Mobility Transformation – the Human Approach

Rethinking the Way Ahead

Jörg Schindler & Martin Held (forthcoming)

A Summary

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A Summary

Jörg Schindler and Martin Held are working on the publication "Mobility Transformation – the Human Approach. Rethinking the Way Ahead". This summary provides an overview of the book as of November 2020, since working on the draft of the book is still in progress. However, most chapters are already written. It is planned to finalise the draft of the book in 2021 and to publish it then.

The summary starts with the full draft of Chapter 1 in order to create an understanding of the approach of the publication, its objectives and its scope. Chapter 1 outlines the full scope of the mobility transformation and its interplay with other parts of the Great Transformation. In this transformation to a more sustainable world, the abandoning of the unsustainable fossil energy regime to a more sustainable postfossil world is only one dimension. The mobility transformation covers a very wide range of topics – from human needs, mobility and transport, energy and metals, technology, infrastructures, public space, health and equity, to name a few. These topics are addressed in the following Chapters 2 to 14. For each chapter, the summary includes the structure and an abstract of the content.

In 2009 Jörg Schindler and Martin Held published a book in collaboration with Gerd Würdemann "Postfossile Mobilität. Wegweiser für die Zeit nach dem Peak Oil" (Bad Homburg: VAS Publisher). We thank Ludwig-Bölkow-Stiftung, Ottobrunn for funding the translation of this book (together with Dr. Joachim und Hanna Schmidt Stiftung für Umwelt und Verkehr, Hamburg). The initial plan was to publish an updated version of this book in English, with only minor modifications.

While working on this update, the authors continually widened their perspective to cover the more comprehensive mobility transformation. In this process, first versions of the translation were a valuable starting point. With the wider scope of the new book, the content moved beyond the original text, leading to a in large parts new book – and as a consequence also to a new title.
We thank Gerd Würdemann for valuable notes for the ongoing work on the manuscript Mobility Transformation.

Neubiberg (DE) and Tutzing (DE), December 2020

Jörg Schindler and Martin Held

Content

PROLOGUE

1.1 Human approach – mobility starting with people

We unfold the narrative of the mobility transformation, progressing from the present unsustainability to a more sustainable mobility, by covering a wide scope of relevant topics. People and the human condition are our starting point. In the beginning of humanity was the upright gait. Walking on two legs was a definitional condition for Homo erectus. Walking was the precondition for the evolution of the human brain and of Homo sapiens. Human beings are intrinsically conditioned to be physically active. Every new-born child develops its potential in grasping the world with its hands, crawling, standing up and proudly making its first steps. These interactions with its environment are stimulating the development of its brain and its cognitive skills. These basic human characteristics are forming an inseparable unity: physical activity, cognitions and emotions. This unity is reflected in the language: physical and emotional movement. This movement is enmeshed in a sensory world. *Senses matter*.[1]

Human beings are intrinsically part of nature. Humans are embedded in nature (and they will ever be). This embodiment expresses itself in active mobility being the basic concept. The human metabolism is an elementary property.

Mobility is all about the human condition and human needs. It is about the fundamental need to be physically active. Mobility is about the need to go to other places and the need to transport goods. Mobility is about accessibility, health, liveable cities, public space, participation and equity.

Transport is not a synonym for mobility. Rather, it is just part of the comprehensive concept of mobility. Transport is about infrastructures, vehicles, technologies and energy.

1 This phrase was coined by Peter Cox, University of Chester, at our Workshop Human Powered Mobility in 2008 (Tutzing, Germany); see also Gehl (2010: chapter 2); Cox (2019).

1.2 Technology approach – transport starting with technologies

The technology approach is different from the human approach. It is focused on transport: vehicles, transport infrastructures, energy and digital technologies of all kind. It is implied that optimising technologies fulfills the transport needs of people and likewise is enhancing the efficiency of freight transport. It is promising a bright future driven by technology and powered by renewably generated electricity and hydrogen. It is a promise of the continuation of BAU – business-as-usual – with minor adaptations: we call it *BAU light*.

In general, problems are defined as being solvable by new and better technologies. The technology approach aims at a limited transformation by confining the transition to one from fossil *transport* to postfossil *transport*.

The digital transformation is a good example to demonstrate the difference between both approaches. On the one hand, the human approach is starting with people: new driving assistance systems for cars, buses and trucks may be used to improve road safety. For example, such a system can be implemented to avoid road accidents with pedestrians and cyclists caused by motorised vehicles when turning. On the other hand, the technology approach is starting with technologies. Mobile robots – usually termed as autonomous vehicles or self-driving cars – are proposed as a solution to prevent this type of accident. However, these mobile robots are not just assisting drivers but are substituting them. These so-called self-driving cars are suited to perform only in controlled environments. As a consequence, the freedom of driving by oneself as well as the freedom of walking and cycling will be restricted. This effect is similar to the effect which the rise of the car-centred city in the 20th century had by transforming public space into roads for motorized vehicles – now by transforming roads to be suited for mobile robots.

The human approach has a wider scope, it is focused on a comprehensive transformation: the transition from the fossil non-sustainable *transport* to a postfossil sustainable *mobility*. Of course, technology is also indispensable in this approach but it is only part of the solution, nevertheless an important part. It comprises the demanding task to transform the fossil shaped infrastructures and transportation structures together with the fossil energy regime. This is a paradigm shift, comparable in many ways to the increasingly frequent efforts to reinstate channeled rivers into free-flowing rivers.

The primary shortcoming of the technology approach is that it conceals the vital role of active mobility. Beyond the transport transformation, the comprehensive human approach opens up the whole solution space of the mobility transformation – active mobility, health and well-being, different settlement structures, multi-functional quality public spaces and the social dimension, long-distance mobility as well as urban and short-distance mobility.

1.3 Space matters – energy matters – metals matter

“Space is at the same time the generator, support and a constraint for mobility.” (Rodrigue 2017: 2) Space is the basic dimension of human settlements, of land use in general and of transport infrastructures. Transport is interaction in space. Spatial structures and friction of space, also called friction of distance, shape the mobility patterns. Friction of space is determined by distance, transport infrastructures, transport modes, energy and material requirements, time, economics etc.

Spatial structures, the location and size of settlements, were shaped in pre-industrial times by the available transport modes of the time. The walking range of people, extended only by the help of animals, confined the size of towns and defined the range of everyday mobility for people and goods. Transport of very heavy goods over longer distances was only possible on waterways and by maritime shipping. With the advent of the Industrial Revolution, size and structure of settlements and transport infrastructures were shaped by fossil transport. The dramatic reduction of the friction of space for transport on land allowed larger settlements and, above all, was the driver for larger settlements away from waterways. In addition, motorized transport was causing the rise of long-distance travel of people – by train, by bus, by car and with aeroplanes.

These factors, together with a growing population, led to an increasing scarcity of space in conurbations. A main driver for this scarcity is the mass motorization after the second World War. Public space has been taken over by the car. Yet, motorized transport is but one use of public space competing with many other uses. A primary aim of the mobility transformation is to regain public space and, especially to enhance the quality of the public space. For this objective, it is necessary to break the dominance of the private car and to make room for a multitude of other human needs.
From the very beginning, the use of energy was a precondition for transport and mobility. In the Industrial Revolution, fossil coal revolutionized the transport system by introducing the steam engine, later on supplemented by crude oil and the combustion engine. To a smaller extent, electric powered railways of all kinds completed the motorized transport system. Obviously, in the transition to a more sustainable mobility system the non-renewable fossil fuels have to be phased out and renewable energy sources have to be phased in. Electric vehicles, powered either directly (as trains via power lines) or via batteries or hydrogen fuel cells, have to substitute conventional vehicles. In aviation, hydrogen is a likely substitute for kerosene. For this to be effective, a global energy transition to renewable energies is a precondition.

In prefossil times, iron and steel were rare and expensive. These metals were only used to a very limited extent for the construction of tools and weapons, for essential parts of wheels, wagons and sailing ships. In the evolution of shipping, alloys like brass were used in instruments for navigation and timing, thus being a precondition for the globalization. In the Industrial Revolution, iron and steel became the twins of coal, together they fired the transport revolution of the 19th century. The use of electricity came a few decades later, based on the use of copper.

In the 20th century, more metallic elements were used in steeply increasing quantities. The rise of electronics and modern communication technologies is based on metals, with transport as an important application. The digitalization was *only possible* by learning how to functionalize all metals (including all semi-metals) of the periodic table, which have a share of about 80 percent of all elements. Humankind has now arrived in the All Metals Age (Held & Schindler 2017).
Put in a nutshell, with regard to energy and metals the mobility transformation, including the relevant parts of the energy transition and the digital transformation, may be summarized as follows (Held et al. 2018):

- *Postfossil is necessary and possible.*
- *Postmetallic is not possible.*

In future, basic metals and technology metals will become even more important in the energy transition and the transition to a more sustainable mobility system. Catchwords are: *low carbon, high metals.* Fossil fuels are no longer available after use. In contrast, metals are still there after use. However, depending on the type of use, they can either not be used again or can be reused only by expending energy using a recycling infrastructure which in turn needs a multitude of materials. At present, a very large share of metals used is dissipated and, therefore, is no longer available. This is unsustainable.

In principle, there is a big potential for the reuse of metals, usually expressed in the paradigm of the circular economy. However, there are thermodynamic laws together with economic and technical limits which determine why a 100 percent circular economy is not possible (see sections 6.4 and 8.6). Nevertheless, the reuse of metals is a sensible and necessary goal. The size of this task is of the same order as the transition from fossil fuels to an economy relying solely on renewable energy.

Energy and metals are two equally important and equally pervasive threads of the mobility transformation. In our book we address the transition from fossil to postfossil energy in detail. In addition, we introduce the fundamental role of metals for the impending mobility transformation and the related parts of the energy transition as well as the digital transformation. The energy transition is now on the political agenda. In this context, some technology metals like lithium and cobalt are perceived as critical metals and as being indispensable for the energy transition and the transport transformation. This focus on "critical metals" may be used to trigger a more general debate about the basic role of metals and the necessity of a more sustainable use and reuse of all metals.

1.4 Equity – the importance of being earnest

In climate policy, many internationally adopted declarations stipulate a fair and equitable implementation of policies on a global scale. In line with climate policy, all over the world *sustainable mobility for all* is a fundamental issue in declarations of commitment to a sustainable mobility.[2] The issue of equity in mobility is genuine to the human approach to mobility. Sustainable mobility for all is an ethical imperative, it comprises the issues of accessibility, inclusion and participation in social life for all members of society. In most cases however, in actual transport planning these issues are not yet accounted for in an essential and pervasive way but rather in an ad hoc manner as add-ons. Examples are e.g. barrier-free accesses to public transport or guidance for blind people and the like.

Growing transport volumes are generally perceived as being positive, as a sign of socio-economic progress, and therefore as an undisputed objective. In this mindset, there is a tendency to assume that greater equity in mobility is in some ways automatically achieved by expanded transport infrastructures and traffic volumes. However, this is a delusion.

Addressing in earnest the actual inequality in mobility changes the perspective on the mobility transformation: equity has to be an integral part of this transformation (Banister 2018). Equity is an

2 Sustainable Mobility for All (SuM4All) is also the name of a coalition of public organisations and private companies initiated by the World Bank in 2017 – see https://sum4all.org

indispensable guideline, on an equal footing with other criteria, for assessing and evaluating alternative technologies, transport infrastructures, settlement structures and public spaces.

Equity is not an abstract concept with little practical consequence. Quite the contrary as is demonstrated by the following examples:

- The free and safe movement of children in the public space. This objective is not met in settlements with transport infrastructures prioritising motorized traffic. Nor is it met for elderly and handicapped people.
- Generally: the prioritisation of motorized transport over active mobility in short-distance travel.
- Settlement structures requiring car use.
- Unequal access to public transport.
- The unequal incidence of emissions caused by motorized transport on different parts of society. As well as higher accident risks for pedestrians and cyclists.
- Unequal income distribution as a cause for unequal mobility opportunities. Who profits from investments in infrastructures (roads, railways, airports)?
- "Western" transport systems and mobility patterns cannot be expanded globally because this would obviously be unsustainable. Reasons are: amounts of energy, materials and metals needed which probably are not there. What is the consequence for the present system?
- What is possible for future generations – everywhere on the world?
- Equal access to resources and energy for all people: what is a sustainable level? Where (countries, regions, cities) is the use of resources already too high and where still too low?

There are many questions and few answers – in politics, science and media alike. Nevertheless, it is a hopeful sign of change that in the big topics of climate policy, energy transition, a Green New Deal (EU) and Transforming our World (UN), in every case a fair, just and equitable transformation is an explicit objective.

1.5 Framing – reframing

Mobility, active mobility, health and well-being, public space, liveability, equitable access to mobility, players promoting or impeding the mobility transformation – we use a specific set of concepts and terms. These terms have their own sound which differs from the terms mainly used in the conventional transport context. This is not by accident.

For example, we propose the term *active mobility.* In contrast, the term most widely used by planners and in politics is non-motorized transport. This term defines walking and cycling in a frame of deficiency: "When defined in this way, walking and cycling are perceived as outdated and inadequate forms of transport to be minimized because they lack an essential component: the motor." (Held et al. 2015: 209; see also Cox 2015) By using active mobility as a basic concept, walking and cycling plus variants such as skating and using scooters and boards, are no longer dealt with as being a residual category which has to be minimized. The term active mobility is easily understood by planners, politicians and the public. This framing significantly affects how transportation problems are perceived and coined as well as how policies are implemented.

An adequate framing is a precondition to understand the necessity and urgency of a transformation of the transport system. This holds for the human approach to mobility transformation as well as the technology approach to transport transformation. It is a precondition in shaping the transition in line with the sustainable development goals (SDGs).

The concept of framing is used throughout our work because it is a basic and powerful concept. Social psychologists Tversky and Kahneman (1981, 1986) reviewed the empirical evidence in different settings: perceptions and decisions are influenced by the way the situation is framed. Many studies in social and behavioural psychology, experimental economics and sociology among other disciplines confirmed and elaborated these findings. Cognitive linguistics are adding to the evidence and are collaborating with researchers from neuronal brain research on framing (Lakoff & Wehling 2012, 2016; Wehling 2018).

Language and cognition are not separated, rather the scientific evidence confirms that *cognitions are embodied*. Frames are "deeply rooted, cognitive structures that drew on world knowledge to attribute meaning to facts" (Wehling 2017). Terms and concepts work as frames via metaphorical mapping. Frames are working on the individual level. In addition, frames are shaped and reinforced by social interaction and the media. In institutional economics this concept is coined as mental models and shared mental models (Denzau & North 1994). In our context of mobility, we refer to this concept metaphorically as mental maps.

Words are not just words. But words and language are shaping perception, thinking and interpreting, valuation and behaviour. They provide value orientation and are influencing beliefs and the formation of attitudes.

Frames concerning our subject were formed in the fossil era and they are a part of mobility cultures. Therefore, different settings and different mobility cultures shaped what is perceived as normal. Frames are powerful and to a certain degree persistent. The beginning mobility transformation requires the formation of its own adequate frames. While part of the framing of the mobility transformation is about switching in transport from fossil fuels to renewables, from combustion engines to electric motors, a more comprehensive reframing of the basic concepts of mobility is necessary.

At present, many different terms are coined, new ones are evolving while others are disappearing: terms like smart city and lively city, self-driving cars and public bike schemes, shared space and intelligent roads, super-sonic aircraft and drones, high-speed corridors and human scale of speed, walkability and seamless transport.

Framing is part of the human approach. Words, language and cognition are typically regarded as parts of a domain of its own (quite often misunderstood as *rationality*), which is separated from the physical world and the human body. Cognitive linguistics has shown that the concept of *frame* is a unifying concept integrating cognition, motivation, the world of values and the brain and senses, as being part of the body. *The frame of active mobility is part of the human approach*. There is a solid evidence that humans are evolved to the need to be physically active. Active mobility is basic for this human condition (see section 8.3). The human approach and the concept of framing emphasize the statement at the beginning: *senses matter*.

Framing is part of the technology approach as well as of the human approach. We will discuss in sections 6.5 and 8.6 the differences as well as the overlapping of the frames characterizing the two approaches.

1.6 History matters – lasting legacies of fossil transport

The mobility transformation is a historically unique period stretching from unsustainable fossil transport to a more sustainable postfossil mobility. In this period, the switch from fossil fuels to renewable energy sources is essential. However, this is just one part of a more comprehensive mobility transformation. Equally necessary is the reframing of the fossil shaped mental map of transport. This transition is not an easy task because of the path dependencies of the transport system.

Path dependency is a concept which was introduced by a study about the layout of the keyboard of American type writers. The order of the letters QWERTY on type writers became the synonym for path dependency (David 1985). This concept is helpful to understand innovation processes and specifically the lasting legacies of the past in the transition period. An example from the 19th century transport revolution is illustrative: George Stephenson used the gauge of tracks in coal mines for his new locomotive and the first railway lines were built accordingly (1435 mm). Issambard Kingdom Brunel could demonstrate that a broader gauge with 2140 mm was more efficient and had a better stability. However, Stephensons's line of invention had already reached a critical mass of already built infrastructure. Therefore, 1435 mm succeeded to become the standard gauge, widely exported to other countries as well. The past is not gone but has a lasting effect for the future: *history matters.*

Mental maps were shaped in the fossil era and they, too, will be prevailing in the beginning of the mobility transformation. In order to understand the boundary conditions at the start of the transition, one has to analyse the fossil transport system and the reasons for its success. Path dependencies are shaping the dynamics of the transition: the legacy of transport systems and their infrastructures, the fossil energy regime, technologies, institutions, industries, retail systems as well as the corresponding mental maps. These frames, shaped in the fossil era, determine the perception of what is regarded as being *normal*. Descriptive examples in industrialised countries, all taken for granted and fixed, are: the dominance of motorized transport, the design and performance of passenger cars, the high levels of long-distance motorised transport, an ever-increasing volume of air traffic. This list can be extended at will. All these perceptions are, often implicit, also basic assumptions in mainstream economic modelling.

The economic and social consequences of the Covid-19 pandemic have shattered many of these assumed certainties, with aviation being the most prominent example. For many, a *new normal* seems for the first time to be a realistic possibility, however undesirable this may be considered.

Path dependencies have very *different time scales*. For example, the built infrastructure – like the road system, railroads, airport infrastructure and ports – has life times of many decades. Likewise, the spatial and settlement structures are governed by equally long time scales. The composition and size of the road vehicle fleet may be changed within 15 to 20 years, but in aviation

the renewal of aeroplanes stretches over a much longer time. In contrast, pedelecs penetrated the market – without political backing and subsidies – in only a few years in some countries, demonstrating their potential to be a game changer for travel distances up to 5 - 10 kilometres. Regardless of these differences, it is necessary to change the fossil mental frame as fast as possible. For this, it is vital to understand the different time frames of the fossil shaped legacies.

One of the most potent legacies of the fossil shaped transport system is its oil dependency. At first sight, it may seem that the corresponding mental hurdles of this legacy have already been overcome. Are climate protection policies not guiding us that we have to decarbonize and phase out fossil fuels as fast as possible anyway – first coal, then oil and eventually natural gas? When envisaging a more sustainable future, why should one bother at all with fossil energies? While it is true that the phasing out of fossil fuels is – as widely accepted – necessary and urgent, the fossil frame defining the *normal* has not disappeared but is still very strong. Vested interests and corresponding hopes are still prevailing, trying to prolongate the fossil energy regime.

In view of the historic success of fossil transport, the change of the energy regime in transport violates vested interests and causes anxieties of an impending deprivation. A thorough understanding of the fossil legacy and its diminishing future role, and the dynamics of change, opens the way for a positive reframing: postfossil mobility is a *freedom frame*, the liberation from the oil dependency of mobility.

1.7 Fossil transport – success and victim of success

Fossil energy is at the core of modern transport. Growing transport volumes are an integral part of dominant Western lifestyles. People and goods in industrialised societies travel longer distances than ever before in the history of humanity – on land, on water and in the air. China's embrace of high mobility patterns as a symbol of modernity is followed by India, countries like Indonesia and Vietnam as well as other countries all over the world.

Transport systems constitute the foundation of the predominant Western economic system. The transport sector contributes a big share to the GNP. Air transport, land and sea-bound freight transport show remarkable growth rates in times of booming economies. Transport infrastructures and the provision of energy for transport build the foundation for the international division of labour. Settlement structures, life styles, economic growth, opportunities for individual development: all contribute to growing transport volumes. "To transport they throng, on transport they depend", to paraphrase Goethe.[3]

This success takes its toll: traffic casualties, noise, land consumption, surface sealing, exposure to particulate matter, emissions of nitrogen oxides (NO_x), carbon dioxide (CO_2), burdens on public finance, to name just some. In conurbations, the growth of motorized traffic has occupied ever more of the scarce public space at the expense of other modes and functions, leading to a severe degradation of the quality of public space.

These effects degrade the living quality in cities and have severe negative effects on human health and well-being. Some of these issues are major topics in the public perception under the

3 Goethe, Faust I, lines 2802 ff: "Nach Golde drängt, am Golde hängt doch alles."

headings of air pollution and climate change. The existing transport system strains its limits. *The consequences of success undermine its foundations.*

Despite the pressing need to reduce emissions of greenhouse gases effectively, the transport sector is still driving emissions. Transport is still almost completely dependent on fossil oil. The demand for fuels for transport is not decreasing. Oil shocks are perceived as endangering the security of energy supply. In addition, consumption of land for new transport infrastructures continues unabated.

The fossil energy system is at a turning point. Therefore, the fossil-dominated transport system is at a turning point as well. The unsustainability of the fossil energy regime is becoming apparent. To paraphrase the R.E.M. song from 1987: it is at the beginning of its end.

1.8 The beginning of the endgame of the fossil age

The success of our present transport system depends on non-renewable fossil energy sources. Its development was fuelled first by coal and later by oil, hand in hand with novel transport technologies: railways, motor ships, motor vehicles and airplanes. The development of transport infrastructures and the resulting land use patterns in the twentieth century were only made possible by abundant and cheap oil. When we use the attribute “cheap” in this context we refer to the historical difference between the relative price of oil after World War II compared to the cost of other forms of energy in the historic past (Pfister 1994, 2010).

This development is unsustainable: It can only continue for a limited period of time. For quite a long time this insight was irrelevant since the limiting factors were deemed to come into effect only in a faraway future.

Those limits are already reached by rapid economic growth accompanied by growing car ownership in countries like South-Korea, China, India and Brazil. We now experience the increasing climate volatility and its consequences: shifting of seasons, drought periods and one-hundred-year event floods in rapid succession, and hurricanes in latitudes where they have never been encountered before. Fossil fuelled transport is still a major driving force for the climate change. Unlike in other energy consuming sectors, no fundamental reversal of this trend is yet in sight for transport, despite some first efforts to introduce electric propulsion systems. In fact: *the oil dependency of transport is still dominant at the beginning of the 2020s.*

To use a metaphor borrowed from chess: the endgame of the fossil age began around the years 2005 to 2007 when *global conventional oil production* reached a bumpy plateau. For a long time, only a simplistic and misleading question has been asked: when will the oil run out? Now, more pertinent questions come into focus: for how long can we meet the growing demand for oil to fuel worldwide transport? And what will happen next?

Over time, cars have become increasingly powerful while advances in energy efficiency have been nullified by the trend to heavier and more powerful vehicles. Whenever oil prices are going down, sales of fossil driven SUVs are on the increase. In addition, there is as global increase in traffic as a result of the growing motorization in developing countries and emerging economies. The indications of imminent upheavals in the supply of oil are getting stronger: increasing tensions in many oil exporting countries, a steep rise of oil prices since 2002 followed by a high volatility

since 2008. Insecurity spreads, the supply of oil is no longer taken for granted. People feel threatened, many people feel that their lifestyle is in danger. The fracking boom of unconventional light tight oil in the USA has masked the peak of conventional oil for a few years – a controversial effort to prolongate the fossil energy regime. Popular fears of a loss of mobility stand in stark contrast to the reluctance of many decision makers to confront their fellow citizens with the clear and unambiguous truth: *the era of ever rising and unlimited supply of oil is gone forever.*

1.9 The beginning of the endgame of fossil transport – the dynamics of prolongation

Corresponding to established lifestyles in Western societies, vested interests of the incumbents are still strong to prolongate the fossil endgame and to maintain basic features of the fossil transport system with only minor modifications:

- The options opened by fossil transport are still attractive in spite of all negative consequences; this can be seen in the globally growing number of aircraft, ever bigger fossil powered vehicles on the road, the construction of new highways even in industrialised countries with an already very extended network of roads and highways.
- People have adapted to the status quo, but adapting to changes causes anxieties.
- Fossil transport promises economic growth; the aim of decoupling transport volumes from economic growth is far from being achieved.

These drivers are at the core of the still dominant *mental frame*, created in the fossil age. However, the Covid-19 pandemic has added to a growing uncertainty whether the status quo can persist.

Some changes are already visible. The insight is spreading that oil is being used up much faster than previously thought. The challenge to secure the energy for motorized transport on roads, sea and in the air is daunting and, in a global perspective, much more urgent than hitherto assumed. The importance of transport for lifestyles and the economy raises questions:

- How can we cope with these challenges?
- Which lines of action are feasible?

Because of the fundamental role of transport for the economy and society, everyone is affected, subject to their specific interests. Therefore, it is only natural that many different analyses and solutions are put forward.

Powerful players avoid facing the endgame of fossil transport right now, instead they are actively prolongating the fossil age. Fracking in the USA is a prominent example. On the face of it, this appears to be an appealing promise: business as usual with as few changes as possible! Deal with the consequences only at the time they actually arise. This goes together with the naive belief that there will always be a technological solution for every problem – the belief in the infinite ingenuity of humankind.

Attempts to prolongate the fossil endgame are trapped in the frame of an unsustainable development. *These attempts are a waste of time needed for transformative change.*

1.10 Players – performers of the mobility transformation

Without players no play. The mobility transformation has to be carried out by the interplay of all players relevant in this transition. Whether they are institutional or individual players, in the end actions are always carried out by individual persons. A closer look at the players is in line with our basic human approach.

For our analysis, the relevant playing fields, the players and their respective roles have to be identified. The description of the role of individual players has to take into account several aspects:

(1) The playing field: freight or passenger transport; transport mode; short-distance (everyday) or long-distance transport; land-use and settlement structures.
(2) Players and their functions: service providers; vehicle manufacturers; building companies for transport infrastructures; energy companies; governments and regulation bodies at all levels; transport planners and regional and city planners; employees; people with their mobility needs and their role as consumers; companies needing transport services for freight and people; the public (e.g. NGOs) and media.
(3) Players and their transformative power: market power and political influence; vested interests; present role and required role in the transformation; different time horizons for transformative change.
(4) Dimensions of sustainability which have to guide the actions of players: energy; metals and other materials; environmental compatibility; health and well-being; social compatibility and equity.

The perspective on the players describes the diversity and complexity of the mobility transformation. It describes the actors and their scope of actions and their actual actions in the real world. It is important to understand the actors, their interests, their motives and their role and actual power to shape the mobility transformation. There are mighty incumbents with vested interests not keen on a transformation which would require a decisive change in business interests and behaviour. And there are others which try to promote a transition to a more sustainable mobility, for quite varying reasons. Above all, time needed for change is a fundamental category posing quite different challenges for different players.

These observations show that there is not a single measure or a set of measures which fits all areas and all players in the mobility transformation. For example, greenhouse gas emission certificates – however necessary they might be – will be only part of the solution, affecting only some areas. When looking at the changes taking already place, the empirical evidence shows that effective actors are often of a kind and location which one would not necessarily expect. This is due to many situational and historic contingencies. As a consequence, there is no way to forecast with some certainty where and how the transformation will gather speed.

1.11 Transport transformation and mobility transformation – rethinking the way ahead

Various concepts of transformation and their relationship are currently debated. In the first place, energy policy with regard to resource availability, greenhouse gas emissions and nuclear hazards became an issue. The concept of *energy transition* is now internationally established to describe the transition from a fossil (and nuclear) energy regime to renewable energies. Implementation strategies and political measures are hotly contested between varying alliances of players showing increasing success in some countries. Energy transition is part of the comprehensive transition towards sustainability, sometimes labelled as the Great Transformation (WBGU 2011, 2016; see chapter 5) or socio-ecological transformation to a sustainable development.

In the last decades, digital technologies were used in ever more applications. This is a pervasive development affecting everyday life of people as well as nearly all sectors of business, media, research and governance. The speeding up of these processes in recent years has led to the concept of a *digital transformation*, transforming not just the technosphere itself but the whole society, cities and economy. Different and, notably, to some degree conflicting goals are pursued in implementing new digital technologies. On the one hand, these processes offer solutions for many problems and in addition open up new options. On the other hand, new fundamental and grave problems arise as part of this transformative development (cyber security, privacy, big brother, unsustainable waste of metals, etc.).

In German-speaking countries, a debate started some years ago, emphasizing the need for a transport transformation and | or mobility transformation. The very first coining of the term transport transformation (in German: *Verkehrswende*) dates back to the beginning 1990s.[4] There is a consensus in the debate that this transformation is to some degree overlapping with the energy transition (Agora Verkehrswende 2017). It is also taken as a matter of fact that digitalisation has an essential role to play in transforming the transport sector. For example, access to the internet has gone mobile and digital mobility services are spreading.

The awareness of the necessity of a *transport transformation* is gaining ground in Germany and Austria. *Mobility transformation* is introduced as a more comprehensive concept. At the international and global level, transport | mobility transformation is not yet a common concept in contrast to the concepts of energy transition and digital transformation.

In our book we propose the concepts of mobility transformation and transport transformation on an *equal footing* to energy transition and digital transformation.

It is urgent to transform the fossil shaped unsustainable transport system, cities and settlement structures by initiating a postfossil, more sustainable development. This urgency is increasingly perceived in many countries by players in different straits of society, culture, economy, politics and science.

In transport, rapid changes are unfolding. In our book, we identify two different frames using ideal types (Max Weber). The first line is deeply rooted in the technology approach. This approach

4 To our knowledge Hesse & Lucas (1991) and Hesse (1993) were the first to coin the term transport transformation (in German: *Verkehrswende*) to be followed by Kemp & Rotmans (2004) and Held & Kümmerer (2005) with transition to sustainable mobility. See also Schindler et al (2009) and an overview by Held & Schindler (2012).

frames a specific understanding of the impending transformation: the transformation of unsustainable *transport* to a more sustainable *transport*.

The second line is starting with people – we term it the human approach. Due to this human approach, mobility is the intrinsically fundamental and comprehensive concept which includes technology in its instrumental function for human needs. Based on these considerations we unfold the new frame of *mobility transformation* in this book: the transformation of unsustainable *transport* to a more sustainable *mobility*.

There is no single way ahead for this transformation. It is a journey into *uncharted territor*y. There are no maps, masterplans, signposts or other means to assist the navigation in this transformative journey. Nevertheless, the frames of the transport and the mobility transformation *provide directional orientation*, derived from the human approach, the energy transition and the growing need of metals.

In our book, we attempt to present universally valid arguments about the structure of the beginning mobility transformation, while being aware that contexts and path dependencies in various countries, regions of the world, agglomerations and smaller places vary to a great extent. Diversity of mobility cultures and their dynamics are intrinsic to this period of transition. Diversity represents itself in a variety of terms and concepts which have different meanings in different parts of the English-speaking world. An obvious example are the terms *mass transport* in the USA and *public transport* in Europe. This has to be taken into account when we make use of specific examples in varying settings. We do not claim to present a global and comprehensive picture. We are aware of the fact that our work is based on the findings and experiences taken from specific selected countries and regions of the world.

Our book is inspired by the insight: everybody has to play its role in this evolving mobility transformation and everybody will be affected by this transition. We outline the potential of this way ahead: towards a socially inclusive, healthy, postfossil and climate friendly mobility using metals wisely.

The narrative of the mobility transformation is intended to inspire the rethinking of the way ahead. It is guided by the human approach starting with the mobility needs of people. All people. Everywhere in the world.

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STARTING POINT – fossil transport is unsustainable

2. Fossil transport – shaping the transport system and its framing

2.1 The historical perspective – the very recent appearance of fossil fuelled transport

2.2 The internal combustion engine – gravitation of transport towards oil

2.3 Interplay between fossil infrastructure and spatial structures

2.4 Shaping the frame of fossil transport

As a vital part of the history of humanity, the long history of transport on water and on land as well as the short history of transport in the air, has seen many fundamental innovations. These innovations like wheel and wagon turned out to be transformative, transforming not only transport but at the same time the development of human societies, political regimes, economies and everyday life; and time and again by transforming spatial structures.

In a historical perspective, the transformative innovation of motorised transport is a very recent phenomenon. It all started some 250 years ago with the steam engine fuelled by coal. Coal enabled the steep increase of the use of iron and steel. In a rather short time, the innovation of the steam engine led to the rise of the railways and the steam ship. Next was the innovation of the combustion engine fuelled by oil. This enabled the construction of motorised road vehicles and aircrafts.

The development of the bicycle in the 19th century brought about many technological inventions. In addition to the combustion engine, these innovations created vital preconditions for the construction of motorised road vehicles and early aircrafts.

With fossil fuelled vehicles, an ancient dream of humanity has come true: convenient and fast travel of people and goods, on land and on water. Even the dream of flying became real.

With the advent of the car powered by combustion engines, crude oil became the dominating energy source for motorised road transport. The combination of the combustion engine with oil as a fuel turned out to be far more convenient and efficient than the steam engine. It made possible the dramatic rise of motorised road transport in the 20th century.

Transport on roads with cars, buses and trucks changed spatial structures. Settlements could grow in areas hitherto not accessible by waterways or railways because the friction of space was now greatly reduced.

The downside of this development was a tendency to dispersed settlement structures and to cities reshaped by prioritising the use of cars. As a result of mass motorisation, in many countries car-centred societies developed.

This development was for many attractive and, therefore, was an overwhelming success in industrialised countries. This led to the shaping of the frame of fossil transport which in turn shaped the very concept of transport. A continuing growth of motorised transport volumes is seen as a sign of economic prosperity and is taken for granted. Motorised transport is the *normal*, non-motorised modes are mainly regarded and treated as inferior.

Oil is a finite resource subject to depletion. The burning of oil emits greenhouse gases and other pollutants. For these reasons, the use of fuels derived from oil in transport is unsustainable.

3. The endgame of fossil fuels

3.1 Fossil options – dragging out the fossil endgame
3.2 Conventional crude oil – peak and decline
3.3 Unconventional oil – unfounded hopes
3.4 All oil – at the cusp of decline
3.5 Natural gas – not a bridge to sustainability
3.6 Coal for transport – not a realistic option
3.7 Fossil fuels for transport – high time to stop the delusion

The vehicle industry is increasing its efforts to introduce electric cars. The switch to renewable electricity and hydrogen is seen as a step on the way to a climate neutral transport, to take place sometime in the future. The overall dependency on oil of the transport system is still growing. This trend is due to the fact that the global number of conventional cars running on petrol is still increasing. As yet, there is in aggregate no substitution of conventional cars by electric cars.

Therefore, it is beyond comprehension why the supply and availability of oil for transport is not a topic in its own right. The common assumption is that the supply of oil is in principle abundant, at present and also in the foreseeable future. This is the – widely shared – perception that the eventual phasing out of oil for transport is only necessary because of climate protection.

Actually, fossil fuels for transport are *unsustainable for two equally fundamental reasons*: (1) the finiteness of fossil fuels and (2) the emission of greenhouse gases when burning them. In order to gain an understanding of the possible and likely unfolding of the energy transition as part of the mobility transformation, the determinants of the supply of fossil fuels have to be analysed.

The present and future *supply of conventional oil* is described. It is shown that the global production of conventional oil is on a bumpy plateau since 2005, and that its decline is imminent. The unforeseen boom of *unconventional oil production* in the USA masked the plateau of conventional oil and led to an increase in global production starting at about 2010. However, this boom of light tight oil in the USA is unsustainable. Taking conventional and unconventional oil *together*, a likely scenario for the oil supply in the coming decades is presented.

It will be interesting to see what the reactions are when the supply of oil no longer meets the present level of demand and its expected increase. There is a tendency to prolongate the use of fossil fuels, even when this contradicts the goals of climate protection. These are all attempts for *dragging out the fossil endgame.*

Other fossil energy sources can be converted to fuels for transport. *Natural gas* is a possible fuel for road transport and is actually used in cars and lately also in shipping. The use of natural gas is promoted by some players as a temporal bridge to a completely renewable energy regime in transport based on the argument of the lower GHG emissions compared with oil.

Coal-to-liquids for transport is not a realistic pathway. However, *coal* may be used for power generation if combined with Carbon Capture and Storage (CCS) to provide sort of a “green” electricity for transport. It is by no means clear whether the necessary coal resources and CCS deposit sites are there, nor whether environmental and economic goals can be actually met.

Nuclear is not a realistic option. The building of new nuclear power stations is by far the most expensive way of electricity generation and time scales are much too long.

4. Struggling with unsustainable transport

The rise of fossil transport started in the industrial revolution. Due to its success, the fossil transport system is reaching its limits – ecological, physical, social – in a very short time span. Its success undermines its very foundation and reveals *the unsustainability of the fossil transport system.* The unsustainability of the fossil transport system has multiple dimensions covering many different issues: *(*1) Use of fossil fuels. (2) Greenhouse gas emissions. (3) Metals and other materials. (4) Unsustainable space requirements. (5) Equity. (6) Biodiversity. (7) Soil degradation. (8) Other impacts on the environment. (9) Physical inactivity and health. (10) Traffic safety.

The listed issues are not exclusive, they are partly overlapping and are interrelated. Each issue on its own reveals the unsustainability of the present transport system. The problems are being experienced in varying degrees all over the world and pose increasing challenges.

Transport is a major source of greenhouse gas (GHG) emissions and a major contributor to global heating and climate change. Main sources are road transport, maritime shipping and aviation. GHG emissions from railways and inland navigation are comparatively low. GHG emissions of transport are still on the rise. Of special concern are the GHG emissions of aviation due to the radiative forcing of emissions at high altitudes.

The fossil transport system is still dominant. It still promises to provide convenience and status associated with certain modes of transport and vehicles, together with the associated emotional appeal. This is not to forget the momentum that such an all-encompassing system – transport infrastructures, spatial structures, mental models, mobility cultures – continues to unfold. Shaped by the framing of fossil transport, vested interests are at work to prolongate the current system: personal as well as institutional interests. Therefore, business-as-usual (BAU) is still prevailing.

Despite the prevailing perception that BAU can be continued for the time being with only minor changes, the problems described above can no longer be ignored and have to be addressed now. Therefore, many relevant players see a solution in the introduction of electric cars and a switch to renewable energies. The hope is that the phasing in of electric cars will be quick enough to attain in time the climate goals for road transport. And in addition, to end the oil dependency of road transport and to reduce the air pollution. There are also technological solutions proposed for shipping and aviation. This assumes that an energy transition will be possible by largely maintaining existing structures – BAU light.

Partial solutions address not all aspects of the unsustainability of transport. In addition, the slow changes envisioned by politics and the players for change in transport are way off the urgency posed by climate change. The costs of inaction are rising. It is high time for the comprehensive transformation of the fossil transport system to a postfossil sustainable mobility.

REORIENTATION – transport and mobility transformation

5. Transport and mobility transformation – part of the Great Transformation

5.1 UN Sustainable Development Goals (SDGs) – Transforming our World
5.2 Great Transformation towards sustainability – supported by the SDGs
5.3 Resilience and reducing vulnerability – a systemic objective prominent in the Great Transformation
5.4 Transport and mobility transformation – part of the Great Transformation towards sustainability
5.5 Great Transformation – active phasing in, active phasing out, conversion
5.6 Transformation – scope and scale, dynamics and timeliness
5.7 All countries are transformation countries – but subject to different circumstances
5.8 Transport transformation – mobility transformation

The transport and mobility transformation is a major building block of the Great Transformation towards sustainability. This is a result of our analysis, it is not yet an established perception. Referring to the work of Polanyi, the German WBGU introduced the term Great Transformation in 2011. The UN, in 2015 with the adoption of *Transforming our World: 2030 Agenda for Sustainable Development*, stated that the world is on an unsustainable path and that it is urgent to change to a pathway heading towards sustainability – the transformation towards sustainability. The Agenda defines 17 Sustainable Development Goals (SDGs). While there is no single SDG explicitly addressing transport and mobility, many of the SDGs are of direct relevance: the SDGs support the transport and mobility transformation.

The new Agenda of the UN, in explaining and substantiating the SDGs, refers pervasively and consistently to *resilience* as an indispensable criterion in the strive for sustainability. Resilience is a property at the systemic level in the transformation. It refers to infrastructures of all kind (e.g. power supply, communication, logistics, etc.) and to social structures as well. Resilience means the capacity to cope with temporary and persistent disruptions of all kinds, not least with the effects of climate change. *Resilience* is strongly related with *vulnerability* (of people and countries), *poverty* and *equity*. The social dimension is in the foreground. This is in agreement with our human approach to the mobility transformation.

The transformation implies the *phasing in* of more sustainable structures (as e.g. the promotion of renewable energies). Transformation research is mainly focused on this aspect by dealing with innovations. However, equally important is the timely *phasing out* of unsustainable structures. This aspect is in most cases dealt with only in an ad hoc manner and not in a systematic way (e.g. ending the mining of lignite in Germany). Phasing in and phasing out are closely related with the *conversion* of existing structures in order to minimise stranded assets.

The dynamics of the transport and mobility transformation can be analysed and described using four parameters: scope, geographical scale, scale of transformative change, and timescales.

The Agenda states: all countries are transformation countries but subject to different circumstances. In this transformation, the traditional concept of development is itself subject to change and is part of the transformation. Development has to be *reframed* as a move away from unsustainability.

6. Transport transformation – the technology approach dominates

6.1 Transport – movement of people and goods
6.2 Space – transport technologies to overcome space
6.3 Transport transformation – focus on vehicles, energy, infrastructure, data
6.4 Drivetrain transformation – electrification, refuelling infrastructures, renewable energies for road transport
6.5 Digital drivers of transport transformation – autonomous, connectivity, sharing
6.6 Metals – recycling, circular economy, technological progress
6.7 Technology approach – frames and values shaping the transport transformation

First, the many dimensions of the transport of people and goods are outlined – modes, distances, motorisation, fuels, technologies, infrastructures, etc.

The relationship of space and transport is fundamental. The function of transport is to overcome space, and to this end to reduce as much as possible the friction of distance. Transport technologies, with motorisation being the main driver, have reduced the friction of distance significantly – on water, on land and in the air. This success was accompanied by an ever bigger space requirement of motorised land transport and the tendency to prioritise the transport function in public space and road space.

This legacy of the success of motorised transport is shaping the technology approach to the transport transformation. The drivers for change are the greenhouse gas emissions and the air pollution caused by fossil transport. A main topic is the transformation of the energy source of road vehicles – from fossil fuels to renewable fuels – by the electrification of the drivetrains. This transformation requires the build-up of new refuelling infrastructures for battery electric vehicles and fuel cell vehicles. A positive effect for climate protection requires a parallel energy transformation to renewable energies on a global scale.

The dynamics of digital technologies are increasingly dominating the narrative of the impending digital revolution being part of the transport transformation. For transport, within the field of relevant digital technologies, three prominent topics can be identified: autonomous, connectivity, sharing. Self-driving cars are a goal of the car industry and tech companies. The technologies are still in their infancy. The consequences for society and infrastructures are hotly debated. Sharing technologies are already applied for cars, bicycles and e-scooters.

In the history up to the industrial revolution, metals like copper and iron were used and reused again and again. This was their unique property. The rise of the fossil transport was made possible by the use of basic metals like iron, copper and aluminium. In the recent development, technology metals (like rare earth metals) and their alloys gain importance. However, mining will not bring about an infinite supply of metals. Today, the use of metals in transport, the energy system and in digital devices, is unsustainable because a big share of metals is not reused or recycled, they are dissipated and wasted. Therefore, they are lost for the future use by humanity. A more sustainable use of metals has to become priority.

The framing of the transport transformation is an expression of the underlying valuations of society. Fossil framing shapes the basic perceptions of transport and mobility, the corresponding values and the actions of key players in industry as well as in politics. The motor still dominates.

7. Mobility – the human approach starting with people

People are the starting point for elaborating the concept of mobility – the needs of people to be mobile and abilities to fulfil activities at other locations. In addition, the interests of companies and people working to provide transport services of all kinds have to be accounted for. This universal requirement applies to people of all ages, everywhere in the world, now and in future.

In the beginning was the upright gait. Walking was the basic and universal mode of mobility in the formation of the human species. Being able to walk became a defining characteristic of the human condition. Humans became bipeds.

There is substantial empirical evidence for the need to be physically active in order to stay healthy – physically and mentally. Evidence was established that the whole range of everyday physical activity adds up and is furthering health: every single step, using stairs instead of escalators and elevators, walking in the neighbourhood as well as walking and cycling to cover longer distances. Physical activity is a universal and integral part of the human condition.

Distance and speed are fundamental dimensions of mobility. The corresponding senses have evolved in line with the speed of walking and running. Human senses provide the biological basis for activities, behaviour and communication in space. Senses for seeing, hearing, touching, temperature, balance and acceleration are constitutive. Sight is basic for understanding how people experience space and for the perception of aesthetics, the world of senses and sensors. Skills are essential for all forms of movement: walking, cycling and driving motorized vehicles. The specific skills needed for the various modes vary widely. Skills are based on senses of perception and on processing information in complex situations. All skills need physical and mental capabilities in various forms. They change with age and they depend on learning and practicing.

Rhythms are fundamental for human life. In chronobiology, daylight is the most important *zeitgeber* to synchronise the multitude of human body clocks. The *rhythmicity* of day and night, of activity and rest, is basic also for mobility.

Many dimensions of the mobility of people are shaped by human nature, however not in a deterministic manner. At all times and locations, cultural settings are likewise shaping and moulding the mobility behaviour of people. This is a variable relationship between characteristics of the human nature and societal traditions leading to the variety of mobility cultures.

The human approach changes the conceptual perspective on mobility. It leads to the inclusion of human properties, needs and abilities shaping the mobility of people. The approach provides vital evaluation criteria for transforming transport and mobility. It integrates these criteria into the concept of mobility in a systematic way by not dealing with these aspects just in an ad hoc manner. It brings into focus the interests of players and people providing transport services. It sets the topics for the next chapters and shapes our comprehensive frame of mobility.

8. Mobility transformation – the human approach dominates

In the human approach, the concept of *mobility* focuses on people, on their needs, capabilities, interests and activities requiring a change of location. Mobility as a comprehensive concept expands the common understanding of transport to include (1) *movability* (i.e. the *potential and ability to move)* as well as (2) the *actual movement* (i.e. *transport*, the multitude of modes of moving people and goods). (3) Mobility comprises as an intrinsic quality the *emotion* associated with movement (motion and emotion) – pleasure and displeasure. The all-pervasive rhythmicity of human life pertains to the rhythmicity of mobility. This is expressed in the dimension (4) of *arrival, rest and pause*, accounting for the diverse valuation of time.

This framing of mobility implies a corresponding *mobility policy*: a policy taking into account all four dimensions of mobility with the objective of establishing a more sustainable mobility – for people and goods, for all people. The concept of mobility is inherently related to the SDGs and the transformational change towards a sustainable development.

Active mobility, walking and cycling, is basic to human nature. In order to make the concept of active mobility intuitively tangible, we introduce the *mobility pyramid* which is inspired by the food pyramid. This didactic tool can be used by individuals, in public debates, planning and decision making. In the mobility transformation, active mobility has to be treated on an equal footing with public transport and motorised individual mobility.

The concept of mobility delivers a new perspective on space. The importance of settlement and urban structures, of land use, and of quality public space, gets into focus. The reduction of the friction of space is no longer the dominant goal. Improved vehicles and electric drivetrains are only one element in transforming mobility, as are digital technologies which have to assist people and not to incapacitate or substitute them. In addition to technological innovations, basic changes are necessary to arrive at more sustainable spatial structures.

The use of fossil energies will come to an end, whereas the need to use metals will not only continue but will rise – in the energy transition, for digital technologies and in transport. This shows itself in the functionalising of all stable metals in the periodic table – humankind has arrived in the All Metals Age. The present use of metals is unsustainable: metals are to a large extent not reused and are dissipated, i.e. lost for ever for humankind. Structures have to change to enable a continuous use and reuse of metals as far as technologically and physically possible. In this process, resource justice is an overall objective.

The human approach shapes the frame of the mobility transformation. This frame overlaps with the frame of transport transformation with regard to more sustainable technologies. Yet, it has a much wider scope with an added emphasis on active mobility, health, equity, lively cities, etc.

BUILDING BLOCKS – paving the way for the mobility transformation

In the course of the Great Transformation, all energy used to power transport will have to be increasingly renewable and used in an efficient manner. The mobility transformation will be increasingly dependent on mineral resources, specifically metals.

With active mobility, human power is the basic renewable energy for mobility. This primary human renewable energy is typically neglected or is downplayed in politics, public debates and in mainstream research focused on renewable energies in transport. Contrary to this perception, human power can play a major role in the transition to renewable energies in the mobility transformation. There is a big potential for increasing the share of walking (shoes being the most basic means of transport), and of the use of bicycles and pedelecs. This requires adequate spatial structures, quality public space, etc.

The energy transition from fossil, and to some degree, nuclear energy sources has to be comprehensive in scope – for cars, delivery vans, trucks, buses, light rail, railways, shipping and aviation – as well as in scale. Battery electric vehicles and fuel cell electric vehicles will be the two major lines of transition in road transport, depending on application. Hydrogen is a possible fuel for aviation. Liquid biofuels can be used to fuel current combustion engines. However, this is an energy source in short supply, limited by competing agricultural and other land uses. Wind energy may be directly used in shipping either with sails, kites or rotors.

Energy efficiency has a major role to play with significant scope for improvements in all segments of mobility. Examples for this potential are the slow steaming in maritime shipping and the down-sizing of passenger cars. The efficient mix of modal shares and the efficient operation of motorised modes are ways to further the energy efficiency of the entire transport system.

The functionalising of all metals will become even more important in the course of the mobility transformation. We present nine guiding principles for a more sustainable use of metals: design to function, design for recycling, interplay of design to function with design for recycling, implementation of a comprehensive recycling system, reduction of metal use, switch to renewable energies and reduction of energy use, social criteria for sustainability, ecology and health, and finally promoting metal awareness. All these elements are a prerequisite for the mobility transformation, the energy transition and the related digital transformation.

Technologies for the use of renewable fuels are available. An increasing share of active mobility and public transport, adapted settlement structures, and vehicles designed and operated to purpose, are the road to limit the consumption of energy and metals at a more sustainable level.

10. Space – reshaping fossil spatial structures

10.1 Space – topography, landscape, land use, distance, speed
10.2 Friction of space – reshaping spatial structures
10.3 Land use functions and scarce space – resolving land use conflicts
10.4 Public space – quality, the human scale of speed and urban structures
10.5 Green space and blue space – well-being, health, microclimate
10.6 Sustainable land use – fertile soil, sealing, land use patterns
10.7 Division of labour – restructuring space
10.8 Cyberspace – a new layer of space
10.9 Mobility and space – the integrated perspective

The transformation of the unsustainable fossil shaped spatial structures to a more sustainable use of space and public space is one building block of the impending mobility transformation. While generally not seen as such, the importance of this issue is on an equal footing with the corresponding energy transition to renewable energies and a more efficient use of energies.

Friction of space – also termed as friction of distance – is a basic category. It is determined by distance, time, topography and administrative divisions. In improving transport, the stated overall objective is the reduction of the friction of space. Intrinsically, in this endeavour multiple trade-offs are inevitable: e.g. reducing the friction of space for one mode increases the friction of space for other modes. Decisions have to be made with regard to the following trade-offs: (1) mode specific; (2) costs, time, energy; (3) within modes; (4) between modes; (5) shorter vs. longer distances; (6) priority for competing mobility goals. A fundamental change of priorities is needed to rebalance the friction of space as a means for reversing the current unsustainable course of transport.

The transport function is but one function of land use and but one function of public space. Transport is taking an increasing share of the scarce space. The trends of the spatial separation of land use functions and of prioritising automobiles within the transport function, should be reversed. Spatial and settlement structures have to be reshaped so that mobility needs can be fulfilled with decreasing transport volumes. The allocation of space within the transport function has to account for the widely varying specific space requirements per person of different modes.

In the dominant frame, urban public space is mainly a space for transport. Within transport, cars are dominating wherever a large share of public space is allocated for the driving and parking of cars. In contrast, the New Urban Agenda (UN-HABITAT III, 2016) reinstates a comprehensive concept of public space by re-embedding transport and ending the prioritising of individual motorised vehicles. This guideline should be used for providing quality public space. Place making at a human scale is part of that task. Creating and improving green spaces – and blue spaces (water) – are essential for well-being, health and the urban microclimate. The Covid-19 pandemic has demonstrated how important this is for people in cities everywhere.

The unsustainable use of land, the sealing and degradation of fertile soils has to be stopped. The regional and global division of labour has to be restructured so that transport volumes can be reduced to a more sustainable level. Cyberspace, a new layer of space, will shape mobility to some degree.

An integrated perspective on mobility and space will transform policies and planning.

11. Equity – pillar for a sustainable mobility

11.1 Mobility for all people – equity is indispensable
11.2 Social inclusion – accessibility for all
11.3 Poverty and distribution – reducing inequalities
11.4 Spatial justice – equity in planning
11.5 Climate justice and resource justice
11.6 Freedom of movement and human rights
11.7 The full scope of equity – from accessibility to inter-generational justice

Unequal access to mobility and unequal distribution of the benefits and burdens of transport are unsustainable. Equity is an essential dimension of sustainability. The transformation to a more equitable and fair mobility is an indispensable building block of the impending mobility transformation – on an equal footing with energy and space.

Accessibility is a main topic in the debate on equity in transport and mobility. This is part of the wider occupation with equity where an extensive body of thinking exists. These concepts of justice and equity are relevant in our context, for instance the capability approach by Amartya Sen and by Martha Nussbaum. In addition, political goals addressing equity give guidelines and focus on the far-reaching implications for the transition towards more sustainability. Prominent are the SDGs formulated in the UN Agenda, stipulating the equal rights of all people.

We build on this body of thinking with our human approach to mobility, starting with people, their needs and their capabilities. Equity has to be an integral part of the concept of mobility right from the start. In contrast, hitherto in transport equity issues are commonly addressed only in an ad hoc manner, but not as a systemic and pervasive category.

Social inclusion, the accessibility to mobility for all, is a basic equity issue. It concerns the accessibility of people of all ages, from children to the elderly people, and of people with certain impairments. It is also a gender issue, regarding e.g. the secure movement of women.

Poverty and wealth determine to a large degree the mobility behaviour. The inequalities are obvious and have to be reduced by an adequate design of the transport system.

Spatial justice refers to the allocation of public space to different functions and to the allocation of road space to different modes. A just and fair allocation is an ongoing task for planners. An example is the reallocation of road space in cities for active mobility.

Climate justice and resource justice address the equal rights and obligations of all people to generate emissions and to use energy and resources, especially metals. In a top down approach, this sets sustainability limits on a global level and, derived thereof, on an individual level.

Freedom of movement is a basic human right. In reality, it is only granted for the wealthy part of humankind.

For equity in mobility, basic issues like accessibility, income inequality, spatial justice and the other issues listed in the overview are the natural connecting points. However, the full scope of equity comprises the wider issues of intra-generational and inter-generational justice as well. These aspects are intrinsic to the concept of sustainability. They are of direct relevance for mobility and the transport system. The use of energy and metals is central. The long-term sustainability of an even more sustainable use of energy and metals than today has to be addressed – in time frames of centuries and millennia.

PLAYERS – interests, stakeholders, and their interplay

Long-distance transport of people and goods in all modes relies nearly completely on the direct use of fossil fuels, electric railways being the only exception. Fossil fuel use is unsustainable. The transition to renewable fuels is one of the major tasks in the transformation towards a more sustainable mobility. The world has to reduce greenhouse gas emissions to zero by 2050. In view of the scope of the task, a time span of only about thirty years is extremely short. This narrow time window precludes a transformation in small steps.

The transformation has to be enacted by a broad range of players concerned with the different transport modes listed in the outline. Players comprise governments and regulation bodies, transport companies, vehicle manufacturers, construction companies, industry associations, NGOs and media. In this process there are many diverging and converging interests at play. A technology shift is linked to mobility and industrial policy goals, regional policies, vehicle industry structures, competition and cooperation. The economics of the transformation depend to a large extent on the scope of the respective necessary changes and the associated time scales for the phasing in of more sustainable and the phasing out of unsustainable technologies and structures.

The hurdles for transformation differ with transport mode. *Shipping* is the backbone of the global division of labour. It is a tremendously challenging task to completely transition to renewable energy in due time. This is even more true for *aviation*. Hitherto, there have been no serious attempts to change the unsustainable course. Due to increasing political pressure, first initiatives for the development of cleaner aircrafts are underway. Comparatively easy is the electrification of *railways*. The switch of *heavy-duty trucks, buses* and *cars* to renewable drivetrains is gathering pace and should be possible in time.

The transformation of long distance transport has to respect the goal of access to mobility for all people, and, therefore, is an equity issue. This poses the question of the sustainable level of transport services for the different modes.

Players have to break the still prevailing global trend of perpetuating unsustainable transport. A number of positive examples may serve as an encouragement on the road ahead.

13. Short distance transport and mobility – a multitude of players and tasks

13.1 Vital transport functions – reduce emissions and equitably allocate scarce urban space
13.2 Active mobility – realise the potential for transforming cities
13.3 Public transport – improve its quality and give it priority over private cars
13.4 Private cars – shift to zero-emission cars and reduce their dominant share of road space
13.5 Logistic services – shift to zero-emission vehicles and provide dedicated space
13.6 Public services – provide for fire brigades, ambulances, police, waste collection, etc.
13.7 Quality public space – upgrade the quality of public space in general
13.8 Urban mobility policy – integrate transport planning, town planning and land use planning
13.9 Interplay of players – public actors, private actors, people, and their conflicting interests

Various transport functions are vital for the functioning of conurbations. These cover the mobility needs of people moving in different modes, the provision of logistic services and the provision of basic public services. Quality public spaces are a precondition for social interaction and the living quality in towns and cities. The dominance of motorised transport, especially of the private car, has affected health, degraded the living quality in conurbations and impaired global climate in an unsustainable manner. This is due to the local and global pollution caused by the use of fossil fuels and the traffic noise. All motorised vehicles relying on petrol have to be converted to zero-emission vehicles. Another corollary of the success of the private car is the ever increasing share which cars have occupied in public space and road space. This dominance is impeding other vital transport and mobility functions and is unsustainable too. The mobility transformation requires a redistribution of public space: granting other functions the space which they need for their vital function – and to which they have a right to. In this process many players are involved, conflicting interests have eventually to be resolved by political decisions.

Active mobility is the basic form of movement for people everywhere and is the most equitable mode. Many of the everyday mobility needs of people can be fulfilled by walking or cycling, provided settlement structures and an adequate share of road space are given. Initiatives are fighting for an increased share of road space for active mobility and a restructuring of land use patterns in the transition to more sustainable towns and cities, others try to delay that transition.

Public transport has to get priority over the private car in conurbations. This requires a good service quality which frequently is not the case. Preconditions are the provision of privileged road space and a corresponding traffic management. Public transport reduces traffic, emissions, and use of energy and resources. And it assures a more equitable accessibility in using motorised transport.

Life in cities depends on the provision of goods of all kind. Logistic services in cities are vital, however they are often performed in an unplanned and therefore chaotic manner. This causes stress for the service providers and for people in all other traffic modes. Basic public services need privileged road space and time slots to fulfil their function.

While the drivetrain of cars has to become electric and powered by renewable energies, this is not sufficient to make the present use of private cars compatible with liveable cities. There have to be fewer cars on the streets. Initiatives like take-back-our streets are active in reshaping neighbourhoods and cities.

Players comprise governments at all levels, the vehicle industry and other businesses. Important in the transition are pioneers like Jan Gehl, local initiatives and networks of cities.

MOBILITY TRANSFORMATION – rethinking the way ahead

14. Mobility transformation – scope, scale, need for action

14.1 The world on an unsustainable course
14.2 Scope – human needs, energy and metals, space, equity
14.3 Scale – local to global, short term to long term
14.4 Need for action – players, costs of inaction, costs of delayed action
14.5 Sustainability transition – a historical period
14.6 Transformational change towards a sustainable mobility – framing of a new narrative

The world is on an unsustainable course. This is a consensus at the highest international level, an assessment expressed prominently in the UN Agenda *Transforming our World* (2015), in the Paris Agreement on climate protection (2015) and in the UN Habitat III (2016). In transport, first steps towards a more sustainable development are taking place. However, globally transport is still overall on an unsustainable course.

The scope of the mobility transformation is defined by taking into account the intrinsic links of mobility with the many unsustainable features prevailing in the present way of life: the fossil energy system, the way metals are used, the dealing with space in its many dimensions, the neglect of many human needs and the prevailing inequity regarding accessibility and mobility potentials. These are the main issues which have to be addressed for reversing present trends on the way towards a more sustainable future. The human approach integrates these phenomena which substantiate and structure our concept of mobility. We start with people, their needs and capabilities. The use of fossil energies has to be phased out whereas the dissipation of metals has to be addressed: one can imagine a postfossil world, but not of a postmetallic one. Space is a scarce resource with many functions and qualities and with many ramifications for transport and mobility, not only in conurbations. Mobility for all is a basic equity issue.

The scales of the mobility transformation stretch from local to global, for people everywhere in the world. The time scales for the transition start with changes in the short term, but they have to be relevant in the long term, for all generations to come. The long term perspective has to guide all actions.

The need for action is undisputed and the direction also. The players have to face the challenges, within their social roles, their responsibilities and their power. They have to be aware of the size of the task, its urgency and of the time constraints. The transition is not without costs. But the players have to be aware of the costs of inaction and the costs of delayed action.

The transition is a historical period of its own, with changing circumstances caused by external events as well as by the actions of players – either promoting or impeding transformational change. It will not be a straightforward process. Incremental change, though helpful, will not be enough. It is time for radical change.

For the transition to gain power and speed, a new narrative is needed. It has to be based on the insight into the necessity of the transformation. It is imperative to place the mobility transformation on the political agenda – from local to global – at an equal footing with the energy transition. Our proposal for an adequate frame is characterised by four properties: renewable, equitable, active, lively.

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He wrote his PhD thesis at the University of Augsburg about mode choice. In an empirical study on the subject, a framing effect shaped the understanding of alternative modes, a finding which fits into the work of Tversky and Kahneman about framing. He worked as a post-doc in the research project "Social compatibility of energy systems", Working Group Environment, Society, Energy (AUGE, University of Essen). Since 1984 he was a lecturer for economics, at the Protestant Academy Tutzing and since 1997 a senior lecturer for economics and sustainable development.

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