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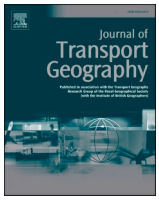

COVID-19 and its long-term effects on activity participation and travel behaviour: A multiperspective view

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ABSTRACT

This paper discusses possible long-term effects of COVID-19 on activity-travel behaviour. Making use of theories and concepts from economics, psychology, sociology, and geography, this work argues that lasting effects can be expected, and specifically that peak demand among car and public transport users may be lower than if the pandemic would never have happened. The magnitude of such effects at the aggregate level in terms of the total travel time of all inhabitants of a country or state is likely limited. Such lasting effects imply that additional infrastructure extensions to reduce congestion on roads and crowding in public transport might have a lower benefit-cost ratio than would be the case without these impacts. The paper discusses avenues for future research, including work on the role of attitude changes, the formation of new habitual behaviour, new social norms and practices, well-being effects, and the role of Information and Communication Technologies (ICT).

1. Introduction

The impact of COVID-19 on travel behaviour has become a major focus. Many papers on this issue have already been published, and very likely, many others will be published in the coming years. For example, Beck and Hensher (2020) show that from late May to early June 2020 in Australia, people started travelling less, especially by car, and for shopping, social and recreational activities. Lamb et al. (2020) show that the decision to fly among people in the USA depends on perceived levels of COVID-19 threat, agreeableness, affect, and fear. Parady et al. (2020) show that in Japan, social influences lead to self-restriction. Van der Drift et al. (2021), for the Netherlands, find strong increases in cycling and that not everyone needs to travel during peak hours, whereas Hook et al. (2021), for Flanders, find an increase in so-called undirected travel trips (i.e., travel without a specific destination).

Of course, many more empirical papers thus far have studied activity-travel behaviour in the short to medium term because the outbreak of the virus only started in late 2019 in China and in 2020 in most other parts of the world. A very important question is "what will happen after the pandemic is over?" To what extent can lasting impacts of COVID-19 on activity-travel behaviour be expected? Will 'the new normal' remain or only temporarily influence behaviour? If there is a lasting impact, which type of impact will result, and what will this mean for, among other factors, the capacity of transport systems, the demand for office space, and the retail and Information and Communication Technologies (ICT) sectors? The answers to such questions are relevant not only to science but also to policy makers because societal challenges (safety, the environment, health, and congestion) and the benefits and drawbacks of policy options depend on travel behaviour developments.

One means to answer this question is to examine comparable (potentially) disruptive trends. Helpful in this respect is the literature review of van Cranenburgh et al. (2012), which shows that most (potentially) disruptive trends, such as 9–11, the oil crises, and ICT, only had relatively minor lasting effects. The authors estimate travel behaviour indicators to be influenced by 5 to 10% (the decrease in travel behaviour indicators such as the number of trips or kilometres travelled is on the order of magnitude of 5–10%). Based on these results, it can be hypothesized that the long-term effects of COVID-19 can easily be overestimated. On the other hand, several of the trends reviewed by van Cranenburgh et al. (2012) only lasted a relatively short period of time, such as the oil crises. This finding is corroborated by Chng et al. (2018), Lattarulo et al. (2019) and Circella (2021), who, in the context of analysing the long-term consequences of observed changes in travel behaviour, find that these changes are difficult to realize. Hence, the results of the past are no guarantee for the future.

Another means to shed light on the long-term effects of COVID-19

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involves reflecting on such effects based on theories and theoretical concepts. This is the scope of this paper. Our main question is as follows: What do dominant theories and concepts tell us about possible long-term effects of COVID-19 on travel behaviour and activity participation? It is important to realize that this paper was written during the pandemic (March 2021), when research on long-term effects could not be carried out (an exception being research conducted in countries where the COVID-19 virus seems to have disappeared). Therefore, it is quite speculative to assume specific long-term impacts.

The methodology used to answer this question involves a combination of selecting dominant theories and concepts; identifying determinants of travel behaviour according to these theories and concepts; and finally reflecting on possible long-term effects of COVID-19 making use of these theories, concepts and determinants.

With respect to theories, we draw upon the fields of economics, psychology, sociology, and geography, which are all relevant disciplines for studying travel behaviour (Dijst et al., 2013; Van Acker et al., 2010). By far, the economic theory most commonly used to study travel behaviour is random utility theory (RUT) (Varian, 1992). In the area of psychology, the theory of planned behaviour (TPB) (Ajzen, 1991) is very frequently used to understand behavioural choices. From sociology, we borrow social practice theory (SPT) (Shove et al., 2012), and from geography, we have the theory of time geography (TG) (Hägerstrand, 1970). This paper departs from these four theories. In addition, following Dijst et al. (2013), this work builds upon the psychology-based needs, opportunities and abilities (NOA) model (Vlek et al., 1997) because it nicely complements the TPB in some respects. Next, the paper covers three concepts: habitual behaviour (Verplanken et al., 1997), attitude changes, and constant travel time budgets. The basis for using these theories and concepts is first that these theories largely dominate travel behaviour studies and second that the combination of theories and concepts allows for a comprehensive understanding of possible long-term impacts of COVID-19 on activity-travel behaviour. However, we realize that the selection of theories is open for debate. We argue that the concepts that we select, such as utility, attitude changes, and constraints, labelled 'determinants for travel behaviour' in Table 1 (see below), are more important than the choice for the specific theory underpinning the existence of these concepts. The reader might have a preference for other specific theories underpinning the importance of these concepts.

The paper is limited to a focus on travel behaviour and activities as far as they are relevant to travel behaviour. For example, the substitution of onsite activities with online activities is within the scope of this work, but the substitution of forms of online activities not influencing travel behaviour falls outside its scope.

Section 2 presents the key determinants of travel and activity behaviour. This is followed by a discussion of the potential lasting effects of COVID-19 based on theories and theoretical concepts. Section 4 summarizes the most important conclusions and discusses findings presenting a research agenda.

Table 1
Determinants for behaviour.

Determinants/concepts	Theories/ sources
Intentions/motivations/needs	TPB, NOA
Attitudes	TPB
Social norms	TPB, SPT
Perceived behavioural control/feasibility of actions/individuals' abilities	TPB, NOA, SPT
Opportunities offered	NOA, UT
Time-space constraints	TG
The utility of the activity	UT
The disutility of travel	UT

TPB: Theory of Planned Behaviour, NOA: Needs, Opportunities, and Abilities Model, SPT: Social Practice Theory, UT: Utility Theory, TG: Time Geography.

2. Key determinants of activity-travel behaviour

The model commonly used to determine the factors that explain and predict activity-travel behaviour is grounded in the activity-based paradigm (Kitamura, 1988; Axhausen and Gärling, 1992; Ortúzar and Willumsen, 2011). In essence, such a model aims to answer basic what, why, where, how, when, and with whom questions. Travel is derived from activity participation. Activities can be spatially localized or not and/or are time constrained or not, leading to more, less, or no travel. When bounded in space and time, choices relating to trip destinations, means of transport, routes, and timing are subject to individual, household, and broader societal perceived constraints, opportunities, preferences, attitudes and social norms.

Table 1 lists determinants that influence behaviour according to one or more of the theories introduced above.

The determinants/concepts listed in this table will be used to discuss the possible long-term impacts of COVID-19 according to the selected theories. Note that the theories and concepts are not necessarily mutually exclusive. Some overlap exists. For example, UT can explain why at the aggregate level, the amount of time people spend on travel is quiet constant (see below). A strong motivation or intention for some behaviour corresponds with the high utility of that behaviour. A low level of perceived behavioural control corresponds with the high disutility of that behaviour. Constraints to activity scheduling as recognized in time geography influence the feasibility of some choice options.

Based on the many publications focused on COVID-19 and travel and activity behaviour (see some examples above), we hypothesize that the dominant impacts of COVID-19 on travel and activity behaviour are first that many people might have become more experienced with respect to online activities substituting for onsite activities such as e-working, e-learning and e-shopping. Next, individuals might have switched modes from public (shared) transport to private (individual) modes (car, (e) bike or moped) due to (expected) infection risks, restrictions on travel for some modes (trains, busses, trams, and aircraft), increased car availability at the household level (the car of the household member who is working from home is now available to other household members), or the lower congestion levels during the pandemic. Third, individuals might have experienced behavioural adaptations being combining destination and mode choices. For example, people might have substituted a holiday in a remote location for which they would have to fly for a domestic (or at least more local) holiday by car. Finally, people might have cancelled certain events, such as a conference for which one would have had to fly not offered online. The activity-travel behaviour impacts of COVID-19 can be understood from the determinants presented in Table 1 because restrictions and risks of travel and the benefits and drawbacks of online activities relate to these determinants. For example, the disutility of travel likely increases due to a fear of infection, and this fear also influences intentions, motivations and attitudes. Additionally, social norms and practices might cause people to travel less. Due to better ICT tools (access to and options offered) and more experience with these tools, individuals' use might become more feasible and not only for the young and technically savvy. A reduced need to travel probably increases one's time-space flexibility.

3. Reflections on theories and concepts

This section more closely examined the selected theories and concepts to better understand the possible lasting impacts of COVID-19 on travel and activity behaviour. Fig. 1 provides an overview of the theories and concepts introduced below and conceptualizes the mutual links between these theories and concepts and long-term changes in activity and travel behaviour.

All direct impacts of activity and travel behaviour according to theories and concepts of these long-term changes are explained below. In addition, the theories are related. Fewer constraints (TG) and changes

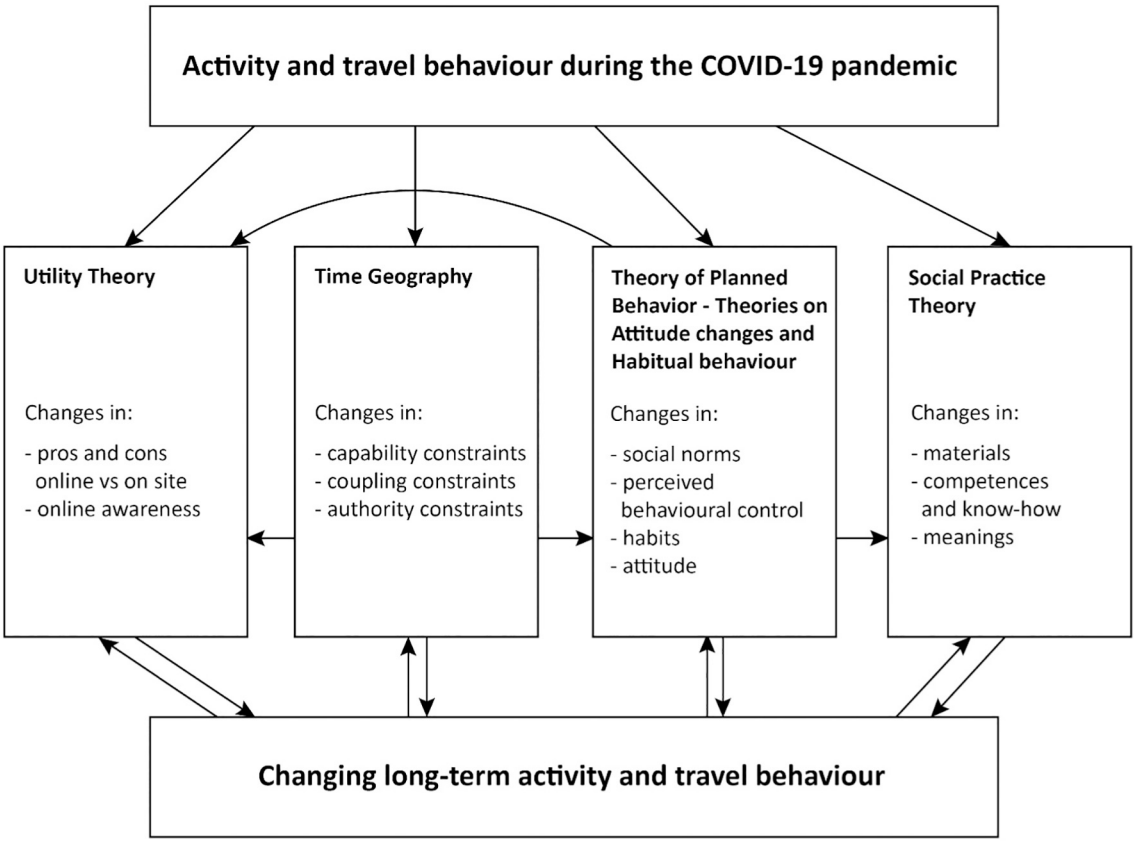

Fig. 1. Long-term activity and travel behaviour model.

in perceived behavioural control (TPB) likely change the balance of benefits and drawbacks towards more online working (UT). Reduced constraints (TGs) likely increase perceived behavioural control (TPB), and changing social norms might influence social practices, at least because of changes in (perceived) competencies. Finally, changes in long-term activity and travel behaviour might influence all theoretical blocks, as have activity and travel behaviour during the COVID-19 pandemic. For example, if more people continue to work remotely (or perform other activities online), this should decrease crowding (public transport) and congestion and change the balance of benefits and drawbacks of online versus on site activities. Long-term changes in activity and travel behaviour influence the constraints affecting people and might lead to changing habits and attitudes and social practices.

3.1. Utility theory

Utility theory assumes that people are well informed and trade-off the positive utility of activities and the negative utility of travel (time, monetary costs, effort, perceived risks, etc.). It is a very influential and frequently used theory for modelling choices in general and for modelling travel behaviour in particular (Ortúzar and Willumsen, 2011).

COVID-19 might have made people more aware of online tools supporting several forms of communication (bilateral or group), with examples including Skype (for Business), Zoom, Teams, and Webex. Such tools are often provided by employers but are also provided by others inviting people to participate in online meetings. Because of the (frequent) use of online tools, many people might not only have become aware of such tools but might also have become more experienced in using them. They might now be more aware of the benefits and drawbacks of online activities. Teleworking is also more broadly accepted by employers, and both employers and employees recognise their benefits. Next, people might become more aware of the benefits and drawbacks of modes of travel. For example, people who switching from local public transport to cycling might experience the flexibility, low cost, health and well-being benefits of cycling, reducing the overall disutility of cycling relative to the pre-COVID-19 era. If this is the case, some long-term impacts of COVID-19 might be expected because such benefits and drawbacks of travel options and online activities will not disappear once the pandemic is over.

3.2. Time geography

From the field of geography, the contribution of time geography as initiated by Hägerstrand (1970) can be helpful for understanding the long-term impacts of COVID-19 on activity-travel behaviour. Time geography emphasizes that people select activity and travel options within the boundaries of three types of constraints: capability constraints (biological, mental and instrumental limitations), coupling constraints (because people need to come together at specific times and often also in certain places), and authority constraints (authority-induced constraints to access, for example, because of restrictions on store open hours).

The most important COVID-19-induced changes influencing activities and travel are probably changes in activities from onsite to online. From online experiences, perhaps after initial struggles to work with online communication tools, people might have increased their capacities to participate in activities online, reducing capability constraints. This process also might have reduced travel-related coupling constraints because travel time is absent, allowing for more flexibility in activity and travel patterns. Finally, some authority constraints, such as those induced by restrictions on opening hours for shops, do not apply if people shop online. It can be hypothesized that people adapt their behaviour based on their positive experiences with some of the reduced constraints, such as those reduced by ICT. Because most reductions in constraints will not disappear after the pandemic, lasting effects of

COVID-19 on activity and travel patterns can be expected.

3.3. Theory of planned behaviour, attitude changes, habitual behaviour

Next, we move to theories and concepts from psychology. The theory of planned behaviour (TPB) (Ajzen, 1991) postulates that behaviour depends on intentions and perceived behavioural control (PBC). Next, PBC, attitudes and social norms influence intentions.

COVID-19 can have an impact on social norms. For example, employers could expect people to work at home as much as possible without forbidding them from working onsite. Alternatively, people might experience criticism from others in their social network(s) from having participated in activities that could result in infection risks. Such social norms next might change individuals' intentions and subsequent behaviour. Additionally, PBC might be influenced by experiences with COVID-19. For example, people might realize that they use online tools more effectively than they once thought. Changes in PBC and social norms can influence behavioural intentions and future behaviour. PBC, as explained, can also directly change behaviour. In this case, changes in the (perceived) skills required to use online tools can directly lead to behavioural changes. Some of the factors leading to behavioural changes, such as social norms influencing infection behaviour influencing risks, will disappear after the pandemic. However, other factors will likely remain after the pandemic, or at least changes in perceived behavioural control in the case of online activities and the use of related tools.

An important concept in psychology in general, and of TPB more specifically, is the concept of attitudes. TPB assumes attitudes to be constant, or – in some modified versions – to only change based on interactions between attitudes, social norms and PBC. Increasingly, the academic literature has recognized that attitudes do not have to be constant. For example, based on a model from Eagly and Chaiken (1993), van Wee et al. (2019) present a model for attitude changes explaining that attitudes can change because of new information ('knowing', the cognitive dimension), new experiences ('doing', the behavioural dimension) and emotions ('feeling', the affective dimension). Triggers can directly influence each dimension, and all three dimensions interact in a complex manner. COVID-19 and related societal changes can be seen as triggers affecting all three dimensions. For example, new information about online tools has likely updated people's cognitive dimension. By using such tools, individuals' experiences may lead to changes in the behavioural dimension. People might experience positive or negative emotions through their adoption of online activities (often communications) over onsite activities. For instance, individuals might view online grocery ordering negatively because they miss having personal interactions at shops or supermarkets, or they might have realized that one does not need to see, smell and feel fresh produce to be able to buy what one wants. Another COVID-19-related trigger is social pressure, as explained above. People, for example, might experience negative emotions if their behaviour is considered by others to increase risks of spreading the virus. If long-term attitude changes occur due to COVID-19-related triggers, a lasting effect on travel behaviour can be expected, as explained by the theory of planned behaviour. Note that some attitude changes might be temporal, especially those related to social norms of behaviour in place during the pandemic or related to infection risks. For example, De Haas et al. (2020) found that in the Netherlands, attitudes towards travelling by public transport have become more negative during the pandemic, and those surrounding car use have become more positive, but it is not clear if such changes in attitudes will last if infection risks disappear after the pandemic.

Psychologists have emphasized that people do not always select all options available and compare all alternatives and finally make the decision that achieves the highest expected level of utility, as already explained by Simon (1955), who introduced the concept of bounded rationality. Bounded rationality leads to people not evaluating all benefits and drawbacks of all choice options, as does the concept of habitual behaviour. In some cases, behaviour is habitual, and this also applies to travel behaviour, especially in the case of repetitive trips (Verplanken et al., 1997). For example, people do not each day consider their mode choices and departure times for their frequent commute trips. From the perspective of economics, this makes sense because it takes considerable effort to compare alternatives every day, and the probability of another choice being made over the typical choice is quite low. Therefore, the additional (transaction) costs do not outweigh the possible gains.

At the time of writing, March 2021, in most parts of the world, the COVID-19 era has lasted approximately three quarters of a year. Although to the best of our knowledge, the literature does not provide clear answers to the question of how long behaviour changes should last to develop new habits, this likely is long enough to change travel habits. If so, new habitual behaviour might have emerged, and it seems plausible that COVID-19 might have some lasting impacts on travel and activity patterns, even if the virus disappears. On the other hand, some people may also tire of activity and travel practices applied during the pandemic, and some might prefer to return to their behaviour before the pandemic, and thus a change in habits after the pandemic relative to those before the pandemic does not have to apply to all.

3.4. Social practice theory

Social practice theory (Shove et al., 2012; Spotswood, 2016) emerged from a response occurring in the field of sociology to understand social action. The unit of inquiry is focused on social practices and how social practices change over time. Thus, we move away from individuals and individual behaviour and from higher structural macro-economic phenomena (economic systems) and focus on the social practices of the groups in which people participate. A social practice (such as driving, cycling to work, or preparing food) is a routinized, automatic action that involves a number of interconnected elements that include materials (objects, infrastructures, and technology), forms of competence and know how (skills), and meanings (required or optional, functional or fun, and individual or group activities). Changes in these elements, as a result of COVID-19, might lead to changing practices that have a much broader and long-lasting impact than individuals changing their behaviour (Breadsell et al., 2019). If the materials (the hardware needed for a social practice) change, such as from access to (better) technologies that allow people to work remotely or improved food delivery apps, this will likely affect individual behaviour, turning it into a social practice with long(er) lasting impacts. The same applies for know-how (referring to the skills required to perform actions that fit with the social practice) and the associated meaning.

3.5. Constant travel time budgets

From our discussion of theories and concepts originating from economics, psychology, geography and sociology, we continue by discussing travel time budgets. A fundamental concept of travel behaviour is the concept of the constant travel time budget (Marchetti's constant). According to this concept, a large group of people, such as all of the inhabitants of a country, at the aggregate level spends, on average, a quite constant share of its total time travelling, 60–75 min per person per day (e.g., Mokhtarian and Chen, 2004). Note that this concept explicitly applies at the aggregate level, not at the individual level. The concept has proven to be quite robust over time. Even though modern transport systems result in higher travel speed, people on average do not travel less time than they did before the introduction of these systems but travel more kilometres within the same amount of time.

According to this concept, it is quite unlikely that due to COVID-19, people over the long term will on average spend less time travelling. If, for example, COVID-19 has a lasting effect on the level of teleworking and people with office jobs commute only two or three days per week and telework on other days, they might accept a job further from home or a house further from their work. Alternatively, individuals might visit

family or friends at night after a full day of working from home. It is important to realize that at the individual level, changes in travel times can occur, and the concept only applies at the aggregate level. For society and policy, aggregate impacts are more important, such as for decisions on infrastructure extensions.

Because of the robustness of the concept (to the best of our knowledge, all research on travel time budget appoints in the same direction), we hypothesize that any scenario in which people on average spend substantially less time travelling should be approached with scepticism. 'Optimistic' expectations implying that because of COVID-19-related experiences, people will spend substantially less time travelling are probably overly optimistic.

Several theories underpin the concept of constant travel time budgets (Peters et al., 2001), and utility theory (see above) is one of them. According to this theory, when travel times decrease, accessibility increases, and people could be willing to travel to a more remote activity location with higher added value. For example, individuals could accept a better job or shop at a less expensive supermarket.

4. Conclusion and discussion

Sections 2 and 3 explain why some lasting effects due to COVID-19 can be expected, with explanations including disruptions to habitual behaviour, changes in attitudes, a new equilibrium between the costs and benefits of behavioural options, changes in social practices, and their causal mechanisms. However, the concept of constant travel time budgets implies that we should be careful in expecting significant lasting effects in terms of a reduction in average travel time expenditure at the aggregate level. Direct effects leading to people spending less time travelling will probably to a large extent be compensated by indirect effects increasing travel times.

However, behind the aggregate constancy, many personal dynamics might occur, so for the discussion of impacts of COVID-19 on travel and activity behaviour, it is very important to distinguish between the microscale level of people and households, the mesoscale level of the group, and the macroscale level of averages for (parts of) societies.

The determination of which theory/concept or combination of theories/concepts can best be used to understand the lasting effects of COVID-19 on travel and activity behaviour depends on the research question at stake. Changes in attitudes and subsequent behavioural impacts can best be understood from psychology, trade-offs between online and onsite settings can better be understood from utility theory, patterns of new trend adoption relate to social practice theory, and the increased time-space flexibility resulting from online activities replacing onsite activities can best be understood from time geography.

From a spatial perspective, the discussion of the long-term impacts of COVID-19 is relevant for at least a number of reasons. First, this discussion emphasizes the need to rethink accessibility because online and onsite accessibility will probably become increasingly interwoven as a result of substitution from onsite to online settings. Second, if this substitution takes place, several location choices will face fewer constraints. This probably applies to residential choices that can be selected with more flexibility relative to work locations, while work locations can probably be chosen more flexibly relative to residential locations. Additionally, the choice of other destination types might become more flexible if people visit these locations less frequently, with the choice of a general practitioner offering online consults or consults at a university serving as an example. Third, if online activity participation becomes more important, in substituting travel to activity locations, the quality of the living environment might become more important.

Regarding the policy relevance of the likely long-term effects of COVID-19 on travel and activity behaviour, lower congestion levels on roads can be expected as well as less crowding in public transport. The precise impacts are still uncertain, and it is too early to say how significant changes will be. The most likely changes should be due to a shift from onsite to online settings and from regular to more discretionary trips. Due to indirect effects, the time saved for travel might be compensated by accepting longer commute distances or additional travel for other purposes. A person who works remotely all day at home might prefer to visit family or friends or go to a bar at night. In the case of commuting and education, at least a reduction in travel frequencies can be expected, and probably also a reduction in rush hour traffic, leading to less congestion on roads and less crowding in public transport. Even if people still travel to work, they will probably be more flexible with respect to when they travel. Individuals might, for example, first work online for one or a few hours and then travel to work after the morning rush hour traffic subsided.

Due to the lower pressure on peak hours, investments in capacity extensions of existing links (such as parts of the motorway network or railway stations and lines) to reduce congestion (roads) and crowding (public transport) might become less attractive, assuming that attractiveness is based on the difference between societal benefits and costs. In addition, policies that encourage cycling might become even more attractive because of the lesser associated infection risks (which might include a short- to medium-term advantage) and due to lasting effects on people who started cycling due the pandemic and have thus become more positive towards cycling (attitude changes).

In addition to these infrastructural implications, spatial planning will probably allow for more flexibility with respect to choosing locations for new residential areas because fewer constraints with respect to commuting will apply. Preferences for dwelling types could change if people continue to work more frequently from home, resulting in the creation of more work spaces and perhaps more outdoor space. Second, because the quality of living environments will probably become more important, as argued above, planning activities leading to more attractive environments will be more beneficial.

Many research challenges related to the impact of the pandemic on activity and travel behaviour remain. Of course, the long-term impacts of COVID-19, as hypothesized in this paper, cannot be validated because at the time of writing (March 2021), the pandemic is still occurring. Validation will be possible over the longer run, perhaps at least one year after the pandemic is over. A very general research challenge therefore is to explore the lasting impacts of COVID-19 on travel and activity behaviour in general and to validate our model (Fig. 1). Such research could explicitly study different groups of the population (workers, students, the elderly, and others), different geographic contexts (OECD countries, rapidly developing countries such as the BRIC countries, and the rest of the word), differences in health safety policies applied during the pandemic (more or less restrictions) and time horizons: Which changes occur along which time scales? We think that the importance of mobility cultures could result in important differences between and even within countries, with cycling culture being an important example. In cities or countries without a cycling culture, the switch to cycling will probably be minimal.

Let us end with some specific research challenges. First, the impact of COVID-19 on activity and travel behaviour provides a unique opportunity to study if, for whom and why attitudes change. Second, we recommend research into the long-term impacts of COVID-19 on social practices. How did/will these impacts change and for whom and why? Third, COVID-19-related changes in travel and activities offer a good opportunity to study changes in habitual behaviour and social practice. How strong are these changes when did they materialize and for whom and under which conditions? In addition, the impact of COVID-19 on activity and travel patterns and future options for activity patterns as addressed by time geography constitute an interesting research avenue. Perhaps people who substitute activities requiring time-consuming trips (work and education) face increased options of activity patterns not available before COVID-19. Research could also test the concept of constant travel time budgets. Will this concept still hold after COVID-19? It probably will, but validation is recommended. Finally, we realize that the theories we discuss here are not the only theories that could be useful for studying behaviour after the pandemic. We

recommend exploring the usefulness of additional theories. For example, prospective theory (Kahneman and Tversky, 1979), and more specifically loss aversion and reference points, could be helpful for understanding why people might prefer to not 'lose' the advantages of certain behaviours performed during the pandemic, such as reductions in commuting time and flexible activity scheduling. Behaviour during the pandemic could become a reference point.

In addition to these research challenges, we see several other opportunities for related research. Without the ambition to provide a comprehensive list, we discuss a few topics. A first topic concerns well-being and health. Health, well-being and quality of life are related not only to the era of restrictions but also to lasting impacts on travel and activities. To what extent do health, well-being and quality of life change and for whom, when and why? The first indications of COVID-19-induced health and well-being effects can be found in, for example, De Vos (2020). Second, equity is an important topic to be studied. Some changes fuelled by COVID-19, such as increased options to work from home, might affect groups of the population differently. Some activities might undergo democratization (such as e-shopping), while others will remain for the happy few. Most likely, higher educated and income individuals with (office) jobs benefit more from the increased online options than others, such as those with blue collar jobs who cannot perform their work remotely. On the other hand, if congestion and crowding levels are lowered, those who still need to travel to work will benefit most from lower congestion and crowding levels. A third focus of future research could be the role of ICT in influencing travel and activity patterns. For example, will better tools for communication be developed? Will people increasingly see online activities as a substitute for onsite activities, and if so, for whom, for which activities, and under which conditions will this apply? Could ICT increasingly become a 'pain killer' in the case of future restrictions due to pandemics? Fourth, we recommend research into policy responses to long-term changes in activity and travel behaviour. Do, for example, local municipalities reallocate public space over modalities? Perhaps such municipalities will provide more space for pedestrians and cyclists at the cost of private vehicles. Fifth, it is slightly speculative to assume that these changes in activity-travel behaviour will have impacts on technical and service innovations, such as autonomous cars, micro-mobility, (e)bikes and mobility as a service (MaaS). We hypothesize that commuting levels of large parts of the population, especially those with office work, and business travel will decrease due to COVID-19. If so, the benefits of autonomous vehicles might decrease, and those of more local modes of travel such as (e) biking, micro mobility, walking, and urban MaaS travel might increase if people substitute commute and business travel time for local travel for other purposes. These changes could also make cars less attractive in general (strengthening the peak car effect). Sixth, in what sense can COVID-19 be considered a potential game with respect to customers' purchasing of goods? Will pandemic experiences of store closures and perceived infection risks of online shopping, followed by substitution from on site to online shopping, have long-term impacts on shopping behaviour? Finally, what are the implications for home deliveries and related logistics?

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References

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Human Decision Process. 50, 179–211.
Axhausen, K., Gärling, T., 1992. Activity-based approaches to travel analysis: conceptual frameworks, models and research problems. Transp. Rev. 12, 324–341.
Beck, M.J., Hensher, D.A., 2020. Insights into the impact of COVID-19 on household travel and activities in Australia – the early days of easing restrictions. Transp. Policy 99, 95–119.
Breadsell, J.K., Eon, C., Morrison, G.M., 2019. Understanding resource consumption in the home, community and society through behaviour and social practice theories. Sustainability. 11, 6513. https://doi.org/10.3390/su11226513.
Chng, S., Abraham, C., White, M.P., Hoffmann, C., 2018. Psychological theories of car use: an integrative review and conceptual framework. J. Environ. Psychol. 55, 23–33.
Circella, G., 2021. Investigating the temporary vs. longer-term impacts of the COVID-19 pandemic on mobility. In: Paper presented at the 3 Revolutions Policy Conference (March 3, 2021). UC Davis Institute of Transport Studies. https://lnkd.in/eQJaqSq. accessed March 18, 2021.
De Haas, M., Faber, R., Hamersma, M., 2020. How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: evidence from longitudinal data in the Netherlands. Transport. Res. Interdisc. Perspect. 6, 100150.
De Vos, J., 2020. The effect of COVID-19 and subsequent social distancing on travel behavior. Transport. Res. Interdisc. Perspect. 5, 100121.
Dijst, M., Rietveld, P., Steg, L., 2013. Individual needs, opportunities and travel behaviour: a multidisciplinary perspective based on psychology, economics and geography. In: van Wee, B., Annema, J.A., Banister, D. (Eds.), The Transport System and Transport Policy. An Introduction. Edward Elgar, Cheltenham.
Eagly, A., Chaiken, S., 1993. The Psychology of Attitude. Harcourt, Brace and Jovanovich, Fort Worth, TX.
Hägerstrand, T., 1970. What about people in regional science? Paper for the Regional Science Association. 24, 7–21.
Hook, H., De Vos, J., Van Acker, V., Witlox, F., 2021. Does undirected travel compensate for reduced directed travel during lockdown? Transportation Letters. https://doi.org/10.1080/19427867.2021.1892935.
Kahneman, D., Tversky, A., 1979. Prospect theory: an analysis of decision under risk. Econometrica. 47 (2), 263–292.
Kitamura, R., 1988. An evaluation of activity-based travel analysis. Transportation. 15, 9–34.
Lamb, T.L., Winter, S.R., Rice, S., Ruskin, K.J., Vaughn, A., 2020. Factors that predict passengers willingness to fly during and after the COVID-19 pandemic. J. Air Transp. Manag. 89, 101897.
Lattarulo, P., Masucci, V., Pazienza, M.G., 2019. Resistance to change: car use and routines. Transp. Policy 74, 63–72.
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. Transp. Res. A Policy Pract. 38 (9), 643–667.
Ortúzar, J. de D., Willumsen, L.G., 2011. Modelling Transport, 4th edition. John Wiley & Sons, Chichester (UK).
Parady, G., Taniguchi, A., Takami, K., 2020. Travel behavior changes during the COVID-19 pandemic in Japan: analyzing the effects of risk perception and social influence on going-out self-restriction. Transportation Research Interdisciplinary Perspectives. 7, 100181.
Peters, P., de Wilde, R., Clement, B., Peeters, P., 2001. A Constant on the Move? Travel Time, Virtual Mobility and Constant Travel Time Budgets (Een Constante in Beweging? Reistijd, Virtuele Mobiliteit en de BREVER-Wet). Maastricht/Ede, Universiteit Maastricht, Faculteit der Cultuurwetenschappen/Peeters Advies.
Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice. Everyday Life and how it Changes. Sage Publications, London.
Simon, H.A., 1955. A behavioral model of rational choice. Q. J. Econ. 69 (1), 99–118.
Spotswood, F., 2016. Beyond Behaviour Change. Key Issues, Interdisciplinary Approaches and Future Directions. Policy Press, Bristol.
Van Acker, V., van Wee, B., Witlox, F., 2010. When transport geography meets social psychology: toward a conceptual model of travel behaviour. Transp. Rev. 30 (2), 219–240.
van Cranenburgh, S., Chorus, C., van Wee, B., 2012. Substantial changes and their impact on mobility: a typology and an overview of the literature. Transp. Rev. 32 (5), 569–597.
van der Drift, S., Wismans, L., Olde Kalter, M.-J., 2021. Changing mobility patterns in the Netherlands during COVID-19 outbreak. J. Location Based Services 16 in pres).
Van Wee, B., De Vos, J., Maat, K., 2019. Impacts of the built environment and travel behaviour on attitudes: theories underpinning the reverse causality hypothesis. J. Transp. Geogr. 80, 102540.
Varian, H., 1992. Microeconomic Analysis. Norton, New York.
Verplanken, B., Aarts, H., Van Knippenberg, A., 1997. Habit, information acquisition, and the process of making travel mode choices. Eur. J. Soc. Psychol. 27 (5), 539–560.
Vlek, C., Jager, W., Steg, L., 1997. Modellen en strategieën voor gedragsverandering ter vermindering van collectieve risico's. Nederlands Tijdschrift voor de Psychologie. 52, 174–191.