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Unleashing the Potential

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DRIVING FORCES OF INNOVATION IN THE TRANSPORT SECTOR

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General Introduction

Economic growth is the foremost feature of developed economies and societies, as the current economic crisis has so starkly reminded us! Once growth falters, the negative effects start to spread fast both for firms and households, so that states have to take far-reaching action, as the rapid increase in public deficits indicates. Everyone thus seeks a return to economic growth and the need for sustainable growth is not linked simply to environmental concerns. While growth must be more responsive to environmental pressures, it must also ensure an underlying rise in production and productivity levels.

Gains in productivity are the condition for economic growth which is not merely the extension or outcome of an increase solely in the quantity of factors of production (Domar, Harror, Kaldor). Technical progress and the productivity gains to which it leads thus have a vital part to play: first, because it underpins the drive to achieve general prosperity; next, because it helps to handle the environmental pressures on economic growth which has drastically to lower its impact on the environment; and finally because, by the same token, technical progress is the condition for dealing equitably with the social issues comprising the third constituent of sustainable development. It is worth recalling from the outset that the Bruntland Report attached the importance it did to the way in which economic, ecological and social aspects are all part and parcel of the concept of sustainability, in order to distance itself from the theoretical arguments of the 1970s in favour of zero growth (Georgescu-Roegen, 1979). For the same reasons, we should mistrust the idea that economic stagnation would be capable of satisfying the threefold requirements of sustainability.

However, re-emphasising the key role of economic growth and technical progress is only a first step forward and a means of dismissing a few mistaken assumptions. That said, we should beware of remaining smugly optimistic about what science and technology can achieve. Both already play a key role and will continue to do so in the years ahead. But the way in which they will be able, through innovation, to help support and redefine growth is far from predictable. The transport sector is a notable illustration of this. As we shall now demonstrate, innovations have played – and are still playing – a key role in the transport sector. However, it should be noted immediately that in any reference to the driving forces of innovation in this sector, we are confronted with two distinct – albeit interrelated – perspectives.

- The first involves examining how the transport sector has been and will remain a mainspring of technical progress and growth, and thus a key factor in improving the well-being of past and future generations.
- The second perspective is so to speak an issue following on from the first. If progress in transport is conducive to economic growth, what then are the mechanisms likely to encourage technical progress in the transport sector?
- Both lines of enquiry are clearly interrelated. We shall therefore consider them jointly though with reference to the distinctive nature of each, by adopting a chronological approach in which both history and economic analysis are combined (Crozet, 1989).
- The first part of this paper will thus be concerned with changes in how historians and economists have viewed the driving forces of innovation in the transport sector. The quickening pace of technical progress in transport in the 19th century was so marked that many regarded it as a driving force in economic take-off (Rostow). Economists in particular considered technical progress, as well as its origins and implications, at length to the point at which they reached the further conclusion that its status in the process of economic growth was endogenous. This situation no doubt accounts for the impression that major technological breakthroughs in the transport sector may belong to the past rather than the future.

- Bearing in mind the lessons learnt from history and economic analysis, while remaining cautious as to what future years and decades have in store, we shall then consider the form and content of innovations which might typify the transport sector throughout the 21st century. What are the most appropriate measures for public policies if the sector is still to make a key contribution to economic growth? What innovations are the most likely or most necessary? And how can one help to initiate them?

1. Technical progress and transport: from the genius of inventors to the collective – process of innovation

In the years 1950-60, when the author of this paper was still a child, the year 2000 was the stuff of which dreams are made. From strip cartoons and science fiction novels we could glimpse a world of all-out three-dimensional mobility. “Flying scooters” and other “virtual motorways” were viewed as the logical sequel to the progress that had been such a feature of the 19th century and the first half of the 20th. Fifty years later, we are bound to acknowledge that these futuristic scenarios are becoming as inevitably distant as the horizon itself. This has given rise to some disillusion and disappointment partly responsible for the impression that in the years ahead we shall experience no more than incremental technical progress, which will cease to provide a basis for any hope of progress in general[1].

The aim of this first section is to show that the foregoing opinion does not reflect reality and instead amounts to an analytical error, or rather a dated view of what technical progress really is. Influenced by the extraordinary changes of the 19th century, and in particular the development of railways, we still regard technical progress as the realm of inventors and inventions, an exogenous phenomenon associated with individuals capable of producing sudden radical breaks with the past (**1.1**). Yet the prevailing reality of today is one of organisations nurturing the rational, sustained and endogenous development of innovations which are above all the fruit of collective endeavour. Technical progress has become institutionalised as we have learnt from Joseph Schumpeter, a theorist of both the first and second approaches to such progress (**1.2**).

1.1 The first age of transport innovation (Schumpeter 1)

It was in 1912 (in *The Theory of Economic Development*) that Joseph Schumpeter set out his first study of innovation in which a key role is ascribed to individuals and entrepreneurs. Such persons possessing special forms of charisma are capable of developing new products and new patterns in production processes. In the same work, he emphasises the intermittent nature of innovation which develops in clusters, stemming from a major original innovation. These major innovations are attributable at the outset to exceptional personalities who have often managed to combine the two roles of inventor and entrepreneur, both clearly distinguished by Schumpeter. This concept of major innovations which are exogenous and intermittent is very widespread. It lies at the heart of historical studies which highlight the great movements represented by the different industrial revolutions and is extended in the idea that we are going to experience – and arguably in the area of transport – a fresh industrial revolution!

These principles of industrial revolution and the gathering speed of technical progress assume concrete form in the epic development of railways in the 19th century. This is truly fascinating and deserving of note in relation to the generally quickening pace of technical progress for which the period was remarkable (**1.1.1**). Yet the concept of accelerated development has to be examined more closely, as does the precise contribution of transport to this new phenomenon represented by sustainable economic growth (**1.1.2**).

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1. It should be noted that such disillusion usually underlies fashionable ideas about decline, which are readily associated with the notion that we are in a “finished” world in all senses of the word. This of course is a mistaken judgement. In their time, David Ricardo, but also Joan Robinson and many other distinguished economists, came to believe that we were destined to reach the stationary state. At the risk of seeming less distinguished, we should strive to be more astute!

1.1.1. *Land and maritime transport – some key 19th century innovations*

The railways are doubtless the finest illustration of the “Schumpeter 1” theories, and of their “romantic” nature that fires the imagination. Here, the decisive, not to say inspired, role of a few individuals is illustrated by George Stephenson and his son. The former brought into service as early as 1814 a first locomotive (the *Rapid*) to haul trucks in the mines of Killingsworth. After that, from 1825, he launched the first passenger railway line (Stockton to Darlington, 39 km). Then, with his son, he developed the *Rocket*, which reached 47 km/h, and in 1830 the Liverpool to Manchester line. Between them, they were to create a flourishing business that would be emulated throughout the world (J. Brasseul).

*** A historic gathering of speed in the transport sector**

The growth of the rail track network itself is a further component of the rail epic. In just a few decades, tens of thousands of kilometres of railway line were built in Great Britain, as well as in France, Germany, the United States and elsewhere. Each country embarked on a vast construction programme which at times accounted for 5-7% of national income, or half of total investment! Approved expenditure for opening railway lines was well above prevailing levels in road construction. Determination at all costs to clear the way for trains required the building of bridges and drilling of tunnels in a way unimaginable in the case of roads and stagecoaches. Development was such that a new railway line cost up to 15 times more per kilometre than a road!

Yet it was all worth the effort. In the modern terms of economic analysis – those developed in the same period by Jules Dupuit (1844) – this huge investment was justified by the size of the credit balance it generated. This surplus, which was the outcome of market area expansion caused by the very significant increase in the average transport speeds of people and goods alike, highlights an essential mechanism, namely that of increasing returns. The key factor in the development of transport and the market area expansion which occurs as a result is the change of scale in production. **Innovation in the transport sector was initially driven by readiness to accept the principle of growing economies of scale.** This is now a well-established theory in economic geography (P. Krugman, M. Fujita, J. Thisse) which, while refraining from the claim that transport is **the** driving force of growth, emphasises the logical relations uniting progress in transport and overall economic growth.

In the 19th century, various forms of progress unquestionably occurred in parallel. Thus, during the Napoleonic Wars not long before the arrival of the railways, armies travelled at a speed similar to that of Julius Caesar’s legions. While lightly loaded horses could reach speeds of 15 km/h, goods and men moved literally step by step. So the increase in an average speed of no more than 5 km/h to values which quite rapidly became ten times greater transformed the entire economy. Towns and cities, in order to sustain themselves, could obtain supplies well beyond the areas normally used for this purpose. In corresponding fashion, as soon as the railway reached farmers in a given region, they could step up production which was now destined for a larger clientele. Tourists who travel to Switzerland, Austria or France and fully appreciate the charm of the countryside and its villages forget that the prosperity of such rural areas, which gave its environment its reputed immemorial form, generally occurred subsequent to rather than before the arrival of railways.

This extension of market areas was not confined within national boundaries. In the same period, maritime transport also underwent major innovations. First came the sailing ships, with the construction in American shipyards of clippers which were to play a vital part in the development of transatlantic trade (in cotton, textiles and machines, etc.). Less rapidly than rail transport but no less decisively, navigation exploited the assets of the steam engine. As early as 1807, Fulton tested steam propulsion on the Hudson. The propeller, which was to markedly improve vessel performance, was “invented” in 1832. Metal hull ships were developed from 1850 onwards. Steamships gradually asserted their supremacy and, at the beginning of the 1880s, their relative share of traffic was greater than that of sailing ships – an overall volume of traffic which grew ceaselessly at the same rate as that of international trade, so much so that the 19th century is the first to have experienced globalisation. The level of economic openness of countries such as France and Great Britain before the First World War was close to that witnessed at the end of the 20th century during what might be termed the second phase of globalisation.

*** The key role of speed**

It is thus clear why those alive at the time themselves spoke of accelerated development. The fact that the average speed of travel increased by a factor of 5 or 10 amounted to a very real revolution which led at the outset to increased movement of goods with a spectacular growth in the amounts exchanged and produced. **Just as market areas began to expand and provide for the development of increasing returns, the benefits of speed were thus one of the first forces to drive innovation in the field of transport, especially where speed also meant reliability, regularity and frequency**. The fact that trains but also fairly fast ships began to circulate regularly between areas of production and consumption altered the scale of the world. This is well worth remembering every morning as we drink our tea, coffee or orange juice for which the raw materials have already travelled thousands of kilometres.

The other major change to which accelerated historical development applies is human mobility. **As in the case of goods, gains in speed, reliability and frequency were the first driving forces of innovation in passenger transport.** Whether we are concerned with the drift from the land or international or colonial migration, the new order in the transport system drastically changed the spatial distribution of mankind. As it did so, transport also contributed through its structural impact to the development of growing economies of scale, by shifting the workforce towards the most productive areas and activities. This is borne out by the findings of geographical economics but also of recent research which tends to attach greater importance to transport infrastructures serving the densest areas, with the highest *per capita* productivity (Venables).

Easier human mobility does not merely change average productivity levels. It also implies a profound transformation in lifestyles, beginning with their most basic component, namely living standards.

Indeed, the distinguishing feature of this period is that economic growth, referring to the increase in the quantity of goods and services available *per capita*, would become a sustainable trend. Previous centuries had experienced good times. Jean Gimpel unhesitatingly referred to an industrial revolution in the European Middle Ages, in the decades prior to the great plague of the 14th century. Periods of global warming or, on the contrary, of cooling had a very real impact on crop conditions and on people's life expectancy (E. Leroy-Ladurie). This tendency of prosperity to wax and wane disappeared in the 19th century. Growth became an irreversible trend as if a threshold had been crossed. By extending market areas, and enabling production to move from the craftwork stage to the fully industrial stage, transport arguably played a key role in this permanent phenomenon of accelerated development. By broadening the horizons of men and enterprises as a result of higher speeds, modern forms of transport, and above all railways, appeared to have a ratchet effect. Once certain standards of living and production levels have been reached, any reversal of the trend becomes most unlikely. Indeed, even the opposite occurs in a kind of constant knock-on effect. Growth gives rise to more growth as different aspects of progress interact.

It is thus easy to link the development of railways to that of the iron and steel and metallurgical industry. At a time when rails had to be changed around once every two years, rail manufacturing became a market that would generate significant progress in the production of cast iron (which in 1840 already stood at an annual 54 kg *per capita* in Great Britain!) but above all of steel (with the Bessemer converter and rolling mill, etc.). This also had repercussions for coal production, which as we know was instrumental in development of the first locomotives, but also of the first steam engines such as the one invented by Newcomen, several decades before that of James Watt.

1.1.2. Innovation in transport: a major factor in growth?

Economists and historians have devised many ways of accounting for the quickening pace of change witnessed in the 19th century, especially with the advent of railways. It should first be borne in mind that the years following the Napoleonic wars were not very conducive to economic growth. It was in this period that Ricardo developed his concept of “stationary state”. As activity had been artificially stimulated by expenditure on war, the iron law of diminishing returns would reassert itself, thereby limiting the likelihood of population growth. An idea which was then developed by another “pessimistic” classical economist, Thomas Malthus. In this respect, the factors of production belonged to a world that was “finished”. But at the same time, yet another classical economist, Jean-Baptiste Say from Lyon, was more optimistic about the potential for sustainable growth, and the 19th century demonstrated that his was the right judgement.

*** Cliometricians create controversy**

But what developments around the years 1820-30 were responsible for progress beyond the critical point at which economic growth becomes an irreversible and sustained (though not necessarily a regular) trend? Interpretations differ. Some have highlighted the growth of international trade which was arguably a powerful factor in raising production levels. Others stress the importance of technical progress and the driving role of transport and rail transport in particular (F. Caron). This insistence on highlighting a key factor has obviously been of interest to cliometricians, *i.e.* those economists who view economic history as a subject governed essentially by the categories of economic analysis and the possibility of performing statistical tests on databases.

They have thus taken an interest in the theory regarding the key role of foreign trade, which they have dismissed. In the view of such specialists who tend to reason in terms of constant returns, this would only have been possible in the event of chronic under-utilisation of production capacity, which did not apply to a world still widely affected by shortage. In the same vein, the principal exponent of cliometrics, Robert Fogel (Nobel Prize for Economics), has challenged the argument that transport and in particular the railways played a driving role. Developing a “counterfactual” historical rationale, he sought to construct a model of what 19th century economic growth might have been without G. Stephenson and his followers. He did so by using what were moreover tried and tested methods involving measurement of the contributions of various sectors of activity to economic growth. Thus what would have happened if there had been no relative fall in prices or no rise in the transport speeds made possible by the railway revolution? **In modern economic terms, what would have happened in the 19th century if general transport costs had remained at the same level as then incurred by road and inland waterway transport, as well as sailing ships**?

R. Fogel’s answer was simple yet unexpected. In his view, the part played by the railways was in the final analysis a minor one. Without them, economic growth would not have been very different. Goods would have moved more slowly and improvements in living standards would doubtless not have been spatially distributed in the same way. Yet this would have been of just secondary importance. The thrust of his argument sought to demonstrate that railways are primarily a facilitator but cannot account for the central phenomenon, namely the growth of production capacity in agriculture and industry. Bringing areas of production closer to market areas has little impact on circumstances without any increase in production capacity. Committed to supply-oriented economic analysis, cliometricians have sought to demonstrate that the availability of railways was only a minor aspect of the overall revolution in supply that the 19th century experienced.

To claim that the work of R. Fogel was widely discussed is an understatement. Numerous historians and economists (including P. Chaunu, B.Rosie and P. Dockès) fiercely objected to the very principle of counterfactual history. Working assumptions as unrealistic as the absence from the constructed model of a key player in the 19th century, the railways, finally brought the feud between economists (cliometricians?) and historians out into the open.

*** Escaping from the fetishism of innovation**

In some respects, **the conclusions of R. Fogel also constitute a challenge for us. By attributing a secondary role to railways during the 19th century, are they not suggesting that the very idea of seeking the driving forces of innovation in transport is pointless**? If the impact of such innovations is in the end only a minor one, why worry about them? The question is important not because it invalidates our work, but because it helps us get it on the right track.

In order to understand it, the role of the railways should not be dismissed but kept in perspective. This simply means focusing on what happened in the preceding period, the 18th century, in which there was also no lack of innovation, particularly in transport. The epic of the railways should not obscure the major transformations of earlier decades, especially in Great Britain. At a time when, as historians have said, “water shortened distances and land made them greater”, canals developed very rapidly. Several thousand kilometres of waterway were opened in Great Britain but also in France, Belgium and the Netherlands. Contemporaries (A. Young) noted how far these changes had already affected the marketing of goods, and especially grain. Neither should it be forgotten that the 18th century witnessed the development of thousands of kilometres of private toll roads in Great Britain. Even though Adam Smith emphasised their poor quality in relation to an often high price (already betraying distrust for monopolies!), this does not alter the fact that these roads had also significantly shifted the horizons of producers and consumers. Progress in means of transport had therefore already occurred before the arrival of railways, which highlights the important role of transport in general but also the fact that railways are just one method of transport among others.

In the descriptions of this period by historians (J. Brasseul), the same observations are apparent as those so clear in the case of the railways. Improvements in transport played a key part in the growth of the agrarian revolution and the exploitation of agricultural land resulting in the enclosures movement to which Karl Marx attached such importance. This point helps us understand the significance of R. Fogel’s message for the present discussion of the driving forces of innovation in transport. Without embarking on any methodological debate on the legitimacy or otherwise of counterfactual history, it may be stated that **economic growth is a global phenomenon which should not be too mechanically linked to one particular factor, even in the case of a revolution as consequential as rail transport**.

There is indeed a risk of fetishism or at the very least of oversimplification when considering the issue of the beneficial effects of innovations in transport. Such fetishism has to be attributed to a conventional view of technical progress (Schumpeter 1), dominated by discontinuity, the role of inventors capable of imparting an exogenous stimulus. The modern form of this oversimplification is to be found in the excessively invoked concept of structural effect. On the basis of the improved access that might be miraculously created by a new motorway or a high speed train, some claim that production and employment is going to grow, and that the gains in GDP one is entitled to expect might even be measurable (J. Poulit)! This kind of approach should be viewed with caution. Transforming the transport system into a potential horn of plenty is a mistake, which R. Fogel sought to expose through performing by way of caricature the diametrically opposite exercise in which the supposed cornucopia disappeared!

It is clear, therefore, that we are not looking in the transport sector for the magic wand which might tomorrow bring us the renewed growth that many are seeking. **We are not looking for the driving forces of innovation in transport to uncover some kind of technological miracle**. We are simply going to consider how technical progress in transport is part of a general trend that we now need to examine.

1.2 From technical progress to innovation: the "endogenisation" of technical progress (Schumpeter 2)

In 1942, Joseph Schumpeter published *Capitalism, Socialism and Democracy*. Three years earlier he had published his theory of *Business Cycles*. The analysis of technical progress and innovation in both works is significantly different from that of 1912. It is one on which there is now quite broad agreement, especially within the evolutionary school of thought (C. Freeman, G. Dosi, D. Foray), and views innovation as a collective, endogenous and continuous (though not necessarily regular) process, as emphasised by the shift in meaning that leads from "invention" to "innovation", from the inventor to the research laboratory. This change will be illustrated with reference to a few of the innumerable innovations that occurred in the transport sector during the 20th century. It will be noted along the way that "product innovations" (the locomotive or motor car, etc.) are not the only ones. They have to be viewed in conjunction with "organisational innovations" (**1.2.1**). On this basis, we shall highlight the now central role of organisations (firms) but also of law and institutions which may have ambivalent effects on the innovation process (**1.2.2**).

1.2.1 Multidimensional and incremental innovation in transport in the 20th century

The relation established between revolution in the transport sector and industrial revolution is not applicable solely to the 19th century. Technical progress did not come to a standstill with the railways. Indeed, from the start of the 20th century, they were in competition with road transport (*i.e.* cars but also, from the outset, utility vehicles) and then later with air transport. Both these modes exemplify one of the driving factors of innovation in transport, namely greater speed, but also reliability and frequency. However, as far as the driving force of innovation is concerned, the century which saw the advent of the motor car and aircraft was not simply one involving pursuit of the underlying gains of speed. **It was also one in which technical progress became a complex form of social production, such that a given means of transport was reflected in a mix of components involving an increasing variety of technical and scientific fields.** Thus in considering a few products that were outstanding examples of innovation in transport in the 19th century, we shall be investigating what happens at an earlier stage than innovation itself, and how it emerges in a world in which technical and scientific activity are increasingly interdependent.

*** Innovation and lifestyle – speed and the enhancement of personal activities**

One decisive innovation of the motor car accounts for its success and the corresponding decline of the railways, namely its ability to provide "door-to-door" transport. This still has to do, therefore, with the issue of the speed of transport and – more specifically – the general cost, which here includes the cost of possible intermediate transfers of passengers or goods from one mode of transport to another. For users, cars represent a major revolution as they satisfy the enormous variety of needs in terms of individual movement while providing unprecedented door-to-door speeds with no intermodal transfer. While railways could reach certain kinds of destination in less time, a considerable share of daily transport in the first half of the 20th century was still undertaken on foot or with horses. The general spread of motor cars along with the development of a tarmacked road network[2], radically transformed lifestyles in urban and rural

2. For several years, one of the main barriers to the development of motor cars was the dust they generated on the earlier metalled roads. Drivers and residents were blinded by clouds of dust whenever a car went by.

areas. For the simple reason that, unlike rail, road offers its users a speed which is roughly equivalent to a train's over a range of 360 degrees[3]. Thus, in virtually all forms of daily travel, average speeds increased by a factor of 5, 10 or more.

As a result, there were major transformations in the use made of time and space. Towns and cities became more spread out, while the siting of residential and recreational areas, as well as those for the distribution and production of goods, was partially freed from the former constraints of urban density. While at the beginning of the 19th century, Americans travelled around 4 km/day, they now cover distances 15 times as great (over 85% of which involve the use of cars), thereby considerably enhancing the scope of their activities. This is now a basic real aspect of human existence, which typifies modern lifestyles. A simplistic reading of Zahavi's hypothesis, which states that travel time budgets remain fairly constant over time, might lead us to believe that gains in speed have in no way affected contemporary lifestyles. Since the time gained through greater speed has been reinvested in further distances, the result might be a zero-sum game! Yet the distances concerned are not covered at random. **As a result of speed, the greater distances and variety of the destinations to which we travel lead to more varied and rewarding programmes of activity which become driving forces behind the demand for innovation in transport**.

Also to be borne in mind are all those innovations that have altered our perception of travel time, through making it useful in its own right. While car radios, global positioning systems (GPS) or mobile phones (with "hands free" kits!) are not innovations confined to the realm of transport, they have lowered our estimates of travel costs. They are indeed a first example of the multidimensional and incremental nature of innovation for users, offering an initial insight into what may become the fresh needs of the years ahead. There will perhaps be less concern with achieving increasingly costly gains in speed, than with providing for optimal use of that scarce resource, time[4].

*** Innovation and production: transport as part of the norm**

The issue of radically altered lifestyles is thus crucial in understanding the key role of innovation in transport. Yet it should also be clear that **the civilisation of the motor car is indicative, at an earlier stage than the actual finished product, of a different kind of process underlying innovation in production, which is itself also becoming multidimensional and incremental.** To realise this, one has only to compare the legacy of Stephenson (father and son) and Ford (father and son). Ostensibly, we have two ideal types of inventor – of the locomotive and the Ford Model T respectively – separated by a period of almost 100 years. Yet the difference between them is substantial. Henry Ford did not "invent" the motor car as a product. On the other hand, he did develop two major and complementary "organisational innovations", namely the assembly line and the fairly cheap motor car. This is a typical example of innovation regarded as a complex process in which consumers have a part to play just as much as engineers or researchers.

These new complex, multidimensional and incremental dynamics in innovation are not confined to the transport sector in general and motor cars in particular. In this process, car manufacture is really no different from other sectors of activity. Like them, it requires ever greater numbers of technicians, engineers and researchers with increasingly specialised expertise who have radically transformed motor cars in just a few decades. Although their use remains unchanged, there are extraordinary differences between the Ford Model T of the 1920s and the models turned out by Ford factories today. Car manufacture has become an assembly

3. As an example, the road network spreads across 1 million kilometres, whereas the rail network limits itself t 30 000 km.

4. One of the trends which is now making motor cars a little obsolete and restoring to favour certain forms of public transport is the fact that time spent in the latter may be more productive when one can use computers or mobile phones.

industry. The growing contribution of electronics and computerisation, the far greater variety of materials and the increasingly specialised production lines peculiar to each component have even led to the belief that car manufacturers might eventually have no factories, merely affixing their maker's name on vehicles that have been assembled and even devised by others. While this stage has not been reached, this does not alter the fact that innovation, like production, has become a compartmentalised activity. Sub-contractors now play an important part in helping car producers to innovate. These innovations relate to matters as varied as windscreen wipers, air conditioning, types of engine, aerodynamics, tyres and bodywork, etc.

Yet no-one recalls the name of the men and women who initiated these innovations which have become collective – and thus impersonal – acts of production. The rationalisation and institutionalisation of innovation processes have become the norm. This is the condition enabling innovations to be perpetuated in continuous existence at the heart of economic growth in general and the transport sector in particular.

With a certain time lag vis-à-vis the car, the same mechanisms apply to air transport. In both cases, there has been a shift in just a few decades from the age of pioneers, the individual inventors, to that of joint developers. Who now knows the name of the engineers and researchers who developed the Boeing 747 or the Airbus A 380? Posterity will remember Neil Armstrong, the first man to have walked on the moon. But the success of this mission was attributable to NASA, an organisation, rather than one individual.

Another way of demonstrating how collective and incremental progress has achieved supremacy over individual pioneering and sudden radical breaks with earlier technology is to compare the fortunes in France of the hovertrain project[5] devised by the engineer Bertin, and the development of high speed trains. The hovertrain attracted considerable publicity in the 1960s and 1970s, as the mode of transport of the future. Yet it could not compete with the demands for mass transport over long distances, which the high speed trains can satisfy while still using conventional railway tracks at the beginning and end of each journey.

The same example also serves as a reminder about an important phenomenon in the innovation process, which specialists refer to as "path dependency". The more varied the history of innovation becomes, the more it tends to point in a certain direction. Once a technological process or mode of transport has established itself, it is not readily abandoned. This is one of the main reasons for the often incremental nature of innovation. As it is hard to start entirely afresh in a sector in which infrastructure bears a heavy share of expenditure, research focuses on the best way of improving what already exists. The success of high speed trains, at least in some countries, is linked to their capacity to use the new railway lines, at high speed, and the standard railway lines, in particular to access city centres. Conversely, it is one of the difficulties faced in developing magnetic levitation trains. Their development costs are enormous and the space available to operate them has become scarce or even non-existent.

1.2.2. The key part played by organisations in ensuring the full development and expansion of technical progress

One cannot therefore conceive of innovation at the end of the 20th century as if the world was still relatively unpopulated and had experienced very little technical progress. The legacy of two centuries of major innovations has to be taken into account. For this purpose, it is necessary – as Schumpeter suggests – to focus our attention on firms and especially the biggest firms now at the heart of the process of innovation, research and development. Firms act as conveyors of past progress towards future innovations; they can heighten or slacken the tempo, and accept or reject certain options open to innovation.

5. The hovertrain was a vehicle that travelled on a cushion of air over a concrete monorail. Like Concorde, developed in the same period, it could carry no more than around 100 passengers. It was propelled using the same method as hovercrafts.

*** The time, size and structure of markets**

Focusing on firms means repositioning them in the context in which they evolve with due regard for the time, size and structure of markets. In this respect, firms cannot be regarded as black boxes (Rosenberg), or simple agencies of production reliant on both work and capital while drawing for their ideas on a reservoir of technical possibilities "available on the shelf", so to speak. The hallmark of innovation at the heart of a firm is precisely its ability to create new products or new combinations of factors of production, which will place that firm at least temporarily in a virtually monopolistic position.

Air transport offers an illustration of this kind of innovation. When a few companies confronted with the deregulation of air transport decided to pursue a *"hub-and-spokes"* rationale, they did not innovate in the realm of aircraft as end-products. However, by devising the best possible transport connections, and concentrating huge numbers of arrivals and departures at well-situated inter-connection hubs, they helped to develop air transport while also gaining at least temporarily a comparative advantage[6]. Similar reasoning might apply to the low cost companies whose success derives partly from limits to the use of hubs by big companies. Yet what is of interest in both cases is the relation between innovation and time. Once an innovation has been successfully launched by a pioneer (whose role is far from obsolete!), it gives the firm a lead in time over others, which ensures that it secures the equivalent of monopoly profit.

It is here that the modern rationale of the firm becomes truly operational, since the foregoing lead will extend itself all along the learning curve. If the firm knows how to preserve its innovative outlook and develop the teams required, it will be able at least temporarily to maintain its lead. While the more the market structure is monopolistic the easier this will be, the benefit to the community will also vary. For the downside of an innovation process developed by monopolistic or oligopolistic firms is the disappearance of the incentive provided by the arrival of new competitors. Thus the instructiveness of Schumpeter's theory of innovation by firms enjoying a virtual monopoly should not obscure the possibly undesirable effects that may stem from it. The "quiet life" that J. Hicks refers to may well be the unspoken aim of monopolies.

The wave of deregulation which has affected the transport sector and network-based industries in general since the end of the 1970s thus reflects the principle that innovation requires incentives. Yet these incentives cannot be provided where there is pure and perfect competition in a market in which firms, like consumers, are many and similar to each other with no market power. On the contrary, the overall effectiveness of the system calls for the presence of big firms usually with increasing returns, which are thus natural monopolies. While this is self-evident in air transport, it applies to rail and maritime transport too. As soon as competition has begun anywhere, it has given birth to large-scale entities, or even partnerships, which dominate markets. Although this very concentrated structure clearly has its risks, it is necessary if markets are to achieve substantial size and the increasing returns that go with it. The issue of innovation thus has to be expressed in a new way. Here, interest is no longer focused on a product or even an organisation, but on a system and its development over time.

6. It is worth remembering that the use of hubs in air transport was first introduced for freight by the founder of Fedex, M. Levy, whose teachers thought his ideas were ludicrous when he described them. Pioneers thus still have their place!

*** Towards an innovation cycle?**

In considering the need for a systemic approach to innovation, the intention is to challenge an excessively linear perspective. As has already been noted several times, the continuous nature of technical progress does not mean that the process is regular. If one accepts the research done by Utterback and Atternaty (1978, quoted by Le Bas, 1995), such progress goes through phases which are directly linked to market structure and various forms of dominance. According to these authors, one may identify three phases, each fairly well exemplified by the transport sector.

- Phase 1 is an uncoordinated stage. In it, competition is very real and production processes are not yet standardised. Product innovations are dominant. There are many of them but, given that demand and supply are low, optimal organisational processes remain unclear. At present, electric car production typifies this kind of situation. There are still many uncertainties surrounding the size of the market, battery technology, the required forms of marketing, and the distribution and invoicing of energy, etc. The situation is an unstable one governed by uncertainty. Innovation is thus often a gamble which may be lost.

- In the second phase known as the segmental stage, a few products come onto the market. As a result, mass production can get under way with the development of increasing returns and some degree of product diversification to distinguish firms from their competitors. Process innovations steadily assume dominance as particular products now become consolidated. With its hybrid vehicles, Toyota has for some years tried to adopt precisely this kind of approach which, despite the difficulties it is currently facing, potentially gives it a lead in time over its competitors (the learning curve) and the chance to benefit from increasing returns in a huge market area.

- The third phase is referred to as systemic. Standardisation reaches an advanced stage which limits the likelihood that innovations (and therefore competitors) will significantly alter the prevailing situation. The market is in some ways closed to other competitors for several years. This applied to innovations for the production of the Ford Model T. Air transport also experienced this kind of situation, initially with the DC3 whose final technological characteristics later became features of the entire sector. Naturally, the third phase is not without risk for the community, in terms of a slackening of either product or process innovation.

But any such risk is also an opportunity given that, when the innovative strength of organisations loses its momentum, this creates prospects for new players. The key question in terms of the general interest is a simple one. **If the innovation process in transport is to be sustained, what mechanisms are needed to ensure that firms retain both their keenly motivated obligation to innovate and their ability to do so?**

2. Transport and innovation from the 20th to the 21st centuries: between the ambitions of organisations and the constraints of abundance

The concept of innovation cycle helps us to understand the current situation. What is now characteristic of technical progress in general and the transport sector in particular is the coexistence of various phases in that cycle.

- Certain areas are still at the uncoordinated stage involving industrial design, which is governed by uncertainty and product innovation (the electric car).

- By contrast, others have reached the systemic stage, which ensures that they will still secure passively many market opportunities, but simultaneously makes them seem somewhat obsolete. This applies to cars powered by heat engines and more specifically cars produced in the USA, as the crisis experienced by General Motors or Chrysler singularly demonstrates.
- As to the activities characteristic of the segmental stage, in which process innovation gradually supersedes product innovation, they are less in evidence, which creates the impression that technical progress in transport may be going through a period of decline.

More generally speaking, we might analyse innovation in the transport sector in the same way that economic analysts anticipate periods of growth, crisis and recovery using advanced indicators. For this purpose they observe the relative situation of different branches of activity and, depending on their position in the production line, are able to forecast the trend in the next few quarters. Can we proceed in like fashion? Is it possible for example to state that innovation is obviously slowing down, if many components in the transport sector have if anything reached the third phase in the above cycle? If high-profile products in the railway, motor car, maritime and air transport sectors are not going to change significantly in the years ahead then we are getting closer to a “finished” world.

Yet nothing precludes an examination of new products and new needs in the transport sector, which points not to an asymptotic trend in technical progress, but its ability to respond in a new way to individual and social requirements that will not be the replica of those in previous decades. This will be demonstrated first by considering how public policies may generically and – in the case of transport specifically – encourage research and innovation (**2.1**). Then, in focusing on the transport sector, we shall hazard a few thoughts as to what might be the major innovations in the sector in the years and decades ahead (**2.2**).

2.1. The role of public policies: ambitions and constraints

One of the major changes distinguishing the present period from the one in which the railways came into being is the central role now attributed to the state. Whether circumstances or structure are at issue, the public authorities are omnipresent. The wave of deregulation that occurred in the 1980s and 1990s has not changed the situation, although this was one of its aims. In the realm of innovation, as in many others, public initiative continues to play a key role (**2.1.1**) which the new pressures imposed by sustainable development are only strengthening (**2.1.2**).

2.1.1. The range of public policies and how they relate to private research

Technical progress and innovations do not occur overnight. As has been noted, they are the outcome of methodical effort on the part of organisations, and particularly firms, which increasingly rely on research laboratories, given the growing technical aspects of products and production processes. One can thus measure the effort invested in achieving innovation and implement the appropriate public policies at macro- as well as meso- and micro-economic levels.

*** From endogenous technical progress to endogenous growth**

The fact that technical progress may be viewed as endogenous has logically prompted economists to view economic growth itself as endogenous. This implies that growth depends on the gains in productivity stemming from technical progress, which themselves may be related closely to expenditure on research and development (R & D), though not exclusively so. One of those who pioneered the concept of endogenous growth, P. Romer, has thereby demonstrated that educational expenditure was a factor conducive to economic growth. Many econometric studies have addressed the question and shown that there was indeed a direct relation between economic growth and the level of expenditure on research or education.

This has had the effect of reviving key concepts in public economics, such as external effects and collective goods, but also increasing returns. These categories characteristic of market failures are thus also a call to public intervention. If public administrative authorities do not assume responsibility for certain kinds of expenditure on research or education, private interests – whether firms or households – will not implement them, as they are collective goods from which all may benefit without having to bear the cost. This applies for example to basic research, as well as a share of applied research.

It is therefore unsurprising to note that the industrialised countries, which seek to sustain this endogenous growth, have set themselves goals as regards the share of research expenditure in GDP, or the proportion of researchers in the working population. Europe refers to the Lisbon Protocol recalling the city in which European countries firmly agreed to place economic growth on the route towards the knowledge economy. Yet the endogenous nature of technical progress and growth does not guarantee that they are automatic or determine their relative significance. Public policies have thus focused attention not just on the vast amounts of public and private money earmarked for research and education but also on how certain special organisations such as universities function. Hence, the Bologna process has standardised academic programmes. Almost everywhere in Europe, the operation of research centres is becoming standardised. Regular evaluations of individuals as well as institutions take place. The allocation of funding to research laboratories is becoming increasingly less recurrent. They are having to fund themselves by replying to calls for tender from national agencies whose priorities are fixed at a political level.

Transport constitutes one of those priorities and public funding has been fairly broadly committed to it in support for research. At European level, the funding earmarked for transport under successive EU Framework Programmes for Research and Technological Development represents billions of euros. National transport programmes also frequently exist, at least in the big European countries. For example, in France, the PREDIT (a research and development programme for innovation and technology in land transport) has received almost EUR 400 million for the period from 2008 to 2012. In the USA, California is developing its own CALTRANS (California Department of Transportation) programme. Everywhere, the leverage provided by public money is sought systematically by linking private and public research funding. Far from being forgotten, firms are even at the centre of this activity.

*** The firm and its environment**

Innovative firms do not come spontaneously into being. They develop in an appropriate environment. Since the pioneering research on “clusters” by A. Marshall, it has become clear that the institutional, cultural, fiscal or scientific context, not to mention the economic one, plays a central role in the emergence of innovative firms. The economics of innovation has thus become an active branch of economic analysis (Le Bas, 1995) through focusing in particular on mechanisms conducive to innovation and on indicators that should be used to define situations that are more or less favourable.

The subject has been approached from many different angles. Much of the research has dealt with comparative trends in the number of patents taken out by sectors of activity or area. Other studies have sought to define and measure accurately R & D expenditure to a greater or lesser extent, so as to test econometrically the relations observed, for example, between R & D expenditure levels and the size of firms. Size has thus re-emerged as a critical issue. This is not because small and medium-sized enterprises are unable to spend money on research. Indeed, in certain dynamic sectors such as computer science they do so on a significant scale. Yet in many cases and especially in the transport sector, a critical size is vital in order to commit to research the enormous sums it needs.

Centres for competitiveness, the *Grand Emprunt* ("big loan"),
university reform, taxation, etc.
France pulls out all stops!

To illustrate the race for knowledge which the major industrial countries have all joined, a selection of measures taken in France in recent years is set out below.

- In 2005, the centres for competitiveness were initiated to stimulate constructive forms of interaction at local level between the worlds of industry, research, and the regional and local authorities. Following a national selection process regularly updated on the basis of evaluations, many such centres have been established, several of them concerned with transport.
- In 2005 the *Agence nationale de la Recherche* (National Research Agency) was also inaugurated. It established throughout the country public funding for specific programmes rather than recurrent funding. However, 25 000 public servants are still employed by the CNRS (National Council for Scientific Research) and in the universities, the vast majority of which are public institutions.
- In 2007, a tax reform was introduced enabling firms to reduce their tax burden significantly by committing expenditure to research.
- In 2007 too, a law reformed the activities of universities so as to increase their autonomy, especially as regards private fund raising, but also and above all by granting them considerable freedom in the area of recruitment and salary levels, etc. They were thus gradually encouraged to adopt a competitive outlook.
- In 2009, a national debate was initiated on the scheme for a "big loan" (EUR 30-35 billion) to fund investment capable of ensuring long-term economic growth. What has counted here is not the idea of borrowing (the state already raises almost a billion euros a day on the money market!) but the fact that there should be public discussion to fix politically the priorities of public research expenditure. **A commission chaired jointly by two former prime ministers was appointed to identify priorities. It is significant that it has excluded transport infrastructure from its terms of reference. It has decided to use almost a third of the sum to provide capital for certain university campuses. Research expenditure on transport strictly speaking (decarbonised vehicles, new types of aircraft engine, etc.) gets only around a billion euros. However, it is also significant that transport is an indirect recipient through research expenditure committed to the fields of energy and new materials, etc.**

Public policies to support research are not therefore merely supplementary policies aimed at reducing taxation or modernising university campuses. They are also relevant to what a few years ago were termed industrial policies. As has been witnessed in the USA with the nationalisation of General Motors (2009), in France with the recapitalisation of Alstom (2003) or in Germany with the generous public funding announced for Opel, the large states are fully aware that their research potential is also dependent on their array of large-scale firms in promising sectors. But is transport still such a sector?

2.1.2. Environmental constraints: towards the emergence of inconvenient innovations?

The issue of transport infrastructure to which reference has already been made is a prime example of the new situation now confronting the transport sector. Indeed, it is now required not simply to innovate generally, but to innovate to lessen its impact on the environment. **Where engineers would like to promote the positive external effects of innovation in transport, the response of citizens and electors is increasingly to require innovations to reduce its external costs**. **They do so without always appreciating the sometimes inconvenient nature of the innovations involved**. Schemes for new motorways or high-speed railways no longer capture the imagination. They tend to be presented as a necessary evil and generally face increasingly determined opposition. Viewed in this light, innovation assumes a new meaning which takes refuge, since it is far from clear, behind the concept of "green growth". And by the same token, innovation in transport lacks the same attractive power as innovation in new information and communication technology.

*** Innovation and "green growth": towards a "Ricardo effect"?**

All big firms, and especially those in the transport sector, have established a directorate of sustainable development. All of them highlight their determination to promote sustainable growth, sustainable energy and sustainable mobility, etc. So much so that this refrain sometimes seems dubious and prompts reference to "green washing" by way of criticism. The same applies at the level of states and international organisations, whether governmental or non-governmental. Sustainable development and sustainable transport are at the forefront of the national and international agenda. The Copenhagen Summit, in spite of its near-failure – or perhaps because of it – represented a key stage, a frightening awareness to the point that it failed to get to grips with these issues. Yet the fact that the heads of state and government could not agree on a credible programme in no way obviates the need for the changes that require us to act. Whether gradual or revolutionary, the reason they are hard to achieve is that the deliberately watered-down concept of "green growth" obscures realities which do not necessarily cast innovation in a pleasant light.

To sell the notion of "green growth", one generally describes its positive effects: on employment, first of all, because new jobs will be created; then, of course, on the environment since soils, water tables and the air we breathe will be protected or regenerated; and, finally, on health because pollution will be limited. Yet less is said about the other aspects of "green growth" which tend to look more like constraints.

- The most conspicuous is that of taxation and pricing. The "polluter pays" principle is not easy to enforce and acceptance of its implementation cannot be taken for granted. Al Gore's film was widely welcomed but how many people actually favour a carbon tax?

- The second is very familiar to business managers and private individuals alike. It obliges them to change their routines and behave differently in a way that is more responsible but also more constrained. It is apparent in all the regulatory restrictions that are already enforced and set to become more pronounced. In the face of global environmental pressures, it is as if at any given time in our daily lives we had to be concerned about the possible negative external effects of our decisions. This is far from the "invisible hand" of Adam Smith who could blandly state that the general interest was served if butchers made do with seeking their own particular interest. The innumerable external effects constantly surrounding us could not be reduced to a few distant state measures for internalisation. When the state acts, we are increasingly made aware of it with a view (for example) to increasing road safety or limiting the use of cars in highly populated areas.

- A third negative aspect which is less conspicuous but more significant still should be mentioned. It concerns another classical economist, David Ricardo, and more specifically to what F. Hayek termed the "Ricardo Effect". Taking his cue from the English economist, the Austrian economist used the term to describe situations in which the production process became cumbersome. When extra capital is needed for a fixed amount of final consumption, we reach a situation of diminishing returns whose reoccurrence Ricardo feared. In modern national accounting terms, this means that measures to protect the environment might increase Gross Domestic Product, but not the Net Domestic Product also called national income.

In some respects, it is therefore not surprising that just when President Sarkozy committed France to the path of "green growth" with the "*Grenelle de l'environnement*" (a long-term environmental planning project), he asked a committee of experts chaired by Nobel prize winners A. Sen and J. Stiglitz to consider a benchmark other than GDP for assessing well-being and national prosperity. Very judiciously, the committee showed that indicators other than GDP were very important (among them education, gender equality, income inequality levels and access to health care, etc). Yet this does not alter the fact that the doubtless inevitable slowdown in rising individual living standards will be a formidable challenge, if only given the risk of growing inequality that generally characterises periods of weak growth. Ricardo's "stationary state" was not an egalitarian society, since rentiers occupied pride of place in it!

*** Inconvenient innovations and disillusion with mobility**

The probably slackening rate at which individual incomes will increase is not the only unexpected effect of the constraints associated with sustainability. There is also a need to consider points arising from the general acceptance of certain norms, which results in innovations that may be termed irksome if not untimely. Consider an extreme example. When the managing director of Ryanair, Michael O'Leary, states that he would find it innovative and profitable to remove toilets from his aircraft or charge for their use, he is from his own angle merely extending the principles of cost and price control on which his company has flourished. There is thus a certain consistency in his reasoning, which should not lead us to forget that all principles have their limits!

The reason for citing this extreme example of disillusion in the light of what air transport could be in past times is that the world of transport is today more generally faced with disillusion concerning ongoing or pending innovations. Innovations in transport are indeed not only about new aircraft or decarbonised cars. Others concerned with regulations, fares or pricing and taxation also seem inevitable. Consider a few examples:

- Speed limits and the increasingly close surveillance that goes with them are obviously of benefit to the community in terms of greater road safety. But this will change our relationship with cars and technical innovation, particularly when the surveillance is performed by GPS installed in our own vehicles!

- It is these same GPS which may be used as identification devices for highway toll billing not necessarily limited to urban areas. The German Toll Collect system is an innovation incorporating many different aspects (technical, regulatory, tax-related, etc.), and will be taken up elsewhere.

- One aspect of these urban toll systems is that they generate income for the community which itself has substantially to subsidise public transport in the process of rapid development. However, when one moves from individual cars to public transport, however innovative, public expenditure (on operation, safety and maintenance, etc.) is substituted for private costs. However essential, innovation in urban transport represents a kind of burden on the urban production process, a local form of the "Ricardo Effect" which becomes apparent through an increase in the tax burden.

- Of course, one might envisage a fall in the cost of public transport. Is it not an activity supposed to bring increasing returns? Yet while deregulation is indeed an innovation, it is not always welcome, either for employees in the sector concerned or for those who might follow them if it succeeds.

- Let us return to the case of air transport. What will be the repercussions for passengers of the innovation concerning tradable emission permits that has been announced? What will be the impact of it on ticket prices and on the density and quality of provision? Will it lead to a rationing process?

- The same fears are associated with carbon tax schemes. Bearing in mind the relatively low consumer elasticity with respect to fuel prices, will this tax have to be increased inordinately for it to have a real impact?

So much for this brief survey of the kinds of disillusion characteristic of the transport sector. Its purpose has not been to state that irksome innovations are untimely but simply to offer a reminder that **innovation in transport is not limited to what we might yearn for. In a world whose population is already over 6 billion and in which economic growth is continuing, especially in highly populated emergent countries, innovation also involves measures which, though conducive to mobility for the greatest number, will make it an ever less gratifying experience in its own right.**

2.2 The future of innovation in the transport sector: between disillusion and fresh enthusiasm

The scene is set. In this final episode in our retrospective and forward-looking discussion of the driving forces of innovation in the transport sector, the challenges faced are clear. Past innovations in the sector have been radical. They have led to a very significant increase in the average speed of our journeys. Yet the continued pursuit of this trend is unlikely to be conspicuous in the decades ahead. With the relative levelling out of average travel speeds, the demand for innovation will be more concerned with the quality of the service provided and processes for optimising results (**2.2.1**). From this come logical recommendations about the entities that take innovation forward, namely organisations and institutions (**2.2.2**).

2.2.1. Innovation and the optimisation of transport services

In national accounting, the transport sector belongs to the category of services rather than goods. Yet in referring to transport, one thinks primarily of goods, whether this means the items transported or, far more commonly, transport vehicles. This tendency explains why research into innovation in transport is concerned primarily with its medium, or carrier, such as a train, lorry or aircraft. Each of these has experienced – and continues to experience – definite progress which has however been concerned with aspects that are overlooked. Consider one example. A modern motor car compared to one in the 1980s contains innumerable radical innovations. Whether we are concerned with engine type, braking systems, on-board electronic systems, safety devices or other accessories, the progress achieved is spectacular. Such features have preoccupied thousands of researchers and led to thousands of patents. Motor cars have undergone more innovation over the last 30 years than in the preceding half-century. Yet there is a commonly accepted idea that today's cars have changed little in 30 years. This impression is attributable to the fact that vehicle speed, whether the maximum shown on the speedometer or the average shown on the car computer (yet another innovation!) has changed little. In fact, the latter has even slightly decreased in recent years.

This intensive focus on speed is a mistaken perspective. For reasons to do with physics, each mode of transport has its maximum, or rather its optimum, speed which cannot be overstretched under normal business conditions. Airliners cannot get too close to the sound barrier. High speed trains are unlikely to exceed 350 km/h by more than a very small margin if at all. Highway and motorway speeds are not set to increase. Gains in speed today do not therefore occur within a particular mode of transport but by substituting a fast mode for a slower one. Of course, one may hope for the emergence of new faster modes, such as magnetic levitation trains, supersonic aircraft and tourist spacecraft. Our grandchildren or their descendants will perhaps witness them and describe these new momentous developments similar to those of the railways. But to suppose that they will account for core innovation in transport is indicative of technical fetishism regarding speed.

The main innovations in transport will be less concerned with improving the speed of carriage than the quality and regularity of the service. Here are a few examples applicable to freight and passenger transport respectively.

*** Freight transport: the increasingly powerful role of information systems**

As far as freight is concerned, one of the main innovations in the past 40 years has been the container. It is a relatively commonplace product whose use first expanded during the Vietnam war, when the American army had to transport supplies to its troops and those of its allies. While this metallic box seemed somewhat inauspicious, it was central to a whole set of innovations which exemplify both present-day and future innovations in freight transport.

- The prime purpose of innovation is gradually to improve the service provided. This applied to the container. As a result of incremental improvements (refrigeration and controlled temperature, etc.), it was able to transport increasingly varied goods, including live animals.

- An innovation generally occurs in clusters, taking on board other components in the transport chain, and borrowing from aspects of science and technology outside the transport sector. As regards the container, therefore, other innovations came to enhance further its potential for market penetration. Here one might cite the development of increasingly huge container ships, the modernisation of ports, gantry ship loaders and container cranes, the adaptation of forms of land transport, and refrigeration systems.

- Innovation is also apparent in the organisation and management of transport flows. Container development called for the establishment of complex information systems. They included loading software to optimise the loading and unloading of ships, but also systems for monitoring the refrigeration chain and for goods monitoring, tracking and tracing, etc.

- A final aspect of innovation involves changes to goods themselves[7] so that they can be transported in a standard size 20-ft or 40-ft container.

The example of the container is a good illustration of how the improvements to be expected are not essentially concerned with speed. It is true that because of the increase in added value per ton of some products, air goods traffic will grow as a result of structural factors. Yet the great majority of goods traded worldwide will continue to travel by sea through ensuring shippers not maximum speeds but a precise period of time between dispatch and delivery. **The future belongs to innovations that will result in seamless transport. Innovation will therefore occur in the least visible part of transport, namely its information systems**. This explains why in the same way that the behind-the-scenes container has played a major part in the surge towards globalisation in the last 20 years, the bar code has also been a discreet but central player in improving the quality of service in transport and distribution. It is now tending to be replaced by so-called radio frequency identification systems (RFID), another example of a major yet low-profile innovation.

The central role of innovations has a further implication for the transport sector, namely that it becomes a sector that follows rather than drives. For example, it is the existence of tracking and tracing systems which obliges railway transport to adapt and offer its customers the possibility of monitoring the movement of goods. Similarly, it is electronic chips and RFID and GPS systems which necessitate adaptations to transport vehicles and their planned itineraries.

7. For example, it is now possible to arrange the container delivery from Canada of houses in kit form. All the items concerned have been accurately measured for packaging within the required volume.

Renewed interest in innovation in transport is thus the outcome of a contagious process involving the transfer and adoption of innovations from elsewhere[8].

As in the example of the decisive yet under-acknowledged progress with cars, this does not mean that technical innovations in transport are of little significance. Thus the development in the railway sector of new communication systems (GSMR, or Global System for Mobile Communications – Railways) or the introduction of the European Railway Traffic Management System (ERTMS), which brings automatic control still closer, constitute real breakthroughs. Yet they improve the service solely in making it more reliable, by encouraging more intensive use of the infrastructure. End-users are largely unaware of the full range of complexities involved.

*** Passenger Transport: the question of optimising transport time**

Passengers cannot be treated in the same way as goods. They possess a sense of what is useful to them, and compare themselves the costs and benefits of their journeys. The first part of this paper revealed how gains in speed represented such important advantages that the volume of traffic grew at the same rate as speed (Schafer). This continued preference for speed is the result of structural factors. Air transport is increasing everywhere, while in the most developed countries the volume of motor car traffic is levelling out. Yet the great majority of journeys are still – and will remain in the years ahead – journeys by road and public forms of land transport which, as already noted, have reached their maximum possible speeds. **Just as we bade farewell to flying scooters, so we shall now find it impossible to revitalise mobility on the basis of speed. We are therefore going to do so, as is already the case, by seeking to optimise the time we spend travelling**.

- Here again, the innovations concerned will be those providing for seamless transport, which once more means incorporating into transport systems innovations that originated elsewhere, including the provision of real-time information about traffic to passengers and smart card season tickets, not to mention improvements in frequency, changeover hubs for transport connections, and also perhaps intelligent roads and automatic vehicle operation!
- It is indeed important to make the most of transport time. Improved comfort and the possibility of accessing the Internet will become pressing demands.

Internet access in trains, as already exists in the Thalys (linking Paris, Brussels, Amsterdam and Cologne) or in some Swedish trains, is itself a major technical innovation which has mobilised a substantial and still continuing research effort. Yet all too often this is not regarded as an innovation in the transport sector, even though it is an important innovation in the service transport provides! This service must now satisfy not just our wish to go from A to B, but cater for the fact that our lifestyles have changed radically in less than 15 years with the general use of mobile phones and the Internet.

Just as the increase in average travel speeds has enabled us enormously to enhance the way we plan our weekly and weekend activities, so mobile phones and the Internet have radically changed our relationship with time and the world. Our contacts are now far more numerous, while our sense of usefulness is very strongly conditioned by our ability to stay "switched on". These are the circumstances to which transport will have to respond through innovation in the years ahead, along with the fact that this far more intensive use of time will lead to increasingly less tolerance of adverse random factors or other breakdowns. Innovation will thus have to satisfy these greater demands.

8. Europe introduced the Galileo programme – a typical instance of public support for innovation – as a result of the strategic role in many different sectors of positioning by satellite.

The issue of reliability in transport systems is both one of the requirements and one of the strong limiting factors in the development of innovation. This is very clear from the example of intelligent roads and automatic car operation in a research programme which already mobilised much money and brainpower in the USA in the 1980s. Many prototypes are still being developed with a view to combining the use of individual vehicles with public management of traffic flows. Yet given the technical complexity of this sort of system and the numerous aspects that have to be considered, including human behaviour patterns, reliability issues face one difficulty. General use of such an innovation presupposes that the risks of breakdown are very few indeed, which is not the case. The innovations geared to the introduction of intelligent transport systems (ITS) will doubtless be many in the years ahead. Communication between vehicles to prevent pile-ups, interaction between the road and vehicles to change their speed, and assistance with vehicle operations, etc. are all going to develop and radically change how cars are driven. Yet individual responsibility and risk will remain ever-present factors, with the result that information systems cannot in all respects replace what drivers themselves do.

2.2.2. Innovations and organisations: unexpected aspects of renewed interest in mobility

The transport sector needs innovation more than ever, since the mobility costs of people and goods are going to increase in terms of the two components of general cost. First, the monetary cost is likely to increase indefinitely as a result of rising energy prices but also of pricing and growing infrastructural costs. But the cost in time is also going to increase, not because speeds are going to fall but because in most modes of transport they will no longer rise notwithstanding the fact that both goods and passenger values of time are still going to do so. From this angle, waiting times, transhipments and delays correspond to times whose unit price value is higher than the average value of time. It is for this reason that the foremost requirement is for “seamless” forms of transport.

*** The need to concentrate on weak points in the transport chain**

To do so, we are going to need large-scale integrated organisations which, through the development of innovations in information systems, will be able to deliver increasing returns for transport services without necessarily increasing speed. Let us examine a few key points underlying this statement.

- First, transport is a service activity but it must conform to the principle of increasing returns. To do so, it must to some degree cater for mass flows which accounts for the large scale needed. In air or rail transport, small-scale firms may exist, targeting certain narrow sub-sectors of traffic and occasionally looking promising in terms of innovation. But the spread of innovation and its conversion into a collective gain requires the involvement of integrated firms for overall management of mobility.

- The management and improvement of information systems is crucial because it is here, rather than with regard to speed, that progress is most needed. Consider the case of aircraft whose operating speeds fluctuate between 600 and 800 km/h. Yet as A. Schafer (2009) has noted, if one takes account of the initial and final stages of a journey, the average door-to-door speed of transport by plane barely exceeds 250 km/h. Even if there were a significant increase in operating speeds, which is hard to achieve, this average speed would change little because it depends greatly on the initial and final low-speed stages. It is thus the latter which require improvement in terms of quality, reliability and capacity, since they constitute the weak points in the transport chain.

- Once again, **the all-important innovations will probably not be those that affect the transport vehicle but rather the system in which it is incorporated**. Consider the example of the high speed train. Many are very concerned about the risks of overcrowding on the Paris-to-Lyon line, which is also shared by trains travelling from

Paris to Marseille, and will soon be used for the Paris-to-Basle connection and later for the lines from Paris to Milan and Barcelona, etc. Yet this is not the key problem. Innovations are already in hand to increase the capacity of the line, to which the general introduction of double-decker trains has already contributed. A new line may also be constructed. However, the risk of saturation is greatest in the stations and in the management, cleaning and positioning of trains on arrival and departure, as well as – to an even greater extent – in controlling flows of passengers who today overcrowd the Lyon Part-Dieu and Paris Gare de Lyon stations. What innovations can be expected to help manage passengers and provide them with information? Should new stations be built? And how might they be linked to modes of transport providing easier access to them?

- The success of self-service bicycles (*Vélo'V* in Lyon and *Vélib* in Paris) is an illustration of how innovation in transport may come from large-scale firms fully proficient in the use of information systems, yet located outside the transport sector. The firms J.C. Decaux or Clearchannel invented neither the bicycle nor the idea of self-service bicycles. But by integrating rental procedures within an advanced information system and envisaging a cross-subsidy derived from advertising revenues, they have offered a multifaceted innovation which has been rapidly expanded. It is one which perfectly meets the need to optimise travel times in a world of individual mobility. The two firms have unexpectedly enhanced transport time, reviving enthusiasm through use of a slow mode which paradoxically enables time to be saved!

The issue of transhipments and the "final kilometre" is also vital in freight transport. In international maritime transport, the critical instants in the transport chain do not occur on container ships but in the ports and their links to the hinterland. It is here that innovations in information systems in particular have made possible the very rapid development of ports such as Rotterdam, Antwerp or Hamburg. In the same way, delivery over the "final kilometre", especially in urban areas, sometimes calls for regulatory rather than technical innovations. The implementation and supervision of authorised parking times and areas for delivery vehicles, urban logistical areas, vehicle fleet rationalisation, and environmental standards are among the regulatory innovations which can do much more to improve urban logistics than starting work on a new vehicle.

*** Innovation and right of ownership**

The fact that regulations are one of the factors in optimising the "final kilometre" in the transport chain is not the sole reason for their significance. In the dynamics of innovation, regulations and legal standards have long played a key role, as D. North (who won the Nobel Prize in the same year as R. Fogel) has emphasised. The patent system already existed in Great Britain when James Watt developed his steam engine. Indeed, it was just when the patent for the Watt condenser came into the public domain that Richard Trevithick in 1801 ran the first locomotive hauling small trucks of coal along rails. The protection of intellectual property is thus a powerful incentive to innovation, since it ensures financial spin-off for its originators.

It may also be regarded as a brake, a means for big firms of freezing certain innovations which might undermine captive markets. The field of software and computer operating systems is a recent example of this. It is therefore necessary for the public authorities to have an evaluation of the beneficial effects or otherwise of rights of ownership in certain areas. For instance, in air transport it is clear that the grandfather right of companies to airport slots is a barrier to the entry of competitive and innovative companies. Similarly, the technical standards established in railways are also a means of limiting the arrival of new competitors.

There is thus a need for regulatory action which, as it has to proceed by trial and error, should assess the ownership rights that require protection and those that may be challenged. Here administrative authorities face a new responsibility, which is associated with so-called economic intelligence and calls for the development of advanced and varied expertise.

General Conclusion

When the subject of innovation in transport is considered it often arouses nostalgia. As we look back at the past, we tend to miss the era of pioneers, the great inventions that propelled us into the modern world such as the train, the motor car and the aeroplane. These extraordinary machines captured the imagination and embodied a sense of freedom, whereas today we have to undergo exacting checks in airports, tread on other people in stations while waiting for our train to be called, ceaselessly watch the speedometer in our car and pay to park or even use it!

Disillusioned, we start hoping for radical innovations and new dynamics to develop the mobility of people and goods. There is a yearning for a return to this idyllic period in which technical progress quickened in pace along with the average speed of transport. Yet nostalgia is a poor guide as it results in mistaken reasoning and misleading parallels. In essence, our disillusion stems from the fact that we equate changes of speed in modes of transport with the speed of technical progress. Both were seemingly rapid at the time of the major innovations, whereas both appear slack today. Yet this view is mistaken.

- Technical progress in the 19th century was extraordinarily slow. However, because the base from which one started was very low, it led to substantial gains in speed. The first machines incorporating fire date from the 17th century, but it took almost 100 years for them to result in Watt's patent, while a further 60 would elapse before the arrival of efficient locomotives using the tubular boiler of Frenchman Marc Seguin. The innovation of the railway line (involving a metallic wheel on a metallic rail, which seems to defy commonsense given the risk of skidding or wheelspin) occurred several decades before the first locomotives. We were therefore already confronted with a process that was incremental and collective (Schumpeter 2) but whose slowness might suggest that it was individual and represented a breakthrough (Schumpeter 1).

- By contrast, innovations are appearing and spreading much more quickly today. They affect many sectors at the same time. It took several years for personal computers to leave the garage of a few pioneers and go into large-scale mass production. And then a few more for the Internet to provide for networking equivalent to an industrial revolution. These innovations also have a bearing on the transport sector as they enable it to develop what it needs, namely mass provision, reliability and regularity, etc. As a result, our transport systems and mobility have changed more in the last 20 or 30 years than in the half-century before that.

There is therefore a permanence surrounding innovation in transport, as well as a rate of expansion far greater than that of past centuries. However, to understand it one should not think solely in terms of gains in speed. A peak has already been reached in this area, in which we cannot expect marked progress where most of our travel is concerned. Because modes of transport such as the motor car or aircraft are becoming within most people's reach and mobility is occurring in an increasingly dense environment, we even have to face up to inconvenient innovations. Whether regulatory or price- or tax-related, they are one of the factors causing disillusion. Yet they are innovations for all that and we need them so that access to modern means of transport – far from being a dream – becomes a real experience for the billions of people who will inhabit the earth.

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