ national roads, to be built, maintained and operated by the national government (*road administration*)
 - ❖ regional and main local roads connecting smaller cities and villages, built, maintained and operated by the department or county government (*road services*)
 - ❖ township or urban roads, built, maintained and operated by the local communities (*road bureaus*)

NATIONAL & INTER-NATIONAL ROAD SYSTEMS





ROAD NETWORK DEVELOPMENT

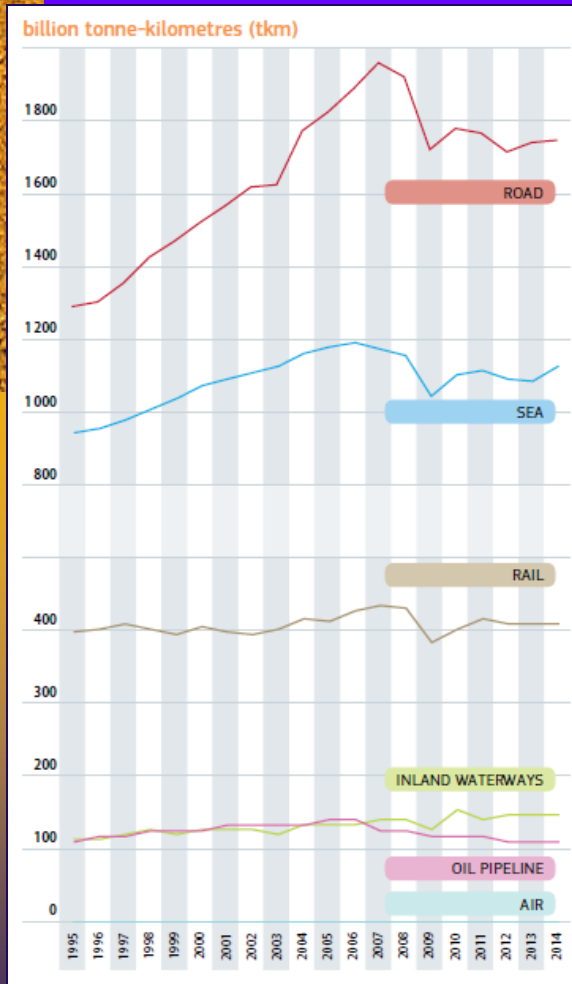
- ❖ Ideally, the development of a major road system is an orderly, continuous, step-by-step process, as follows:
 - 1) assessing road needs and transport options;
 - 2) planning a system to meet those needs;
 - 3) designing an economically, socially, and environmentally acceptable set of roads;
 - 4) obtaining the required approval and financing;
 - 5) building, operating, and maintaining the system;
 - 6) providing for future extensions and reconstruction



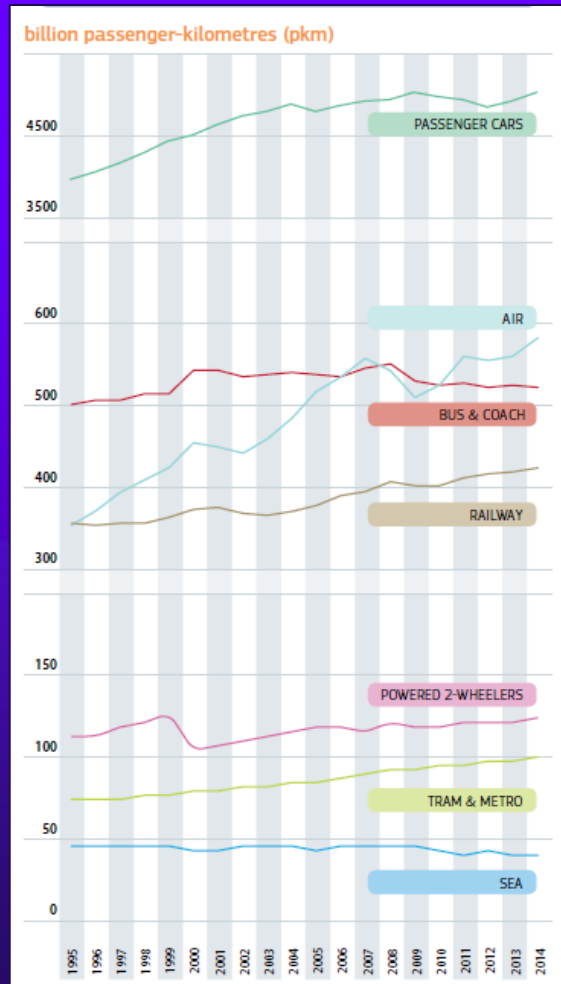
ROAD DESIGN

- ❖ **Engineers must meet many safety, service and performance standards when designing roads for certain site topography**
- ❖ **Engineers who design the geometry of roads must also consider environmental and social effects of the design on the surrounding infrastructure**
- ❖ **Design considerations include (among others):**
 - Design speed
 - Design traffic volume
 - Number of traffic lanes
 - Level of Service (LOS)
 - Sight Distance
 - Alignment, super-elevation and grades
 - Cross section
 - Lane width
 - Horizontal and vertical clearance
- ❖ **Operational performance of a highway can be seen through drivers' reactions to the design considerations and their interaction**

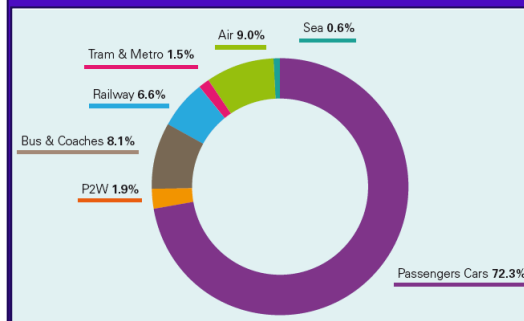
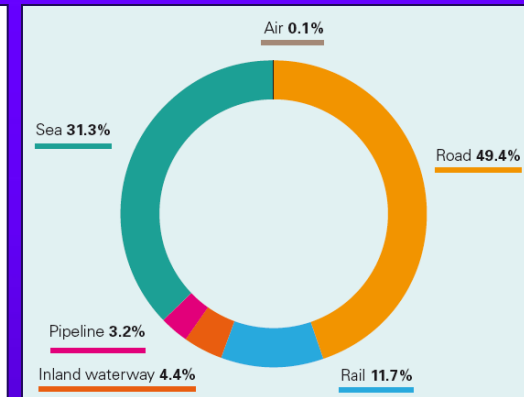
PERFORMANCE OF TRANSPORT 1995-2014 (EU28)



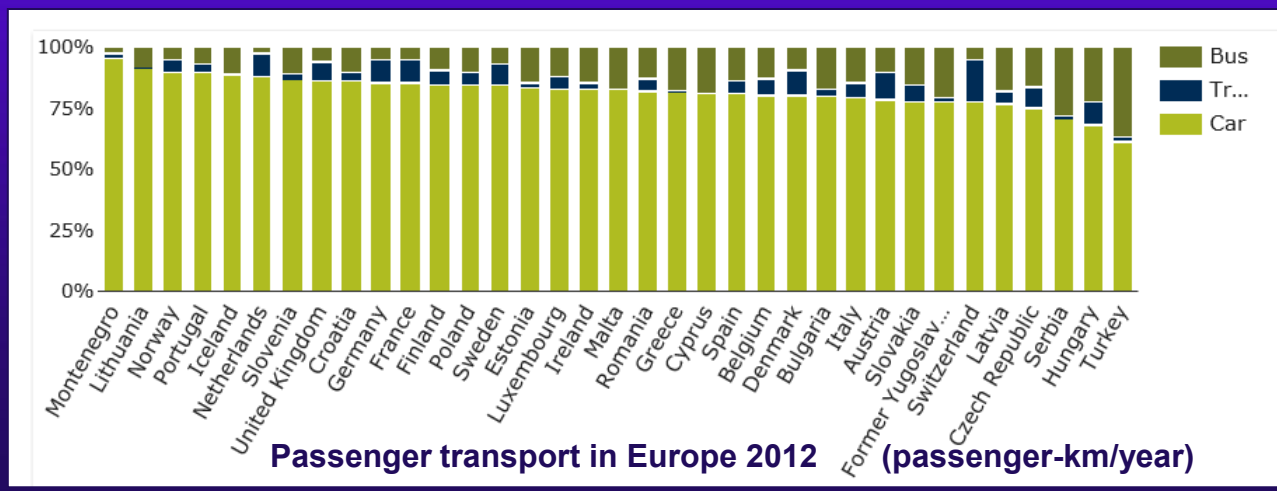
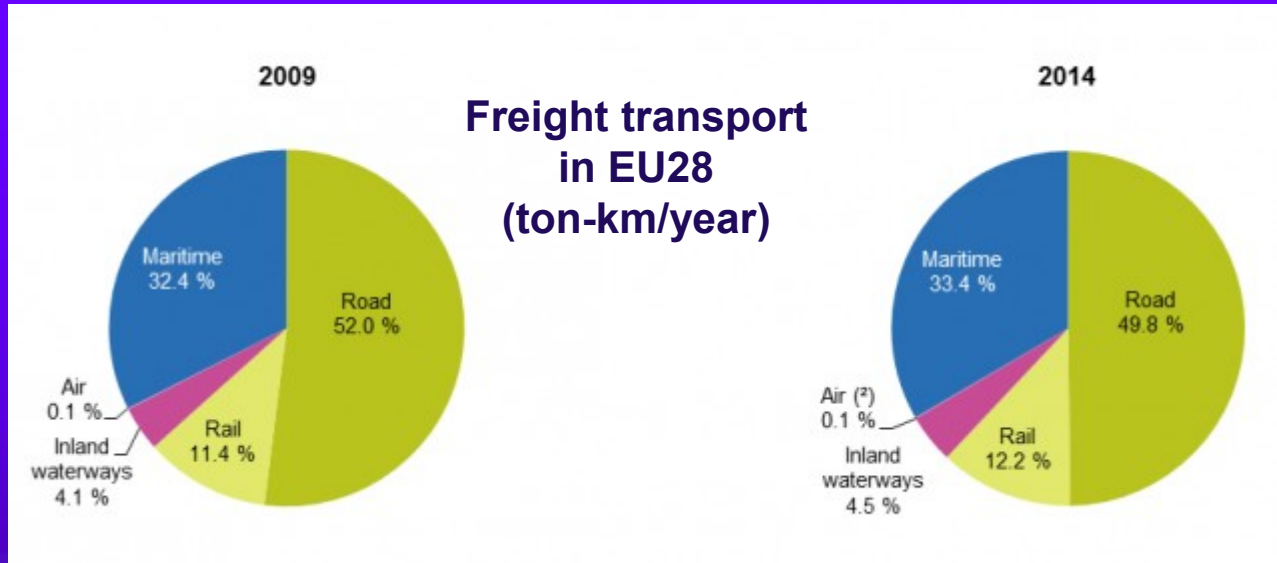
FREIGHT TRANSPORT



PASSENGER TRANSPORT



MODAL SPLIT IN EUROPE

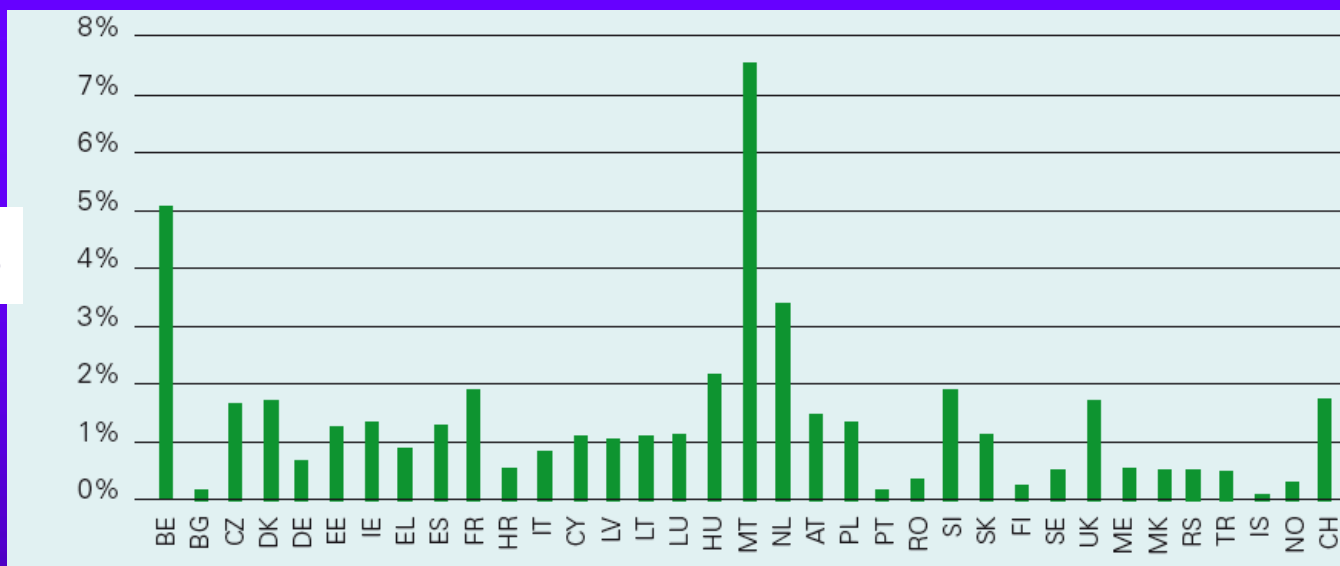


DENSITY OF ROAD & MOTORWAY NETWORK IN EUROPE

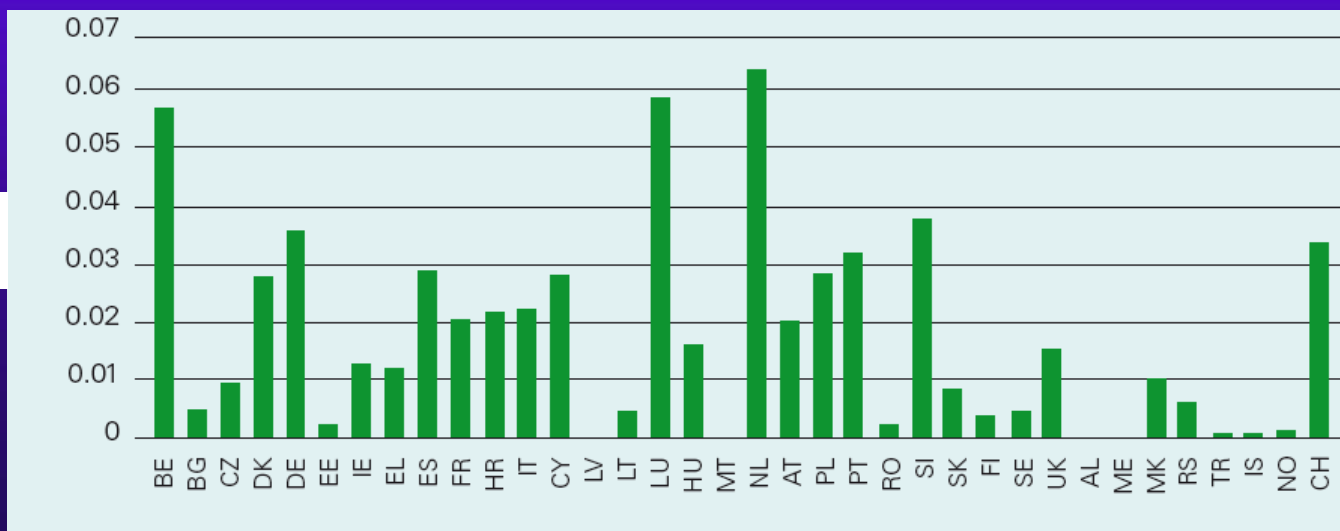
(2012; km/km²)



ROADS

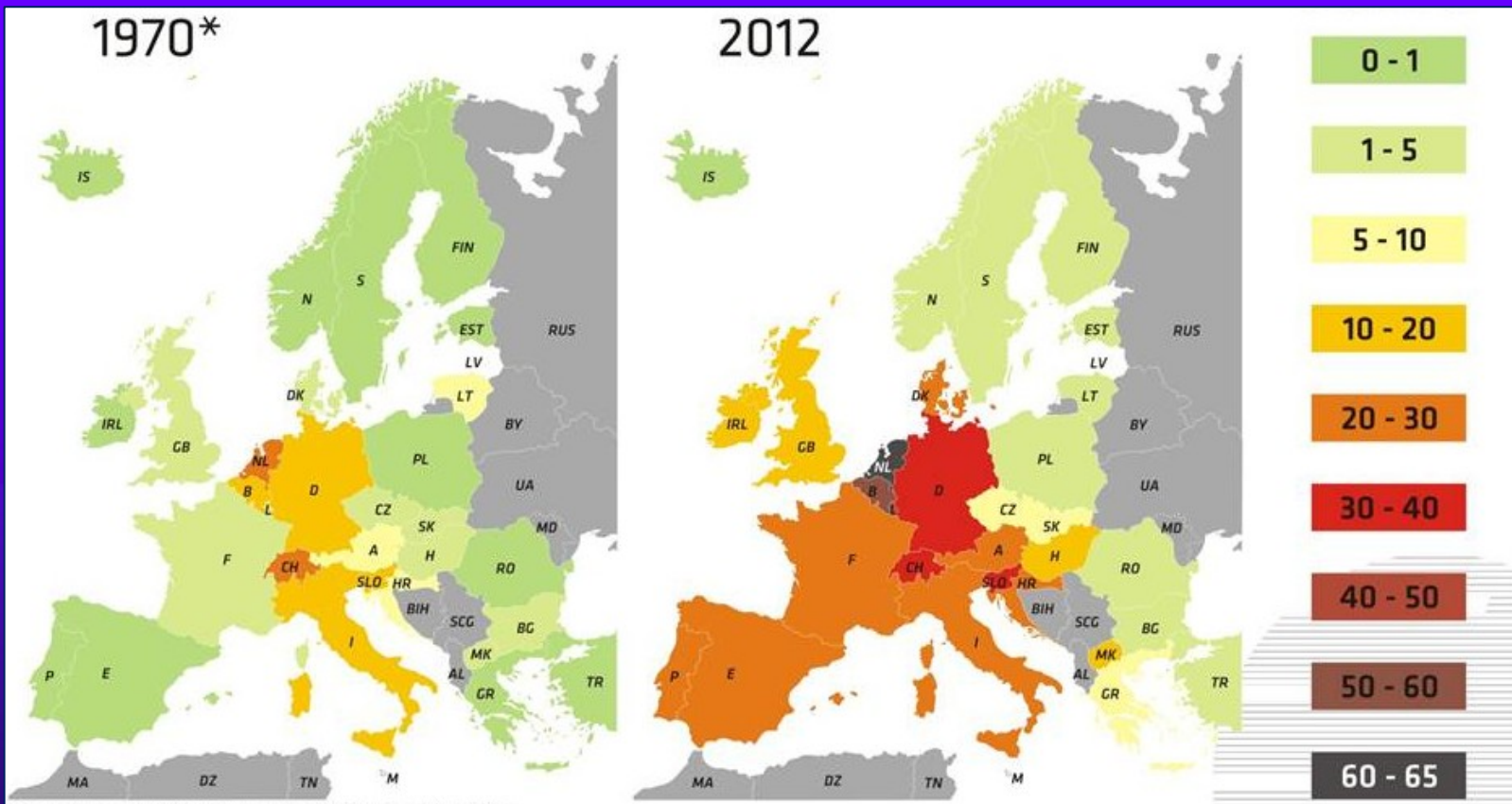


MOTORWAYS



DENSITY OF MOTORWAY NETWORKS IN EUROPE

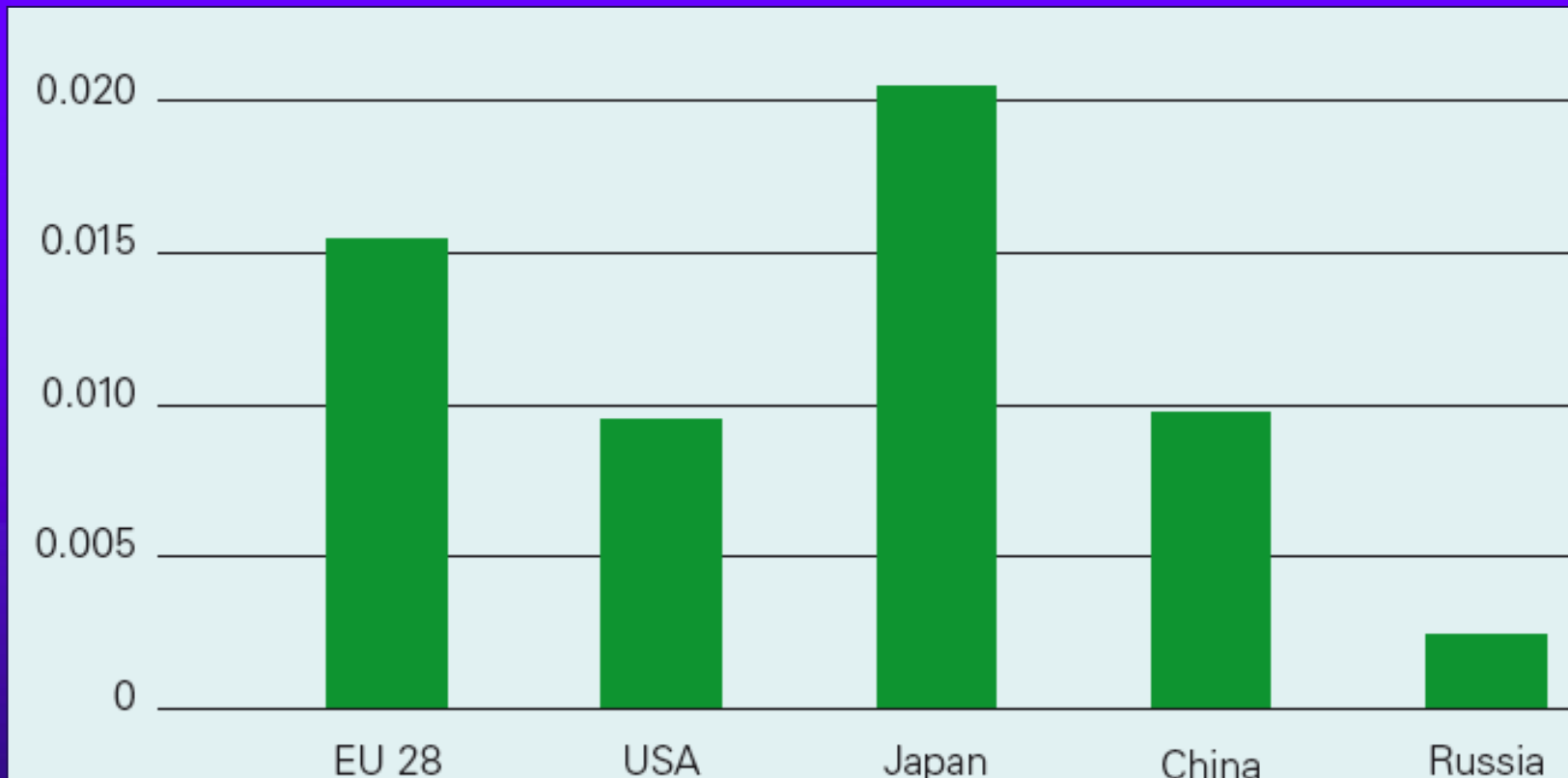
(km/km²)



* For BG, CZ, EE, HR, CY, LT, HU, PL, RO, SI, SK, MK, TR, CH data of 1990

DENSITY OF MOTORWAY NETWORK

(2012; km/km²)

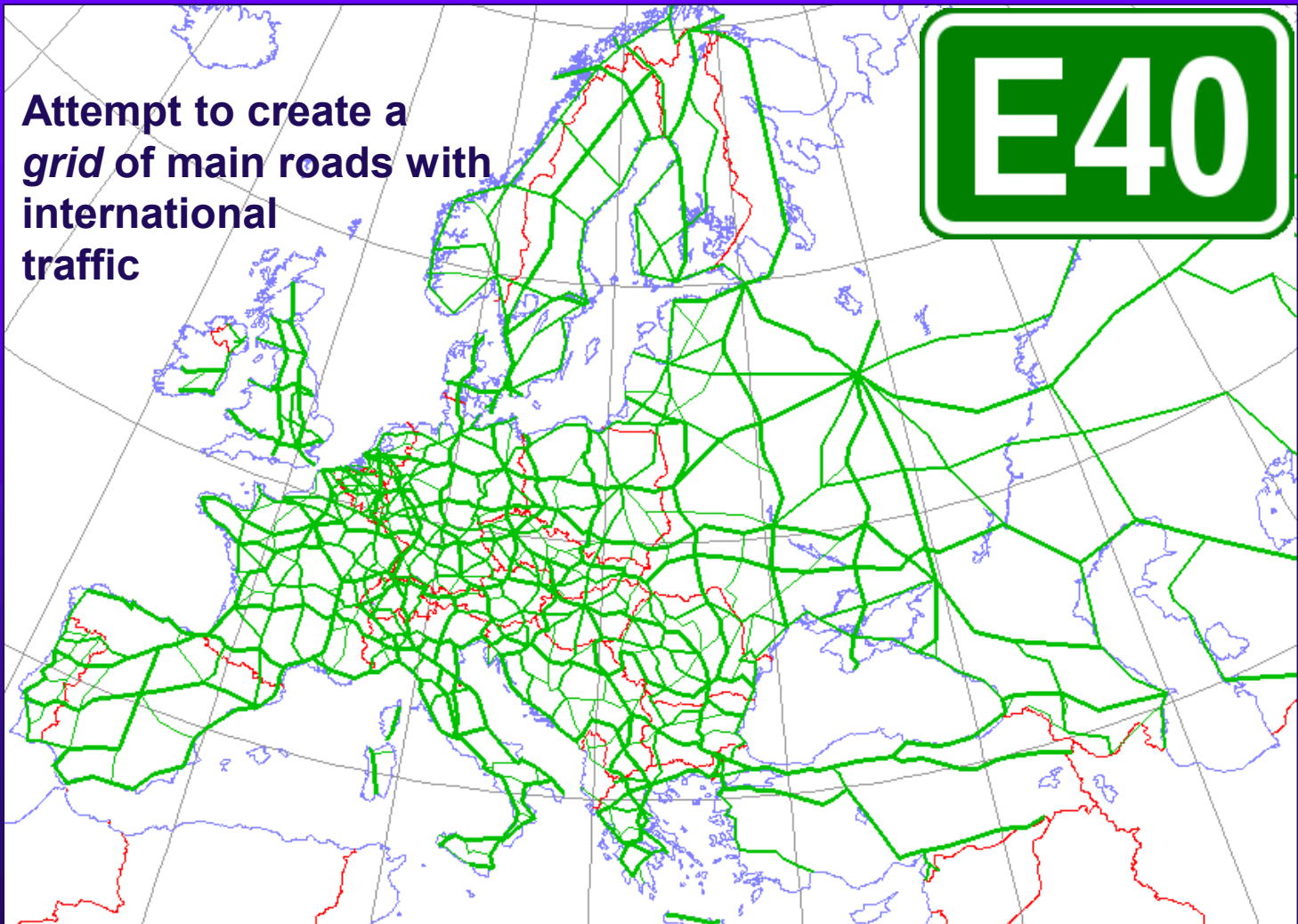


CARS PER 1000 INHABITANTS (2013)

	EU 28	USA	Japan	China	Russia
Motorization	491	739	557	53	273

E-ROAD NETWORK OVER 1990 BORDERS

(UNECE, 1975)



MOTORWAYS IN EUROPE (2014)



MOTORWAY M60 NEAR *PÉCS* (HUNGARY)

