Introduction: Transport Revolutions Ahead

What Is in This Book

This book examines the kinds of change that motorized transport around the world could undergo during the next few decades. Today, 95 percent of this transport is fueled by products of petroleum oil, chiefly gasoline, diesel fuel and jet kerosene. We believe world oil production is on the verge of peaking and the amount available for use will decline progressively after about 2012. Meanwhile, demand or potential demand for oil could continue to increase, chiefly to fuel growing motorized movement of people and freight. A shortfall between what people want to use and what is available could cause petroleum prices to rise, perhaps steeply.

High oil prices, or even the anticipation of them, could cause at least four kinds of transport revolution:

1. *Now,* almost all transport is propelled by internal combustion engines. *In the future,* transport could be propelled increasingly by electric motors, using electricity that is increasingly generated from renewable resources.
2. *Now,* almost all land transport is by vehicles that carry their fuel on board: gasoline or diesel fuel. *In the future,* much land transport could be in electric vehicles that are grid-connected; that is, they are powered while in motion, from wire or rails or in other ways, because of the efficiency inherent in this means of providing electricity to vehicles.
3. *Now,* almost all marine transport is propelled by diesel engines. Their use will continue but with considerable assistance from wind via sails and kites.

4. *Now,* air travel and air freight movement have been the fastest growing transport activities. Soon, they could begin a continuing decline because there will be no adequate substitute for increasingly expensive aviation fuels refined from petroleum. Air travel and air freight movement will continue, but at lower intensities and mostly in large, more fuel-efficient aircraft flying a limited number of well-patronized routes, also with some use of partially solar-powered airships (dirigibles).

Four other factors could support and shape these revolutions:

1. Concern about pollution in cities, today caused mainly by the burning of petroleum fuels in vehicles, as we note in Chapter 4. Electric motors produce no such pollution at the vehicle.
2. Concern about how human activity, particularly transport, may be contributing to climate change, also touched on in Chapter 4. Vehicles using electric motors can be readily fueled from renewable resources that make no such contribution.
3. Concern with achieving sustainability, so that succeeding generations can have a reasonable measure of well-being. Sustainability requires reliance on renewable resources that can be as available in the future as they are today. Oil is not a renewable resource, but electricity can be.
4. Avoidance of international conflict over energy resources, which will become more intense as oil production declines unless strong steps are taken to reduce oil consumption, particularly for transport.

The four revolutions we explore in this book may not be inevitable, at least not within the next few decades. Enough oil *could* be found to maintain incremental growth in today's forms of transport activity. Petroleum-based transport fuels *could* be replaced by a to-be-developed liquid fuel that can be renewably produced in sufficient quantities. However, in our view, neither is likely to happen. After about 2012, as we will explain in Chapter 3, the world will enter an era of oil depletion characterized by progressively declining oil production. As we will explain in the same chapter, biofuels, liquids from coal and other products will nowhere near make up for the decline.

A more likely impediment to these revolutions will be lack of timely preparation. High oil prices will cause change, but the change will be

destructive if it is not anticipated, as occurred in 2008. In one of many dismal scenarios, car-dependent suburban residents who can no longer afford to refuel their cars, and have no alternative means to travel to work or buy essential goods, will have to abandon their homes or live at a subsistence level on what they can produce from their backyards. If a region dependent on food imports by truck can no longer afford the transport costs, and there is no alternative means of moving food, residents will have to rely on what can be produced in the region, which may be too little for the numbers of people who live there. There have been hints of such a scenario in part of the US over the last few years, as we shall note in Chapters 3 and 6 in discussions about how high oil prices may have contributed to housing woes.

Economic and social collapse is a real prospect if our oil-dependent societies do not prepare and implement workable plans to anticipate oil depletion. Then, there will be another kind of transport revolution, resulting in very much less motorized transport activity than humans now enjoy. This would be a transport revolution to avoid. Again, there have been hints of such a decline in transport activity and loss of amenity as a result of the rising prices of transport fuels during the last decade.

The four transport revolutions noted above could allow humanity to continue with at least the comfort and convenience of present arrangements—and quite possibly more. How people and goods move will be different, but they will still move, with all the benefits of such movement. Moreover, there will be fewer of the costs we accept today as being the price of progress such as transport-related poor air quality.

In Chapters 5 and 6, we discuss how transport-related preparations for oil depletion could unfold, with a focus on the US and China. These are respectively the most challenging among richer and poorer countries. We propose a process for initiating the required transport revolutions and offer some suggestions as to how matters might transpire during the first stage of these revolutions.

Four chapters prepare the ground for Chapters 5 and 6. Chapter 1 sets out what we mean by a transport revolution and looks back at five earlier examples to gain perspectives on what transport revolutions bring about.

Chapter 2 reviews current transport worldwide, including the movement of both people and freight. Much more information is publicly available on the movement of people, and we spend more time discussing

this matter. However, we note that in many respects the movement of freight is as important and deserves more consideration than we and most others have been able to give it. For both people and freight we discuss local movement and movement among cities, countries and continents, considering differences between richer and poorer places. We look at recent trends and current projections, and discuss some of the causes of the transport activity. Almost all of our discussion concerns motorized transport, but we do touch on cycling and walking.

Chapter 3 focuses on transport and energy. We begin by explaining why we believe oil production will soon reach a peak and then decline progressively, noting the likely role of rising oil prices in the 2008 recession. Next we consider alternatives to oil as a transport fuel, focusing on electricity, which we believe to be the most viable alternative. Different kinds of electric vehicle and delivery system are assessed, and we conclude that grid-connected systems offer the most promise in an era of energy constraints. Finally, we consider how enough electricity might be generated to support widespread replacement of internal combustion engines by electric motors.

In Chapter 4, we discuss transport's adverse impacts, beginning with consideration of the global impacts. Currently, the most newsworthy potential impact is climate change, but we also consider other global impacts including stratospheric ozone depletion, dispersion of persistent organic pollutants, and ocean acidification. Then we move on to local and regional impacts, including air pollution and noise. Finally, we discuss what might loosely be identified as the adverse social and economic impacts of transport, the most salient of which are the outcomes of transport crashes and collisions. We note in several places in Chapter 4 that many of the impacts of transport would be reduced were electric motors to replace internal combustion engines as the prime means of traction.

Chapter 5 is the core of the book. There we look ahead to 2025 and show how for the US and China high levels of transport activity can be maintained while substantially reducing oil use. The overall framework for Chapter 5 is the amount of oil we believe will be available in 2025, based on the analysis in Chapter 3. This will be about 17 percent below what was produced in 2007. We expect that the US, as the example of a richer country, will achieve a greater reduction—in the order of 40 percent. China, as the example of a poorer country, will increase its oil

consumption from the 2007 level, but by much less than current trends suggest. Moreover, by 2025, after reaching a peak in about 2020, China's consumption will be falling with further declines to come.

For both the US and China, and for the movement of both people and freight, we set out mode by mode how transport activity could change between 2007 and 2025. We stress that the detailed proposals implied by our scenarios for 2025 are of much less significance than the process used to figure out, for example, how much of China's movement of people might be by grid-connected high-speed train, or how much movement of freight in the US might continue to be moved by diesel-fueled trucks. We stress too the advantage of beginning transitions to new transport arrangements as soon as possible compared to waiting for additional episodes of very high prices and their accompanying turmoil to trigger change.

In Chapter 6, we expand the discussion we begin in Chapter 3 of the remarkable happenings with respect to oil and transport before, during, and after 2008. We sketch out a "vicious cycle" of high oil prices, economic recession, collapse in oil prices, economic recovery, and high oil prices again, a cycle that if repeated could become a spiral into economic crisis. We suggest that the US and other countries may be in such a vicious cycle and propose that a way out of it is massive investment in the kind of agenda we have proposed in Chapter 5. Moves have been made in the right direction in the US, but they are not evidently sufficient. The vicious cycle touched China but major timely investments toward electrification of transport appear to have contributed to early economic recovery and perhaps even turned the vicious cycle into a virtuous cycle. China's Achilles' heel could be the parallel continued growth in transport activity that depends on oil. We conclude by stressing the role of leadership in securing necessary transport revolutions, in the US, in China and elsewhere.

Who Could Benefit from This Book, and How

The information and analysis presented in this book could be of interest to many people who would like to know more about today's transport activity, its energy use and impacts, and how these things could change. Some readers will have a general interest in this profoundly important aspect of modern societies. Other readers will have a professional

perspective, perhaps that of transport or land-use planner, policy adviser or traffic engineer—or as a student in the process of gaining a professional perspective. Here we discuss what these two groups of readers—general and professional—could gain from spending time with *Transport Revolutions*.

General readers could learn from this book how to be better prepared for and how to influence what happens during oil depletion: that indefinite period after the world peak in oil production when the oil that fuels our present transport will be less and less available. If we are prepared, the transport revolutions ahead could be relatively painless, and even provide for an era of peace and prosperity. At the other extreme, lack of preparation and difficulty in keeping modern mobility functioning during oil depletion could trigger massive social unrest, economic decline and international conflict.

People in richer countries often spend more on mobility than they realize, with direct expenditures on transport usually being second only to housing costs in the typical household budget. Transport's contribution to costs rises further when the transport component of other costs (e.g., food and clothing) is factored in. Transport's contribution rises even further when the influence on asset values such as real property, equities and pension plans is also taken into account. The overall result is that much personal welfare is at stake in transport system performance beyond being able to move with ease from one place to another. In richer countries, the remarkable effectiveness of our complex transport systems is mostly taken for granted. But these systems could fail in the event that oil becomes costly or scarce, or both.

Transport that does not adapt to oil depletion could make most things much more expensive, including food and medicine, and lower the value of homes and savings. There were hints of the turmoil that can be unleashed by disruptions in the supply of transport fuels during the oil crises of the 1970s, during the protests against high fuel prices that occurred in the UK and elsewhere in Europe during September 2000, and the 2007 riots when gasoline rationing was introduced in Iran. People of many countries, notably the US, are still coming to terms with the economic turmoil unleashed by the 2008 oil shock.

Knowing the challenges in developing transport options that can function without oil or with less oil, and initiating efforts before oil deple-

tion becomes acute, could motivate demands for workable programs of transport redesign from governments. Understanding what may lie ahead could also encourage some people to make different decisions about their own living arrangements in anticipation of the coming transport revolutions. Where one lives and works could be of profound importance during oil depletion. Life in a car-dependent neighborhood could be much harder than one where most places to be reached are a walk or a bicycle ride away, or a short journey by public transport.

Quality of life can be vastly improved or greatly diminished by the way transport works, at local, national or global scales. Safe and welcoming communities, healthy cities and peaceful countries are all facilitated by successful transport systems. Success in achieving these ends will depend increasingly upon the ability to stop using oil as a fuel. Learning that it is possible to move large numbers of people and high volumes of goods without oil could be a surprise to many people. Understanding why this is so and how to make it happen will help general readers hold leaders accountable for delivering on the promises of transport revolutions.

Tomorrow's transport professionals will have important roles to play in implementing transport revolutions, but the roles will differ from those of today. For example, there will be less need for the technical skills that go into building roads, airports and motor vehicles in a world in which cars and aircraft are used less and grid-connected vehicles—many operating on rails or other guideways—are used more. Much current work is guided by the models of economists and others that predict demand for mobility. These models will become unreliable as oil depletion becomes a major influence, but it is not yet clear where planners will be able to turn for help in anticipating changes in transport demand.

There will be a need for new skills in both the technical and strategic domains of transport system development. This book offers insights into both. In Chapters 4, 5 and 6, there is a focus on what we have come to call *energy redesign,* that is, refashioning transport systems to accommodate new energy realities. This will become a core planning skill. Electrical engineering will become a much more central feature of the technical expertise needed to develop land transport systems.

Transport professionals who can see the changes ahead will be better prepared to assume new responsibilities in the coming transport revolutions. Some transport careers will flourish because of abilities to deliver

mobility without oil. Other careers will stagnate or even terminate after oil-dependent mobility begins to decline. Retraining to plan, build and manage systems that deliver mobility without oil may be a challenge for some of today's transport professionals, but their future careers could depend upon it.

Government officials will be held accountable for society's ability to make a smooth transition to transport systems that require less oil. This book could stimulate them to look for more and possibly even better advice in their formulation of the policies that guide us. Much of what is presently received as wisdom in government circles deserves to be challenged. We have heard, for example, that there is no need to worry about oil depletion because of all the oil in Alberta's tar sands. We have heard too that if there are transport-related challenges, they can be satisfactorily addressed with vehicles that use hydrogen fuel cells or biofuels, or both. In Chapter 3, we provide reasons for being skeptical about the efficacy of such "cures."

The most important feature of coming oil depletion we want to convey to government officials is its imminence. In respect to oil production, the world appears to be in a similar situation to that of the US in 1970. In that year, the US produced more than ever before (or since) and the high levels of production were comforting. The decline began in 1971 and by 1973 US production was down by three percent. This was enough, with the actions of the Organization of the Petroleum Exporting Countries (OPEC), to precipitate the first "oil crisis" in late 1973, leading to large price increases for transport fuels, fuel rationing (as noted above) and major declines in stock values. Today, the world is at or near a peak in oil production, again with some of the comfort brought by high production levels. That production is inexorably declining may not be apparent until about 2015 or later. If moves toward transport revolutions are not made before then, too many years will have been wasted.

There appear to us to be some government officials who understand something about oil depletion but believe the challenges to be so far in the future that early, effective action is not warranted. Such a disposition favors the promotion of uncertain, long-term solutions such as hydrogen fuel cells. "If they don't work," the attitude seems to be, "there will be time to try something else; and in any case I will be long retired and therefore absolved from responsibility." An understanding of the potential immi-

nence of oil depletion could be a stimulus to timely and effective policy making.

There will be huge amounts of money to be made, and lost, in the coming transport revolutions. In the business world, the difference between riches and ruin is often a matter of timing. An owner who sells a shopping center that will not be well served by transport once oil depletion sets in could avoid a large loss. Similarly, purchase of a presently depressed property that will be well served by electric transport could result in considerable gains.

Comparable opportunities and risks from oil depletion await business leaders in manufacturing, trade and finance. This book could help some get ahead of others in profiting from the considerable adjustments to come. The return on business leaders' time and money spent on this book could be among their better investments.

Lastly, we commend our book to students in the academic fields that fill the ranks of the transport professions. They will find it differs considerably from most of the books and articles assigned during their training to become transport engineers, managers and planners. Few, if any, of the tools, models and techniques presented to today's students will be helpful in making the most of the coming transport revolutions. Most current university transport programs prepare students to continue supporting transport arrangements that will not survive the coming oil depletion crisis.

Ideally, of course, we would like this book, or similar analyses, to become assigned reading for students in transport courses, including courses in engineering, business, economics, geography, political science and other programs that have some focus on transport. Short of that, we urge students to use this book to help them challenge what they are taught. Such challenges should always be offered judiciously, in the recognition that much of what we have to say is about the future, which will surely produce surprises.

We hope this book has another kind of value to students and to researchers generally. It brings together in one place an unusually large and varied amount of information about the state of transport today, and transport's energy use and impacts. We have taken pains to be accurate and balanced in our presentation and, even more, to provide readily accessible sources where the information can be checked and further analyzed.

For all these reasons, we believe this book will be of value even if our basic argument turns out to be wrong. We could be wrong in several ways. The peak in world oil production could be far ahead rather than "just around the corner." In that case, transport revolutions could well be driven more by a perceived need to avoid climate change, and much of what we say could apply. The peak in oil production could be in 2012 as we expect, but not trigger steep increases in the prices of transport fuels. Steep price increases could occur, but with little impact on transport activity. Even if we are wrong in one or more of these ways, we hope there is enough in the book to provide a solid resource about transport's present and to stimulate thinking about transport's future.

We believe our basic argument—oil depletion, high energy prices, serious impacts—is the best conclusion that can now be made about the future. The prospect of depletion of the main energy source for systems we rely on completely should be truly alarming. It is as if the power for our life-support system were about to be cut off by a blackout—or at least limited by a brownout. We are alarmed, but we also are confident that solutions exist to deal with our predicament. These solutions involve redesign of the transport sector, which need not wait for breakthroughs in technology and could begin today with good planning and effective leadership. We hope this book will help you participate in these transport revolutions and inspire you to make them happen soon.

Sources and Terminology

We have tried to be scrupulous in providing pointers to sources for all the information provided in this book. Where no source is given, it is an oversight, or the information is common knowledge or it is the result of an analysis by the authors during the book's preparation. *Superscript numbers provide the links between the text of each chapter and source and other notes at the end of the book.* The sources of material in boxes, figures and tables are also given in these notes, referenced by the superscript numbers at the end of their captions.

Sources are usually substantial documents such as government reports, books and articles in academic journals. Such sources are compiled in a reference list at the end of each chapter. They are referred to in the source notes using the Harvard system, e.g. Gilbert and Perl (2009). Some sources are more ephemeral; for example, newspaper articles.

These sources are listed fully in the source notes, usually with the uniform resource locator (URL) that points to the web page where the source is available. URLs are also given for sources in the reference lists, where they are available. *All sources we give were available during July or August 2009. All the URLs we give worked during that period.*

The notes at the end of the book are chiefly about sources, but a note can also contain additional information relevant to the part of the text to which it is linked. We urge readers to consult the notes, where there are often answers to questions begged by the text. Some of the notes may be considered to be interesting reading in their own right. Material is there rather than in the text because it is more technical or because it would interrupt the flow of the text.

This edition of *Transport Revolutions* is being both written and published in Canada where metric units increasingly prevail. We follow Canadian practice in using kilometers and liters rather than miles and gallons. A kilometer is roughly six-tenths of a mile. A liter is roughly a quarter of a US gallon. Vehicle speeds are in kilometers per hour (km/h). Mass is usually in kilograms (roughly 2.2 pounds) or (metric) tonnes. Each tonne is 1,000 kilograms, or about 2,200 pounds, or about 1.1 (short) tons.

Energy terms, too, are metric: for example, joules rather than British Thermal Units (BTUs) and exajoules rather than quads. A thousand joules or kilojoule (kJ) are roughly the same as a BTU. An exajoule (EJ) is a billion billion (10^{18}) joules and is roughly the same as a quad (which is a million billion BTU).

Perhaps the most confusing presentation for readers who use miles and gallons is that for vehicle fuel consumption. We use liters per 100 kilometers (L/100km) rather than miles per gallon. In this metric representation of fuel use, lower numbers mean lower fuel use. Five L/100km is roughly equivalent to 47 miles per US gallon (m/g); 9 L/100km is about 26 m/g; 16 L/100km is about 15 m/g.

By way of compensation for using units and terminology that many people in the US (and some elsewhere) are unfamiliar with, we have put all monetary values in US dollars unless otherwise indicated.

The only non-metric measure we use often is "barrel," because in Chapter 3 in particular we say much about oil production and consumption and so many of the available data are in barrels. A barrel is about 159 liters, or 42 US gallons.

For exact equivalents for the above units and many others, we recommend among several good sources the relevant part of the website of the US National Institute of Standards and Technology (NIST) at physics.nist.gov/cuu/Reference/unitconversions.html.

Finally, we should apologize for the large number of abbreviations used in the book, for measures, organizations and countries. They have been used chiefly to reduce the book's length, although they are sometimes an aid to reading. We apologize particularly for the ungainly "US," used for the United States of America. The more usual abbreviations are U.S. and U.S.A., but these look odd against the standard abbreviation for the United Kingdom—UK—and odd in combination with certain kinds of punctuation. We use US often, partly because the book has a focus on this most transport-intensive country and partly because we have often stayed away from using America or American(s), at least until Chapter 5, in order not to confuse or irritate people in other countries of the Americas. Unfamiliar abbreviations are defined quite often in the text and the notes, and there is a compilation of all abbreviations used, and what they stand for, at the end of the book.