



# Autonomous shuttles contribution to independent mobility for children – a qualitative pilot study

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## ABSTRACT

Children's mobility and the opportunity to get around the city on their own has decreased and is today limited to a large extent by unsafe traffic situations. Due to their limited independent mobility, children are excluded from the urban space and its facilities. Independent mobility can be related to several dimensions of children's social, physical, mental and cognitive wellbeing. The purpose of this study is to investigate if and in what way autonomous buses can contribute to children's independent mobility and, using children's experiences, provide insights into this before the introduction of autonomous buses in cities and public transport systems. To do so, the two research questions "How can autonomous buses in the transport system contribute to children's independent mobility?" and "What prerequisites are necessary for autonomous buses to contribute to children's independent mobility?" are answered. The survey is based on a case of introduction of autonomous buses in urban environments. Three focus groups with students in a primary school were conducted with the aim of gaining the participants' experiences. The results indicate that the introduction of autonomous buses in an urban area can contribute to children's independent mobility in several ways and that the buses have certain characteristics that enable them to be adapted to children's conditions. The low speed of the shuttles, which is often seen as an obstacle when it comes to time efficiency, has a positive effect on perceived safety in this case. The mobility solution is also child-friendly in that it is accessible in terms of trip planning and payment. However, it is important to consider the risk that the bus might replace active transportation modes, like cycling. To avoid this, autonomous shuttles should be integrated in a way that complement, not compete with, active travel.

## 1. Introduction

The possibilities for children to get around the city on their own has decreased and is today limited to a large extent by unsafe environments. Due to their limited independent mobility, children are often excluded from the urban space and its facilities (Mitra & Abbasi, 2019). Enhancing opportunities for independent mobility through planning and development of the physical environment will promote the benefits that the freedom to move around urban environments can have on children's mental and physical development (Alparone & Pacilli, 2012). Most research and practical initiatives in sustainable urban mobility have focused on the needs and preferences of adult citizens. Assessments are often made based on the value of travel time between home and work and therefore do not naturally include children's travel. The responsibility for children's transport needs is thus placed on the parents, why it is important to be aware that children's needs differ in many ways

from adults'. Children perceive the built environment differently, and their independent mobility is based on factors that they cannot influence (Waygood, Friman, Olsson & Taniguchi, 2017b).

Children's independent mobility refers to the opportunity, ability and freedom to get around the immediate area on their own without adult supervision (Mitra, Faulkner, Buliung & Stone, 2014; Riazi & Faulkner, 2018; Shaw, 2019). How the city was built and developed historically has thus had an impact on children's freedom (Alparone & Pacilli, 2012), and the future development affects not only children's mobility, but also their well-being, physical and mental health and social development (Shaw, 2019). One way to reduce the constraints on children's mobility and their need to be transported by their parents is to increase their autonomy and safe independent travel. To achieve this, it is important to consider relevant aspects of mobility from a child's perspective in urban development and transport planning (Waygood et al., 2017b), which includes obtaining a deeper understanding of

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young people's mobility (Saarinen, Ihlström & Wallsten, 2020). In general, there is reason to consider the needs and wishes of more vulnerable groups in the implementation of mobility services in an urban context (Mouratidis & Cobeña Serrano, 2021; Soe & Müür, 2020).

Autonomous shuttle services for urban environments are currently under development. In several cities, demonstrations of this mobility solution are already taking place (Anund et al., 2022). Autonomous shuttles can be used as a mode of transport to complement and enhance public transport systems (Bucchiarone, Battisti, Marconi, Maldacea & Ponce, 2020). They have the potential to contribute to a more sustainable transport system, both environmentally, through reduced need for cars and thus reduced emissions, economically, through lower operating costs, and socially by meeting more of the inhabitants' needs for transport (Milakis, 2019). To realise these benefits as well as acceptance for the shuttles, it is important that the service is adapted to be accessible and efficient for as many citizens as possible. Previous studies have explored the general public's opinion on autonomous shuttles as a mobility service in urban environments (Hilgarter & Granig, 2020; Mouratidis & Cobeña Serrano, 2021). There have also been studies focusing on older adults to examine their needs, expectations, and concerns regarding the implementation of this service (Booth, Tan, Norman, Anund & Pettigrew, 2022). The children perspective on such future operation is not very well known and hence an important issue to consider. For children to be able to use autonomous buses in their journeys, their circumstances must be considered in the development and implementation of these services (Mouratidis & Cobeña Serrano, 2021; Soe & Müür, 2020). Being able to influence one's local environment is also a right that is included in the Convention on the Rights of the Child (Unicef, 2018, Article 12) and experiences and opinions that are included in planning can contribute to better informed decision-making and an urban environment that promotes children's independent mobility (Johansson, Mårtensson, Jansson & Sternudd, 2019; Waygood & Manaugh, 2019).

The aim of the study is to investigate if and in what way autonomous shuttles can contribute to children's independent safe mobility taking children's experiences into consideration and provide insights before the introduction of autonomous shuttles in cities and public transport systems are realised. To do so, two research questions are investigated: "How can autonomous buses in the transport system contribute to children's independent mobility?" and "What prerequisites are necessary for autonomous buses to contribute to children's independent mobility?".

## 2. Material and methods

In spring 2020 autonomous shuttle buses were introduced to the Linköping university campus area in Sweden. The shuttles are part of the research platform Ride the future, which is a collaboration between several actors in the local and national research and mobility sector. The purpose of the project is to demonstrate how an autonomous, electrified bus can be part of the modern densified city, and to offer a platform for research and united action for regional development. During 2021, the area served by the shuttles was expanded to a nearby residential area (Fig. 1). This area is characterized by mixed-use and has about 1000 dwellings as well as housing for elderly people and a municipality owned school for children aged 6-13 years old. The area is newly built and will continuously be developed during the coming years. This will result in construction work which will lead to increased traffic and less opportunities reaching the school and senior housing by car.

The present area included in Ride the future consists of a 4 km long route with 13 predefined bus stops (Fig. 2). The shuttles are programmed to go around the route autonomously, but there is also a safety operator on board. It takes approximately 40 min to go around the route and the trip is for free. The bus normally stops at all bus stops, but it is possible to communicate with the safety operator to also stop at other places along the route. The role of the safety operator is to solve



Fig. 1. Ride the future shuttle bus in residential area.



Fig. 2. Ride the future bus stop on campus area.

unexpected and varying problems during the trip, to assist the passengers and to inform about technology and research. The autonomous shuttles used in Ride the future has six to eleven passenger seats (Fig. 3). At the time of the data collection there were two shuttles going around the area. Due to the corona pandemic, the platform was used at the time only for testing and research, and therefore there were no other passengers allowed.

The method for this study was qualitative and combined co-occupant studies with follow up focus group discussions. Children from the school in the residential area was recruited to try out the shuttles and share their view on the useability of the service. Three co-occupant and focus group occasions were carried out with children in grade 5 (12–13 years old). In total, 7 girls and 3 boys participated. The school has no specific catchment area and the student come from different neighbourhoods, with varying socioeconomic profile, around the city. Most of the participants lived 2–4 km away from their school. Two children lived very close to the school (<100 m) and hence usually walked there. For the remaining participants, common transport modes used to get to school were bicycle, bus, or car. Most of the children expressed that they prefer cycling to going by bus or car. Two main reasons for this were the feeling



Fig. 3. Shuttle bus interior.

of being independent by not having to adjust to their parents' schedules and availability to drop or pick them up and to avoid the stress at home in the mornings. There were, however, seasonal differences. During wintertime the children preferred to go by bus, since the road conditions might be bad and they don't feel safe going by bike.

Participant recruitment was done with the help of the teacher at the municipality owned school in the area. The children were asked if they wanted to participate and if they expressed an interest the parents were then asked to agree. The study was done in line with the Helsinki declaration and routines for ethical considerations at Malmö university. Signed informed consent was given by parents.

All data collections were done in the afternoon during the spring of 2021. The study was carried out during three occasions with three different groups of students. Each occasion included a co-occupant shuttle ride around the route, and the follow up focus group discussion. During the co-occupant part of the research, the safety operator was accompanied by the moderator of the focus groups. The bus tour that was carried out before the focus group discussion was the participants' first experience of riding the autonomous buses in this area. The participants in each of the three different data collection occasions received the same instructions before the bus trip and then went on the same bus, on the same road and speed. Each group consisted of 3–4 participants and the following focus group discussions lasted for 40–60



Fig. 4. Pictures from co-occupant occasion 1.

min (Fig. 4).

The purpose of the co-occupant part of the study was to provide the participants with experience of riding the shuttles around the area. The experience was then used as a background for further discussions during the focus groups. The focus group discussion has its starting point in the case study where autonomous shuttles are considered as a part of the urban mobility solutions providing independent school transportation for children (Yin, 2018). The focus was on the participants experience from the co-occupant travel considering their view of how this solution might contribute as a mobility solution for them. The goal was to find out everyone's perception of the case and this was done through an open and relatively unstructured discussion between the participants and the focus group leader. The students were asked to reflect on their new experiences and discuss how this new mobility solution relate to their current options and previous experiences related to school trips. The questions in the interview guide are based on previous research in the areas 'children's independent mobility' and 'user adaption of shared autonomous mobility solutions'.

Children need structure in the conversation, but there is a risk that the power structures that exist between the leader and the participants affect the dialogue and consequently the information that emerges (Porter, Townsend & Hampshire, 2012). Therefore, encouraging children's own thoughts and opinions was important. It is also important to reflect on what happens to children's information when it is interpreted by an adult. There is a risk that one's own experiences of childhood and what is "the best interests of the child" play into this interpretation (Cele & Van der burght, 2015). Research that includes children should consider that creative approaches are generally more child friendly as they allow children to start from their concrete experiences and actively show what they mean (Cele, 2014). It is also important that methods and topics are meaningful, and that the relevance of participation is clear and valuable to children (Porter et al., 2012). To adapt the focus groups to this target audience, the questions were formulated from a perspective based on the children's everyday life and previous experiences. These questions were also revised and developed after each focus group occasion to be further adapted to the participants. In addition to the traditional conversation in the group, the children also had the opportunity to draw something that they associated with their experiences. The drawings were used as a starting point for the discussions but not included in the analysis.

In studies that include children, an ethical problem arises in that the children may not have knowledge and experience of what the research entails. Extra sensitivity and consideration were therefore required during both the actual data collection and compilation and analysis of this (Johansson, 2003). The children's participation was established through the school, and they were given information about the purpose of the study and how their discussions would be used in the final report. They were also involved in the composition of participants in each focus group to make them feel comfortable in the situation.

The discussions were voice recorded and analysed by a thematic analysis approach suggested by Braun and Clarke (2006). The qualitative thematic analysis is a method for identifying, analysing, and presenting patterns in the data. Themes are used to illustrate analyses of the material that are identified as central to an idea or concept. Each theme represents a pattern that capture something important in the material in relation to the research questions. The qualitative aspect entails that there are no quantitative indicators defining which patterns are relevant. In some cases, a theme consists of commonly occurring codes, but this is not decisive. The themes should not be perceived as comprehensive for the material, but rather aim to provide a more in-depth picture of the participants perspective on the issue in an exploratory way. The thematic analysis has been done inductively, which means there are no predefined coding scheme, and the themes presented have a strong connection to the material.

The practical approach for analysing the material from the focus groups followed a number of recommended steps for thematic analysis

(Braun & Clarke, 2006). Initially, a transcription of the discussions was made. The next step consisted of a systematic production of codes where interesting aspects of the material were identified and compiled into categories, and then in the third step, sorted into potential themes and an overall structure. Reviews were then made to ensure the relevance and validity of the preliminary themes for the individual codes as well as the empirical work as a whole. In the final steps, the presentation of the analysis was designed and examples from the material were selected to illustrate the sense of each theme. The analysis resulted in four themes: Perceived safety, Efficiency, Accessibility and Future vision, which are presented in chapter 3. 'Result and analysis' together with extracts from the material.

### 3. Result and analysis

The results from the focus groups were consolidated into four themes: Perceived Safety, Efficiency, Accessibility and Future vision. The themes are discussed in the following section.

#### 3.1. Perceived safety

The safety of the bus was a topic raised both during the journey and in the discussions. Overall, all participants thought it felt safe to ride the bus, and most did not think it was much different from riding a regular bus. However, in all discussions it was pointed out that the safety driver played a role in the overall safety experience. In one group they said that even though it was not scary that no one steered the bus, it was nice that there was a person in charge on the bus to whom they could ask questions if a problem occurred. In one discussion it was apparent that if they had been completely alone on the bus it might not have felt as safe. It was also reflected that it might feel safer when passengers have more experience of riding such a bus. The fact that the driver did not drive the bus also had other advantages according to the children. They mentioned for example that the driver might have more control over other things around and in the bus.

Hard braking was something that all groups had opinions about. One person thought it was a bit unsettling the first few times the bus stopped, as it felt like something might have happened. Another person had paid attention to warning signs for hard braking and was more prepared for it. Overall, most children thought it was good that the bus braked hard, since there is less risk for collisions with obstacles outside. Several participants thought that it felt safer than a regular bus, partly because it drove slower and partly because they knew that it would stop if something got in the way. They further emphasised that it is important that there are seat belts so that no one inside the bus is injured if the bus needs to brake for something that gets in its way. One child sitting facing backward pointed out that it felt a little unsafe not to be able to look ahead in the direction the bus was going. They also discussed that the braking can be a danger if someone is behind the bus when it stops, or if you happen to get up too early when it is time to get off. The children expressed that hard braking is good, but at the same time they do not like hard braking for not relevant things like leaves. Things that children mentioned could have increased the feeling of safety were if the bus was programmed to stop at all pedestrian crossings and also that there was a separate road for the bus.

Most children stated that they trust the technology to work, though some were a bit hesitant. At the beginning of the bus trip, one student thought it was a bit scary and was worried that something might go wrong with the technology and said: "At first I thought we would drive into a lamppost". They had confidence in the bus's technology and experienced that it brakes better and more safely than a regular bus, but at the same time something can fail, and then they would not have been as positive. Someone said: "If something had gone wrong it would not have been so fun".

#### 3.2. Efficiency

A big difference between the autonomous bus and regular buses was, according to all groups, the speed. Some children thought it was a bit boring to take the bus when it went slow, while other children worried that it would be difficult to get to school in time if they were in a hurry, though it might still be faster than walking. For them to see the bus as a time-effective way to get there, it would need to go faster. They also discussed the risk that the complicated technology could run into problems which would make the bus late. In one of the discussions, the children said that even though the bus runs slower than a regular bus, it is more fun to ride, and "has cooler stuff".

The children discussed the size of the bus as one of the things that was different from a regular bus. They noticed that there were fewer seats and that not as many passengers could ride the bus. However, several of them felt that there were other benefits. For example, one participant said: "The bus is smaller than a regular bus, but better". In some of the discussions, it emerged that the advantage of a smaller bus is that it can travel on smaller streets, such as cycle paths, and thus get to more places. One participant described what the trip to school could look like with the bus: "My bus stops at Nobelorget, but if next to the buses/ bus stops that go there (the regular buses) you could make a bus stop for the small bus, and also its own little road where it can go, because there is a huge bike path there, it would probably be good. Then I would definitely hop on that bus after the usual one, if it went a little faster". Another participant identified that one difference from regular buses was that this bus does not need to be steered with a steering wheel, which means that the driver can focus on other tasks, such as assisting the passengers.

The children expressed that the bus can be a smooth and efficient way to get to and from school. The main efficiency concern was however how those who have a bicycle would be able to use the bus if they want, or need, to cycle to the first bus stop. The children discussed that those who normally cycled to school would have difficulties using the bus as they can neither take it all the way between home and school, nor take the bike on the bus. Several suggestions were given supporting that it would be good if the bike could be taken on the bus, for example when you are tired. Though, if they do not need to cycle, or if they live closer to the school, they can use the bus for the last part of the trip. It also works well if you go to school by bus as you can switch to the autonomous bus at some of the regular bus stops.

#### 3.3. Accessibility

One aspect that the children highlighted as positive for accessibility to ride the bus was that it is for free. The participants also noticed that it was adapted to persons with special needs. Many mentioned that it was "cool and good" that there was a ramp that could be folded out automatically if someone needed to get on the bus with, for example, a wheelchair or a stroller. They also reasoned that the bus can be a good choice if you are tired. One participant said that "It would be good to be able to ride the bus, for example, if no one can take you to school or if the bike or car does not work". They did, however, wish there were stop buttons on the bus. The children were also concerned that the size of the bus would not allow everyone to fit their belongings.

According to the children, the easiest way to get to the bus would be to walk. Some had difficulties imagining the way to the bus stop, but would appreciate clear signs with pictures where the bus stops so they know that it is the right place to wait. It is important that it is quick to get to the bus, and one child thought it would be good if it was somehow possible to see if there are seats still available on the bus while they are waiting for it. In one of the discussions, it was agreed that the bus would feel more accessible if there was an app that shows what times the bus runs. Most children felt that the bus needed to run at least a couple of times per hour to be useful for them. The children also mentioned that it is positive if they can hop on the bus at any time without having to book

or plan the trip ahead. The fact that the bus can travel on other roads than the usual buses is something the children saw as an opportunity because it means that those who do not usually have access to public transport could still travel with this bus. The children suggested several other places that the bus could go to, including grocery stores and leisure centres, and said that the route should be varied so that as many people as possible will benefit from it. Most participants expressed that it was positive that the bus will go to their school, and that the bus schedule should be adapted to match the start of the first lesson.

### 3.4. Future vision

All participants' first impression after the bus ride was that it was "fun", "good" or "cool". It was exciting to get on the bus and it felt new and a little unusual that no one was driving it. One of the children said: "If you are going to school and you're in a hurry, you might take the regular bus because it goes faster, but this one is much more fun to ride". Some participants thought that they became less motion sick than in regular buses and that it was good that the bus was less noisy, and some thought that it was boring when the trip was over, and that they would have liked to continue riding. Others, however, expressed that they got a bit bored because the bus was slow. Some participants said that at the beginning of the ride they had felt a little bit scared, especially when the bus braked hard, but that it became less scary when it had been going for a while and that it felt good that there was a person on the bus who was in control of everything.

Overall, the students thought the introduction of the bus was a good thing, and most participants believed that it would be easier to get to school, or that they can use it in other situations. However, the usage would depend on how often the bus runs and what the rest of the trip looks like. Some children thought that those who live in the area will have greater use for it than those who live further away, since they can also use it for leisure trips in their free time. The general experience was that it was cool to ride the bus. Reasons for this were various technical solutions such as that it had sensors and knew when it needed to stop, that there was a ramp and that it drove automatically, but also that it felt like something that we will see more of in the future and that it was cool to get to try it out.

During the bus trip and the discussions, the children often referred to how autonomous buses will be present in cities in the future. Several children saw it as something they believe will be more common in the future, and some even thought that there will be less need for regular buses. They expressed an understanding that the buses are new and imagined how they can be developed and become, for example, larger and faster in the future. The groups also discussed the advantages of the bus being modern and that it runs on electricity and how this is better for the environment than many ordinary buses.

## 4. Discussion

Autonomous shuttles could contribute to children's independent mobility, but conditions that are specific to children need to be considered. Insights from the study can contribute to an understanding of how, from children's own perspective, independent mobility can benefit from such a solution. In addition, the findings suggest how the service needs to be developed to adapt to more user groups, in this case children, when autonomous buses to a greater extent will be implemented in the city.

### 4.1. Autonomous buses contribution to children's independent mobility

Unsafe traffic situations are one of the most common reasons why children have limited independent mobility (Shaw, 2019). The results from the focus groups indicate that autonomous buses can function as a safe mode of transport that can be used by children. One aspect that helped the participants feel that the bus ride was safe was the safety

driver who could do other things than steer the bus, such as answering the children's questions if they felt unsafe and helping them if a problem would occur. This perceived safety may be a value that can contribute to social capital in the area which previously have been proven to support children's independent mobility (Fegan-Watson, Shaw, Bicket & Mocca, 2015; Mitra et al., 2014; Shaw, 2019; Waygood, 2019). The fact that the bus runs slower than normal motor traffic can also be positive for children's independent mobility since it better matches their natural rhythm (which is different from that of adults) (Mouratidis & Cobeña Serrano, 2021; Waygood et al., 2017b). The low speed was something that the participants thought contributed to safety, however similar to the results from previous studies, it is also evident that it can be a problem if the bus runs too slowly (Chinen, Sun, Matsumoto & Chun, 2020; Mouratidis & Cobeña Serrano, 2021; Rombaut, Feys, Vanobberghen, Cauwer & Vanhaverbeke, 2020; Salonen & Haavisto, 2019). The participants pointed out that the bus may be too slow to meet the needs they have for school trips as the students are often in a hurry and worry about arriving too late. Efficient travel as in time savings is thus not the main reason for using the autonomous buses according to the participants in this case. However, the buses can be effective in meeting other needs that are important in children's travel.

Development and adaptation of public transport is important to promote independent mobility and active travel (Masoumi, van Rooijen & Sierpiński, 2020), and autonomous buses mean more opportunities to get around on smaller streets and thus to more places that may be important to users. If these are available to children, there is a possibility that they will have access to more destinations that can meet their needs in the city (Waygood & Manaugh, 2019). Autonomous buses can be used as a complement to other public transport and with minimal new infrastructure cover critical areas and solve problems within the existing systems. The solution can be adapted to different groups and needs and contribute to sustainable and integrated mobility (Bucchiarone et al., 2020; Winter et al., 2019; Zubin, Van Oort, Van Binsbergen & Van Arem, 2020). This was something that the children discussed, and they saw the autonomous buses as an opportunity to facilitate travel in the area.

Children's transport opportunities are characterised in several ways. For one, they have limited ability to pay for travel (Waygood et al., 2017b). The fact that the buses are free is therefore a factor that can contribute to independent mobility. They can facilitate the children's need to make spontaneous trips without a lot of planning when they may not be able to walk or cycle. This can contribute to more active trips with the bus as a complement and to the children not feeling limited by the fact that they must pay for or plan their trip in advance. The system thereby becomes more child-friendly. Another reason why children's independent mobility is limited is that they normally only have access to active modes of transport, which may restrict them from destinations further away (Waygood, Friman & Olsson, 2017a). Autonomous buses can act as a "first-last mile" solution and complement travel made by other means of transport (Bucchiarone et al., 2020). This may enhance access to public transport and contribute to children being able to move independently in a larger context while not being dependant on their parents to carry out these journeys, which was an important value according to the children (Alparone & Pacilli, 2012).

The fact that the children saw the bus journey as a positive experience and an attractive means of transport can contribute to the acceptance of autonomous buses and that these can be implemented to a greater extent. This in turn leads to more journeys becoming possible and that the buses can be seen as an alternative to the car (Chinen et al., 2020; Mitra et al., 2014). However, the fact that the autonomous bus is seen as an attractive and comfortable mode of transport for children also poses a risk that it will replace journeys that would have otherwise been active. There is a strong link between children's active travel and physical health (Badland et al., 2016; Waygood et al., 2017b), and the autonomous bus should be used to promote, and not compete with, active transport such as walking and cycling. Overall, still, children's perception of the bus as an attractive and also sustainable way of

travelling is positive. The fact that they see opportunities for the solution to be used to a greater extent in the future can contribute to the transition to a less car-based society and thus in the long run benefit children's independent mobility (Shaw, 2019; Smith et al., 2019).

#### 4.2. Conditions for autonomous buses contribution to children's independent mobility

In order to contribute to children's independent mobility, it is important that the implementation of autonomous buses is based on children's needs and conditions. Child safety in traffic is fundamental to independent mobility. For the autonomous buses to be accepted and contribute to children's independent mobility, they need to feel safe, both on board and around the bus. To achieve a feeling of safety, the children said that it is important that there are seat belts and that the bus stops at all pedestrian crossings. The reliability of the driver on the bus also has an impact on the perceived safety, which has been reported in previous studies on the general perception of autonomous shuttle buses as well (Chinen et al., 2020; Mouratidis & Cobeña Serrano, 2021; Salonen & Haavisto, 2019). Even though the bus stops at all predefined bus stops, the children mentioned that they would have preferred it if there was a stop button on the bus with which they could communicate that they want to get off. This might be because they are used to buses where they must press a stop button. Which means there might be a need for an introduction of this "unusual" system.

Something that is mentioned by both participants in this, and previous studies, is that hard brakes that the bus makes need to be smoother for the journey to feel safe (Anund et al., 2022; Chinen et al., 2020; Mouratidis & Cobeña Serrano, 2021; Rombaut et al., 2020). However, the children stated that the bus's consistent braking at the slightest obstacle was something that made them feel confident that the bus would not collide with anything. A prerequisite for future use of autonomous buses is that there is a trust in the technology. In previous studies, results have indicated that technical problems have a major impact on the feeling of safety and security (Salonen & Haavisto, 2019; Soe & Müür, 2020; Wicki, Guidon, Becker, Axhausen & Bernauer, 2019). Also in this survey, the participants imply that their attitude to this type of transport would deteriorate if something went wrong. The students' generally positive attitude towards technology and the advantages that come with it nevertheless indicate that there is a technical acceptance, which is usually true for young people (Salonen & Haavisto, 2019).

Previous studies show that children and adolescents need smooth, safe, calm and cheap public transport that is adapted to everyday life (Saarinen et al., 2020). Also in this case, the participants said that it is important that the bus is an efficient and cheap way to get to the destination. If the bus is to be used for school trips, for example, it needs to be reliable in terms of time keeping as well. Moreover, it is important that the autonomous bus can take users to places other than the regular bus so that other needs can be met. It needs to be integrated in a way that makes it compatible with other transport systems so it can be part of a "whole-journey perspective". The children saw difficulties in including the autonomous bus in a trip that also includes a bicycle, and they expressed that it would be good if it was somehow possible to bring the bicycle on the bus. Since the bicycle is an important mode of transport for children's independent mobility, this new service needs to be adapted to be experienced as efficient in the journeys that are already taking place. Integrated modes of transport that take children longer can lead to more independent travel and reduced car use. This is also important for the bus to function as a complement and not a competitor to active modes of transport (SKR, 2013; Westman, Friman & Olsson, 2017).

When designing services with children's needs in mind it is important to consider that it should be easy to find the bus and that it should be accessible, both in terms of distance to bus stops and frequency in departures (Johansson et al., 2019). To meet mobility needs, it is also important that routes and departures match the times that the children

want to get to and from school. Experience and knowledge of autonomous buses can influence parents' attitude to let children use these for independent travel and are therefore important to consider in the implementation (Jing et al., 2021). The participants could see potential in the autonomous buses as a mobility solution and believed that they can provide more value in the future. In order to promote children's independent mobility, the focus should be on making the environment accessible and safe. This also includes involving children and young people in this progress and valuing the knowledge and insights they have (Shaw, 2019). Putting children's needs at the centre of development usually results in more human-friendly environments that work better for everyone (Fegan-Watson et al., 2015; Waygood & Manaugh, 2019).

#### 4.3. Limitations

There are some limitations to be considered. First of all, this is a pilot study with a small number of participants. In this study, it was possible to conduct three occasions. The population is limited to students in one grade and thus does not include children of different ages at the school. As the selection of participants was made from a homogeneous and limited group, these students constitute a significant part of those included in the case. However, to validate the results, the study would need to be upscaled, including more children with diverse needs and conditions. Also, the test opportunity only gives access to limited knowledge about child experiences, as it cannot be equated to a real experience of using the bus. Although the material was collected over a short period of time, participants may also have varying experiences from testing the bus. The different groups' experience of the bus journey may have been characterised by external conditions during each occasion, such as weather conditions and technical problems. Due to the corona pandemic there were no other passengers to consider during the data collection. This might have affected the focus group discussions, since there is a possibility that concerns or opinions related to travelling with other passengers would have been raised if this was included in the co-occupant experience. When the bus line is active and available for use in natural contexts, there are greater opportunities for residents to form an opinion about the situation. Secondly, both age and gender may have affected the participants' experiences, which was not considered in the analysis. In addition, the participants had different backgrounds and preconditions regarding distance to school, access to different modes of transport and independent mobility. These are factors which may have affected the result, and which are relevant to consider in order to get a better idea about how autonomous buses as a mobility service can be adapted to individuals with different prerequisites. Thirdly, this study was limited to children's experiences of autonomous buses in the public transport system. It would be valuable to be able to relate the results more systematically to similar studies of children's experiences of, for example, traditional city buses. Finally, this study has indicated that there is also a need to further investigate the relationship between autonomous bus travel and active travel modes, and how autonomous buses can promote these, as part of children's independent travel solutions. It would also be valuable to examine other journeys (than school journeys) that are important for children, as well as parents' experiences and opinions on their children using autonomous busses and also, experiences based on having used the service for a longer period of time.

#### 5. Conclusion

The technical development of autonomous buses is advancing rapidly and research on user experiences has grown in recent years. Still, there has been a need to integrate the experiences of more diverse user groups (Mouratidis & Cobeña Serrano, 2021; Soe & Müür, 2020). This study investigates how the mobility service fits into children's independent mobility and experience of the transport system. The analysis indicates that the introduction of autonomous buses in an urban area can

contribute to children's independent mobility in several ways and that the buses have certain characteristics that enable them to be adapted to children's conditions.

Based on the case used in this study, the buses can in some situations be said to contribute to the children's mobility. However, conditions that are specific to these particular children set limits to the possibilities. Many of the children preferred cycling as a mode of transport, and as this, according to them, is currently difficult to combine with the bus, they cannot use both modes of transport in the same journey. Development and improvement of cycling infrastructure may therefore be more effective in increasing independent mobility in this case of school journeys, although there may be greater possibilities to use the bus in other situations, like going around the immediate area. The benefits are more obvious for students who normally walk, get a ride by car or use public transport since the autonomous buses can function as a complement to these trips. The limited opportunities to access public transport around the school area also constitutes a purpose of an autonomous bus.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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