Life-Cycle of Structures and Infrastructure Systems – Biondini & Frangopol (Eds)

Travel time gains VS time constancy - An irresolvable contradiction?

M. Hoffmann
Institute of Transportation, TU Wien, Vienna, Austria
Hoffmann - Consult, Vienna, Austria

ABSTRACT: Systematic analyses of market developments and transport trends are the basis for the evaluation of investments in transport infrastructure in common approval procedures. Traditional cost benefit analysis (CBA) considers time savings between connected locations as a key benefit of the expansion of transport infrastructure. With reference to almost constant time expenditures for mobility, some researchers argue that there are no relevant time savings and thus no real benefits. As the literature analysis and empirical data show, both the time savings between locations after expansion and approximately constant time expenditures for mobility in the transport system over the long term can be observed. Resolving this issue is therefore the key for consistent economic analysis of transport infrastructure investments. Using a location-theoretic model and empirical data, the paper shows that expansion projects reduce transportation costs, increase efficiency, and largely translate the time savings into accessibility benefits. The centralized production and division of labor is then the basis for economies of scale efficiency gains with diminishing marginal utility. As the resulting environmental impacts and resource consumption are not adequately reflected in standard economic theory, the development in transport is largely unsustainable yielding high external costs. A possible solution would thus be to contrast the efficiency gains in the market with the life cycle costs and external costs of these investments.

1 INTRODUCTION

1.1 *Impacts and comparison of projects*

The origins of such an economic evaluation of projects can be found in the development of welfare economics at the end of the 19th century. The first regular systematic comparisons of benefits and costs of public infrastructure projects are known from the U.S between 1930 and 1940. The pressure for more efficiency led to a subsequent standardization and increasing use of cost-benefit analysis (CBA) from 1950 to 1970. Between 1970 and 1980, the concept of life-cycle cost analysis (LCCA) considering all costs and benefits was established. The concept of "whole life cycle costing" (WLCC), developed in the period from 1990 to 2000 takes the stochastic nature of input parameters, possible risks and external effects into account. As life cycle cost analysis requires extensive data and knowledge, it has rarely used in decision practice.

Investigating transport investment projects and alternatives with a cost-benefit analysis (CBA) is a well-established practice in transport planning since decades. The main methods in CBA are Impact Analysis (IA), Utility Analysis (UA), Cost Effectiveness Analysis (CEA), Benefit-Cost Analysis (BCA). The IA is a pure comparison of the pros and cons without overall decision criteria a as first starting point. The UA allows an evaluation according to weighted criteria and is well suited for topics that are difficult to quantify. The CEA contrasts the quantitative costs with a qualitative benefit i.e. how much benefit can be achieved per cost unit. The BCA compares quantified costs and benefits in a limited time frame. Depending on the selected method and parameters the results may vary significantly.

DOI: 10.1201/9781003323020-400

Since no infrastructure project takes place in a vacuum, the decision is usually based on a comparison of existing transport networks without further investment (Option #0) and alternative courses of action (Option #1 to #n) in a given time frame (Figure 1). For any project assessment, the system delimitation regarding function, space, and time has to be assessed. In terms of investment costs considering initial investments or the entire life cycle is a crucial difference. Assessing benefits is critical if only revenues or greater economic effects such as time savings, traffic safety, etc. during service life are taken into account. Since the majority of the costs are incurred in the initial phase, and the benefits are mostly generated later during service life with increasing capacity utilization, the selected interest rate is also crucial as later benefits and costs are depreciated.

From a cost perspective, emissions and impacts on the environment occur primarily during construction and deconstruction, and to a lesser extent during rehabilitation. In the operating phase, there are generally negative effects as a result of traffic emissions which can have a negative impact on the economy. However, as environmental quality is not adequately represented in standard economic theory, mainly negative aspects of transport infrastructure are largely underestimated in decision making. The concepts to incorporate environmental costs range from inadequate (e.g. “willingness to pay”) to promising (e.g. “costs to repair/replace”). As there is still no functioning market for environmental quality in capitalist societies these aspects are underrepresented in economic decisions explaining the low sustainability in the sector (Hoffmann 2019).

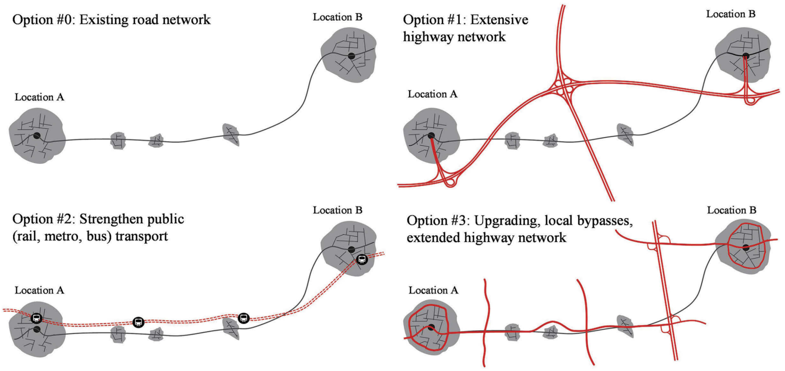

Figure 1. Development and comparison of transport infrastructure projects and alternatives.

1.2 *Travel time gains from A to B*

In individual choice on traffic mode and route selection as well as in aggregated Cost Benefit Analysis (CBA) the travel time between locations is a key factor. In a typical Benefit-Cost Analysis (BCA) the monetized time savings between locations account for 70 to 80 percent of benefits. The remaining benefits are mainly related to reduced accident rates and lower emissions from fewer traffic jams. The main advantage of using monetized time savings is the possibility to predict and observe increased average speed and reduced average travel time on existing and new routes on the short run. Figure 2 provides an overview on the relevant literature on this topic.

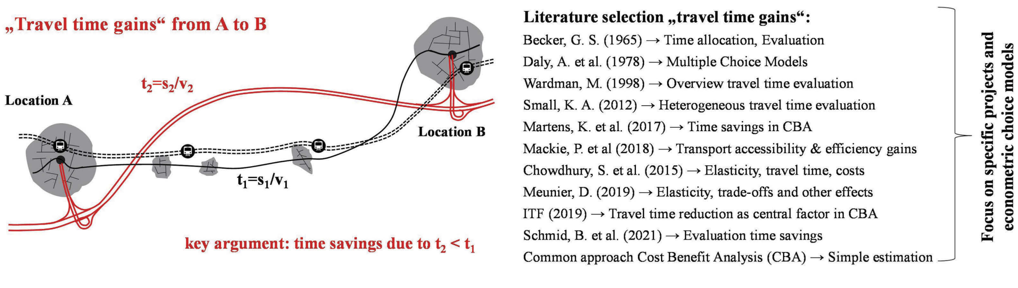

Figure 2. Travel time gains from A to B due to infrastructure improvements with selected literature.

1.3 *Time constancy in transport systems*

With the CBA becoming more popular in the last five decades the critique regarding the methods, the system delimitation, and the parameters has been mounting. As Flyvbjerg et al. (2003) and others have shown there is ample evidence on deliberate systematic decreasing of costs and increasing of benefits to improve success in the approval process. With the focus on time savings as a key factor there is substantiated critique both regarding the methods and results. The literature survey consistently shows that the total travel time in the entire transport system has remained largely constant over decades (Figure 3). This holds true for regions all over the world despite huge differences both in population, regional development, economic growth and transport investments. According to the CBA that would mean that there are no benefits from time savings. Furthermore, building roads to fight congestion is mostly a temporary solution. Despite observed accessibility gains there are saturation effects on medium to long-term and the improved transport network is becoming congested again. The data consistently shows that increasing transport speed and efficiency leads to longer transport distances and higher transport volumes with overall negative environmental effects. As there is a clear relation between transport network length and efficiency to economic growth, investing in transport infrastructure is not a zero-sum game. In summary, the argument of a lack of benefits due to approximately constant time expenditures in the system is therefore just as untenable as the focus on local time gains of individual projects.

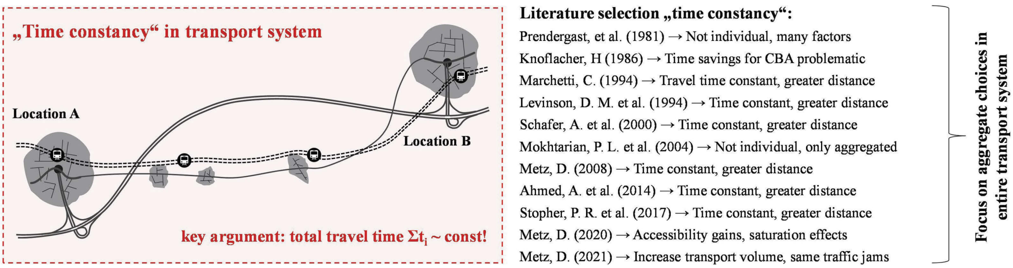

Figure 3. Time constancy in systems regardless of infrastructure improvements with selected literature.

2 AN EMPIRICAL LOOK AT THE WORLD

2.1 *Motorization, highway length, and transport*

Transportation infrastructure represent an essential social and economic resource. They structure the use of space and enable access to and exchange of people and goods between locations having a significant influence on economic development. The motorization rate increases with economic growth slowing down for a GDP/Capita of $20,000 to $50,000 (Figure 4). Apart from saturation effects the quality of public transport in agglomerations is the main explanatory factor. The network length of paved roads increases with the level of wealth, reaching about 4 m/C. on average at about $10,000 and about 9 m/C. at $50,000. A highway network emerges only above a certain level of development and wealth at a GDP/C. of $3.000 to $5,000 growing also slightly degressive with increases in wealth. In contrast, passenger and freight transport performance grows almost linearly with increasing levels of prosperity and is on average 12,000 pkm/C. and 5,500 tkm/C. per year for a GDP/C. of $50,000. The large deviations at the same level of wealth are mainly related to territorial, spatial and other structural factors that are not considered here.

2.2 *Energy consumption, emissions, investments, and travel time*

Technological and economic development are major explanatory factors in relation to the increase in life expectancy, the reduction in birth rates and the development of energy consumption. As shown in Figure 5 the energy consumption increases degressively with increasing wealth whereas the total CO_2 – emissions per Capita increase at first until a GDP/Capita of roughly $10,000 and stagnates thereafter. This effect is related to the ability to afford cleaner technologies despite higher energy consumption. However, this currently does not hold true for the mobility sector as both the mobility and the emissions exhibit a degressive increase with increasing wealth.

As positive economic developments generate taxes and funds for further investments, there is a clear relation between economic welfare and investments in transport infrastructure. The wide range of data shows that a comparable level of prosperity does not necessarily require a large high-level transportation network. The degressive growth of the prosperity level with increasing network length, can be seen in the meta-analysis from the literature (e.g. Melo et al. 2013) confirming the decreasing marginal utility for consecutive periods. As the negative environmental impacts are largely not accounted for in the classical economic view it can be assumed that the benefits of additional highways in developed societies will be very limited in most cases.

As previously shown the time savings due to improved (road) transport infrastructure can be directly experienced and measured before and after the implementation of projects. Therefore, this aspect is very well known both at the level of planners and the general population. Revisiting and extending the data on travel time budget proves that the total time spent in traffic largely remains the same regardless of the level of welfare or the spending's on transport infrastructure (Figure 5). With both empirical observations being more or less true, the common models are clearly failing to account for previous and actual developments. Thus, there is a need for a conclusive unifying theory as a basis for an efficient and sustainable transport planning of the future.

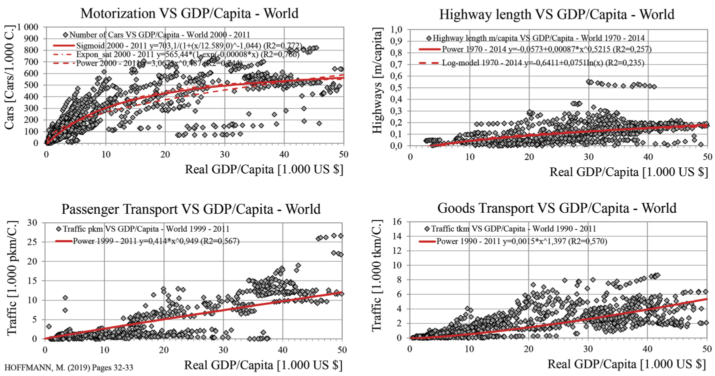

Figure 4. Motorization, highway length, passenger & goods transport VS real GDP/Capita in the world.

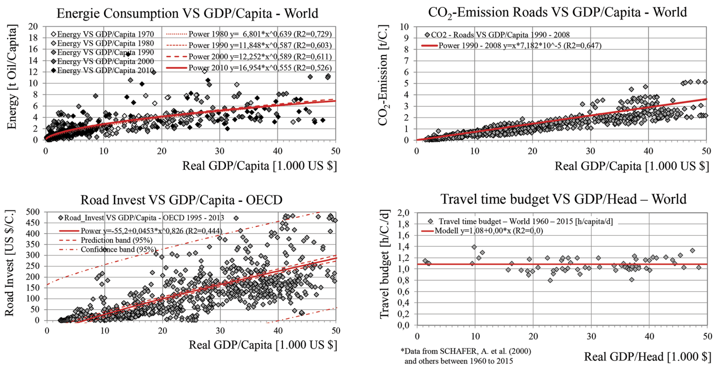

Figure 5. Energy consumption, emissions, investments, and travel time VS real GDP/Capita in the world.

3 SOLVING THE CONTRADICTION

3.1 *A new theoretical framework*

As current approaches are of limited value in solving these contradictions, there is a need for a theoretical framework providing a consistent explanation. This framework must be applicable both for developing and developed countries providing consistent explanation for past and predicted developments. As a framework accounting for all possible factors is beyond the scope, only the main factors shall be addressed here. A largely extended analysis and a vast array of empiric data on these issues can be found in the literature (Gruebler et al. 1991, Rodrigue et al. 2013, Hoffmann 2019).

The theoretical framework in Figure 6 provides an analysis of the impact of transport infrastructure on market equilibrium, consumer prices, regions, and population in three steps. Starting from two central locations each producing a comparable product ("A" ≈ "B") at defined unit costs, the costs for supplying the market will increase with the distance to the production location (costs for transport, wear and tear, loss, etc.). Price levels in this initial state before expansion of the transport network may differ due to differences in conditions at the locations (wage levels, materials, etc.). High transport costs will therefore have a prohibitive effect on the import of the particular product for similar products, thus staking out the primary catchment area of the market. Transport distances beyond the limit of equivalent product prices will accordingly be uneconomical and therefore the exception.

For the second step the transport network between the two locations is significantly expanded increasing transport capacity with decreasing travel time and transport costs as a short-term effect. As the transport costs of the connected locations are reduced equally, the geometric analysis directly shows that the location with lower unit costs in production is favored (expansion of catchment area). In the case of perfect competition and infrastructure equipment, the costs of expansion and any consequential costs for the environment and third parties are offset by the savings from lower prices (consumer return), and the use of additional opportunities of available services. In the case of imperfect markets and neglect of environmental impacts as external costs, there will be an over-provision of transport infrastructure and correspondingly unsustainable developments.

The third step includes the medium to long term reaction of the market participants to the new opportunities created by the expansion of the transport infrastructure. The combination of growth in the catchment area of central locations and further expansion of the transport infrastructure allows more economical central production of the product at location "A" due to falling unit costs for large quantities (economies of scale). This immediately increases consumer returns at both locations due to cheaper products, but leads to the abandonment of production at location "B". As a consequence, additional jobs and opportunities are created at location "A", which are lost at "B". If these losses cannot be compensated by competitive or non-substitutable other products or opportunities, there will be a further migration of population, production, and services from "B" to "A" as an increasingly dominant central location.

An increase in transport costs by internalizing external costs of the transport infrastructure leads to a parallel shift of the cost function for all market participants in the case of one-time access costs (vignette). Mileage-based costs make products from central production locations more expensive and thus have the opposite effect as an expansion of transport networks. The life-cycle costs of transport infrastructure are therefore always paid for indirectly via taxes (with or without taking external effects into account) or directly as a user charge. However, this does not mean that the expansion of transport infrastructure is a zero-sum game. On the contrary, it is the expansion of the transport infrastructure that allows for a division of labor in production and efficiency gains.

As with any production function, there is a decreasing marginal benefit as shown in several meta-studies (e.g. Melo et al. 2013). Extrapolating the economic benefits from past projects generally leads to an overestimation of the benefit/cost ratio, since the benefit decreases degressively and the costs of higher-ranking transport infrastructures increase progressively, especially at central locations. Furthermore, the expansion of transport infrastructure has the effect of redistributing benefits and costs with a shift to high-ranking locations and low-cost production sites (globalization) and is accompanied in the medium to long term by emptying peripheral areas and strengthening of agglomerations (polarization). Along developed routes, transport prices become less important with products and price levels converging on the global market (homogeneity).

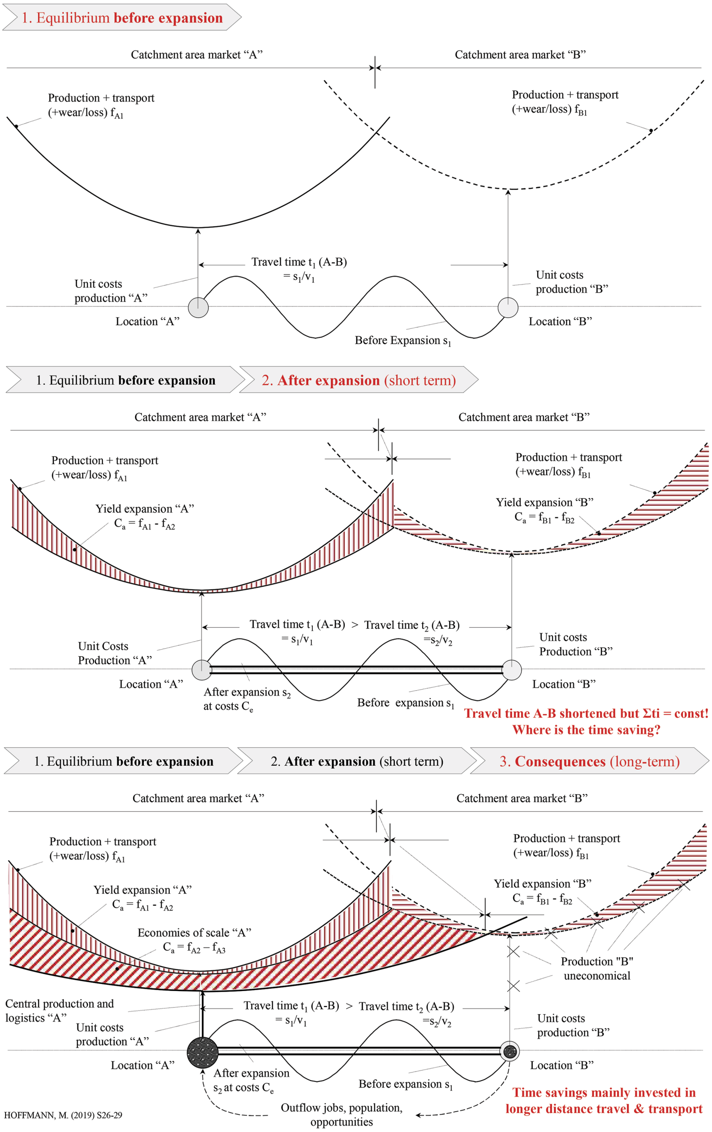

Figure 6. Impact of transport infrastructure on market equilibrium, consumer prices, regions, and population.

4 CONCLUSIONS

The development of regions, population and their economy are closely linked to their transport infrastructure enabling access to resources, products, and markets. The volume of the transport market can be seen as a function of population, economic power, production, and market shares in relation to surrounding locations. If the economic power and population in regions grow, the demand for goods, services and the possibilities increase and the transport market together with the demand for infrastructure rise accordingly. With transport infrastructures demanding high initial investments and ongoing reinvestments, they constitute a long-term commitment of limited resources. Since decades it is therefore a well-established practice to investigate transport planning strategies and projects with different types of economic analysis.

Traditional cost benefit analysis considers local time savings and avoidance of traffic jams on project level as key benefit of transport infrastructure investments. As these investments have been mostly temporary solutions and the travel time budget in the transport system has remained largely constant critics argue that there are no relevant time savings. Using a location-theoretic model and empirical data, the paper shows that expansion projects reduce transportation costs, increase efficiency, and largely translate the local time savings into accessibility benefits. The centralized production and division of labor is then the basis for economies of scale efficiency gains with diminishing marginal utility. With environmental impacts and resource consumption not being adequately reflected in decision making, the development in transport was and is largely unsustainable yielding high external costs.

Econometric input-output analysis based on elasticities are also a classic method to assess the benefits of transport infrastructure investments on the economy. With diminishing marginal returns towards an economic saturation level looking to past benefits when there was no developed transport network is grossly misleading. Furthermore, the average benefits of projects bundles cannot distinguish between efficient and meaningless specific projects. In addition, the negative effects are systematically underestimated in this type of analysis as there are no functioning markets and limited awareness for environmental quality. Thus, even using revealed and stated preference approaches for accounting of environmental effects largely underrate these costs.

The provided theoretical framework in this paper explains both the short and long-term effects and interactions of transport infrastructure investments on market equilibrium, consumer prices, regions, and population. Furthermore, it explains why high-level transport infrastructure does not benefit all connected locations equally driving competition in extended markets. In this regard transport infrastructure investments are drivers of globalization increasing urbanization in agglomerations and depopulation in peripheral regions. Although this development is largely unsustainable, a radical turnaround with unilateral pricing of external costs has severe repercussions due to increasing consumer prices and loss of competitivity. As a general strategy, a multilateral shift on a transnational level to a sustainable, efficient, multimodal transportation system minimizing externalities would be optimal. With diminishing marginal returns and the majority of the environmental impact in the construction phase, an efficient operation and maintenance is key. Finally, with an intact environment as a key future resource countries prioritizing sustainable modes of transport and efficient investments will have a competitive edge on the long run.

REFERENCES

Ahmed, A., & Stopher., P. 2014. Seventy Minutes Plus or Minus 10-a Review of Travel Time Budget Studies; Transport Reviews 34 (5): 607–625. https://doi.org/10.1080/01441647.2014.946460.

Chowdhury, S. & Ceder, A. & Schwalger, B. 2015. The effects of travel time and cost savings on commuters' decision to travel on public transport routes involving transfers; Journal of Transport Geography Volume 43, February 2015, Pages 151–159; https://doi.org/10.1016/j.jtrangeo.2015.01.009.

Daly, A. & Zachary, S. & Hensher, D. & Dalvi, Q. 1978. Improved multiple-choice models; in Identifying and Measuring the Determinants of Mode Choice.

Flyvbjerg, B. & Bruzelius, N. & Rothengatter, W. 2003. MegaProjects and Risk: An Anatomy of Ambition; in International Journal of Public Sector Management 17(3); DOI: 10.1108/09513550410530199.

Gruebler, A. & Nakicenovic, N. 1991. Long Waves, Technology Diffusion, and Substitution; International Institute for Applied Systems Analysis Laxenburg; Reprinted from Review XIV(2): Spring 1991, pp. 313–342.

Hoffmann, M. 2019 Lebenszykluskosten der Straßeninfrastruktur Optimierung von Investitionsstrategien und technischen Maßnahmen, Bau- und Betriebsweisen für Straßenanlagen in ihrem Lebenszyklus; ISBN 978-3-901912-36-8, Habilitationsschrift (Monographie) an der TU Vienna – Institut für Verkehrswissenschaften; Wien; 560 S.

ITF. 2019. What is the Value of Saving Travel Time?, ITF Roundtable Reports, No. 176, OECD, Paris.
Knoflacher, H. 1986. Kann man Straßenbauten mit Zeiteinsparungen begründen?, Internationales Verkehrswesen, 38, 454–457.
Levinson, D. M., & Kumar, A. 1994. The rational locator: Why travel times have remained stable. Journal of the American Planning Association, 60(3),319–332. https://doi.org/10.1080/01944369408975590.
Mackie, P. & Batley, R. & Worsley, T. 2018. Valuing transport investments based on travel time savings—a response to David Metz; Case Studies on Transport Policy Volume 6, Issue 4, December 2018, Pages 638–641; https://doi.org/10.1016/j.cstp.2018.08.002.
Marchetti, C. 1994. Anthropological invariants in travel behavior. Technological Forecasting and Social Change, 47, 75–88.
Martens, K. & Di Ciommo, F. 2017. Travel time savings, accessibility gains and equity effects in cost–benefit analysis, Transport Reviews, https://doi.org/10.1080/01441647.2016.1276642.
Melo, P. C. & Graham, D. J. & Brage-Ardao, R. 2013. The productivity of transport infrastructure investment: A meta-analysis of empirical evidence; Regional Science and Urban Economics Volume 43, Issue 5, September 2013, Pages 695–706; https://doi.org/10.1016/j.regsciurbeco.2013.05.002.
Metz, D. 2008. The myth of travel time saving. Transport Reviews, 28, 321–336. https://doi.org/10.1080/01441640701642348.
Metz, D. 2020. Time constraints and travel behavior; Transportation Planning and Technology, https://doi.org/10.1080/03081060.2020.1851445.
Metz, D. 2021. Economic benefits of road widening: Discrepancy between outturn and forecast; Transportation Research Part A: Policy and Practice Volume 147, May 2021, Pages 312–319; https://doi.org/10.1016/j.tra.2021.03.023.
Meunier, D. 2019. Mobility Practices, Value of Time and Transport Appraisal, International Transport Forum Discussion Papers, No. 2019/12, OECD Publishing, Paris.
Mokhtarian, P.L. & Chen, C. 2004. TTB or not TTB, that is the question: a review and analysis of the empirical literature on travel time (and money) budgets, Transportation Research Part A: Policy and Practice, Vol. 38, Issues 9–10, Pages 643–675, ISSN 0965-8564, doi.org/10.1016/j.tra.2003.12.004.
Nadiri, M. I. & Mamuneas, T. P. 1996. Contribution of highway capital to industry and national productivity growth; FHWA Report; USA.
Prendergast, L. S., & Williams, R. D. 1981. Individual travel time budgets. Transportation Research A: General, 15, 39–46. https://doi.org/10.1016/0191-2607(83)90014-6.
Rodrigue, J.P. & Comtois, C. & Slack, B. 2013. The Geography of Transport Systems, 3rd Edition ISBN: 978–0–203–37118–3 Routledge, NY.
Schafer, A. & Victor, D. G. 2000. The future mobility of the world population; Transportation Research Part A 34 (2000) 171–205; https://dx.doi.org/10.1016/S0965-8564(98)00071-8.
Schmid, B. & Molloy, J. & Peer, S. & Jokubauskaite, S, & Aschauer, F. & Hössinger, R. & Gerike, R. & Jara-Diaz, S. R. & Axhausen, K. W. 2021. The value of travel time savings and the value of leisure in Zurich: Estimation, decomposition and policy implications; Transportation Research Part A 150 (2021) S186–215; https://doi.org/10.1016/j.tra.2021.06.015.
Small. K. A. 2012. Valuation of travel time; Economics of Transportation Volume 1, Issues 1–2, December 2012, Pages 2–14; https://doi.org/10.1016/j.ecotra.2012.09.002.
Stopher, P.R., Ahmed, A. & Liu, W. 2017. Travel time budgets: new evidence from multi-year, multi-day data. Transportation 44, 1069–1082. https://doi.org/10.1007/s11116-016-9694-6.
Wardmann, M. 1998 The Value of Travel Time: A Review of British Evidence; Journal of Transport Economics and Policy Vol. 32, No. 3 (Sep., 1998), pp. 285–316 (32 pages); https://www.jstor.org/stable/20053775.