Global Environmental Challenges and Railway Transport

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Over the last two decades, a consensus of scientific opinion has developed which suggests that the waste products produced by the activities of mankind have begun to adversely affect the dynamic equilibrium of our planet's climate. Growth in the levels of economic activity, both through raised living standards and an increase in the world's population, has led to questions being posed about the continuing sufficiency of resources and energy. This article examines some of the evidence supporting the above statements, attempts to define economic activity in terms of physical rather than monetary fundamentals, and considers some of the threats and challenges that may affect the transport industry of the future.

If we look up to the stars on a clear night, we are seeing events that happened long ago. Because of the finite speed of light and the immense distances involved, we don't know if what we are seeing now still exists. We become aware of the infinity of space and perhaps wonder if someone out there is looking at us. To any such beings, our home, planet Earth, would appear as a tiny dot. I ask my students to make this kind of observation to remind them of our humble role in the greater scheme of things and to recognize our Earth, for what it is; a minute speck in the universe and of a fixed size.

The next observation is to look around our immediate surroundings. Everywhere we see man-made objects. Some to satisfy our most basic needs for heat, light, warmth, shelter and food; some to satisfy more advanced desires such as entertainment, travel, and communication. Everything we see is produced by the same sequence of winning resources from the earth, processing these materials using energy, generating waste products en route, and eventually discarding the products, again producing waste.

These two simple observations should be sufficient to pose some vexing questions affecting our future. How many people can our finite planet support and at what level of economic activity?

Smokey Mountain on the outskirts of Manila is a monument to urban waste, a health hazard, but a source of income for poor squatters living nearby. *(K. Fukuma)*

World Population Trends

Since the Industrial Revolution, the earth's population has grown dramatically. After taking 200 years to double from 0.5 billion in 1650 to 1 billion in 1860, the next doubling took only 80 years, and the next just 45 years (Fig. 1 and Table 1). The current population of about 6 billion is distributed very unevenly, with 90% living in the Northern Hemisphere, while 60% of the earth's land surface is unpopulated. In dense urban areas, such as Mong Kok in Hong Kong, as many as 160,000 people live in 1 km^2. This inequality is caused by many factors—pulls such as mineral resources, temperate climate, and availability of water and fertile flat land. Push factors, on the other hand, include hostile climates, dense vegetation, limited accessibility and man-made reasons such as political or religious oppression.

As long ago as 1800, Malthus, whose name is now eponymously associated with economic and environmental pessimism, suggested a crisis was nearing because populations grow geometrically, but food supplies only grow arithmetically (see information box). In fact, his ideas were premature, largely because of massive net emigration from Western Europe to America and huge increases in efficiencies of food production brought about by the technical achievements of the Industrial Revolution.

Although population growth rates have slowed in the already developed countries, rapid increases are expected in the developing nations, which even now represent nearly 80% of the world's population. The 'catch-up' expansion of these economies is a real cause for environmental concern.

Figure 1 World Population Growth

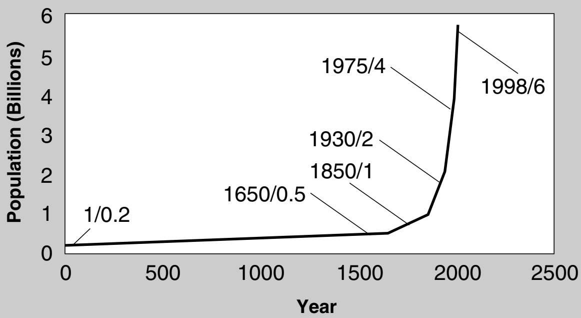


Table 1 Population Growth in Various World Regions

Area	1950		1991		2025**	
	Pop.*	%	Pop.*	%	Pop.*	%
More developed countries	832	33.1	1,219	22.6	1,412	16.3
European Community	278	11.0	346	6.4	348	4.0
United States	152	6.1	253	4.7	334	3.9
Japan	84	3.3	124	2.3	135	1.6
Less developed countries	1,684	66.9	4,165	77.4	7,234	83.7
World total	2,516	100.0	5,384	100.0	8,646	100.0

* Population in millions
** Projected

Source: Eurostat Demographic Statistics 1993

Thomas Robert Malthus (1766–1834)

A pessimistic English economist and pioneer of demography, educated at Jesus College of the University of Cambridge, of which he became a Fellow in 1793. Later a country priest, he became Professor of History and Political Economy at Haileybury College in 1805. His *Essay On The Principle Of Population* written in 1798 and revised in 1803, argued for population control, since populations increase in geometric ratio (1, 2, 4, 8...), but food supply increases only in arithmetic ratio (1, 2, 3, 4...). His starting point was the two postulata: 'That food is necessary to the existence of man.' and, 'That the passion between the sexes is necessary and will remain nearly at its present state.' Malthus saw war, famine, and disease as necessary checks on population growth. In later editions of his book, he suggested that moral restraint, delaying marriage and sexual abstinence before marriage could also keep numbers from increasing too quickly, a statement used by the early advocates of birth control.

Although Malthus' view proved too pessimistic in view of circumstances in the 19th century, it is now accepted that, up to a point, he was correct. Both plant and animal populations tend to increase faster than the resources needed to sustain them until some check slows their growth. Malthus influenced Charles Darwin (1809–1882) who proposed in his book the *Origin of Species* that the transformation or extinction of species depends on their response to changing environmental factors.

Physical Nature of Economic Growth

Conventionally, economies are measured in financial or monetary terms. Actually, these descriptions are merely convenient advanced measures of exchange of, for example, labour for goods or relative performance between nations. As previously indicated, economic activity is essentially physical. We should recognize that the laws of mass conservation and thermodynamics of energy exchange are more fundamental than monetary parameters. We can trace all the materials we win from the planet through their production, distribution, use, and disposal, and the mass remains constant eventually to be returned to the earth or the atmosphere as waste. Furthermore, considerable quantities of energy will have been consumed, irreversibly and thermodynamically inefficiently, in every stage of this life cycle.

Our society has developed an economic system that relies on growth to satisfy consumers. The three macro-parameters we use to monitor the health

Macau and Hong Kong have some of the world's highest urban density. *(K. Fukuma)*

of an economy are the rate of unemployment, the inflation rate, and the rate of growth of output. Using Gross Domestic Product (GDP) as an integrated measure of the latter, we have grown accustomed, perhaps even dependent upon, annual increases in the order of a few percent to about 10%. If these growth rates are sustained over a reasonable number of years, we can model the growth as an exponential function; in other words, the growth rate is proportional to some fraction of the current size. Exponential functions are characterized by very short doubling times (the time that the described activity takes to double in size); an annual growth rate of 3% leads to doubling in 23 years, 5% in 14 years, and 10% in only 7 years. However, more significant is the fact that the consumption of resources during the doubling period is equal to the sum of all the resources consumed in all the previous doubling periods. Starkly put, this means that if the world's economy grows at a relatively modest rate of 3% per year, then in only 23 years we will consume as many material and energy resources as we have consumed throughout history until today.

Effect of Economic Activities on Earth's Climate

There have been periods in the earth's history when the climate has swung between cold and warm conditions. The Ice Ages were typical long-term climate changes. In contrast, the local weather varies day to day. It is very important, but rather difficult, to identify artificial or human-induced climate changes in these long- and short-term fluctuations. However, evidence is gathering that human activities are changing or perhaps accelerating, climate change. Indeed, in 1995, the United Nations Intergovernmental Panel on Climate Change concluded that 'The balance of evidence suggests a discernible human influence on global climate.'

Some key evidence includes:

- Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapour are all Greenhouse Gases that trap heat radiation from the earth's surface back into space, keeping the earth about 30°C warmer than it would otherwise be.
- Levels of these three gases have increased rapidly: CO_2 levels in the atmosphere have risen by about 25% in the last 200 years, CH_4 levels have doubled in the last 100 years, N_2O levels are rising at about 0.25% each year.
- Average global temperature has risen by 0.6°C in the last 130 years (Fig. 2).
- Global sea level has risen by between 10 and 25 cm over the past 100 years due to melting of the Polar ice caps.
- Recently, anomalous extreme weather has occurred in many localities; for example, three of the five warmest years in Central England's 337-year-old temperature records, have occurred in the last 10 years. Recently, Vice President Gore announced that this summer (1998) has been the warmest on record in the USA. Now almost everybody knows about El Niño in the Pacific.

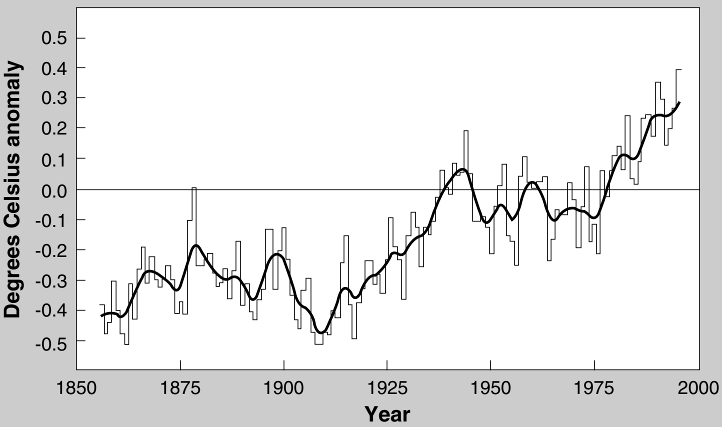
Global Consequences of Climate Change

If Greenhouse Gas emissions continue on a business-as-usual basis, it is predicted that CO_2 levels will double from pre-industrial levels by the end of the next century, producing an estimated average global temperature rise of between 1.5° and 4.5°C—the most likely value being 2.5°C.

The most important impacts on global climate of such a rise in temperature include:

- Sea levels will rise by 50 cm over the next century.
- Extreme weather, such as heat waves,

Figure 2 Global Temperature Rise in Last 130 Years



Source: Hadley Centre for Climate Prediction and Research, University of East Anglia

Freak weather resulting from El Niño wreaked havoc in San Francisco this year. *(Kyodo News Agency)*

floods, droughts, and storms will occur more frequently.

- Deserts will become hotter and desertification will increase.
- There will be major shifts in the world's vegetation zones.
- Half the world's glaciers might melt and the Polar ice caps will decrease in extent, (although there is still debate about the extent of this effect). This would also provide a positive feedback driving the process further because the darker exposed land area would absorbed more solar radiation.
- Mass migration of people from flooded, arid or waterless regions could trigger international tensions and conflict.

The pressing nature of this problem is amplified by the fact that CO_2 has a residence lifetime in the atmosphere of about 100 years, so atmospheric concentrations respond very slowly to changes in emissions. If we stabilize CO_2 emissions, as agreed by the developed nations at the 1992 Earth Summit in Rio de Janeiro, the rate of climate change will slow down, but we need to reduce CO_2 emissions by about 60% globally to prevent concentrations from rising further. The problem is the extreme variation in existing CO_2 emissions between countries at different stages in their development. Table 2 summarizes some typical data. Perhaps the most important column is that of annual emissions generated per person. Typically, developed nations emit five times more CO_2 per inhabitant than China, and 50 times more than Kenya. How can we expect developing counties, where population increase is likely to be greatest, to moderate emissions when they are so far behind developed countries in their present development levels? More optimistically, the similar levels of the former USSR and Germany, give reason to hope that cleaner technology fixes can make an important contribution because Germany has achieved a much higher GDP per head of population than its Eastern neighbours.

Although the Framework Convention on Climate Change (Climate Treaty), signed at the Earth Summit in 1992 agrees that the major industrialized nations must bear the brunt of the first round of emission cuts, in fact, most will fail to stop their emissions rising by 2000, much less achieve the reductions called for by the Kyoto COP 3 Convention of 1997.

Table 2 Variations in CO_2 Emissions by Country

Country	% of current human carbon dioxide emissions	% of world's population	Annual metric tons of carbon dioxide per person
United States	22.0	5.0	20.0
Former Soviet Union	18.0	6.0	13.5
China	10.0	22.0	2.3
Germany	4.6	1.5	14.0
Japan	4.5	2.5	8.5
India	2.7	17.0	0.8
United Kingdom	2.5	1.0	10.0

Data are for 1988 and are drawn from *Trends '90: a compendium of data on global change*, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, 1990.

Resource Depletion

The other key question posed by population growth and increasing levels of economic activity, is that of resource depletion. How much longer can the finite resources of Earth continue support exponential rises in consumption? There are many conflicting predictions for different resources, but it is clear that limits must be reached eventually. Even water, which is recycled by nature, is likely to be in short supply, thereby causing conflicts. For example:

- The number of people living under water-stressed conditions is expected to increase fourfold to nearly 2 billion by the middle of the next century.
- China now recognizes that 300 of its largest cities are facing water shortages. In the spring of 1994, the government banned farmers from using reservoirs in the agricultural regions near Beijing, because all available water was needed by the city.
- 5500 gallons of water are required by a typical Californian cattle ranch to produce 1 kg of steak.
- Two-thirds of all streams and rivers in the world will be dammed, channelled, diverted, or otherwise controlled by 2000.

Perhaps the most obvious potential shortage is energy, in which oil plays the major role (Fig. 3).

World energy demand in 1995 was nearly 8.6 billion tonnes oil equivalent. It was satisfied from five main sources: oil 37%, gas 22%, coal 26%, renewables 8% (nearly all hydro), and nuclear 7%. Demand is expected to double in less than 50 years, but pressure to reduce CO_2 emissions means that the mix must change markedly. To hold CO_2 emissions in 2050 at the 1995 level needs a shift to something like oil 21%, gas 12%, coal 10%, renewables 40%, and nuclear 17%. It is imperative that solutions are found to improve the safety and public perception of the safety of nuclear power and that its true lifetime (including long-term disposal management) costs are dramatically lowered. It is worth noting that of the 428 operational reactors in the world today, exactly half are in just three countries: 104 in the USA, 58 in France, and 52 in Japan. There have been many estimates of the life of oil reserves; new reserves continue to be found and short-term prices are very low. This is folly of the highest order because remaining reserves of all fossil fuels must be husbanded to buy time to develop the nuclear and renewable options.

Figure 3 Exhaustion of World's Oil Resources

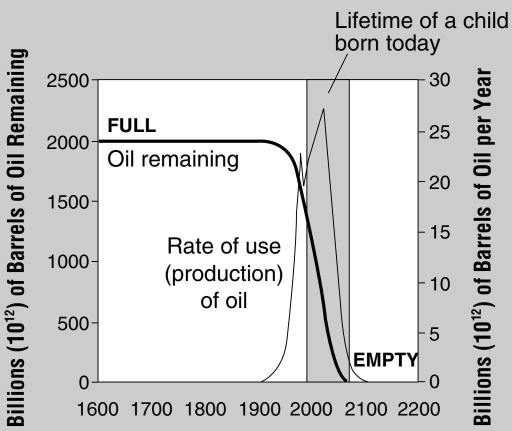
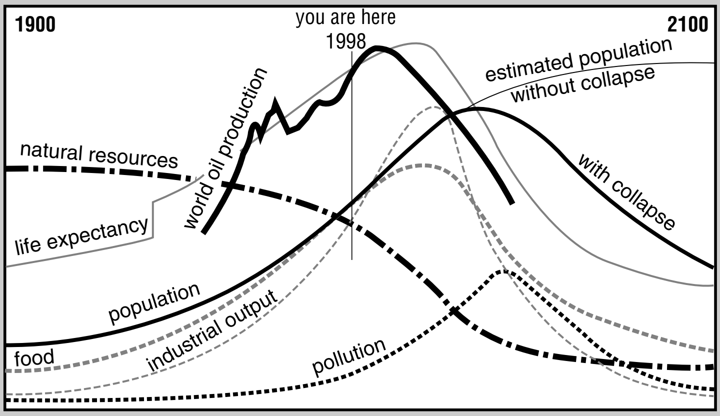


Figure 4 Visions of the Future?



Source: Beyond The Limits of Growth, Meadows et al., 1992

Julian Lincoln Simon (1932–1998)

An optimistic American economist, Professor of Economics & Business Administration at the Universities of Illinois (1969–83) and Maryland (1983–98). He refuted Malthus, saying: 'The world can indeed accommodate a lot more people, because future generations will produce enough geniuses to solve the problems that more people would cause.' He espoused the view that population increase is the mother of economic and social invention. One typical prediction was that humanity's condition will improve in just about every material way, but that people will continue to sit around complaining about everything getting worse. He is probably most famous as the man who bet Paul Ehrlich, the author of *The Population Bomb* (1968), that the price of a basket of metals would go down between 1980 and 1990, rather than up, as those he characterized as doom-mongers predicted. He won, and neo-Malthusians never forgave him.

Important industrial resources like lead, copper, etc., exist in finite quantities. Over the long-term, followers of the American economist, Julian Simon should not expect to repeat his success in betting that the price of a basket of metals would fall between 1980 and 1990 (see information box). It is true that new reserves will be discovered, that human ingenuity will develop as yet unthought of alternatives and that technology will generate clean ups and fixes. The only real debate remains about the time scale when shortages will bite. The overall picture may look something like Fig. 4. We face stark choices; on one hand, termination of growth by self-restraint and conscious policy, on the other, a termination of growth by a collision with natural limits, resulting in social collapse. Which way will we choose—a gentle soft degradation, or violent collapse?

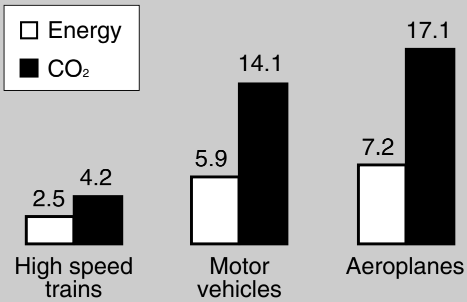
Mobility, Economic Growth and CO_2 Emissions

Historical data shows that, throughout the world, personal income and traffic volume grow hand-in-hand. As average income increases, the annual distance travelled per capita by car, bus, train or aeroplane, rises roughly in the same proportion. The average North American earned US$9600 and travelled 12,000 km in 1960. By 1990, both per capita income and traffic volume had approximately doubled. Indeed, this proportionality of income and traffic volume has been demonstrated over several orders of magnitude of average income, for a wide range of countries and economies. Therefore, an explosion of transport and corresponding emissions will accompany further economic growth.

Furthermore, over this huge income range, the amount of time that people are willing to spend on travel, (their daily travel-time budget), has remained remarkably constant at approximately 1.1 hours per day. This means that as people get wealthier, they use faster modes of transport. Foot successively gives way to horse, cycle, bus, automobile, train, and finally aeroplane. The number of flights flown by the average American citizen is 100 times the average in China and India.

In terms of CO_2 emissions, the proportion of the world emissions originating from transport has increased from 18.4% in 1980 to 20.5% in 1995 and will continue to increase further. It has been calculated that if the number of automobiles in China increased to West European levels, not only would China

Figure 5 Comparisons between Energy Consumption and CO_2 Emissions for Various Transport Modes per 100 passenger-km



Riderships: high-speed trains 50%, aeroplanes 65%, and automobiles 1.7 passengers

consume the total crude oil production of Saudi Arabia, but also the resulting CO_2 emissions would increase by 2 billion tonnes, or half the world's transport emissions in 1990.

Can Railways Help Solve These Problems?

All these trends have implications for the future of railways. They are apparently well placed in developing countries to satisfy the growth in transport, but in developed countries they must offer faster services to compete with automobiles over short distances and with aeroplanes on journeys of up to 5 or 6 hours. Not only can railways compete in terms of speed, but a strong case can also be made for their environmental benefits.

At first glance, if a comparison is made in terms of passenger-km (Fig. 5), trains offer substantial energy efficiencies over competing transport modes. Furthermore, in terms of their overall contribution to the transport market, trains consume a much lower proportion of the energy budget than their proportional share of the market (Table 3). For example, trains in Sweden use only 1.8% of the total transport energy to carry 7% of the passenger-km and 38% of the freight tonnes-km. In Japan, trains have a very high 30% share of the passenger market, but consume only 7% of the total transport energy.

A major environmental advantage of the train is its ability to run on electricity generated from 'clean' energy sources. For example, all Swiss trains are electric and 97% of their power comes from renewable hydropower. In France, electric trains carry 77% of railway passenger-km and the vast majority of the electricity comes from nuclear power stations, which produce almost no Greenhouse Gas emissions. There are very strong environmental grounds for increasing train electrification, especially if the power is generated from non-fossil fuels. However, short-term economic arguments often prevail over long-term investment in train electrification for the future.

Can Railways Maintain Their Environmental Advantage?

Although it is presently true that railways have considerable advantages over competing transport modes, the global auto industry has taken great strides using an almost unlimited R&D budget to improve environmental performance. Car fuel consumption has been greatly improved, and emissions have been reduced by catalytic converters on tail pipes, etc. New electric and hybrid cars are appearing. Developments in telematics and control systems mean that the car of the near future will perform much more like a train, with the possibility of harnessing cars into electronically linked convoys,

Table 3 Rail's Share of Energy Consumption and Transport Volumes

Country	Energy consumption (%)	Passenger-km (%)	Freight tonne-km (%)
Germany	3.3	6.7	19.4
France	3.8	7.5	25.0
Sweden	1.8	7.0	38.0
Switzerland	4.0	18.0	35.0

Source: UIC, 1995

enhancing both fuel efficiency and safety, while increasing the capacity of existing roads. Trains have a long life cycle of up to 30 or 40 years, meaning that new technological developments are slow to make widespread impact. This extended 'technology window' is a major handicap preventing rapid response by the railway industry to technical change.

So far, very few railway companies have responded to the challenges presented by the environment; JR East is a notable exception. After the 1992 Earth Summit in Rio de Janeiro, JR East formed an Ecology Committee to tackle the problems systematically. Quantitative targets were set for performance improvements to be achieved by 2001. These include 10% reductions in energy consumed per unit transportation volume and CO_2 emissions from JR East power stations, coupled with 40% reductions in NOx emissions. Other targets have been set involving recycling of paper and rubbish, a reduction in water consumption, and a programme to plant 30,000 trees along the company's tracks each year. One of the most interesting features of the programme has been the Series 209 'halved weight, cost, and service life' commuter train, which uses less than half the energy of the trains it replaced. Many technical features make this a role model for other companies. The need to internationalize railway research is essential in order to transfer best practice through an industry that has been generally conservative in the past.

Action Now!

The problems facing our current lifestyle, which is based on ever-increasing economic growth fuelled by consumption of energy and exploitation of resources, are real and pressing. It is generally acknowledged that we need to change our lifestyles, in order to safeguard the ability of future generations to have choices about their own lives.

But the political will to make these changes is largely lacking because of the unpopularity of the choices that need to be made. We all see very clearly the need for others to change! In the area of transport, we all recognize the need to do something about the emissions and gridlock on the land and in the air. Perhaps travel demand will decrease because of the rise in electronic communications, but this trend is not evident yet.

Railways can play a useful role in promoting a better lifestyle, but the industry should not be complacent; rival modes are now closing the advantage gap that railways currently hold. All the short-term improvements for which we strive, such as improved services, better information, increased comfort, better intermodal exchange and more economic operation, can serve as pull factors to attract passengers to the railways. Negative pushes, such as congestion, need to be supplemented by urgent action at national and international levels to educate people about the reality of the situation and to provide greater incentives to assist their choices in choosing environmentally less damaging lifestyles. ■

Are high-speed trains like these French TGVs the answer to future transport needs? (EJRCF)

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