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Context

This research agenda is an initiative of the NWO National Initiative Brain and Cognition (NIHC) with involvement of the Behavioural Insight Team of the Dutch Ministry of Infrastructure and the Environment (IenM). The authors were asked to identify human behaviour issues, in particular issues that are of direct relevance to IenM policy and that require a multidisciplinary scientific approach. The issues identified illustrate how important it is to establish a link between human behaviour research and IenM policy areas. Please note that the issues identified are not intended to be exhaustive but that the agenda represents a first step towards a concrete research programme that also complements national and European policy frameworks and programs, for example through Dutch top sector policy, the National Research Agenda 2020 and Horizon 2020.

Introduction

The Dutch Ministry of Infrastructure and the Environment (IenM) focuses on liveability, accessibility and safety. It works to achieve effective connections by road, rail, water and air; connections that ensure the free flow of traffic in well-designed, clean and safe surroundings. It also protects the Netherlands from floods and works to improve air and water quality. The areas in which IenM works therefore involve human behaviour. Policy influences the choices and actions of individuals and, in return, the behaviour of individuals influences the extent to which IenM policy objectives are achieved.

We have learnt a great deal about the origins of human behaviour in recent decades – what we do and why we do it – and this learning has recently accelerated so that we are now discovering more by using new, advanced methods in behaviour research. Developments in sensor technology, for example, make it possible to record the behaviour of individuals under conditions in which this was previously impossible. Using brain scans, we can see which brain processes take place when observing and processing information. Psychologists, cognitive scientists and brain scientists are therefore learning how dynamic the human brain is and what it is good at and what it is less good at, but also how to understand the differences between individuals. Newly developed equipment and analysis techniques also make it possible to accurately monitor the behaviour of small or large groups. In this way, we can learn more about the interaction between policy and behaviour.

Measuring behaviour

To understand individual behaviour, it is important to measure this behaviour reliably, validly and efficiently. Research into sustainable behaviour, for example, often focuses on intentions or preferences rather than on actual observed behaviour. Recent technological innovations, however, make it possible to measure behaviour or behavioural outcomes, for example using in-car technology, GPS, smart meters or sensors. This increases our understanding of the factors that underlie actual behaviour and behavioural change. Researchers can also analyse the brain processes that steer behaviour using technologies such as neuroimaging and eye tracking. They can also study the effects of the characteristics of specific situations in a controlled manner, for example using virtual reality and simulators.

The authors hope that this research agenda will encourage research that can be used to enrich IenM policy practice with new knowledge of human behaviour. Some of the many questions relating to the work of IenM are: how can we encourage people to travel outside rush hour? How can we motivate people towards continued sustainable behaviour? To what extent are choices conscious or subconscious? What role does 'habit' play and how do habits develop? How do people differ from each other? What is the role played by different behavioural motives? To what extent is behaviour determined by the context in which choices are made? Is it possible to predict traffic safety in shared space traffic zones? Why is it often difficult to influence socially desirable behaviour in the long term?

To answer these and other questions, multidisciplinary collaboration is required between researchers working in psychology, cognitive science, brain science and other scientific disciplines that are able to explain, describe, measure, analyse and model behaviour in the IenM domain. Behaviour is influenced on the one hand by external factors such as social and cultural environments. On the other hand, it is also influenced by internal factors such as knowledge and habits. Which factors play a role and when varies per person and depends on the situation. IenM needs to increase its understanding of the relative importance of these various factors and the possible inter-actions between them. Collaboration between the various research disciplines can therefore help translate the understanding of human behaviour into effective IenM policy. This means that a multidisciplinary scientific research agenda is required with a strong focus on possible applications of the knowledge developed in the IenM policy area.

This research agenda focuses on those behaviour issues that are of the most relevance to IenM: those that relate to liveability, accessibility and safety. Each issue is preceded by a brief description that addresses questions such as: which particular behaviour is addressed and which behaviour is problematic or desired? Which factors influence that behaviour? What favourable policy interventions exist for influencing this behaviour and which factors influence the effectiveness and acceptation of these interventions? Which models that include behaviour (e.g. computational models, forecast models, analysis models and explanatory models) are already available? How good are they and how can they be improved using behavioural knowledge? Do the models also improve our understanding of human behaviour (as an outcome) and make it possible to predict human behaviour at the group and individual levels?

The term 'behaviour' in this agenda refers to the actions and choices of individual people as studied in psychology. These behaviour insights may also be translated into 'actions' and 'choices' at the organisational or enterprise level.

Modelling

Many models exist for analysing the dynamics in physical, economic or demographic systems. Examples are the Landelijk Model Systeem *(LMS; Dutch National Transport Model System), the National Energy Outlook (NEV), the* Nieuwe Regionale Modellen *(NRM; Dutch Regional Transport Model System) and car ownership models (such as Dynamo). In these models, the behaviour components mainly focus on 'what' people do, with much less of an emphasis on 'why' people display certain behaviour. In addition, most of the existing models pay very little attention to the influence of the cognitive processes that underlie behavioural choices ('why', 'what' and 'how').*

In addition to these descriptive models, models from the fields of cognitive psychology and artificial intelligence are also becoming increasingly popular. These models focus more on trying to determine the reason for certain behaviour. The models help us understand how and when the various internal and external factors influence behaviour and how these factors interact with one another. Such knowledge is important if we are to understand what the effect of policy interventions might be. Here too, collaboration is required between behavioural scientists and scientists from other disciplines such as the spatial sciences, economy, business administration, traffic engineering and environmental science.

It is also becoming increasingly possible to register the behaviour of traffic participants electronically and at a large scale, which makes it easier to monitor the effects of policy measures. The big data approach also makes it possible to search for patterns and predictability in behaviour, often without the need for predefined expectations. As we increase our understanding of the choices that people make, the big data approach makes it possible to implement policy interventions more effectively. This 'data-driven' form of modelling is able to process the behaviour of individuals as well as that of groups who, for example in the event of a calamity, may display different behaviour than would be expected based on individual behaviour patterns.

In safety research, a simulator for example can be used to replicate dangerous situations. By accurately recording and modelling behaviour under different simulated conditions, we can increase our understanding of how the decision-making process influences behaviour. The origin of unsafe behaviour can be even better understood using behavioural observation combined with psychophysiological measurements and the further development of neurocognitive models. This can enable policy development to focus on situations in which safety is an issue but in which intervention is effective.

1 | Liveability

Sustainable behaviour is conducive to liveability. Many environmental problems, such as climate change, are caused by human behaviour and can therefore be lessened by encouraging people to make sustainable choices. Examples are the use of sustainable energy sources (such as solar panels) and technologies (such as electric cars), investment in energy-saving measures in homes (such as insulation), the purchase of low-energy equipment (such as high-efficiency boilers and equipment with an A+ label) and changes in user behaviour (such as cycling rather than using the car, taking a shorter shower and eco-driving).

The social and behavioural sciences have many theories that can explain sustainable behaviour and that consider various determinants and processes. Although there is some understanding of the conditions under which these theories can be applied to explain different types of sustainable behaviour, more systematic research is needed. Because sustainable development requires people to act sustainably in many different areas, it is very important to understand the generic factors that motivate people to act sustainably, time and time again and in different situations. Values, for example, or a person's general goals, play an important role in this; these values determine which aspects of choices people find important and therefore take into consideration. Which behaviour is

displayed in a certain situation also depends on situational factors that determine the costs and benefits associated with certain behaviour. For example, public transport is more limited in rural areas than in urban areas and is therefore less attractive to people who live in the countryside. It is also important to explore the extent to which individual or collective cost and benefit considerations determine behaviour; does this vary for different types of behaviour and/or different groups? In the case of sustainable behaviour, we are mainly interested in the conditions under which people are prepared to act in the collective interest (towards sustainability), despite the 'cost' of these actions when sustainable behaviour is not the most attractive option. An intrinsic motivation to contribute to collective objectives also plays a role here. One important question is: which internal and external factors influence the decision to display sustainable behaviour? In addition, an understanding is required of the extent to which, and under which conditions, conscious choices or more subconscious choices or habits are displayed.

Specific research questions:
- Which theories can be validly applied to explain sustainable behaviour?
- Under which conditions can these theories predict different types of behaviour? How reliable are these predictions?
- To what extent, through which processes and under which conditions do internal factors (such as different types of values) predict sustainable behaviour?
- To what extent, through which processes and under which conditions do different external (or situational) factors predict sustainable behaviour?
- To what extent do individual and collective costs and benefits determine sustainable choices and does this vary for different types of behaviour and groups?
- Which factors reinforce the intrinsic motivation to act sustainably and what differences exist between individuals?
- Under which conditions do people make conscious decisions and which factors cause people to act more out of habit?

Policy interventions

Although various interventions have been found to be successful in encouraging sustainable behaviour, there is little understanding of their effects in the longer term. For example, are new habits formed? There is also a lack of understanding of the underlying cognitive processes, which is important for the development of theoretical knowledge and for determining how to make policy even more effective. Interventions that focus on extrinsic factors, such as pricing policy and legislation, can have serious negative side effects. More systematic research into the underlying mechanisms and the conditions under which various interventions are effective and acceptable is therefore required. It is also important to gain insight into the interventions that help ensure that people do not just display the intended behaviour, but that through this behaviour other sustainable behaviour is also encouraged.

Specific research questions:
- Which interventions are effective in terms of encouraging general sustainable behaviour in both the short and the long term?
- What are the processes through which interventions result in behavioural change and under which conditions are they effective?
- What are the possible side effects of interventions that focus on extrinsic factors and how can negative side effects be prevented?
- Which factors influence the level of acceptance of interventions and policy and how can acceptance be improved by addressing potential policy concerns?

2 | Safety

Safety is a broad subject. However, this research agenda concentrates on safe or unsafe behaviour relating to passenger and goods transport. Although we concentrate on road traffic and transport, the research questions can also be applied to other areas. Safe transport by road, rail, water and air, with the unavoidable intersecting transport flows, requires safe behaviour. Two factors that influence safe behaviour are legislation and spatial design. For much of the time, traffic participation involves routine behaviour, which means that traffic rules and design should be developed so that routine activities are possible and do not present any danger. The main threat to safety occurs when a destination cannot be reached using routine behaviour. Examples are situations that deviate from the normal state of affairs (such as a diversion) or that require high levels of concentration (such as unclear traffic signs or dangerous weather). Another example is situations in which there are large differences between traffic participants (such as differences in speed between e-bikes and normal bicycles on a bicycle path). Undesirable behaviour in traffic is therefore mainly due to the limited ability to act sensibly and attentively in all situations. This may be a particular problem for people whose ability in this is limited (e.g. inexperienced drivers or the elderly) and in situations or conditions in which people's powers of observation are affected (e.g. limited visibility due to darkness or poor weather conditions, alcohol consumption or tiredness). Poor choices prior to traffic participation (such as poor vehicle maintenance) can also increase the traffic risk.

Specific research questions:
- How can legislation, rules and traffic environments be developed to reinforce safe routine behaviour?
- Which behaviour-determining factors result in dangerous behaviour, in what way and to what extent? What are the exact determinants, conditions and tasks?
- How does vehicle automation influence behaviour and the risk profile of traffic participants?

Policy interventions
Behavioural traffic safety interventions are possible when designing the traffic environment (e.g. speed-limiting objects) and developing information (e.g. awareness campaigns) and legislation. Behaviour research can clarify which type of intervention is effective (and how exactly) for different forms of high-risk behaviour. It is very important to first determine whether undesirable behaviour in traffic is due to external factors (such as the design of the traffic environment or legislation) or internal factors (such as human limitations or wrong choices). As a rule, it is recommended to intervene at the source of the undesirable behaviour. Behavioural research can also show to what extent the behavioural change is enduring and to what extent the intervention can be applied to the target group.

Research can also show how new policy can encourage desirable behaviour without requiring individuals to make a conscious choice. An example is the use of visual illusions that affect the perception of speed. If people need to be made aware of a danger to achieve the desired behaviour change, the usual option is to provide information. This can be made more convincing and therefore effective using virtual reality, serious gaming or personalised information. Behaviour research is also required in the case of interventions in vehicles (such as the introduction of autonomous systems); this can help assess the possible side effects of the intervention on driver behaviour.
     The acceptation of policy measures depends on the extent to which people consider the measures to be necessary and effective, as well as the extent to which they feel they are acting of their own free will. Measures that are perceived to be unnecessary and ineffective or that require too much from the individual may encounter resistance. Behaviour research can show which measures will be accepted and under which conditions, for example because they have a subconscious effect or because they make desirable behaviour more attractive.

Specific research questions:
- How can information be developed so that it can be easily processed by people?
- How can surroundings be designed so that they result in desirable behaviour, whether consciously or not?
- Are interventions required to ensure that desired outcomes are stable and permanent (reward schemes, training)?
- For which type of information and for which target group is awareness-raising effective and why does it work?
- How does automation influence the behaviour and risk profile of individuals?
- Which factors determine whether a measure will be accepted, and can this be predicted?

3 | Accessibility

Accessibility represents the ease with which people can reach various places, for example for work, leisure or school activities. Improving accessibility is a core task of IenM and an important task of provinces and municipalities. Behaviour influences accessibility, while accessibility influences behaviour choices. The influence of behaviour on accessibility concerns choices that people make relating to (1) the activities they want to undertake, (2) the locations at which they undertake those activities, (3) the method they use to travel to and from those locations, (4) the time of day at which they travel, and (5) the route that they take. In return, such choices depend on the perceived level of accessibility.

Accessibility also depends on characteristics of the transport system, in other words infrastructure characteristics such as the availability of roads, bicycle parking facilities and railways. It also depends on fuel costs and public transport prices, as well as 'softer' factors such as how easy it is to make a transfer or the attractiveness of a station. Also relevant is where people live and the physical layout: what is located where? Where, for example are the jobs, shops, schools, hospitals and restaurants? If too many people want to join the same motorway at the same time, the result will be congestion and a decrease in accessibility for everyone. If too many people want to get on the same train at the same time, some people will need to stand and their perceived accessibility will decrease. If people choose to live far from the public transport network, they will probably soon choose the car as their main form of transport. The choices that people make therefore depend on the transport system and spatial planning, but also on their personal preferences. Such preferences often develop within a social setting, and factors such as income, age and level of education can influence this. Finally, the technological environment can also explicitly and implicitly steer people towards certain choices, for example because it provides information about alternative methods of transport. Examples are traffic signs over the road or navigation systems that show the delay on each route.

There is still a considerable knowledge gap when it comes to the perception of accessibility, the internal and external factors that people take into consideration, the mechanisms that underlie their behaviour choices and the influence of travel characteristics other than time and cost (such as comfort, reliability, transfers, the availability of seats and the weather). There is also little knowledge available on the influence of new technologies such as the e-bike and autonomous vehicles, and the continuous availability of information, on behaviour choices and therefore perceived accessibility.

Specific research questions:
- What choices do people make with regards to the place that they live, their activities, the locations at which they conduct these activities and the means of transport that they use to get there? On which accessibility characteristics are these decisions based?
- Which mechanisms underlie these choices? Examples are fixed rules and habits (personal rules of thumb) and the distinction between reflex, habit and considered behaviour.
- What influence do 'soft' transport system characteristics (such as ease of transfer and station attractiveness) and technological developments have on behaviour choices, and what are the mechanisms behind this?

Policy interventions

Accessibility policy encompasses governmental, provincial, municipal and public transport company policy that focuses both on the transport system and spatial policy. The opening hours of shops and day-care centres, for example, are also relevant. Accessibility policy focuses very much on infrastructure and public transport (service provision, prices/subsidies). We have a fair idea of how people and companies respond to this, but less of an idea about the influence of other, more innovative, policy instruments on people's behaviour. Examples of such instruments are tradeable permits for peak hour congestion, the stimulation of the e-bike and cycling in general, measures focusing on autonomous cars, spatial policy and extended opening hours for shops and amenities.

Specific research questions:
- Which behavioural changes follow as a result of measures that influence accessibility? Why are measures effective (processes) and under which conditions?
- To what extent are extrinsic rewards effective (financial rewards, as in the Noord Brabant province peak hour plan to get individuals to drive at different times), through which cognitive processes and under which conditions?
- Which measures ensure not only temporary behavioural change, but also structural, permanent change? Through which processes and under which conditions?