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Chapter 7

Public acceptance of hydrogen technologies in transport: A review of and reflection on empirical studies[1]

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Abstract

This paper reviews a number of quantitative empirical studies on public acceptance of hydrogen technologies in transport (published before May 2008) and provides a reflection on their use of terminology and theory. Looking at the terminology, we argue that the selected papers suffer from a lack of coherence and consistency in their usage of terminology. For example, terms like acceptance and perception have been assigned different meanings across studies. This limits the wider understanding of the results for hydrogen technology acceptance. Based on findings in other acceptability and acceptance research, we suggest ways to increase the consistency of terminology on acceptance and knowledge-related terms. In addition to these terminology-related issues, we show that the majority of reviewed studies lack a firm foundation in relevant theoretical frameworks, such as a broader theoretical framework that incorporates attitude and association measurements. This severely limits a thorough understanding of the issue of acceptance as well as the wider implications of empirical findings. We discuss in depth several avenues for improvement, by referring to available theories in the field of social psychology. Specifically, we show that application of the theory of planned behaviour and dual-processing theories, as well as findings on the influence of

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knowledge and information, lead to an increased understanding of the current results. Finally, we review the findings of the papers to discuss the acceptability and acceptance of hydrogen technologies and the determinants of acceptability and acceptance. The findings of the studies indicate that hydrogen public buses generate quite positive attitudes and positive but diverse willingness-to-pay values. Only a few studies have been conducted for other hydrogen technology applications. A host of factors is found to influence acceptability and acceptance, divided into demographic, psychological, situational and knowledge-related factors. We suggest studying acceptability and acceptance in a more extensive and comprehensive way, taking the influence of the many possible determinants into account.

7.1. Introduction

It is increasingly acknowledged that the rapidly growing energy demand, urgent environmental problems and depletion of fossil fuels demand immediate and global action (International Energy Agency, 2007). Zooming in on the field of transport, one of the major sources of energy and environmental problems worldwide, both researchers and policy makers have often suggested replacing fossil fuels with other, more sustainable energy carriers, such as hydrogen, bio fuels or electricity stored in batteries. Of these alternative carriers, hydrogen is increasingly recognized as a potential future energy carrier leading to a sustainable future energy system (e.g. Banister, 2000, European Commission, 2006).

More specifically, hydrogen-powered fuel cell vehicles are expected to offer potential solutions to a number of problems related to transport and/or energy use, such

as noise, air pollution, global warming and the security of energy supply (Banister, 2000, European Commission, 2006, Ball and Wietschel, 2009). Traffic noise is likely to decrease if fuel cells instead of internal combustion engines are used for propulsion. Also the level of emissions, which is known to influence global climate change and local air quality, can be reduced by using hydrogen as a fuel in transport[2]. Finally, reducing fossil fuel use potentially increases the security of supply by reducing our dependency on finite stocks of fossil fuels and avoiding geopolitical struggles resulting from this dependency.

However, before hydrogen can be successfully implemented as an energy carrier in transport, a great number of barriers need to be tackled, such as: the lack of refuelling infrastructure, the high costs of fuel cells and of low-carbon hydrogen production, technology immaturity, safety issues and public resistance (McDowell and Eames, 2006). The first barrier, a lack of refuelling infrastructure, is likely to prove a difficult one to overcome. The installation of hydrogen refuelling stations requires a great deal of investment and will only be worthwhile if hydrogen is used by many vehicles. Car drivers, however, will not find hydrogen vehicles attractive if there is no ready access to fuel (e.g. Struben and Sterman, 2008). This chicken-and-egg problem could be overcome if government policy support stimulates both the installation of fuel stations and the use of hydrogen cars up to a certain “critical mass”. Struben and Sterman (2008) also argue that the same chicken-and-egg problem applies to the availability of spare parts and the repair services associated with hydrogen fuels. Costs and safety issues may be diminished by technological research (Edwards et al., 2008), which is increasingly taking place in scientific institutes as well as in industry. The European Commission (2006) also

[2] Note that the actual emission reductions strongly depend on the source of energy that is used for the production of hydrogen (e.g. Ball and Wietschel, 2009).

indicates that hydrogen-related safety issues are expected to be tackled by setting regulations, codes and standards. However, all these investments in terms of time, effort and money from the side of industry and the government are deemed to have only a very limited effect if the public disagrees with the use of hydrogen as an energy carrier in transport. Reasons for diverging public opinions might include a greater perceived safety risk (as suggested by e.g. Bain and Van Vorst, 1999) or because of a general preference for vehicles other than those fuelled by hydrogen. Therefore, while enormous investments need to be made in research, development and implementation, it is of critical importance to gain knowledge about hydrogen acceptance among the general public, both in the role of citizens and consumers. Reacting to this need, a number of empirical studies into the public acceptance of hydrogen technology in transport have been published in recent years.

The goal of this chapter is to critically review this body of research into the public acceptance of hydrogen as an energy carrier in transport.[3] In line with the approach adopted in most of the available studies, we focus on quantitative studies. The contribution of this chapter to the literature is threefold. First, after having presented our selection of empirical studies, we review and reflect on terminologies that have been applied in these empirical studies. Specifically, we argue and illustrate that the current use of terminology is inconsistent across studies and provide definitions of and distinctions between terms based on wider research on technology acceptance. Second, we review the theoretical frameworks adopted in the studies and argue that what is often

[3] During this paper's review process, another review of empirical findings, which includes identifying gaps in research, has been provided by Ricci et al. (2008). Compared to that study, we focus more heavily on quantitative studies and discuss more elaborately the terminology and theoretical approaches adopted in the reviewed studies.

lacking is a clear theoretical foundation underlying performed measurements and explanations of obtained results. Several theories from the field of social psychology are presented, showing fruitful avenues for improving hydrogen acceptance research. Third, we highlight the main empirical findings presented in these studies, showing that hydrogen buses have received positive acceptance so far, and showing that several variables have been found to influence acceptance. We suggest that more research is needed to better understand the role of the several variables. The last section presents conclusions and recommendations for further research.

7.2. Selection of empirical studies

Empirical hydrogen acceptance papers were collected from scientific journals up to May 2008. An additional search using the snowball method provided extra papers. In total, eleven journal papers and one conference paper were found. Table 7.1 shows information on the retrieved publications, including the specification of the type of hydrogen application for which the studies measured acceptance.

[insert table 7.1]

As Table 7.1 shows, most of the studies concern transport applications; only two studies measure acceptance of other types of applications as well (Molin, 2005, Zachariah-Wolff and Hemmes, 2006). We will not discuss the empirical findings on these other applications.

Eight studies deal with acceptance of hydrogen buses. Six of these studies were connected to a hydrogen bus project that was actually implemented, five of which concerned fuel cell buses and one concerned a bus with an internal combustion engine

(ICE). The study on the ICE hydrogen bus (Hickson et al., 2007) also stands out in terms of being the only study that was entirely outside Europe; the hydrogen bus study of O'Garra et al. (2007) also provided data from Perth in Australia, as well as three European cities. Two of these studies and the four other studies measured acceptance of other applications than buses, including hydrogen cars (Molin et al., 2007, Molin, 2005), hydrogen taxis (Mourato et al., 2004, Zachariah-Wolff and Hemmes, 2006), hydrogen vehicles in general (O'Garra et al., 2005) and hydrogen refuelling stations (O'Garra et al., 2008).

7.3. Review of and reflection on the use of terminology

Looking at the papers, it shows that the terms *acceptance*, *perception*, *attitudes* and *preferences*, as well as *knowledge*, *awareness*, *familiarity* and *need for information* were often used. In this section, we will look at definitions or, when absent, at the implicit use of the words to gain a better understanding of how the terms are used in the papers. Then we will look at the wider available literature to find suggestions for improvement. We grouped together the first four terms, all representative of the wider understanding of acceptance, and the last four items, all related to knowledge which could influence acceptance.

7.3.1. Acceptance, attitudes and perception

Terminology in the selected papers The use of acceptance and seemingly related words in the selected papers are presented in Table 7.2. These words were gathered from the title, abstract and body of each paper.

[insert table 7.2]

Two findings stand out from reviewing the papers. First, explicit definitions are very rarely given, and none of the papers provides a definition for acceptance. Two papers (Molin, 2005, Zachariah-Wolff and Hemmes, 2006) provided definitions for the words attitude, perception and willingness to use. The other papers only implicitly provided interpretations of the terms, by the measurements taken. Second, Table 7.2 shows that a myriad of terms and measurements were chosen and often even seemed to be used interchangeably. Acceptance or acceptability, for example, was measured by asking for opinions, attitudes, beliefs and willingness to use, and sometimes even by asking for preferences, WTP and willingness to use. In addition, the terms support and opposition were used. The objects of acceptance measurements concerned actual hydrogen projects or suggested future applications of hydrogen; some papers combined both measurements. *Attitudes* were measured in many different ways, asking for people's opinions on a wide array of topics and with many different answering scales, such as opinions towards the transition to a hydrogen economy (the scale went from bad to good), trust in safety regulation (from disagree to agree), need for information (from no to yes) and support (choice options were: support, opposition, indifferent or need more information). The term *perception* was often used interchanged with associations, beliefs and attitudes. Furthermore, it was used for opinions with respect to the use of hydrogen in general and the respondent's own use of hydrogen or for opinions with respect to aspects directly related to the use of the technology, such as the safety of hydrogen vehicles and aspects indirectly related to the use of the technology, such as emission reduction.

The inconsistency of the usage of terms between papers, as well as the fact that the meaning of terms is often not made explicit in the papers, hampers the understanding of the wider value of the studies for interested readers.

Avenues for improvement: terminology in wider literature Several studies, in the field of psychology in general or research into acceptance of other technologies, have yielded insights that can provide useful starting points for improving the understanding of the reviewed terms. Based on these studies, we will suggest clarifications for the terms acceptance, acceptability, attitudes and perception.

While the term acceptance was used most often, the term acceptability was also used in one paper. From comparing the several papers it is not clear what the difference is between these two terms. Schade and Schlag (2003) discussed the distinction between the words acceptance and acceptability in the context of urban transport pricing strategies, noticing that these two words were often used with several meanings and without clear definitions. The authors made a distinction between the two terms by saying that acceptance refers to attitudes after the introduction of the technology or measure, while acceptability is the prospective judgment to introduction in the future. These definitions do not include behaviour, or do not distinguish attitudes from behaviour. We propose, therefore, using the term acceptance for actual behaviour in reaction to the technology, and acceptability for attitudes towards the technology and towards possible related behaviours. This is more in line with Wolfse et al. (2002), who describe a framework for the acceptability of controversial technologies. They suggest that acceptability considers people's willingness to consider the technology seriously and acceptance refers to the formal decision to implement the proposal.

Furthermore, papers usually use one term for acceptance, ignoring the heterogeneity that the term acceptance can encompass. Wüstenhagen et al. (2007), for example, described three different kinds of acceptance in the context of sustainable energy technologies: socio-political acceptance, community acceptance and market acceptance. Socio-political acceptance concerned acceptance at the broadest, most general level, including acceptance of both policies and technologies; it concerned acceptance by citizens, stakeholders and policy makers. Community acceptance was defined as local stakeholders' acceptance of locating renewable energy projects. Market acceptance concerned the adoption of the innovations. For *public* acceptance, which is our concern here, we suggest that three similar types should be distinguished: (1) socio-political acceptance, which can be defined as political and social behaviour by the public in reaction to national or even international (e.g. in the European Union) policy making (2) citizen acceptance, which can be defined as responses to situations where the public is faced with the use of technology in one's living areas as a result of others, and (3) consumer acceptance, which can be defined as the public's reactions to the availability of innovations on the market (in other words: the purchase and use of products).

To illustrate the proposed terminology for city buses, the public can have attitudes (acceptability) and behaviour (acceptance) in reaction to (1) the implementation of extra national taxes to realize hydrogen city buses (2) the realisation of these buses and refuelling stations near their dwellings, and (3) the availability of hydrogen buses, giving the public the option of being a passenger in these new buses. It is expected that people have different attitudes and behaviours for these different hydrogen-technology related events. For example, it was found that people have a different opinion about underground

carbon storage when they were asked about it in general versus when it concerns usage of this technology within their own living environment (Midden and Huijts, 2009).

The word attitude is regularly used in the papers, referring to many different measurements. We would like to suggest definitions from the field of psychology. Eagly and Chaiken (1996) defined attitude as “a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour.” Also Ajzen (2001) stressed the evaluative component of attitudes, stating that this evaluation is measured on scales like “good-bad, harmful-beneficial, pleasant-unpleasant.” Additionally, Crano en Prisline (2006) suggest that attitudes represent evaluative integrations of cognitions and affects experienced in relation to an object. So we suggest to use the word attitude for evaluative judgments. For attitudes in the context of hydrogen acceptability and acceptance, Molin (2005) and Zachariah-Wolff and Hemmes (2006) defined attitude as an “evaluative component denoting whether a transition towards a hydrogen economy is good or bad.” Attitudes may, however, also concern evaluations towards other aspects, such as characteristics of the technology and specific reasons to implement the technology (e.g. climate change). In economics the term preferences is often used. Attitude is different from preferences in the sense that attitudes measure peoples’ evaluation of something, without explicitly referring to a certain set of alternatives. Preferences are always dependent on the alternatives from which people have to choose.

Another term that has come up several times is perception. The interpretation of this word in the reviewed papers concerns a broader use than is common in the field of psychology. Psychologists usually use a definition that is directly related to sensation:

perception involves the interpretation of sensations, giving them meaning and organisation; sensation refers to the immediate and basic experiences generated as stimuli fall on our sensory systems (Matlin and Foley, 1997). This definition from the field of psychology is more “a quick immediate and intuitive cognition” (Merriam-Webster Incorporated, 1997), while hydrogen acceptance studies seem to use a wider definition such as “a mental image” (Merriam-Webster Incorporated, 1997). Terms used in psychology for this are attitudes (see above) and beliefs. A belief can be defined as a “conviction of the truth of some statement or the reality of some being or phenomenon especially when based on examination of evidence” (Merriam-Webster Incorporated, 1997). Ajzen (2001) connects beliefs and attitudes by saying that “beliefs that are readily accessible in memory influence attitude at any given moment.” We suggest making the meaning of terms more explicit in studies and taking the proposed definitions in mind when studying the public acceptance of hydrogen technologies.

7.3.2. Knowledge, awareness, familiarity and need for information

Terminology in the selected papers Table 7.3 gives an overview of knowledge-related terms in the selected papers.

[insert table 7.3]

Several papers mentioned and measured knowledge or related items. The terms that were used included awareness, familiarity, having heard of something and need for information. Clear definitions, distinguishing the knowledge-related measurements from each other, were not given in any of the papers.

Knowledge was tested in many different ways. First, knowledge was tested by checking the ability to answer test questions correctly. These tests comprised several items that combined knowledge about environmental problems, the physical properties of hydrogen and the consequences of different fuels. Second, some studies asked for self-reported knowledge, asking people to indicate how much they knew about hydrogen, fuel cells or other related issues. Third, the terms awareness and familiarity were used and seemed to measure being knowledgeable about events or information. Fourth, several studies investigated the need for more information. We can conclude that also for knowledge-related items, a myriad of words and conceptualisations were used. The meaning of the terms and the wider implications of the findings were often not elaborated on.

A reflection on the terminology We will now reflect on this diverse use of the terminology and suggest some definitions for terms and distinctions between meanings of terms by using dictionary information and findings from knowledge-related studies in other research fields. First, the difference between the knowledge indicated by the participants themselves and the knowledge measured by tests needs to be understood. It is unlikely that these two items have perfect correlations, and it is even uncertain whether they have reasonable correlations, since people may not be very good at judging their own knowledge as compared to other people's knowledge and may have a different perception of what knowledge is than the researcher. This may be illustrated by a meta-study in the field of genetically modified food acceptance, which compared the two ways of measuring knowledge in American and European studies (House et al., 2004). Self-

rated knowledge was called subjective knowledge and knowledge calculated from the percentage of correctly answered test questions was called objective knowledge. The study showed that the two knowledge measurements did not measure the same construct in the gathered studies; the average correlation between the two items amounted to only 0.36 ($p<0.01$, $n=309$). The study also showed that the two knowledge measurements correlated to different variables; while both objective and subjective knowledge correlated with education, subjective knowledge was also correlated with religion, location of the respondents and willingness to eat GM food products. Based on these findings, we suggest making a distinction between objective knowledge and subjective knowledge when trying to explain the role of knowledge in the formation of hydrogen acceptance.

Second, awareness was examined by posing the question whether people had heard of hydrogen and fuel cells or whether they were aware of certain developments or projects. Familiarity, on the other hand, was elicited by asking for familiarity with certain information. It seems that these measurements are quite related. The dictionary definition of awareness (Merriam-Webster Incorporated, 1997) that is closest to the way the awareness is used here is: “having or showing realization, perception or knowledge.” This definition includes the term knowledge and therefor gives an overlap with the factor knowledge. It is suggested to use the term awareness only in the context of having realisation of the existence of an object (like “having heard of it”) and to use the term knowledge when people know specific facts. For familiarity the definition is: “close acquaintance with something” (Merriam-Webster Incorporated, 1997). While awareness seems closer to mental processes or mental constructs, familiarity seems closer to

experiences. The term familiarity can be used as a realisation of the technology based on personal experience with hydrogen technology, such as having already used a hydrogen vehicle, or other more extensive involvement with it, like having read a lot about the subject.

Third, several of the selected hydrogen papers reported the need for more information. Need for information was measured on two different scales. One scale was an agree-disagree scale, thereby determining the amount of information need in general. The other scale asked people either to give an outspoken opinion by choosing support or opposition, or not to give an outspoken opinion, by choosing need for information or indifference. This way of measuring need for information will indicate whether people feel knowledgeable enough to support or oppose the use of hydrogen technologies. The two ways of eliciting need for information are different by nature and can elicit different responses from people. They cannot therefore be directly compared. We suggest that a general interest in information, and the specific need for information in order to give an answer to evaluative answers to questions should be distinguished in order to be able to answer certain acceptance questions.

Based on these deliberations, we suggest that the following six knowledge-related factors need to be distinguished: (1) objective knowledge, (2) subjective knowledge (3) awareness of the technology, or related aspects, in the sense of having realisation ("having heard of it"), (4) familiarity with the technology, in the sense of having had personal experience of it, (5) interest in more information (6) need for more information in order to be able to answer acceptance questions.

7.4. Review of and reflection on the use of theories

Looking at the selected papers, we noticed that often a strong theoretical framework was lacking; important theories and theoretical notions were often not explained. Most authors did refer to findings in previous hydrogen and/or acceptance studies. Molin's (2005, p.115) study was the only paper that described a causal model which was "loosely based on attitudinal theories that can be found in psychology literature." Acknowledging the theoretical knowledge base per se does not increase the value of a paper; however, applying these theories to improve the distinctions between the concepts, as well as putting the results in a larger context and explaining the value of the outcomes, will increase the value of the research.

Although the studies did not describe relevant theories, they did seem to make several implicit assumptions. This was most clear for three different topics that are related to well-known theories in the field of psychology: (1) the relationship between attitudes, intention and behaviours, (2) the influence of psychological constructs such as associations and trust on acceptance, and (3) the role of knowledge, awareness and familiarity. In this section, we will describe the implicit assumptions more elaborately and we will reflect on theories that can improve the understanding of the available results and the quality of future studies. Due to the limited use of theories in the selected papers, we will mainly elaborate on the reflective part.

7.4.1. The relationship between attitudes, intentions and behaviours

In general, when talking about acceptance, it is often hoped that not only the attitude but especially the behaviour of people is positive towards the technology. For example, it is hoped that people will use the hydrogen bus once it is implemented and that people do

not protest against a hydrogen refuelling station that has been planned by policy makers. In order to indicate current behaviour or predict future behaviour, attitudes are often measured, even though the connection between attitudes and behaviour is usually not explicitly discussed. The same counts for the relation between intentions and behaviour. Several of the selected papers on hydrogen acceptance measured attitudes and intentions to behave, as can be seen in Table 7.2, but of these studies, only Molin's (2005) paper explicitly postulated that attitudes influence intentions to use, and intentions to use influence behaviour. However, a specific theory on this topic is not explicitly used to choose and support the measurements. We will describe the dominant model for predicting planned behaviour in the field of psychology and other theories that complement or criticize this theory, in order to present current insights into the value and role of attitudes with respect to behaviour.

First, the widely applied theory of planned behaviour (Ajzen, 1991) says that attitudes towards behaviour influences the intention to behave, which in turn influences the actual behaviour. This shows that attitudes influence behaviour indirectly rather than directly, via the intention to behave. Second, the theory postulates that also subjective norm and perceived behavioural control influence intention to behave. This means that attitudes are not the only predictors for intention to behave. Third, moods and habits can also influence behaviour (see e.g. Ajzen, 2001), showing that also other variables can have additional explanatory power for behaviour. While the theory of planned behaviour is a model that predicts planned behaviour, i.e. following from thoughtful decision making (Crano and Prislin, 2006), it is increasingly being recognized that people often show automatic behaviour, habitual behaviour, or behaviour influenced directly by

feelings. Adding these variables to the model could increase the predictive value of an acceptance model[4]. Fourth, the predictive value of the applied model is also strongly influenced by the way variables are measured (Armitage and Connor, 2001). For example, attitudes have to be consistently measured with the specific behaviour. Fifth, the attitude needs to be strong (stable and resistant to change) in order to have a relatively high predictive value of later behaviour (Ajzen, 2001); it needs to be recognized that often hypothetical cases are studied and people's attitudes and intentions will not be the same in reality (Crano and Prislin, 2006).

We will illustrate a few of these insights in the case of hydrogen vehicles. People's car behaviour can be predicted by asking a number of people about their intentions to buy a car and by asking about their attitudes towards the car. This can be done in a very specific way by asking people about their intention to buy a specific car within a specific timeframe in a specific location, which can be predicted by their attitude towards buying the specific car in the specific time frame and the specific location. The actual buying behaviour could, however, also be influenced by the idea that the vehicle is not available at short notice because of rumours that the time between ordering and receiving the vehicle is too long (perceived behavioural control is low). In addition, the intention to buy the car will also depend on the image of the vehicle that prevails among colleagues, neighbours and friends (this is related to social norm) and on the past behaviour of buying cars since, for example, people who are used to visiting a Ford garage are not likely to switch to Toyota (habit). And if people expressed their attitude

[4] A meta-study (Armitage and Connor, 2001) has shown that the theory of planned behaviour on average predicted 39% of the variance in intention and 27% of the variance in behaviour in 185 studies up to the year 1997.

when it was not a very strong attitude, the attitude is likely to have changed by the time they actually buy a new car.

Recognizing the value of measuring attitudes is important for studying hydrogen acceptance. We suggest that future studies are improved by, first, using extra predictive variables, especially for the case that behaviour is not planned, second, to attend the specificity and strength of measured attitudes and intentions, and, third, to measure actual behaviour or try to simulate real life events so that the predictive value increases.

7.4.2. The role of associations, trust and affect

Several papers measured variables such as associations and one paper measured trust. The presence of many positive associations and the limited presence of negative associations were sometimes seen as a sign of acceptance. Trust was found to be related to acceptance. Related theory on these factors was not discussed in the reviewed papers. Both trust and associations seemed to concern intuitive notions, especially in the case of affective trust or distrust reactions and instant, free associations. In the field of psychology, a growing body of research discusses the role of intuitive processes for attitude formation and for behaviour, including trust, associations and affect. We will discuss these here.

Dual-processing theories (e.g. Smith and DeCoster, 2000) postulate that there are two pathways in thinking that lead to behaviour. One pathway is the rational or analytic one, where reasoning leads to attitudes towards an object and to behaviour, while the other pathway is more intuitive and based on heuristics, leading to automatic or spontaneous behaviour. Heuristics can be considered short-cuts in thinking, where instead

of spending the time and energy that rational thinking takes, people use faster and more efficient routes in their mind, basing their decisions and behaviours on previous experiences, feelings or other easily retrievable mental objects related to the situation or object. In general, it is assumed that both pathways are used together to come to attitudes and behaviours. Using associations to form your opinion or basing your reaction on trust and affect rather than a deliberate processing of size and likeliness of the effects, can be considered examples of heuristics or short-cuts in thinking that influence attitude formation.

Several studies investigated the role of associations, trust and affect for acceptance of technologies. Visschers et al. (2007), for example, showed that semantic associations with other risks are found to influence the perception of a new risk. Trust is shown to influence the perception of both the risks and benefits of technologies (e.g Siegrist, 1999, Siegrist and Cvetkovich, 2000, studying acceptance of biotechnology), leading to an inverse relationship between the perceived risks and benefits. The same effect was also found for the variable affect, influencing the acceptance of nuclear power (Peters and Slovic, 1996). It has been found for trust that this factor plays a particularly important role in attitude formation for relatively new and unknown technologies (Siegrist and Cvetkovich, 2000, Midden and Huijts, 2009), when little information is available to deliberate upon. More intuitive factors, such as affect and associations are more likely to influence attitude formation and behaviour where relatively unknown technologies are concerned and we therefore suggest including these factors as determinants for acceptance in hydrogen acceptance studies.

7.4.3. The role of knowledge-related items

Knowledge-related variables were treated in the papers, sometimes as a finding by itself, sometimes as a predictor for an acceptance measurement. Several authors found that higher scores on the knowledge measurements led to higher acceptance measurements. That can easily lead to the idea that more knowledge automatically leads to higher acceptance and that knowledge can be increased by providing information. For example, O'Garra et al. (2005) suggested that "there is a strong need to raise awareness [knowledge] among the London public specifically about hydrogen and fuel cells, as this seems to be key to public acceptance of H2-based technologies". We acknowledge that knowledge can play an important role in acceptance, although the influence of knowledge on acceptance is not as straightforward as is sometimes thought. The positive relationship between knowledge and acceptance could also be caused by the fact that the people who already had an interest in hydrogen informed themselves more thoroughly, or had a technical education and therefore have more knowledge and also a more positive attitude towards technology in general. We can therefore not assume that increasing knowledge automatically increases acceptance. In other fields of technology acceptance, for example windmill acceptance, the findings did not indicate that people with a low acceptance have less knowledge: on the contrary, "objectors actually appeared to be extremely well informed" (Ellis et al., 2007, p.520). More research into the effect of knowledge in an experimental setting is suggested to gain a clearer view of the relationship between knowledge and acceptance. To increase understanding, we will first discuss some theory on the effect of knowledge.

Two mechanisms could block the positive effect of information on acceptance. The first mechanism is that people do not use information to change their opinion in a positive direction. Instead they may judge information based on whether it corroborates their opinion and consequently either strengthen the opinion they already have, or, if the information does not agree with their opinion, disregard it (Marsh and Wallace, 2005). People may also discard or even oppose information provided because they distrust the providers of the information (e.g. Cvetkovich et al., 2002). The second reason for the possible limited positive effect of information on acceptance is that people often do not choose to study the available information at all. Ter Huurne (2008) showed that some people actually avoid information. She mentions several reasons for information avoidance. One reason could be that the gap in information is either too small or too large. If the gap is small, people might feel they can bridge the gap themselves, so they do not need to get information from others. If the gap is large, people could fear an emotional risk. This could include fear of bad news, fear of failure, or fear of increased uncertainty, fear of being incapable of making adequate decisions. Another explanation may be the principle of least effort: people can reduce effort by avoiding information acquisition and processing (Payne et al., 1993)

Whether more knowledge leads to more positive acceptance or not, it will probably lead to more stable opinions (Daamen et al., 2006), which would give more definitive answers to how accepting people are of hydrogen technologies. They may still be positive or negative attitudes and behaviours, but it can also lead to neutral attitudes and behaviours, because people realise the complexity of the topic (Hibino and Nagata, 2008) and can therefore not make up their mind one way or the other.

Based on these findings we can conclude that knowledge is important, but that providing information is not a straightforward solution leading to increased acceptance from the lay public. Besides the ethical aspects of using information to influence people, information might not always (Hibino and Nagata, 2008) reach the public, and when it does, it does not automatically increase acceptance. More research is needed to find out the circumstances in which people take up information and how information and the context of the information influences acceptability and acceptance.

7.5. Review of empirical findings on acceptance, acceptability and determinants of these

In the light of the discussed terminology and theories used in the papers, we will give a summary of the findings divided into acceptance-related findings (including all the different terms that have been used) and the determinants of acceptance.

7.5.1. Findings for acceptance

In this section we will summarize the findings of three categories, namely acceptability and acceptance, willingness to pay (WTP) and knowledge. As a result of the larger number of hydrogen bus studies, these results are mainly related to this hydrogen application. It should be kept in mind that different hydrogen applications will elicit different attitudes, different benefit perceptions and different safety perceptions.

All studies found high acceptability rates for hydrogen fuelled buses; the acceptability number ranged from 68 to 95% of participants (O'Garra et al., 2007, Hickson et al., 2007, Heinz and Erdmann, 2008, Molin, 2005). Small percentages (about 1 to 3%) of participants particularly objected (O'Garra et al., 2007, Hickson et al., 2007),

mainly because of safety concerns, even though other studies found that a sizeable group mentioned negative associations with hydrogen in general, such as “bomb” and “explosive” (Zachariah-Wolff and Hemmes, 2006). Overall, this indicates high support for hydrogen buses and little influence of the perceived safety issues. People often seemed to associate hydrogen fuelled buses with environmental friendliness (Hickson et al., 2007, Zachariah-Wolff and Hemmes, 2006, O'Garra et al., 2005) and assigned a positive rating of the comfort of the bus, compared to that of conventional buses (Haraldsson et al., 2006). Quite a large proportion of people, however, indicated that they needed more information before they could actually decide whether they supported or opposed the technology. Acceptability or acceptance of other applications in transport, such as taxis or boats, has not been measured and requires further research.

Stated willingness to pay extra for hydrogen fuelled buses has also been measured by several studies. Stated willingness to pay is used to predict consumer acceptance or adoption, but does not equal actual consumer acceptance. Two studies measured willingness to pay in two very different ways. O’Garra et al. (2007) measured the specific amount that one was willing to pay extra. This was measured in four cities at the same time. After explaining that hydrogen buses would emit zero air pollution, be less noisy and more efficient than conventional buses, the average WTP for bus tickets per city varied between €0.27 and €0.40 (€0.32 on average). The average extra annual tax that London and Perth residents would alternatively be willing to pay for these buses was €24 and €16 respectively. These numbers are reasonably close to each other, showing only moderate differences between the cities. The study also showed, however, that 24% of all participants were not willing to pay anything extra, which is a considerable proportion.

Haraldsson et al. (2006) measured in Stockholm only whether people were willing to pay more, rather than how much more they were willing to pay. Two measurements were taken during a hydrogen bus project. It was found that no less than 63% of the bus passengers were not willing to pay extra at the beginning of the project and 61% after one year. There was therefore not much change in the number of people that were willing or not to pay extra for hydrogen buses between these two points in time. The number of people not willing to pay more was much higher in this study than in the study by O'Garra et al.. However, due to the different ways of measuring the WTP as well as the diverging circumstances, it is not possible to really compare these findings. A very different but cost-related measurement in a third study (Zachariah-Wolff and Hemmes, 2006), measured the public's reaction to higher costs, which were not specified. The reaction to the suggested higher price of using hydrogen buses instead of diesel buses was that 37% of the Dutch participants in the study changed their preference from hydrogen buses to diesel buses (the preference for the hydrogen bus over the conventional bus went down from 95% to 58%).

Only a few studies have looked into the willingness to pay for private vehicles and taxis. One study, using discrete choice modelling, specifically provided insight into how people balance the different drawbacks and benefits of private vehicles in theoretical situations (Molin et al., 2007). The results indicated that both a higher fuel price and a higher vehicle price each decreased the preference for a hydrogen vehicle over the current vehicle; however, a strong CO_2-emission reduction of 30% did offset the extra purchase costs of €1000,- but was not enough to offset 50% extra fuel costs. Another study in London investigated taxi drivers' willingness to pay for a hydrogen fuelled taxi.

In this case, 69% was willing to pay extra for a vehicle with extended range and a lower fuel price, even with only 10 available refuelling stations in the city (Mourato et al., 2004).

WTP values could be more extensively researched for different conditions of hydrogen use and for different circumstances. Difference in WTP values can result from several factors. In the first place diverging WTP values result from the differences in the questions asked to the participants, as we saw in the bus-related studies. Other reasons for differences are often related to the context of the WTP question (see Sevdalis and Harvey, 2006, who have been measuring context effects). First, WTP will be influenced by the way that the hydrogen bus is introduced to the respondents in the study, for example as reducing air pollution (as in the study by O'Garra et al.) or without introduction. Second, WTP for one specific option will be influenced by whether people are aware of alternative technologies. Third, WTP will be influenced by the way that extra costs are charged. For example, charging the whole population for using hydrogen to fuel the entire stock of public buses might be more acceptable than charging specific groups of people for single buses. Finally, measured WTP values might also be different from actual WTP values because people are less aware of the consequences of their choice in hypothetical situations than in real life situations (e.g. Hensher et al., 2005). See also Mitchell and Carson (1989) and Carson et al. (2001) for an extensive review of the pitfalls associated with retrieving WTP responses to hypothetical choice situations. These factors will likely also influence acceptability and acceptance findings.

Knowledge-related items were measured in diverse ways in several studies. The studies showed quite consistently that the respondents had little knowledge of hydrogen

technologies and the properties of hydrogen itself (Zachariah-Wolff and Hemmes, 2006, Molin, 2005, O'Garra et al., 2007, O'Garra et al., 2005, Mourato et al., 2004) and/or many respondents would like to have more information at the time of the research (24 to 73% of the respondents, Haraldsson et al., 2006, O'Garra et al., 2005, O'Garra et al., 2008, Heinz and Erdmann, 2008). These findings indicate that little is known about people's acceptability and acceptance when people are more informed and feel they have sufficient knowledge.

Based on these findings, hydrogen bus acceptability by bus users if the bus does not cost extra for the user is quite positive. However, the findings are inconclusive for diverse price schemes, for citizens living near bus routes and refuelling station locations, for socio-political acceptance and for different kinds of acceptance for other hydrogen applications than buses.

7.5.2. Possible determinants of acceptance

Several potential determinants of influence to public acceptance were measured in the reviewed papers. Two categories that were also distinguished in previous sections are:

1. psychological variables (such as attitudes and preferences towards aspects of the technology, general attitudes such as environmental attitudes, associations and trust)
2. knowledge-related items (such as prior knowledge about the topic, awareness of the projects)

A third category is discussed in several papers, but has not been part of the terminology and theory sections. This concerns:

3. demographic and situational variables (such as education and distance from a refuelling station)

We will look at the measurements for these determinants in more depth per category.

Psychological variables Reactions to characteristics of a hydrogen vehicle were measured in two studies that differed in hydrogen application, level of experience, and in type of measurement (attitudes vs. preferences). Hickson et al. (2007) measured hydrogen bus passengers' attitudes with respect to riding comfort, noise level and temperature comfort, based on personal experience. They found that a majority of their respondents rated the comfort of the hydrogen bus more highly than a conventional bus, while a minority judged it as being equal. Molin et al. (2007) measured car drivers' stated preferences for future cars, based on various characteristics that future cars might have, and found that the perceived utility of cars was influenced by fuel type, the amount of CO_2 reduction, fuel price, the purchase costs of a new vehicle, the detour necessary to reach a refuelling station and the range of the car, but not by decreasing the motor performance by 20%. The respondents valued hydrogen as a fuel higher than biodiesel and even more highly than hybrid vehicles. Due to the large differences in the setup of the two studies, we cannot compare the results, However, while the first study did not show a correlation between the rated items and the acceptance of hydrogen buses, the second study explicitly studied the influence of aspects of the hydrogen-fuelled car on preferences, showing which characteristic had most influence on the choices that people indicated.

One example of general attitudes and beliefs that are possibly, but not necessarily related to hydrogen in transport is environmental concern. This psychological variable has been measured in several ways and has mainly been tested in WTP studies. O'Garra et al. (2007) found that giving high priority to public spending on solving environmental problems positively influenced WTP extra for hydrogen buses in two out of four cities and that the frequency of donations to environmental groups or organisations also positively influenced WTP in three of the four cities. So, this factor did not influence WTP values in all cities. The measurement of the attitude towards the priority of solving environmental problems with public spending was not significantly influential when considering whether to support or reject the introduction of hydrogen vehicles in London (O'Garra et al., 2005). For taxi drivers, WTP for acquiring a fuel cell taxi in the future was found to be influenced by concerns about the perceived personal risk of suffering health problems from air pollution, while WTP for participation in a fuel cell taxi pilot project was not influenced by these environment-related concerns (Mourato et al., 2004). These diverse findings show that environmental attitudes do influence stated WTP answers, but this does not seem to occur in all contexts. The diversity in environmental attitude-related questions makes it difficult to make a comparison between the studies and draw stronger conclusions. We suggest a more thorough approach to measuring the effect of environmental concern.

Three of the twelve papers asked the respondents for their associations with hydrogen. O'Garra et al. (2005) elicited free associations using open-ended questions. Both Zachariah-Wolff and Hemmes (2006) and Molin (2005) measured free-associations with open-ended questions, as well as close-ended questions, asking the respondents to

indicate to what extent they associate terms such as “dangerous” and “environmentally friendly” with hydrogen, on a Likert-scale. The latter measurement seems to be very close to the attitude measurements described in the previous section. Related to these measurements, Hickson et al. (2007) asked two open-ended questions about perceptions related to hydrogen as a fuel: one on the positive aspects of hydrogen as a fuel (“good points”) and one on the negative aspects of hydrogen as a fuel (“bad points”). Of the three studies measuring associations, only Molin calculated the correlation between the close-ended associations with hydrogen and, on the one hand, attitudes towards the general use of hydrogen and, on the other hand, indirectly with willingness to use hydrogen applications. He found a positive correlation between the association “environmentally friendly” and both (1) attitude measurements towards the use of hydrogen and (2) willingness to use measurements with respect to hydrogen applications. He found a negative correlation between the association “unsafe” and both (1) the attitude measurements on hydrogen use in general and (2) willingness to buy and use hydrogen applications. Based on the measurements summarized here, the meaning and role of associations is not quite clear.

Trust was measured in one paper. O’Garra et al. (2008) found that trust in safety regulations positively influenced support of local development and decreased opposition towards a hydrogen storage facility near the respondent’s home. Although this variable has been measured in only a single study, it seems to be relevant for more situations and transport applications and therefore should be further researched.

Knowledge-related items Several studies measured knowledge-related items, but not all of them explicitly studied and explained the relevance of this variable. Saxe et al.

(2007), for example, measured the need for information and noticed that the number of respondents needing more information went down from 44 to 36% after running a hydrogen bus project for one year. The influence of the need of information on WTP was not measured. Heinz and Erdmann (2008) and O'Garra et al. (2008) asked people to choose between support, opposition, indifference and the need for information, indirectly assuming and enforcing that the need for information is opposite to indicating acceptability in terms of support, opposition or indifference.

Five studies measured the influence of knowledge on acceptance. Molin (2005) and Zachariah-Wolff and Hemmes (2006) measured the influence of positive, negative and mixed information on attitude, using the same dataset. Molin found that positive information had a positive influence on intention to use and negative information had a negative influence on intention to use. The latter was larger in effect size, so it was not surprising to see that mixed information, containing elements of both positive and negative information, also had a negative influence on intention to use. This was an indirect effect; the perception of safety was an intermediate variable. This means that information influenced the perception of safety which in turn influenced intention to use. Molin also measured the knowledge level of people before giving the information and found that this prior knowledge level also positively influenced attitudes. The findings in this study indicate that balanced information does not always increase acceptance; it can also decrease acceptance. Zachariah-Wolff and Hemmes found that the three different types of information influenced different perception items, which is probably a direct result of the content of the different compositions of the information blocks. O'Garra et al. (2005) measured, first, the influence of whether people had heard of hydrogen and

fuel cell vehicles. The results indicated that having heard of hydrogen vehicles and to a smaller extent having heard of fuel cell vehicles had a positive influence on support of the introduction of hydrogen vehicles in London. Second, they measured the influence of environmental knowledge by asking whether the respondent knew that the ozone layer is not the main cause of climate change. The researchers did not find an additional explanatory effect for this knowledge-related item. O'Garra and Mourato (2007) found significant positive correlations between, on the one hand, knowledge about hydrogen vehicles and, on the other hand, WTP for the air and noise pollution reduction associated with the introduction of hydrogen buses in London. O'Garra et al. (2008) measured self-reported knowledge on hydrogen vehicles and found that people with self-reported prior knowledge on hydrogen were four times more likely to support than oppose local developments with respect to hydrogen refuelling facilities. These studies show that several knowledge-related measurements, such as self-rated knowledge, information, or having heard of something, can influence acceptance items. Several studies showed a positive relation between knowledge and acceptability and acceptance-related measurements, although sometimes no relation was found. Molin's study showed that providing information, which can be assumed to increase knowledge, does not necessarily increase acceptability and acceptance. Considering the limited knowledge that people have now, it is important to understand the effect of information, increased knowledge, and a feeling that one knows enough to form an opinion.

Demographic and situational variables Many of the studies measured demographic variables and several studies reported correlations with acceptance. O'Garra et al. (2005) found that gender, age and income did not influence support for hydrogen vehicles, while

gender and age did have an influence on prior hydrogen and fuel cell knowledge. Men had a higher score on both knowledge items than women. Higher age had a positive influence on prior knowledge of fuel cell vehicles. O'Garra et al. (2008) found that a higher age increased opposition and decreased support of local hydrogen storage at existing refuelling stations. They also found that a higher income marginally decreased opposition but did not increase support and, finally, that gender did not significantly influence opposition or support. Molin (2005), used structural equation modelling[5] to provide information on the direct and indirect effects of demographic variables on willingness to use. The study showed that respondents' age, gender and education level had a direct and/or indirect influence on the intended use of hydrogen applications. Age had a reasonably strong negative direct and indirect influence on intended use of hydrogen applications. The indirect effect of age concerned a negative influence on the perception of environmental friendliness, which had a positive influence on attitude and intended use. Both gender and level of education had an indirect influence on intended use. Men and higher educated people, on the one hand, had more knowledge of hydrogen than women and lower educated people, which led to a more positive attitude towards the use of hydrogen and to a higher intention to use hydrogen applications. On the other hand, men and higher educated people perceived hydrogen applications as more unsafe than women and lower educated people, which had a negative influence on attitudes towards hydrogen use and intention to use hydrogen applications. Combining both effects, men and higher educated people had a slightly higher willingness to use than women and lower educated people. We can conclude that the findings of the studies on

[5] Structural Equation Modelling (SEM) enables a simultaneous estimation of direct and indirect effects, controlling for correlation between covariates.

the influence of demographic variables are quite diverse and sometimes even contradictory. This may be caused by using different measurements for the same concept, or because it concerns different hydrogen applications. A more thorough study of the relation between demographic variables and acceptability and acceptance is needed.

Zachariah-Wolff and Hemmes (2006) looked at the influence of demographic variables on more specific, single perception and attitude measurements. They found that educational level, age and gender influenced a number of perception and attitude measurements. Educational level, for example, positively influenced the perception that hydrogen was environmentally friendly and the attitude that "investments in hydrogen buses are good," while it negatively influenced the attitude "we should convert to hydrogen when fossil fuels run out." The age of the respondents had a negative influence on the perception of environmental friendliness and a positive influence on the attitude measurement "we should convert to hydrogen when fossil fuels run out." The *middle* age levels had higher values than the lowest and highest age levels for perception of inexhaustibility of hydrogen and for attitudes that "hydrogen buses are good" and that "introducing hydrogen is good for the environment." Gender was found to influence only hydrogen perceptions: men had higher scores on both positive and negative perceptions: "environmentally friendly", "inexhaustible fuel", "explosive" and "dangerous". None of these demographic variables were shown to influence perception of expensiveness or the attitudes "eliminate negative effects before hydrogen" and "convert to hydrogen as quickly as possible." This detailed information can provide insight into the specific beliefs of groups of people and can possibly explain differences in findings on the effects of several demographic variables.

Demographic variables also influenced WTP measurements. Mourato et al. (2004) found that education and age positively influenced WTP for a fuel cell taxi, but did not influence WTP for participation in a pilot project. O'Garra et al. (2007) found that income and age, but not gender and university education, had in some cases a significant influence on WTP extra for hydrogen bus fares or extra tax, but not for all four cities. London respondents with a higher income indicated a slightly higher WTP. Older people indicated a significantly lower WTP in Berlin, London and Luxembourg. Finally, O'Garra and Mourato (2007), using the method of quantile regression, found that income and the frequency of bus use had a positive influence on WTP, while age and university education had a negative influence on WTP. Gender had no significant influence. Interestingly, only some lower WTP values were influenced by the frequency of bus use, age and university education. Apparently, people that indicated willingness to pay a reasonable amount of money were influenced by other factors than people that were willing to pay nothing or only a small amount of money. Here we also find diverse findings.

One situational variable is the distance to a potential hydrogen refuelling station. This distance was found to be relevant for acceptability of hydrogen refuelling stations: residents living 200 to 500 meter away from a hydrogen refuelling station are more opposed to the proposed installation of hydrogen storage facilities at existing refuelling stations than people living less than 200 meter away from the location (O'Garra et al., 2008). Another situational variable is the current frequency of bus use. O'Garra et al. (2007) asked for the bus use frequency but found no correlation with WTP to support the introduction of hydrogen buses in the city. Hickson et al. (2007) did notice that frequent

bus users (more than 4 trips per week) had a more positive attitude towards using hydrogen as a fuel than less frequent bus users.

Apparently, demographic and situational variables influence acceptance in certain situations or in certain acceptance measurements. More thorough research could combine and compare the measurements of different situations and hydrogen applications.

7.6. Conclusion and discussion

Hydrogen is a potential solution to problems related to transport, energy use, the environment and the security of the energy supply. However, several barriers need to be overcome before successful implementation can be realised, including possible negative public acceptance. The aim of this chapter was to critically review the available quantitative hydrogen acceptance studies in the field of transport and to provide suggestions for improvement. We have briefly reviewed the use of terminology and theory in the selected papers and provided suggestions for improvement, by referring to general psychological theories and wider literature on acceptance. Finally, we reviewed the actual findings on acceptance and determinants of acceptance and indicated knowledge gaps.

First, with respect to terminology use, we noticed that terms were not used in a coherent and consistent way across the studies. We discussed the use of the terms acceptance, acceptability, attitude, perception, knowledge, awareness, familiarity and need for information, and suggested usage of terms based on literature. A more explicit use of terminology and related measurements, in studies, indicating what concepts mean and do not mean, would improve the readers' understanding.

Second, we noticed that the majority of the studies lack a firm foundation in relevant theoretical frameworks. We suggested that future studies provide more scientific underpinning by making use of several theories developed in the field of psychology, for example dual-processing theories and the theory of planned behaviour. This will be helpful because it will provide a more complete overview of the underlying mechanisms and determinants and because it will increase understanding of the wider implications of the findings.

Third, we have briefly summarized the findings on public acceptability, acceptance and determinants. Since most of the studies focused on acceptability with hydrogen buses, we can draw some careful, tentative conclusions with respect to this. The findings on this topic suggest that test projects with hydrogen buses, as well as the idea of future hydrogen bus projects, receive positive attitudes among the public. However, it should be kept in mind that most of these bus projects and related studies took place within large cities and towns in Europe and might not equal the acceptability in other places. Within the studies the findings were also quite diverse. The knowledge level of the respondents in all the studies was quite low and people often indicated they needed more information. Based on the discussion of theory on knowledge-related factors, we realise that this might imply that acceptability and acceptance may easily change. More research is needed for acceptability and acceptance for consumer acceptance of private hydrogen vehicles, for citizen acceptance (for people living near bus routes and refuelling station locations) and for socio-political acceptance.

Fourth, several determinants of hydrogen technology acceptability and acceptance have been measured in the selected studies. Demographic variables were found to have

varying (positive, negative or no) influence on acceptance. Environmental attitudes and knowledge measurements mostly showed a positive correlation with acceptance, but also here diverse findings were presented. Other variables which were measured but whose influence still needs to be confirmed were, first, situational variables such as distance from house to a refuelling station and frequency of bus use, second, psychological variables such as attitudes and perception towards technical aspects of hydrogen applications, associations with hydrogen and trust in actors involved with implementing hydrogen applications and, third, knowledge-related items such as the need for information and received information. Although the studies provided a useful palette of relevant influences on acceptance, none of the studies have measured these influencing factors in a comprehensive way.

While this chapter has focused on the person-related factors that influence acceptance (socio-demographics and other person-related situational variables, psychological variables and knowledge-related variables), obviously also other more general situational circumstances will influence acceptance. This includes the way that the technology is introduced (e.g. by whom, which brand, which object, forcefully or with the consent of all parties, etc.), the way that the hydrogen is produced (from oil, gas or more sustainable sources), the exact design of the technology (materials used, shape, safety standards, etc), the available alternatives and their characteristics (including other energy carriers like bio fuels and electricity), and other societal circumstances (e.g. the perceived severity of the expected and believed climate change, price and availability of fossil fuels and alternatives, etc.). Finally an important role will also be played by the way that society as a whole frames and talks about the problems that we face, the

desirable pathways for future energy and transport systems, and the availability of and views about possible alternatives. These are important factors influencing acceptance that need to be studied and elaborated on in future research.

Besides terminology and theory use, which we focused on in this review study, several other study-related factors can influence the acceptability and acceptance findings. One factor which can influence findings relates to the study design, such as the introduction of the interview, and the choice of answering scales. Furthermore, and even more unavoidable, language differences will influence the comparability of the results and the transferability of the findings to other language areas. Finally, we need to note that the findings also strongly depend on the appropriate choice and use of methodologies. We will not elaborate on that here; methodologies used in hydrogen research are discussed by Yetano Roche et al. (2010).

Note also that we have focused on quantitative studies. While quantitative studies have benefits, especially as they provide quantitative results representing the opinion of a larger population and the relative strength of influencing factors, these studies are also criticized for the fact that they cannot grasp the entire complexity of the problem and do not give people the opportunity to formulate the issue in their own words (e.g. Ricci et al., 2008). Qualitative research provides a valuable addition to quantitative research in understanding people's underlying reasoning and beliefs. We refer to the work of Ricci et al. for a review and more insights from qualitative research on hydrogen technology acceptance.

All in all, we conclude that acceptance of hydrogen is probably not a major barrier for the successful implementation of hydrogen as a fuel in public transport buses,

but that more insights are needed to fully understand the determinants of acceptance and the interrelation between these factors, and more insights are needed into the acceptance of other transport-related hydrogen technology applications. Furthermore, insights are needed into acceptance under diverse conditions (for example, differing in the way that hydrogen buses are introduced or the way that the extra costs are retrieved from the public) and about the factors influencing information processing and attitude changes resulting from information uptake. Finally, we advise researchers to make more thorough use of theories, to use terminology in a clearer and more consistent way, to study all possible determinants in a more comprehensive way, and to discuss the transferability of results.

7.7. Literature

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