Welcome back to the course.

In previous parts of this course we explained how large scale infrastructures emerge through interconnection across regions and national borders.

Continental electricity infrastructure is a system composed of national systems, which are composed of regional systems, which are composed of local systems.

Such a constellation of systems is known as a system-of-systems. The aggregated system can only function as a system thanks to the adoption of interconnection and interoperability standards.

To make you understand the implications of standardization issues involved in building today's large scale infrastructures, let me go back to the mid 19th century, to the revolutionary event of the adoption of standard time. Until then, each city had its local time. Before the use of mechanical clocks in the 1400's, even the length of the hour still varied between locations and with the seasons. The standard time was produced by the Royal Observatory of Greenwich in London. Why was it adopted? Standard time became a necessity because of the roll-out of national infrastructure systems, for postal services and railway transportation – and it became possible to distribute standard time by the implementation of another new infrastructure: the telegraph communication system. On December 11, 1847, British railways switched from local mean time, which varied from place to place, to Greenwich Mean Time. Until then, the railway system was run by private railway operators each of which based their timetable on their own local time standards, so you can imagine the delays and accidents caused by the lack of standardized time. In fact, so influential was the role of British railways in the adoption of standardized time, that Greenwich Mean Time became also known as railway time.

It is difficult now to imagine a world without standardized time zones, as a prerequisite for worldwide transportation and telecommunication networks enabling global trade. However, given the local origins of these networks, you can now start appreciating the standardization issues..

that had to be overcome to bring continental and global infrastructure systems into being. When you buy a car, the steering wheel will be on the left side of the car if your country's rule of the road dictates right-hand traffic, and on the right side if the rule of your country is left-hand traffic. This is unlikely to bother you, unless you drive into a country where the opposite rule applies, which will bring you as a driver in a position with a reduced line of sight on the traffic. For commuters between Macau and mainland China, this is an everyday experience.

Driving your car across national borders, you also expect the fuel supply to be of a standardized quality, so that you do not have to worry about your car's performance or potential damage to its engine if it so happens that you need to refuel it abroad. You furthermore expect that traffic signs that look the same, also carry the same meaning as those in your home country.

For the road network it seems easy and straightforward enough to standardize rules between countries, but in the case of the railway infrastructure quite a few physical barriers need to be overcome to ensure interconnectivity and interoperability. One of the key issues here is the track gauge (width between the rails' inner sides). Today, 60% of the world's railway lines use the so-called standard gauge, also known as international gauge, UIC gauge or normal gauge. Normal gauge is also the standard for all high-speed lines, except for Russia and Finland, where broad gauge is the standard for all railway lines. Australia is a special case, with six different railway gauges, as nobody in the mid 1800's had the foresight to even imagine the need for an Australia wide railway system. Another standardization issue encountered in long distance, especially international, railway networks is concerned with the electrical power supply standards to electrified railway lines.

Different countries and regions apply different standards, some AC, some DC, with different standard voltage levels. This necessitates costly investments in auxiliary equipment on the electric locomotives on international railway lines, so that they can adjust to different electrical standards.

Standardization issues are a given in most infrastructure networks. An international pipeline system for natural gas requires all users, both suppliers and buyers of the gas, to agree on a standardized gas quality. If different countries apply different national gas standards, they have to modify the gas quality before feeding the gas into their national transport and distribution system. In other words, quality conversion units are needed to ensure interconnectivity and interoperability between national and international gas infrastructure. Whereas in the electrified international railway system the electrical conversion units are mounted on the rolling stock, in the natural gas infrastructure the gas quality conversion units are part of the immovable infrastructure.

As Professor Johan Schot will explain later, standardization issues are usually tackled in lengthy negotiations between technical experts – they are dealt with as technical issues - which obscures the huge political and commercial interests involved. Standardization issues still hamper the smooth operation of many international infrastructure systems – they are a nuisance for end-users like you and me, who have to carry adapter plugs around the world.

Thank you!