Human Demands of Sustainable Aviation

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(Confidential Document with sensitive Information)

1. Introduction

1.1 Aim and Objectives of the Project

The first phase of the project, which lasted from October 2020 to May 2021, comprised an analysis of the approaches and tools that are used by the engineers within the SE^2A research cluster. A main aim was to reveal tacit assumptions, which guide the work of the engineering projects, and to investigate parameters and metrics that are applied within these projects. Here, the focus was on the engineers' understanding of sustainability as well as their underlying assumptions of passengers' and airport residents' needs and demands with respect to sustainable, low-noise, safe and reliable aviation.

4. Research Results

4.1 Definitions of Sustainability

4.1.1 Ecological Sustainability and the Economic Imperative

Within the cluster of excellence, sustainability is predominantly defined in ecological terms. Moreover, economic feasibility sets the scene for the ways sustainability is as an overall target of the engineering projects. Mostly, the projects aim at the reduction of the emission of greenhouse gases such as CO_2 or NO_X. To achieve this, various approaches are used to develop new configurations of aircraft which are light and do need less kerosene or no kerosene at all. In this context, economic feasibility forms a main constraint of developing sustainable technologies. This, for example, is illustrated by one of the engineers stating that instead of searching for radically new aircraft configurations, in the end, „we need to have something that we can actually do". In sum, the projects aim at developing technologies which can be produced by industry and sold in high quantities.

Economic feasibility also plays a role with respect to reducing noise emissions of airplanes. One of the engineers told us that in theory, one could design airplanes that are adapted to the airports and the environments at which they are operated. This adjustment to local sites could help to reduce the noise that is perceived on the ground. However, he called this approach an unrealistic scenario as it would be way too costly.

In sum, within the cluster of excellence, sustainability is addressed through developing technologies that fit current mobility demands and the requirements of industrial mass production. In contrast to that, radically new concepts of mobility or utopian, creative solutions, are not considered. In addition, an increase in the demands of flights is a basic assumption of the engineering projects. Taking the increase of demands for flights for granted, the engineers see sustainable technologies as a solution to climate crisis and noise annoyance. The possibility that there exist other, more diverse demands and that people might wish for

sustainable mobility concepts that not necessarily comprise (conventional) air traffic, is not taken into account. Above all as for long-distance flights there does not exist any alternative to flying, which could bridge distances in a comparable time span. Thus, the research projects of the cluster are guided and legitimised by an assumed practical necessity (Winner, 1980) of ensuring the possibility of air traffic in the future. This is a goal not only set by research itself, but also one that is on the political agenda, as the Flightpath 2050 objectives of the European Union illustrate (Flightpath 2050). There, technologic innovation, economic wealth and growth are listed among the main goals tob e achieved by research on aviation. Moreover, they mirror the framework of the so called ‚innovation society' (Hutter et al., 2016) in which both technological and economic innovation form guiding principles and legitimising strategies not only for applied, but also for basic research. In this sense, what Hutter et al. (2016) call the ‚economic imperative' limits the configuration of new technology within the cluster to improvement of preexisting technologies.

4.1.2 Social Sustainability

Within the cluster of excellence, social sustainability is only considered in the realm of Social Life Cycle Assessment. Although the engineers of the cluster are aware of the fact that ecological, economic and social sustainability intersect, and that sustainability can mean something different in different contexts, the marginal treatment of social sustainability is due to several reasons. First of all, the DFG guidelines do not allow for broadening the scope of the cluster to institutions outside of the region around Braunschweig, Hannover and Göttingen. Therefore, as we were told, it was not possible to include experts on social sustainability into the cluster's knowledge base. Interestingly, this rationale sheds light on the notion of expert knowledge which underlies the cluster. Experts on social sustainability are defined in terms of researchers in academia. However, from a Feminist STS perspective, it is debatable if these people are the only ones holding ‚expert' knowledge on social sustainability and whether expertise on related questions only derives from academic research (Haraway, 1988).

Moreover, several engineers mentioned that taking into account social sustainability is problematic as engineering disciplines deal with ‚hard parameters'. For the fact that the range of social parameters was extremely wide, the engineers consider it difficult to include them into their models and make profound and unambiguous statements on the relationship between social sustainability and sustainable aviation. Thus, treating social sustainability only in the margins of the cluster, is caused by limited understanding of expert knowledge as well as disciplinary and respective methodical constraints, which predefine which parameters and data can be included into research projects.

4.1.3 Sustainability in Terms of Noise Reduction/Annoyance Reduction

Besides developing technologies which enable the reduction of greenhouse gas emissions, sustainability also addressed by reducing noise emissions. In this regard, the objectives of the engineers are also in line with the Flightpath 2050 vision, which sets the goal of reducing the „perceived noise emission of flying aircraft (...) by 65%“ (Flightpath 2050). At first glance, this seems like a clearly set target. But talking to the engineers revealed that it is not clear at all what the reduction of perceived noise actually means. Besides, there exists no unambiguous definition of what a low noise aircraft is. One of the engineers reported on conversations he held with his colleagues:

> „Es gibt im Grunde keine Metrik, die abbildet, was ein lärmarmer Flieger ist. (...) Was ist ein lärmarmer Flieger? Wenn du da nachhakst, fangen alle an zu schwimmen.“
> *There is no metric which can represent low-noise aircraft. What is a low-noise aircraft? If you ask about it, everybody will be floundering.*

Many studies on aviation noise and noise annoyance are motivated by local airport expansions (Postorino & Mantecchini 2016; Schreckenberg et al. 2010; Thomas, Hume & Hooper 2004) and the fact that over the last two decades, air traffic has increased considerably (Chen et al. 1997; Wiechen et al. 2002; Thomas, Hume & Hooper 2004; Hardoy et al. 2005; Bartels 2014; Postorino & Mantecchini 2016; Gagliardi et al. 2017). It is known that traffic noise and also aircraft noise have negative impacts on humans, causing cardio-vascular diseases, sleep disturbance, cognitive disturbance or psychological issues (Aydin & Kaltenbach 2007; Gagliardi et al. 2017; Chen et al. 1997; Hardoy et al. 2005; Stansfeld & Matheson 2003; Schreckenberg et al. 2010). Moreover, air traffic noise can have an impact on social inequalities, for example with a view to housing prices (Thomas, Hume & Hooper, 2004; Cohen & Coughlin 2008; Van Praag & Baarsma, 2005). For all of the given reasons, noise emission and noise annoyance remain important issues in scientific research.

Over the past decades, the impact of aviation noise on humans frequently has been measured in terms of a dose-response relationship (Stansfeld & Matheson, 2003; Schomer, 2005...). Most famously, the so called Schultz-Curve (Schultz, 1978) has been used to determine (community) noise annoyance (...). However, the approach has been criticised for the rather arbitrary use of certain threshold values such as the 65dB DNL (day-night average sound level) as a significant noise level and its purely descriptive and simplified representation of community noise annoyance (Fidell, 2003). Today, different approaches are used to determine noise annoyance, for example the application of psychacoustic metrics () or soundscaping (). Moreover, the impact of noise has been assessed by employing various sociological methods such as questionnaires (Wiechen et al. 2002; Laußmann et al. 2013;

Bartels 2014; van Praag & Baarsma 2005, Midema & Vos 1999, Lee et al. 2008; Genlyd Report; Hardoy et al. 2005; Schreckenber et al. 2010). Many studies also investigate non-acoustic factors which play a role with regard to noise annoyance (Wiechen et al. 2002; Laußmann et al. 2013; Bartels 2014; van Praag & Baarsma 2005, Suau-Sanchez, Pallares-Barbera, Paül 2011; Postorino & Mantecchini 2016, Midema & Vos 1999, Genlyd Report; Chen et al. 1997; Thomas, Hume & Hooper 2004; Schreckenber et al. 2010; Schomer 2005). Furthermore, empiricial studies have proved that noise is perceived differently by different groups of people and that reactions to noise vary by context and situation (Thomas, Hume & Hooper 2004; Stansfeld & Matheson 2003; Schreckenberg et al. 2010). Still, as Bartels states in her dissertation (2014: 19), there does not exist a clear and shared definition of noise annoyance within the literature. This difficulty derives from the fact that noise perception and the feeling of annoyance are highly subjective; they depend on cultural context and situational factors and the interplay of different sound sources. The engineers who were shadowed and interviewed by us are well aware of this issue. Therefore, some of them do not solely focus on noise in terms of measurable loudness, but deal with the assessment of sound qualities of certain aircraft designs. Still, defining the reduction of noise emissions in terms of reducing loudness, measured in dB, plays an important role within the investigated acoustic engineering projects. As will be outlined later, this not only seems to be caused by external requirements, such as the Flightpath 2050 targets which demand measurable reductions of noise emissions, but the focus on loudness is also due to established disciplinary approaches that are still employed today and use dB as a parameter to determine noise annoyance, as a view to the literature indicates (Postorino & Mantecchini 2016; Lee et al. 2008; Aydin & Kaltenbach 2007; Gagliardi et al. 2017; Chan et al. 1997; Stansfeld and Matheson 2003; Ozkurt et al. 2014).

4.2 Safety vs. Sustainability or How to Distribute Risks

In aviation engineering, safety is one of the most important constraints regarding the development and implementation of new technologies (Flightpath 2050). With a view to the shadowing sessions, the provocative question whether sustainable technologies could be developed more quickly if safety standards were neglected, created interesting insights regarding the notion of risk that underlies the engineering approaches. Apart from the fact that safety standards are important in certification of new aircraft, the engineers argued that when a plane crashes, many people will die at once, which is why safety is considered extremely important. On being asked about the appropriateness of putting safety in front of sustainability, while people in other locations – mostly women and people in the global south – severely suffer because of climate change induced effects such as droughts, flooding or storms (IPCC, 2019; Allen et al. 2018; Alston, 2013; Isreal & Sachs, 2013; Bauriedl, 2013; Röhr, 2013; Wonders & Danner 2015), one of the engineers

stated that it is „just not possible“ to substitute safety for sustainability. Furthermore, he said that even people affected by climate change would argue in favour of safe air travel and never choose to use a sustainable but doubtful aircraft when being asked. Although this might be true, the statement shows that safety, within the engineering projects, is defined in terms of safe technology use by aircraft passengers. Definitions of safety that take into account the needs and living worlds of people affected by climate crisis are only addressed after reducing the risks of plane crashes. Here, the power gap between the mostly white, male engineers in Northern countries and people affected by climate crisis, mostly living in the southern hemisphere, and in poverty, becomes visible. First of all, the assumption that these people would also prefer to use a safe airplane remains hypothetical. Most of them will probably never be confronted with making the proposed choice. Instead, the engineers indirectly make this choice for them, not considering their demands and notions of safety or physical integrity. In addition, the engineer just cited announced that he regards the idea of a passenger deliberately using a risky technology for the sake of sustainability, a kind of „rare altruism“. Here, I would like to insist that delegating risks to people living in the southern hemisphere and legitimising this action by assuming that they would also prefer to travel by plane safely, can be called a forced altruism. Moreover, some of the engineers said that, in the end, industry and ‚the market‘ will decide which technologies will be produced and purchased. The same engineer who had just been cited, in this context, stated that also developing countries currently buy the latest and safest aircraft, to underline that not only industrialised countries hold the power to decide which technologies are used. Still, it seems debatable to expect that this decision will be made by people most severely affected by climate crisis. The decisions and interests of certain airlines or even governments, here, seem to be mistaken for the demands and interests of different individuals.

In summary, safety, in the engineering projects, is equated with safe technology use and, in this way, is a major constraint to sustainability. Defined in terms of safe technology use, safety plays an important part in establishing global power imbalances. The aim here is not to argue that the objective to develop safe technologies should be abandoned altogether. However, against the background of already noticeable effects of climate change, I would like to make the claim of a need to establish and maintain discussions on different forms and distribution of (technical) risks, particularly in engineering projects such as the ones investigated by us. Moreover, I would like to point out that the shadowing sessions revealed the difficulty of applying the concept of fairness in the context of climate change as it impacts people in very different circumstances. The conversations with the engineers mirrored certain problems which also form part of global politics, as Israel and Sachs demonstrate:

„But agreements of justice and fairness are difficult to achieve because, as Parks and Roberts (2010, 148) suggest, we live in “morally ambiguous” times with

notions of fairness in climate change varying by circumstance with some countries blaming their situation on Northern consumption, others desiring to develop their economies using a carbon-based economy, and still others such as small island nations calling for an end to carbon trading. They
suggest that inequality between the North and South makes agreement on a fairness principle unlikely and that consensus will require “a hybrid justice solution that accommodates the different circumstances and principled beliefs of many parties” (2010, 152).“ (Israel & Sachs, 2013: 41)

4.3 Fairness vs. Economic Benefits or How to Distribute Noise

A recurrent issue, that came up during shadowing sessions with acoustic engineers and in interaction with airport residents, was the question how to distribute aircraft noise. The airport residents reported that their choice of moving near to an airport was mainly motivated by financial reasons. Houses near airports were cheaper than in other neighbourhoods. While they had been ready to accept the airport noise, they are frustrated by the increase of noise over the part years. Moreover, they complained about politicians who put economic benefits in front of the well-being of citizens as, for example, penalties for landing and departure at night are low.
Both residents and engineers agree on the fact that it is difficult to decide how to distribute noise. Should runways be used in a way that all airport residents are equally affected by aircraft noise or should those runways be frequented which lead to noise exposure of residential areas where, in absolute numbers, there live less residents than in other areas around the airport? According to one of the engineers, it would be a ‚win-win situation‘ if a hundred people would have to suffer from noise or move to other parts of the city, while some thousand others, in consequence, would not be affected by aircraft noise. Interestingly, this engineer regards respective decisions issues of an ethics board. In contrast to that, the residents regard politics as responsible for enacting rules that restrict air travel that lead to noise reduction, above all during nighttime. However, both assumptions reveal that responsibility is externalised to formal institutions.

4.4 Interim conclusion

Two aspects regarding the engineers‘ notion of sustainability are worth to discuss in more detail. First of all, the focus on measurable impacts and statistics seems to form the basis of the engineers definition of a fair distribution of risks. A fair distribution of noise means to distribute noise on least people possible. This is based on the underlying assumption that all people perceive noise equally. With regard to safety, the engineers‘ notion of a fair distribution of risks comprises an assumption of a common agreement of all people in the world that the use of safe technologies is preferable to the use of insecure ones, no matter which negative indirect impacts the use might cause to non-users. Moreover, the engineers do not regard fairness decisions as their concern. They see their task in providing accurate statements on noise distribution, to become are part of the knowledge base on

which political decisions or decisions of ethics boards are made. Also, they seem to consider the development of more sustainable and less annoying aircraft as detached from questions of how to distribute negative impacts of technologies. Coming from a Feminist STS perspective, it seems important to evoke a sense of ‚response-ability ‚(Haraway, 1988) in terms of empathy and change of perspective, as Haraway (1988) defined it, in order to make the demands of airport residents and other people affected by the use of aircraft part of the knowledge base of the engineers. It is necessary to de-construct the idea that the issues of climate crisis and noise annoyance can be solved solely by technology improvement and that there exists a straightforward division of labour between engineers who develop technologies and politicians or political advisors who decide on how, where and when to use them. One possible means to bridge this response-ability gap could be to bring engineers and airport residents together. Another means, of which shadowing proved to be a start, is to sensitise the engineers for the particularity of the knowledge they produce, the power structures on which it is based as well as the power they hold in designing future technologies. Most importantly, however utopian it might be, it would be worthwhile to take a step back and consider what kind of mobility concepts could lead to more sustainable futures. The presented research was conducted in a cluster on sustainable aviation. Therefore, one cannot expect that mobility in general is addressed in more general terms by the projects it comprises. Still, the gained results raise the thought that an interdisciplinary cluster focusing on new mobility concepts instead of focusing on the adaptation or improvement of existing technologies in view of new requirements, seems worth considering. There seems to be much potential, and many valuable tools to find (technical) solutions. However, at the moment, their creative application is constrained by the primacy of economy and practical necessity (Winner, 1980; Hutter et al. 2016), which seem to dominate the research landscape and the goals set by funding agencies.

4.5 Focus on Material – Exclusion of Practice?

During the shadowing sessions and telephone interviews, several of the engineers pointed out that with a view to the emission of greenhouse gases and noise, not only the material composition of an airplane is important, but also the way the aircraft is operated. So, not only the design of the aircraft, which is at the centre of the engineering projects, is relevant in order to address sustainability and reduce air traffic induced annoyance, but also the situational use of the machine – the interaction of human and artifact. To put it in the words of current (Feminist) STS approaches (Barad, 2007; Suchman, 2007), sustainability is enacted through the material practice of operating a certain aircraft. The enactment will vary depending on the specific aircraft design, the way it is operated in a certain situation and under specific environmental conditions. Even though the engineers are aware of the importance of practice in realising sustainable aviation, respective considerations

hardly play a role in models and simulations. If practice is considered, then in terms of physical variables such as velocity and not in terms of situational, embodied and ephemeral interactions between crew and airplane – between humans and the machine. The basic conception of problems in the projects and their focus on material design as well as the aim of making problems and solutions quantifiable, seems to lead to a preference of material and a degradation of the relevance of practical interaction/intra-action (Barad, 2007) and its effects.

4.6 Unlacing the Mathematical Corset

One of the main aims of Feminist Science and Technology Studies is to challenge the notion of scientific objectivity in terms of neutral descriptions of the world from an outside position. Donna Haraway (1988) was one of the first scholars setting this agenda for Feminist STS by arguing for an inclusion of regularly marginalised knowledges into scientific knowledge production. This, she regarded as a means of making science a response-able endeavour. With these assumptions in mind, we entered the shadowing sessions. Soon, we were confronted with the fact, that all engineering research, more or less, relies on concrete calculations and numeric metrics. Most engineers stressed the importance of reliable data and accurate calculation in order to generate sound results. This was mentioned as one of the reasons why it was regarded so hard to take social sustainability into account, as the respective data were regarded uncertain. Moreover, with a view to acoustic engineering, noise annoyance was considered difficult to quantify, because the perception of annoyance is highly subjective. According to the engineers, the same holds true for taking into account the different (cultural) contexts and situations in which noise annoyance is perceived. Concerning this matter, one of the engineers pointed out:

> „We all have some physiological similarities, but of course we have a subjective [pause] and I don't know [pause] culturally, that's pretty complex! That's too difficult to take into account. [pause] I don't think that this is even possible. In a model it's too difficult."

Meanwhile, another acoustic engineer called the use of metrics that portray annoyance „fraglich und wissenschaftlich diskutabel [doubtful and scientifically questionable]" and that trying to measure annoyance means to create too many problems that one cannot solve [„macht mehr Fässer auf, als man wieder zumachen kann"]. This reveals that the shadowed engineers regard complexity as uncertainty. What cannot be quantified is uncertain. They try to reduce this uncertainty or avoid it by a focus on metrics that, from their point of view, do not rely on subjective, and therefore biased, data. This mindset seems to be based on a kind of efficiency-oriented-thinking that aims at reducing the amount of problems, on the disciplines' focus on numbers and numeric models, and the goal of achieving valid and comparable results.

However, the shadowing sessions revealed that the engineers are well aware that the models they generate comprise a simplification of certain problems and are uncertain as well. Moreover, they know about the limits of validity of the metrics they use, as the following quotes illustrate:

> „Häufig sind bestimmte Datensätze nicht verfügbar oder nur schwer zu bekommen. Deshalb muss man bestimmte Vereinfachungen machen."
> *In many cases, certain data sets are difficult to get or they are not available at all. Therefore, certain simplifications have to be made*.

> „We look for the best solution. But in real life, the actual system might not work that well."
> „Frequency is not something that exists, it's a mathematical concept."

> „Oh that was an aesthetic decision, they could also have used any other function."

On discussion dB as a measure to quantify noise annoyance:

> „Wenn du ein Zahlenschieber bist, kann man das schon so machen. Stellst du aber den Menschen in den Vordergrund, geht es stattdessen darum, das Stresslevel zu reduzieren. Dann ist es egal, wie die Lärmteppiche aussehen. Wichtiger ist zum Beispiel, wie die Bevölkerung um den Flughafen verteilt ist."
> *If you see yourself as a human addiator, you can do it that way. But if you focus on the human, it is more important to reduce the stress level. In this context, it doesn't matter what noise maps might look like. It is more important to consider the distribution of residents around an airport.*

> „Annoyance ist mathematisch nicht genau definiert. Das ist ein subjektiver Begriff, der versucht wird, in ein mathematisches Korsett zu zwingen. Man muss viel argumentieren. Es ist nicht möglich, wie bei einer Berechnung einfach zu sagen ‚siehe da, so ist es'."
> *Annoyance is not clearly defined as a mathematical equation. It is a subjective descriptor that people try to force into a mathematical corset. You have to discuss a lot. It is not possible to just say ‚this is the exact result' as it is the case with calculations.*

When confronted with the question whether it was difficult to publish articles on noise annoyance that comprise qualitative arguments, one of the acoustic engineers pointed out that the possibility of publishing depends on the journal, the reviewer and the quality of the discussion. In a psychological journal this might be easier, while, according to the engineer, in journals of aviation engineering this

would be way more difficult. This shows how strongly academic culture influences which research questions can be asked, which metrics are applied and which results will be produced by a certain field.
Furthermore, the acoustic engineers agree on the fact that measuring loudness in dB is not sufficient to determine the impact of aviation noise on humans. However, metrics such as the EPNL (efectively perceived noise level) or a-weighted sound pressure levels in dB(A) are continuously used as they represent established measures in both scientific research, certification processes and political handling of aircraft noise (Gurski, Schreckenberg & Schmeumer, 2017...). So, the engineering projects seem to be clutched by a mathematical corset that is established by both scientific and publishing culture and the epistemological key assumption that only quantifiable results are meaningful and reliable results.
But how to unlace this mathematical corset? First of all, we used the shadowing sessions to get into dialogue about the relevance of different life worlds and different human beings when it comes to developing sustainable technologies and low-noise or low-annoyance aircraft. As will be outlined in more detail later, this kind of dialogic intervention already caused the engineers to reconsider assumptions that previously had remained unquestioned. Besides, one of the acoustic engineers told us about his work on psychoacoustic metrics, which do not only consider loudness but also other qualities of sound. The discussion we had about these metrics generated interesting insights in what diversity and reality mean in an engineering context. To begin with, I confronted the engineer with what I had read in the papers and books he had recommended to me. There, it was frequently stated that listening tests in the context of research on psychoacoustics metrics were conducted with people with ‚normal hearing' – meaning young people without any hearing deficiencies (Fastl & Zwicker, 2006; Hülsmeier et al. 2014; ISO 532-1:2017-11) – and that many of these tests had been done in a laboratory environment. However, in some papers, people with hearing deficits and real life contexts were considered (Fastl, 2006). Besides, I talked with him about a paper on the assessment of classroom noise, where I had read: „Stereo photographs taken by a photogrammetric system were exploited to determine the respective dimensions of the head, pinna and torso. The simplified head's shape is based on the statistical evaluation of these dimensions." (Fels, Schröder, Vorländer, 2007). Concerning this matter, I explained that coming from a feminist STS perspective and using methods from Participatory Design Research, we would, always try to include many different people into empirical studies and, for example, enter real classrooms instead of merely modelling them. To this, the engineer answered that, although he understood the point I was making, diversity, to him, was about exceptions and that general statements could only be made about the majority. Models, he told me, were made to match the „average perception". The majority, he was referring to, he defined in terms of all of us having „the same average body", adding that it was the size of our heads or our hair, which separate our ears – „our

two microphones“ as he called it – which make us perceive sounds differently. Furthermore, in another conversation, he proposed to introduce diversity through the help of another technological approach:

> „It is physiological but it is also subjective at the same time. What you see and smell is also important, maybe your skin feels dry or your head…“

> „There you agree with me; if we have some metrics describing sound and physiology something still is missing – what you call context. Maybe a neural network could take all this into account. Or a person who would talk about the sensations while playing a sound.“

Apart from neural networks, he mentioned the possibility of creating virtual realities to introduce people's perceptions into research approaches related to psychoacoustics:

> „There are some guys in Aachen that have some really sophisticated equipment. People can walk through the environments and it feels very real.“

To put it in a nutshell, both the literature review and the shadowing sessions show that the acoustic engineers are aware of the fact that diversity, in terms of differences in cognitive and bodily features of people, (social) roles, cultural contexts and concrete real life situations, play a part in sound perception and noise annoyance. Still, diversity is neglected within the engineering projects as it is equated with exception, and regarded a constraint to accuracy. Still, as one of the engineers put it, it is not always accuracy that is a limiting factor, but „you have to start with something“. This something, the shadowing sessions made clear, ultimately seems to be quatifable data. Moreover, within the projects, the technological mindset of the engineers misleads them to consider technological approaches, such as neural networks or virtual reality as a means for taking into account diversity, and prevents them from considering to get into dialogue and interact with real people.

> „You have to be accurate; you cannot be too much accurate. By the way, do you know this joke about engineers? In calculations it is important to take numbers. Physicists and mathematicians take it really accurately, engineers say ‚Oh it's just fine'.“

One surely cannot say that the engineers do not reflect on diversity and the need to take different knowledges into account. But once again, the quest for quantifable results, the mathematical corset, forces them to stick with a limited version of diversity – even if this means to make certain cuts (Suchman, 2007; Strathern XX), which, from a feminist STS perspective, lead to exclusion of certain knowledges….

5. Airport Residents

What does aircraft noise mean to airport residents? How does it impact their every day lives? How do they define sustainability and a sustainable lifestyle? Which demands and wishes do they have with a view to future mobility? These questions guided a first telephone interview I held with residents of the airport of Hamburg (Hamburg Airport Helmut Schmidt, former airport Hamburg-Fuhlsbüttel). The couple I interviewed are parents of a friend of mine. They are in the beginning and end of their 50s and live in a single-family house. Now that their children are grown-up, they live there alone.

To begin with, the interview illustrated that aircraft noise has a strong impact on the daily routines of airport residents. For example, the couple told me that they like to sleep with the window open, however, on the weekends, they get up at six o'clock to close their bedroom window as this is the time when the aircraft begin to depart from the airport nearby. Moreover, they told me that the airport noise frequently interrupts their conversations when they are in their garden. Frequently means every 2-3 minutes. Although, while gardening, they do not consider the noise that disturbing, they are highly annoyed by the interruption of their talk. According to the couple, they got used to the situation, but many guests are annoyed by the aircraft noise. To sum up, noise annoyance has a particular impact with regard to daily routines and triggers certain behaviours or coping strategies in airport residents. In addition, the current corona situation and the cancellation of flights to them is a relief. Personally, they would like this situation to remain.

On asking whether they sometimes go by plane, the couple told me that they have not used an airplane for ten years and only recently went by plane on holidays once. Interestingly, they told me that they seldom fly, because of their high annoyance by the airport noise. Their personal dismay is the cause of their rejection of flying. Besides, they stated that to them flying is something they easily can forgo. So, the conclusion can be drawn that the lack of a feeling of sacrifice, and personal dismay by negative impacts of technology form the basis for a more sustainable lifestyle. Although it has to be mentioned that the interviewed couple itself stated that they are highly environmentally conscious in general.

In my conversation with the husband about his political engagement in the Fluglärmschutzkommission (aircraft noise protection commission), I rediscovered certain issues which already came up during the preceding shadowing sessions with the engineers. To begin with, he regards measuring loudness in dB to make a statement on airport noise annoyance as inconclusive. The problem is that average values are used to determine loudness around the airport while, according to the resident, the single overfly events are most annoying and the sounds by different aircraft are perceived differently. Apart from that, the interviewed resident is frustrated by the primacy of economics on which political decisions concerning

noise annoyance are made. Thus, the primacy of economics pervades both politics and the investigated engineering projects and seems to be the severest obstacle for enacting sustainability.

3. Reflections on the Methodical Procedure

In order to get an insight into the engineering projects and the underlying assumptions regarding sustainability, noise, noise annoyance and human demands of sustainable aviation, shadowing as a form of one-on-on ethnography (McDonald, 2005; McDonald et al., 2014: Gill, 2011) was used as a method. The shadowing sessions were conducted in the offices of the engineers and in laboratories which are part of their institutes. The shadowing consisted of phases of naive and informed observation (Laudel & Gläser 2007). During our visits, the engineers were asked to explain and describe the tasks they were fulfilling. Moreover, they were interviewed on the aims, motivations, methods, tools and first results of their projects. Usually, we jointly sat at the engineer's desks, but the shadowing sessions also comprised participation at meetings and joint lunch breaks. Particularly the latter ones allowed for detailed conversations on personal attitude towards sustainability and informal chats about the respective research projects.

It turned out that the sheer presence of another person asking naive questions about the engineers' work already induced self-reflection on the assumptions that underly the various projects. For example, one of the acoustic engineers, when asked about the meaning of so called noise-footprints that are used to determine the noise impact of airplanes, he explained that there is no concrete mathematical definition of the concept and that is was rather a general term. Laughing, he further said that never before had he actively reflected upon this matter. This example reveals that getting into dialogue is a form of intervention, because it inspires questioning taken for granted assumptions that guide scientific endeavours. Shadowing, therefore, can be regarded a means of enabling and facilitating dialogic intervention.

Regarding the interview sequences of the shadowing sessions, it turned out to be good to ask the engineers for some literature on their projects in advance. Having read some papers on the questions and topics of the respective projects facilitated to pose questions and to understand what the engineers were doing. This was the case even though we could not make sense of every aspect that was dealt with in the papers. Moreover, reading papers on the projects' issues seemed to help in establishing discussions on an equal footing. One the one hand, our detailed preparation was recognised as a strong interest in their projects and, on the other hand, made the shadowees feel that they could talk to us rather like a colleague than an ignorant intruder from outside. However, there were situations in which the different disciplinary backgrounds and respective knowledge gaps became visible. Once, for example, while being shown around in a laboratory, a shadowee after having explained the use of a certain artifact apologetically proclaimed „Oh it's too

many technical terms.“ This experience demonstrates that shadowing involves the difficulty of bridging certain knowledge gaps. This is only possible to a certain extent. Still, the existence of knowledge gaps between shadower and shadowee did not inhibit the gathering of valuable and interesting results. So, as a shadower, one does not have to understand everything to get answers to one’s own research questions. However, it is open for methodological discussion how much information to gather on the shadowee’s work prior to the shadowing sessions. Surely, this varies by the concrete research question. In the present case, sometimes it proved good to know a lot about the projects, while, at other times, naive questions were most suitable to get interesting results. So, we cannot provide a straightforward recommendation. Rather, the shadowing sessions will show whether it is necessary to read more or gather more information on a project. This is why it seems a good advice to conduct more than on shadowing session with a shadowee.

Short meetings prior to shadowing enabled us to get first insights into the projects and to develop informed and targeted questions for the shadowing sessions. In addition, shadowing sessions were more productive when the atmosphere was open and friendly. As shadowing is an intimate research approach, a feeling of mutual interest, collegiality or friendship made it easier to put critical questions and to get honest answers or answers which revealed personal motivations and attitudes. In general, all shadowing sessions were conducted within a friendly atmosphere. Though, in one case, the shadowee withdrew participation for the reason that this engineer did not feel comfortable with the publication of what had been said during the shadowing sessions. This example underlines the importance of explaining beforehand how data gained during shadowing will be used. Even though we had provided a declaration on privacy issues and explained that quotes would only be published anonymously, even more transparency on how we deal with our data might have helped to avoid the withdrawal.

Against the background of our theoretical perspective, our shadowing experiences once for confirmed a central conjecture Feminist STS. Scientific research is not a process of mere rational problem-solving and production of truths, but personal attitudes and the situatedness (Haraway, 1988) of the subjects involved in research play a crucial role with regard to research questions, methods and the produced results. The shadowing sessions illustrated this in two ways: firstly, some of the engineers told us that they had personal interests in engaging in the development of sustainable technologies. Secondly, shadowing as a method itself revealed the ways personal relationships influence research results and once again proved that also methods of social sciences are not to be seen as neutral tools (Law & Urry, 2004).

Over time, we got the impression that shadowing sessions were more productive when they resembled a dialogue. Sometimes, the engineers themselves posed questions about our opinion on certain objectives of their projects or the methods they use. This lead to interesting discussions on different ideas of sustainability as

well as on assumptions of human demands in the context of mobility. For example, one of these discussions, as has been outlined above, revealed that for the engineers diversity means paying attention to exceptions, while we regard diversity as an important concept to introduce different and numerous life worlds into engineering research. In addition, being asked questions as a shadower inspired reflections on our own position as researchers and our own assumptions deriving from feminist STS theory, which underlie our approach. For example,...

Apart from getting into dialogue, it proved beneficial to offer the shadowees pen and paper or let them draw into one of our notebooks. Often, this procedure helped to create a shared understanding of certain technical terms or methods. Also, during one of the shadowing sessions, me and one of the acoustic engineers listened to different sound files that served the purpose of explaining the meaning of different psychoacoustic metrics. For me, this made it easier to gauge what he was working on. So, all these experiences show that shadowing is more than mere observation or interviewing. It has an emotional dimension and should involve more than one of our senses. As a last remark, it is advisable to also use voice recording and write field-notes as soon as possible after the end of a shadowing session. This helps to remember all important impressions and reduce misunderstandings. Also, it was advantageous to send the generated field notes to the shadowees and ask them to comment on them. This procedure helped to clarify uncertainties, generate a joint understanding of terms and to stay in a continuous dialogue.

Side Note: Shadowing in Times of Corona

Due to the Corona pandemic, some shadowing sessions had to be substituted by telephone calls or interviews conducted with the help of digital conference tools. Here, the importance of being physically present in shadowing became apparent. First of all, note taking is more difficult with a telephone in the other hand and when the interviewed person does not see the interviewer taking notes. The latter creates the problem that the interviewed person goes on talking while the interviewer is still writing and, therefore, might miss to write certain statements down. Also, in both telephone interviews and digital conference calls, background noise often disturbed the conversations I had with the engineers. Apart from that, joint drawing or listening were more difficult to perform. Also the atmosphere of the conversation was more distanced in emotional terms, compared to when meeting in person. Last but not least, I considered it way more difficult to ask questions that would lead to the answers that I was looking for, because there was no visible context – no tasks to be observed – that could serve as a basis to create new questions or questions which targeted tacit or embodied knowledge of the engineers.

5. Literature

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