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Effects of public transport vouchers on children's mobility: a Real-world Laboratory (RwL) approach in Lucerne, Switzerland

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Abstract

Children's and adolescents' independent mobility without being accompanied by others, such as parents or grandparents, and their use of active modes of transportation, such as walking and cycling, have both declined in recent decades. Awareness campaigns promoting such mobility exist in Switzerland. Yet, reducing affordability barriers to public transport (PT) by means of vouchers to improve independent mobility and reduce car use has not been introduced and evaluated as an intervention. This paper describes a large-scale experiment in the city of Lucerne, embedded within a Real-world Laboratory (RwL). RwLs are a participatory methodology in transformative sustainability research. The provision of PT vouchers was initiated as part of a participatory process anchored in the Children's Parliament. The Parliament assumed that the introduction of vouchers creates an incentive to use PT. Overall, multivariate statistics indicate higher PT trips in the voucher years. Specifically, count models show significant increases in PT use for school and visiting trips. However, as no corresponding reductions in car, walking, or cycling trips were observed, the findings primarily point to induced demand rather than modal shifts towards PT. From a policy perspective, we conclude that PT vouchers have the potential to contribute to more independent and sustainable mobility opportunities for children and adolescents as part of their mobility socialization.

Scientific highlights

- A three-year trend study evaluated the uptake and use of a city-wide public transport voucher for pupils.
- Logistic and negative binomial models indicate higher PT trips in the voucher years.
- The voucher increased the number of PT trips per pupil, while no significant reductions in other modes were observed, indicating primarily induced demand.
- Effects differ by trip purpose, with the strongest increases in PT trips being for school and visits.
- Affordability appears to be an important factor in shaping children's public transport use.

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Policy and practice recommendations

- Children's parliaments can initiate effective urban mobility measures.
- Real-world laboratories provide robust evaluation of real-world experiments.
- Public transport vouchers can strengthen children's independence and mobility.
- The public transport voucher experiment design is transferable, but the expected effects depend on local spatial and institutional conditions.

Keywords Real-world labs, Pupils, Public transport, Vouchers, Mode choices

Introduction

Children' and adolescents' independent and active mobility are important for both organizing daily activity patterns and achieving long-term developmental outcomes. Mobility patterns change with age, with younger children relying more on parental accompaniment and adolescents showing increasingly independent mobility. Studies show that the independent mobility trips of children and adolescents, without parents or guardians to accompany them is associated with higher levels of physical activity, as well as psychological benefits such as autonomy, social participation and a reduced risk of depression throughout life (Duffy et al. 2024; Ferreira et al. 2024; Riazi et al. 2022). According to Faulkner et al. (2009) and Riazi et al. (2022), children of primary and lower secondary school age who experience independent mobility are often more physically active and develop important skills such as problem-solving than their less independent peers.

While walking and cycling are important forms of independent mobility, Goodman et al. (2014) and Khaleghi, Kato and Oono (2021) show that public transport (PT) also plays a key role in expanding young people's personal independence. Unlike car travel, which typically requires adult supervision, PT enables young people to navigate their environment on their own and to access a broader range of destinations without relying on adults. European studies indicate that walking or cycling to school has declined in recent decades (Kyttä et al. 2015; Shaw et al. 2015), with a shift towards car use for school commutes in several European countries (Haug et al. 2021), while PT use has remained stable (Beck et al. 2023).

In Switzerland, despite efforts to promote independent and active mobility, children's and adolescents' travel patterns have shifted over the past two decades towards motorized transport (Sauter and Wyss 2024). While most school trips are still made on foot or by bicycle, the overall decline in independent and active mobility is linked to rising car ownership, urban sprawl, and longer travel distances between home and school (Grize et al. 2010; Masoumi, van Rooijen and Sierpiński 2020; Sauter and Wyss 2024).

As a policy measure, PT vouchers may reduce affordability barriers. Free or reduced ticket prices or travel passes may increase PT use among school-age children, thus improving their independent mobility, reducing car use (e.g. Cats, Susilo and Reimal 2017; Guzman, Cardona and Ochoa 2024) and increasing the demand for PT (Gómez et al. 2024; Guzman et al. 2025; Guzman, Cardona and Ochoa 2024).

Although free or subsidized PT has been evaluated in various contexts, little is known about how universal, age-targeted subsidies operate within RwLs. Moreover, existing studies rarely analyse whether such measures generate substitution effects between different modes of transport or induce additional travel. In Switzerland, no PT voucher targeted at children and adolescents has ever been evaluated empirically. Although various Swiss cantons and municipalities have launched initiatives such as awareness

campaigns, infrastructure improvements and school travel-planning programmes, efforts have largely focused on behavioural change without offering financial incentives. As such, the potential of PT vouchers to support sustainable travel behaviour among children and adolescents remains unexplored in Switzerland.

Accordingly, in the city of Lucerne, a PT voucher was introduced by the city authorities and monitored within a Real-world Laboratory (RwL) setting as a sustainability experiment (e.g. Schneidewind et al. 2018). This large-scale, three-year time-limited experiment includes the yearly distribution of a PT voucher worth 300 Swiss francs for each pupil. This paper investigates the resulting change in pupils' mobility behaviour based on a three-year trend study. The study focuses specifically on children and adolescents aged 6 to 16 years enrolled in elementary and secondary schools in the city of Lucerne.

Against this background, this study addresses the following research question: *To what extent does a public transport voucher for 6- to 16-year-old pupils increase public transport use, and if it does, for what purposes? Does it lead to modal shifts by reducing the use of other transport modes than PT or primarily generate induced demand instead?*

The remainder of the paper proceeds as follows. Section "Literature review" provides a literature review of work on children's active and especially independent mobility and the role of PT vouchers. Section "Study background, data collection and evaluation" introduces the "City of Lucerne" RwL, outlines the PT voucher experiment, and describes the data collection. Section "Analysis" presents the modelling approach (logistic and negative binomial count models). Section "Results" reports the empirical results for different trip purposes. Section "Discussion" discusses the findings in the context of the existing literature, evaluates the experiment's results, addresses limitations, and offers policy recommendations and directions for future research.

Literature review

Mobility behaviour of children and adolescents

Historically, Europe's streets have served as multifunctional public spaces and playgrounds for children. However, since the 1950s mass motorization has transformed streets into car-dominated zones, restricting children's access to public spaces and opportunities for outdoor play (see e.g. Hartt, Lee and Empey-Salisbury 2024; Stenning and Watson 2024). Intergenerational comparisons show that today's parents had significantly more freedom to move around alone or with their peers during childhood than their own children (Bhosale, Duncan and Schofield 2017; Crawford et al. 2017). This shift has led to an interdisciplinary interest in children's mobility and its spatial conditions, involving urban planning, transport science, developmental psychology and pedagogy (e.g. Bongard and Winterfeld 1977; Moore and Young 1978; Schulte 1978). In particular, children's independent and active mobility, including walking, biking, scooter-riding and independent PT, became a policy and research focus (see e.g. Marzi and Reimers 2018).

Mobility entails more than just physical movement: it also enables participation in social life and interaction in social space (for early research in this connection, see Jahn and Wehling 1999). Developing safe streets and public spaces is a growing objective in urban planning and public health (Hartt, Lee and Empey-Salisbury 2024; Stenning and Watson 2024). Children and adolescents are regarded as key actors in the future of sustainable mobility. Their travel behaviour, attitudes and habits influence lifelong mobility patterns. Research shows that mobility decisions are shaped early in life,

particularly during childhood and adolescence (Flade 1997, 1999; Limbourg, Flade and Schönharting 2000). This underlines the need to examine the mobility behaviour of children and adolescents, especially during their transition and change into adulthood (Hunecke 2002; Tully and Alfaraz 2017). Encouraging active and independent modes can lead to healthier, less car-dependent societies with reduced environmental impacts (Haug et al. 2021; Lee 2020; Marzi and Reimers 2018).

Across Europe, studies continue to document a decreasing trend in children's active and independent mobility and a rise in car use, despite interventions such as traffic education and child-friendly urban design (Haug et al. 2021; Lee 2020; Marzi and Reimers 2018). In England, the proportion of children who were allowed to travel home from school alone dropped from 86% in 1971 to just 25% in 2010, showing a decline in independent mobility (Shaw et al. 2015). Over a twenty-year period from the early 1990s to 2011, the independent mobility of Finnish children declined significantly, particularly in small towns and rural areas (Kyttä et al. 2015). Motorized modes of transport such as cars are used more often due to increasing distances between home, school and urban sprawl (Masoumi, van Rooijen and Sierpiński 2020). The decline in active and independent school mobility is attributed to longer distances, heightened parental safety concerns and increasing car dependency (Ahern et al. 2017; Bhosale, Duncan and Schofield 2017; Fyhri et al. 2011; Hecker et al. 2025). Recent international reviews have found that psychosocial factors such as parental norms, perceived safety and children's self-efficacy play a central role in shaping independent mobility (Savolainen et al. 2024). Research in general links children's independent mobility to higher levels of physical activity and broader well-being (Duffy et al. 2024; Riazi et al. 2022). Recent overviews emphasize autonomy as a key ingredient of healthy development (Ferreira et al. 2024). However, independent mobility is increasingly restricted by parents who fear the dangers of the road or of strangers (Cadima and Pinho 2024).

Despite initiatives in Switzerland promoting active and independent mobility, such as road-safety education and child-friendly urban design, Grize et al. (2010) found a decline in walking and cycling among Swiss children between 1994 and 2005. By analysing the Swiss Mobility and Transport Microcensus (MTMC), they linked this to rising car ownership, urban living and barriers discouraging walking and cycle use on roads. In his trend analysis of the MTMC between 1994 and 2021, Sauter and Wyss (2024: 70ff.) show that in 2021 children aged 6 to12 completed about two-thirds of their everyday trips actively (55% walking, 10% cycling), while 26% of their trips involved being chauffeured by car and 8% were by PT. Today, among adolescents aged 13 to 15, 36% of trips are made on foot, 18% by bicycle, 23% by PT and 21% by car. Sauter & Wyss further show (2024: 90f.) that use of parental cars on school trips remains limited but non-negligible. Among 6- to 12-year-olds, about 9% of school trips were car-based in 2021, with the highest share among 6- to 7-year-olds of 11%, 9% among 8- to 9-year-olds and 8% among 10- to 12-year-olds. The largest increase over time was observed among the 10- to 12-year-olds, while among the younger children the rise since 1994 was smaller and even declined slightly in 2021.

Taken together, Swiss children's and adolescents' mobility patterns have shifted over the last twenty years towards increased reliance on motorized transport, reduced active and independent travel, and changes influenced by longer distances and the built

environment, understood as features of a community (e.g., street networks, density, proximity) (Sauter and Wyss 2024; also; Bringolf-Isler et al. 2008).

Beyond the dominant role of distance, attitudinal and parental perceptions, household car ownership and built-environment features are associated with less walking to school (Lee et al. 2013). The built environment, when consisting of dense, pedestrian-friendly residential areas with safe sidewalks and short distances, promotes active mobility, while car-centred urban structures inhibit it (Sharmin and Kamruzzaman 2017). Children in urban areas with good access to schools and leisure facilities are more likely to walk or cycle, while in suburban or rural areas they often use cars (Curtis, Babb and Olaru 2015; Mehdizadeh, Mamdoohi and Nordfjærn 2017). For adolescents, mode choice varies by destination, travel distance and degree of urbanization. Girls are more likely to use passive modes (car, bus, train/metro, motorbike) for school trips, whereas active modes (foot, bike, e-bike) dominate for shorter distances (Beck et al. 2023).

In sum, research consistently shows a long-term decline in children's active and independent mobility and a growing reliance on motorized transport, driven mainly by increasing distances, parental safety concerns, car availability and built-environment conditions, such as discontinuous street networks, traffic-heavy streets, limited pedestrian infrastructure and the spatial separation of residential areas from schools and leisure destinations. While the benefits of independent mobility for health, development and sustainable travel behaviour are well established, existing policies have only partly reacted to these trends. However, important gaps remain. In particular, little research examines children's use of PT, the role of affordability barriers, and the effects of real-world policy interventions that directly target these barriers. Evidence on whether reducing PT costs can influence children's mobility behaviour is especially scarce.

Public transport vouchers

High transport costs can limit children's use of PT (International Transport Forum [ITF] 2024). For school-age children, these costs are borne at the household level, meaning that parental income and willingness to pay influence access to PT. Consequently, subsidies can support youth mobility by reducing PT's financial barriers for families (ITF 2024, 7). As a policy measure, PT vouchers are explored by cities and municipalities to enhance affordability, encourage modal shifts towards sustainable modes of transport, and reduce transport-related social exclusion. Unlike fare-free PT (FFPT), which abolishes fares within a given network, PT vouchers typically operate as a subsidy instrument granted to specific population groups such as low-income households, job-seekers, or children (e.g. Greenstein 2022). However, FFPT schemes themselves are not always universal. Many are "socially-limited," providing fare-free access only to particular user groups (e.g. the young, the elderly, and low-income populations) (Kębłowski 2020). Both instruments can therefore be implemented in targeted or universal forms, but they differ in their policy mechanisms, namely fare abolition versus individual subsidies. The primary goal of PT vouchers is to lower direct mobility costs and improve access for vulnerable groups (Root 2001). Compared to subsidies such as general reduced prices, PT vouchers offer a focused and potentially cost-efficient strategy, as vulnerable groups are specifically targeted (Guzman and Hessel 2022; Guzman et al. 2025). Socially, vouchers lower the affordability barriers to use PT and improve independence. Environmentally, they aim

to shift demand from cars to PT (Bull, Muñoz and Silva 2021; Guzman, Cardona and Ochoa 2024; Rozynek 2024).

Recent (quasi-)experimental studies show that financial support can influence travel behaviour. In Bogotá, Colombia, Guzman, Cardona and Ochoa (2024) found that monthly PT vouchers increased PT use by 9%, mainly at peak hours, and that they improved affordability for low-income households by up to 26%. In Santiago (Chile) Bull, Muñoz and Silva (2021) reported a 12% rise in trips during a two-week unlimited travel trial, mostly off-peak and leisure trips, reflecting induced demand rather than modal shifts; this was consistent with other fare-free PT programs (Štraub 2020). Credits that can only be spent on PT further reduce cost barriers and raise usage (Gómez et al. 2024). In the UK, Root (2001) observed high levels of acceptance and increased operator revenues with a rural PT voucher. Arranz, Burguillo and Rubio (2019) showed that a youth pass in Madrid cut transport spending for middle-income youngsters by 42–49% and improved accessibility for low-income youngsters. Beyond savings, vouchers and passes can support inclusion and promote positive attitudes towards PT (Bull, Muñoz and Silva 2021). According to Basnak and Giesen (2023), fare-free systems are more viable in small cities, while vouchers are cost-effective in larger urban areas with service improvements. Still, concerns remain about financial sustainability, substitution effects, induced non-essential travel and subsidizing existing trips (Arranz, Burguillo and Rubio 2019; Rozynek 2024; Volinski 2012). From a policy perspective, PT vouchers offer flexibility and budgetary control but face challenges in targeting beneficiaries, administration and misuse prevention (Bua, Paina and Kiracho 2015).

While Switzerland has a highly developed PT network and comparatively high levels of income and PT use, existing efforts to promote active and independent mobility among young people have taken different forms. Several cantons and municipalities have introduced campaigns and infrastructure improvements aimed at promoting walking and cycling. Others have focused on travel training or participatory planning processes to raise awareness and empower young people to shape their mobility environment (e.g. Sauter and Wyss 2024: 100ff.). These approaches differ from vouchers in that they do not address the affordability barriers to using PT. No PT voucher specifically targeting pupils has been systematically implemented or empirically evaluated *to date*. Most of the Swiss projects have been locally confined and lacked systematic evaluation regarding their long-term impact on modal choices. Introducing a timely-limited PT voucher for pupils to improve independent mobility and address affordability barriers is a novelty for Switzerland.

Study background, data collection and evaluation

Real-world Laboratory and sustainability experiments

Following Parodi et al. (2016a, 2016b, 2017, 2024) and related work in transformative and transdisciplinary research, RwLs are scientifically initiated, co-created research settings that integrate experimentation into real-world contexts to generate actionable knowledge for societal transformation. RwLs are anchored in local structures, operate under authentic boundary conditions, and combine experimentation and evaluation within one framework (Parodi et al. 2016a, 2016b, 2024; Schäpke et al. 2018; Torrens and von Wirth 2021). Their emergence reflects efforts to align research with sustainability goals (Schneidewind and Singer-Brodowski 2014). RwLs are conceptually grounded

in transdisciplinary research, real-world experimentation and transformative science (Bergmann et al. 2021). In this sense, they conduct sustainability-oriented science for, with and in society, which differentiates them from both technology-driven Living Labs (Bulkeley et al. 2016; Schuurman et al. 2013) and Transformation Labs, which lack a long-term focus and structural integration (Leminen, Westerlund and Nyström 2012; Luu 2022).

Constitutive characteristics of RwL's discussed in the literature include a transformative orientation (normativity toward sustainability), purposeful experimentation in the real world, transdisciplinarity and participation, reflexivity and iterative learning, scalability and model character, a laboratory character (structured yet open exploration under real conditions), long-term embedding, and an educational dimension that builds competencies for transformation (Parodi et al. 2016a, 2016b; Schäpke et al. 2018; Singer-Brodowski, Beecroft and Parodi 2018). Participation typically spans a spectrum from information to co-decision, while the transdisciplinary core is the joint problem-framing and co-design of experiments and co-evaluation of outcomes. Trenks and Bögel (2024) demonstrate how RwL participation leads to empowerment and role transformation through embedded agency. RwLs are uniquely characterized by their normative framing, systemic change orientation and deep actor integration (Parodi, Seebacher and Trenks 2024, Walz & Engels, 2018; Schäpke et al. 2018). RwLs are also "learning environments" that promote individual and collective learning, especially sustainability competencies (Singer-Brodowski, Beecroft and Parodi 2018). Despite conceptual clarity, practical challenges persist, such as short-term funding, institutionalization barriers and managing conflicting perspectives (Schecke, Fichter and Tiemann 2021; Walz & Engels, 2018). Researchers navigate tensions in their dual roles as facilitators and scientists (Rogga, Zscheischler and Gaasch 2018).

Real-world, time-bound and structured sustainability transformation experiments are the central method in RwLs (Beecroft et al. 2018; Schäpke et al. 2018). RwL experiments generate transferable knowledge while enabling real-world impacts. Systematic data-collection must be integrated to enable behavioural, infrastructural and institutional impact assessments (Parodi, Seebacher and Trenks 2024; Schäpke et al. 2018). In the transportation sector, evaluating the impact of RwL experiments requires context-sensitive data. As a result, quantitative monitoring is crucial (Balthasar et al. 2024). In the following, this framework will be applied to our PT voucher experiment.

RwL-setting and the PT voucher experiment

In September 2020, the Children's Parliament of Lucerne submitted a motion proposing subsidized or free PT for children and adolescents in fare zone 10 (city area). The aim was to strengthen independence and reduce reliance on parents' cars among 6- to 16-year-old schoolchildren. In May 2021 the City Council approved this initiative, thereby supporting the vision of promoting sustainable and child-friendly mobility. A total budget of CHF 5 million was allocated for the three-year-pilot. The PT voucher was developed through a participatory process by the Children's Parliament and the City Council, enabling political engagement for a group that is otherwise excluded from formal processes (Dachverband Schweizer Jugendparlamente [DSJ] 2019: 4f.). The PT voucher aims to reduce the financial barriers to PT, promote leisure access, and build mobility awareness from a young age.

The resulting large-scale experiment is the provision of a PT voucher worth CHF 300 on a yearly basis for a three-year trial period, covering about 50% of the cost of an annual youth pass in zone 10. The PT voucher is available to all pupils attending elementary and secondary school in the city, regardless of their household income and residential neighbourhood. Pupils' home addresses from the registers ensure coverage of households across Lucerne.

The PT voucher can be used for defined products, including monthly- and annual passes, multi-day- and multi-ride-tickets (if fare zone 10 is included) and the children's General Abonnement (GA) which is a flat rate travelcard for one year. The pilot project runs from 2023 to 2026, with annual PT voucher distributions beginning in summer 2023 and continuing in 2024 and 2025. In the first pilot year (2023/24), 60.7% of the vouchers were redeemed. In the second pilot year (2024/25), 67.8% of the vouchers were redeemed.

Within the conceptual framing of RwL, the "City of Lucerne" qualifies as an RwL: it is co-initiated by the Children's Parliament and politically anchored by the City Council. It is implementing an experiment (annual PT vouchers for school-age children) under institutional and market conditions that go beyond traffic trials by explicitly aiming at transformative learning and sustainable mobility (Glock 2023). Furthermore, it is accompanied by embedded, multi-year quantitative monitoring (three survey waves) and ongoing stakeholder dialogue, and it follows an iterative, reflexive logic (e.g. coordination meetings and interim result presentations enabled iterative feedback and adjustments during the pilot phase.). The project features a transformative sustainability approach (modal shift and mobility socialization), transdisciplinarity (city administration, families, schools, researchers), a longer-term perspective (a three-year pilot linked to a policy decision point), a model character (transparent design and reporting for potential transfer) and an educational dimension (children's engagement and learning through the Children's Parliament).

As such, the Lucerne PT voucher serves as an "RwL experiment" that combines experimentation, evaluation and learning to produce robust knowledge for sustainable urban mobility. Figure 1 illustrates the timeline from proposal initiation by the Children's Parliament to iterative adjustments and policy integration.

Governance of the RwL was organized through a collaborative structure involving the City Council, the Children's Parliament, the municipal transport administration, and the research team. The experiment was broadly supported politically and publicly, although discussions in local media and municipal committees primarily focused on the budgetary implications. Overall, the RwL operated as a structured co-creation process linking political decision-making, stakeholder dialogue, and scientific monitoring.

Data collection

The study follows a cross-sectional trend design with three survey waves conducted in March 2023, March 2024 and March 2025. This enables both cross-sectional and longitudinal analyses of pupils' transport behaviour before and after the introduction of PT vouchers. The surveys examined pupils' choice of mode for school, leisure, accompanying and visiting trips using a retrospective three-day travel diary approach.

The study population comprised all pupils in the city of Lucerne. A multi-stage cluster-sampling procedure ensured representativeness and comparability across waves

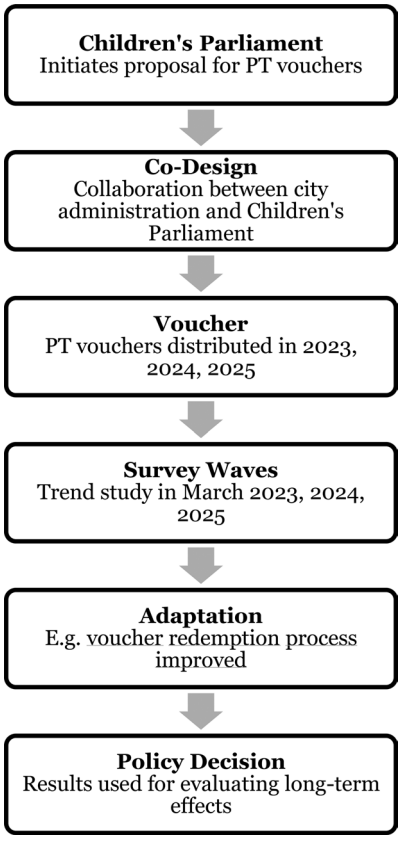

Fig. 1 Real-world Laboratory (RwL) process of the PT voucher experiment in Lucerne

(Kauermann and Küchenhoff 2011, 160–162). In the first stage, eight of the nineteen schools were randomly selected using stratification by school type. In the second stage, five classes per school were randomly chosen, resulting in a total of forty classes. All pupils within the selected classes were invited to participate.

Households received a mixed-mode survey package consisting of a covering letter, a paper questionnaire and a QR code for online participation (German and English). Parents were asked to complete the survey together with their children. Participation was voluntary and anonymous, and no incentives were provided.

Pupils reported their travel behaviour for a typical school week using a three-day travel diary covering Monday, Wednesday and Saturday of the third school week after carnival holidays in each survey year. The questionnaire collected information on use of transport mode, trip purposes and sociodemographic characteristics. The full survey instrument is provided in Appendix B.

Survey waves and representativeness

The random sample at the class level reflects the proportions in the population. Overall, the class composition of all pupils in the city of Lucerne is comparable to that of the samples in the surveys (*see Appendix A*). Using this method and the structure of the data over the years, the impact of the PT voucher on the population of all pupils in the city of Lucerne can be reliably determined over the three years based on a trend study design. Table 1 presents the survey waves, response rates and the distribution of pupils across primary and secondary school levels.

Table 1 Survey waves and sample characteristics

Survey wave	Response rate (%)	Primary school (%)	Secondary school (%)
2023	55	70	30
2024	52	71	29
2025	47	69	31

The distribution across primary and secondary levels in the sample mirrors the population shares of all pupils in the city of Lucerne across the surveys. This is a prerequisite for a comparative analysis of the survey results in relation to the population (representativeness). The data were not reweighted, since this degree of deviation can be tolerated.

Dependent variables

The analysis examined pupils' PT use across trip purposes. We use binary indicators (0 = no, 1 = yes) and counts of reported trips. Over all modes of transport, 99.6% of the sample ($n = 951$) reported a trip at least once, with an average of 10.44 trips (range 0–15 trips) for the whole reference week covering three days.

75% of the sample ($n = 951$) reported using PT at least once, with an average of 3.59 PT trips (range 0–15 trips) for the whole reference week covering three days. PT use for school trips was reported by 26% of respondents, with a mean of 0.98 trips (range 0–6). Leisure trips by PT were more common, with 59% reporting at least one trip and an average of 1.11 (range 0–3 trips). Accompanying trips by PT were reported by 46% of respondents, averaging 0.82 (range 0–3 trips), while visiting trips by PT were reported by 35%, with a mean of 0.68 (range 0–3 trips).

Independent variables

The primary independent variables were year dummies indicating the survey year (*see Appendix A*). In total, 35% of cases in the data set were from 2023, 36% from 2024, and 29% from 2025 ($n = 951$). All variables were coded as binary indicators, with 2023 serving as the reference category in the time-series analysis.

Control variables

Control variables were included to account for attitudinal as well as sociodemographic and contextual factors (see Appendix A). Attitudinal indicators targeted mobility-related opinions that the literature highlights as central for youth transport choices: household car dependency, multimodality orientation, and perceptions of PT independence and accessibility. This choice is supported by existing transport behaviour research on children and adolescents (e.g. McCarthy et al. 2017; McMillan 2007). The variables capture the main sociodemographic, household and perceptual drivers of children's and adolescents' mobility behaviour.

Car dependency, multimodality attitudes and positive attitudes towards PT were measured on a five-point Likert scale. On average, respondents tended to agree that they choose the most suitable mode depending on the occasion (mean = 3.90, range 1–5) (*multimodality*). They also agreed that their child can move freely and safely with PT (mean = 4.17) and reach leisure activities well by PT (mean = 4.31) (*positive attitudes towards PT).* By contrast, fewer agreed with the statement that they cannot imagine leisure without a car (mean = 2.42) (*car dependency*). Gender was self-reported (male,

female or no answer) and was coded as a binary variable (0 = female, 1 = male; 46.5% female). Age was measured continuously (range 6–16 years, mean = 11.06).

Analysis

To evaluate the effect of the PT voucher on children's and adolescents' PT usage, we estimated two complementary model types for each outcome: a binary logistic regression for the likelihood that a child used PT at least once during the reference week for a given purpose (0 = no, 1 = yes) (*to account for probability*) and a negative binomial regression for the number of PT trips (counts) during the reference week (*to account for intensity*).

The negative binomial (NB) model was chosen to count outcomes due to overdispersion, where variance exceeds the mean, violating poisson assumptions (Hilbe 2011; Pagui, Valen and Yu 2022). By introducing a dispersion parameter, the NB specification provides more reliable inferences and can accommodate excess zeros without assuming distinct latent processes[1]. We rely on the NB variance function and observed covariates to account for the data's zero mass (non-PT users in this case). Model quality was assessed using the log-likelihood and the Akaike Information Criterion (AIC). For logistic models, we report model χ^2, Hosmer–Lemeshow tests and pseudo-R^2 measures (Cox and Snell, Nagelkerke). For interpretation, we report odds ratios ($OR = \exp(\beta)$) for the logistic models and unstandardized regression coefficients (β) for the negative binomial models. In the negative binomial models, a positive β indicates higher expected trip counts, and a negative β indicates lower expected trip counts. All analyses were conducted in SPSS (version 30.0).

Results

Descriptives across the three survey years

Descriptives across the three survey years show variation in selected transport mode and contextual factors (see Tables 2 and 3). For any PT trips in the travel diary (binary), 75.2%

Table 2 Descriptive results (binary variables, percentage)

Variable (any trips in travel diary, yes)	Overall	2023	2024	2025
Over all modes of transport	99.6%	100.0%	100.0%	98.5%
Bike	24.9%	24.2%	28.1%	21.8%
Foot	85.8%	86.9%	85.8%	84.5%
Car	46.1%	47.2%	44.9%	46.1%
PT	75.2%	74.9%	76.8%	73.4%
PT school	26.4%	23.6%	26.7%	29.5%
PT leisure	59.0%	57.0%	60.3%	59.8%
PT accompanying	45.5%	44.2%	45.5%	47.2%
PT visiting	35.4%	29.9%	35.1%	42.8%
Bike school	5.9%	5.4%	5.2%	7.4%
Foot school	77.1%	79.7%	75.1%	76.4%
Car school	1.6%	2.1%	0.9%	1.9%
Gender (female)	46.5%	47.1%	48.5%	47.9%

Source: own data

[1] Zero-inflated or truncated NB models were rejected because they require "structural non-users" (Hagen, Reinfeld and Saki 2023; Lambert 1992), whereas our three survey waves show zeros reflecting temporal non-use rather than permanent non-users. Hurdle models, which separate participation from intensity (Mullahy 1986; Warton and Hui 2011), were also unsuitable, as our focus is on year effects on overall usage frequency, rather than distinct mechanisms of use versus non-use.

Table 3 Descriptive results (number of trips for three days of the reference week, mean)

Variable	Overall	2023	2024	2025
Over all modes of transport	10.44	10.25	10.34	10.80
Bike	0.53	0.53	0.55	0.51
Foot	4.72	4.90	4.63	4.60
Car	1.08	1.15	1.03	1.04
PT	3.59	3.16	3.65	4.07
PT school	0.98	0.85	1.04	1.06
PT leisure	1.11	1.05	1.11	1.19
PT accompanying	0.82	0.74	0.81	0.93
PT visiting	0.68	0.52	0.68	0.89
Bike school	0.17	0.15	0.15	0.21
Foot school	3.16	3.25	3.15	3.05
Car school	0.03	0.02	0.02	0.05

Source: own data

of participants reported usage overall, with 74.9% in 2023, 76.8% in 2024 and 73.4% in 2025. The mean number of PT trips rose from 3.16 in 2023 to 4.07 in 2025 (overall 3.59). Any PT school trips (binary) were reported by 26.4% overall, with an increase from 23.6% in 2023 to 29.5% in 2025, while the mean of PT school trips grew from 0.85 to 1.06 (overall 0.98). Any PT leisure trips (binary) remained relatively stable (57% in 2023, 59.8% in 2025), with the mean of PT leisure trips rising slightly from 1.05 to 1.19 (overall 1.11). For any PT accompanying trips (binary), 44.2% reported usage in 2023 and 47.2% in 2025 (overall 45.5%), with mean counts rising from 0.74 to 0.93 (overall 0.82). Any PT visiting trips (binary) showed growth, from 29.9% in 2023 to 42.8% in 2025 (overall 35.4%), with the mean of PT visiting trips increasing from 0.52 to 0.89 (overall 0.68). Any school bike trips (binary) were reported by 5.9% overall, with values of 5.4% in 2023, 5.2% in 2024 and 7.4% in 2025, while the mean number of bike school trips increased from 0.15 to 0.21 (overall 0.17). Any foot school trips (binary) were reported by 77.1% overall, with 79.7% in 2023, 75.1% in 2024 and 76.4% in 2025, while the mean number of school by foot trips decreased from 3.25 to 3.05 (overall 3.16). Any car school trips (binary) were rare (1.6% overall), with values of 2.1% in 2023, 0.9% in 2024 and 1.9% in 2025, while the mean number of car school trips increased slightly from 0.02 to 0.05 (overall 0.03).

When compared across modes, any trips on foot (yes) were consistently highest, with 85.8% overall (stable across years) and a mean of trips on foot at 4.72. Any car trips (yes) were reported by 46.1% overall, with a stable yearly distribution and a mean of car trips of 1.08. Any bike trips (yes) were less frequent (24.9% overall), with a mean of bike trips of 0.53 and some year-to-year variation but no clear trend.

Attitudinal measures also varied slightly over time (Table 4). Agreement with "We are not committed to a specific transport mode – depending on the occasion we choose the most suitable one" decreased from 4.03 in 2023 to 3.78 in 2025 (overall 3.90). Agreement with "We cannot imagine our leisure time without a car" rose from 2.36 in 2023 to 2.57 in 2025 (overall 2.42). Perceptions of independence remained high: "Our child can move freely and safely using public transport" ranged between 4.08 (2024) and 4.24 (2023), overall mean 4.17, while "Our child can reach leisure activities well by public transport" remained above 4.25 (overall 4.31). Sociodemographic factors were stable: gender indicated about 46.5% female across years and age averaged 11.10 years in 2023, decreased to 10.83 in 2024, and increased to 11.28 in 2025 (overall 11.06).

Table 4 Descriptive results (control variables, mean)

Variable	Overall	2023	2024	2025
We are not committed to a specific transport mode—depending on the occasion, we choose the most suitable one.	3.90	4.03	3.86	3.78
We cannot imagine our leisure time without a car.	2.42	2.36	2.35	2.57
Our child can move freely and safely using public transport.	4.17	4.24	4.08	4.21
Our child can reach leisure activities well by public transport.	4.31	4.37	4.26	4.29
Age	11.06	11.10	10.83	11.28

Source: own data

Table 5 Modelling results for public transport trips

	Logit model (any PT use)		Negative binomial model (trip counts)	
Variable	**OR**	***p*-value**	**b**	***p*-value**
Constant	0.17	0.001	−0.703	0.010
(Reference: 2023) Year 2024	1.31	0.169	0.223	0.017
Year 2025	1.06	0.784	0.291	0.003
Not committed to a specific transport mode	0.93	0.305	−0.135	<0.001
Cannot imagine leisure time without a car	0.84	0.002	−0.030	0.295
Child can move freely/safely by PT	1.28	0.002	0.114	0.006
Child can reach leisure well by PT	1.35	<0.001	0.067	0.122
Gender (ref. = female)	0.75	0.085	−0.003	0.971
Age	1.14	<0.001	0.138	<0.001
Model specifications and variance explanation:	Model fit χ^2 (8) = 94.12, $p < 0.001$ Hosmer–Lemeshow χ^2 (8) = 9.93, $p = 0.270$ Cox & Snell $R^2 = 0.101$ Nagelkerke $R^2 = 0.149$		Log-Likelihood = −2039.88 AIC = 4097.76	

n = 887

Overall public transport trips

A binary logistic regression was conducted to examine the factors influencing whether children used any public transport (PT) trips during the observation week (Table 5). The model was statistically significant, χ^2 (8) = 94.12, $p < 0.001$, and the Hosmer–Lemeshow test was non-significant, χ^2 (8) = 9.93, $p = 0.270$, indicating a good fit. The model explained between 10.1% (Cox & Snell R^2) and 14.9% (Nagelkerke R^2) of the variance in PT usage. Significant predictors of increased likelihood of any PT trips included "Our child can move freely and safely using public transport" (OR = 1.28, $p = 0.002$), "Our child can reach leisure activities well by public transport" (OR = 1.35, $p < 0.001$), and age (OR = 1.14, $p < 0.001$). "We cannot imagine our leisure time without a car" was negatively associated with PT use (OR = 0.84, $p = 0.002$). Gender showed a marginal effect, with male pupils being less likely to use PT than female pupils (OR = 0.75, $p = 0.085$). No significant effects were observed for Year 2024 or Year 2025, indicating no level increase in the likelihood of PT use since the voucher was introduced.

To analyse the number of PT trips, a negative binomial regression model was estimated (Table 5). The model showed a good overall fit (log-likelihood = −2039.88, AIC = 4097.76). The multimodality statement "We are not committed to a specific transport mode—depending on the occasion we choose the most suitable one" was negatively associated with the number of PT trips (b = −0.135, $p < 0.001$). A significant positive predictor of the number of PT trips was "Our child can move freely and safely

using public transport" (b = 0.114, $p = 0.006$). Age showed a positive association with the number of PT trips (b = 0.138, $p < 0.001$), indicating that older pupils reported more PT trips during the reference week. Gender was not significantly related to the number of PT trips ($p = 0.971$). "We cannot imagine our leisure time without a car" and "Our child can reach leisure activities well by public transport" did not show significant effects in the count model. The year dummies showed positive effects: both Year 2024 (b = 0.223, $p = 0.017$) and Year 2025 (b = 0.291, $p = 0.003$) were associated with higher trip counts compared to 2023. This indicates a level effect whereby more PT trips were reported after the voucher was introduced.

Compared across modes, only PT showed significant year effects, with PT trips increasing in both Year 2024 and Year 2025. No comparable year effects emerged for any car trips, any foot trips or any bike trips (*see Appendix A*). While descriptives showed decreases in car and walking, these changes were not statistically significant in the regression models, indicating that temporal variation was specific to PT. "We cannot imagine our leisure time without a car" consistently reduced PT use, underlining its central role in shaping children's travel behaviour. In contrast, positive perceptions of PT, captured by "Our child can move freely and safely using public transport", were linked to more PT trips, highlighting the importance of confidence in PT for everyday mobility. Age effects revealed a decline in walking and cycling alongside a greater likelihood of any PT trips, while both the likelihood of using PT and the number of PT trips increased. Finally, the multimodality statement "We are not committed to a specific transport mode: depending on the occasion we choose the most suitable one" was negatively associated with PT trip counts, while in other models it was linked to cycling, suggesting that flexible household mobility cultures distribute travel across modes in complex ways.

Together, the models show how the PT voucher explicitly targets number of PT trips, but not the overall likelihood of having any PT trip, while not influencing other modes of transport. This gives us the first hints of induced demand rather than modal shifts.

School trips

A logistic regression predicting the likelihood of any public transport (PT) school trips was statistically significant, χ^2 (8) = 142.29, $p < 0.001$, with a good fit according to the Hosmer–Lemeshow test, χ^2 (8) = 12.37, $p = 0.136$ (Table 6). The model explained between 14.8% (Cox & Snell R^2) and 21.8% (Nagelkerke R^2) of the variance. Significant predictors included "Our child can move freely and safely using public transport" (OR = 1.42, $p = 0.001$) and age (OR = 1.40, $p < 0.001$), both of which increased the likelihood of PT use for school trips. The multimodality statement "We are not committed to a specific transport mode—depending on the occasion we choose the most suitable one" was negatively associated with PT use (OR = 0.87, $p = 0.033$). No significant year effects were found for Year 2024. For Year 2025, the model suggests a marginal increase in the likelihood of using PT for school trips (OR = 1.49, $p = 0.060$), i.e., weak evidence that the user share increased only in the second voucher year. No significant effects were found for gender, "We cannot imagine our leisure time without a car" and "Our child can reach leisure activities well by public transport".

To analyse the number of PT school trips, a negative binomial regression was estimated (Table 6). The model showed a good overall fit (log-likelihood = –1052.13, AIC = 2122.26).

Table 6 Modelling results for PT school trips

	Logit model (any PT use)		Negative binomial model (trip counts)	
Variable	**OR**	***p*-value**	**b**	***p*-value**
Constant	0.002	<0.001	−4.487	<0.001
(Reference: 2023) Year 2024	1.32	0.176	0.305	0.016
Year 2025	1.49	0.060	0.329	0.014
Not committed to a specific transport mode	0.87	0.033	−0.147	<0.001
Cannot imagine leisure time without a car	1.09	0.184	0.102	0.007
Child can move freely/safely by PT	1.42	0.001	0.180	0.007
Child can reach leisure well by PT	1.02	0.879	0.004	0.948
Gender (ref. = female)	0.95	0.757	−0.017	0.869
Age	1.40	<0.001	0.311	<0.001
Model specifications and variance explanation:	Model fit: χ^2 (8) = 142.29, $p < 0.001$ Hosmer–Lemeshow χ^2 (8) = 12.37, $p = 0.136$ Cox & Snell $R^2 = 0.148$ Nagelkerke $R^2 = 0.218$		Log-Likelihood = −1052.13 AIC = 2122.26	

n = 887

Significant predictors of trip counts included the multimodality statement (b = –0.147, $p < 0.001$), "We cannot imagine our leisure time without a car" (b = 0.102, $p = 0.007$), "Our child can move freely and safely using public transport" (b = 0.180, $p = 0.007$), and age (b = 0.311, $p < 0.001$). Year effects were also observed: both Year 2024 (b = 0.305, $p = 0.016$) and Year 2025 (b = 0.329, $p = 0.014$) were positively associated with the number of PT school trips compared to 2023. No significant associations were found for gender or "Our child can reach leisure activities well by public transport."

For school trips, the results indicate that the voucher increased PT trip frequencies in both voucher years (2024 and 2025), while the likelihood of using PT for school trips shows weak evidence of an increase in 2025 ($p = 0.060$).

Leisure trips

A logistic regression predicting the likelihood of any public transport (PT) leisure trips was statistically significant, χ^2 (8) = 85.633, $p < 0.001$ (Table 7). The Hosmer–Lemeshow test was significant, χ^2 (8) = 19.796, $p = 0.011$, indicating deviation from perfect fit. The model explained between 9.0% (Cox & Snell R^2) and 12.1% (Nagelkerke R^2) of the variance. Significant positive predictors included "Our child can reach leisure activities well by public transport" (OR = 1.41, $p < 0.001$), "Our child can move freely and safely using public transport" (OR = 1.18, $p = 0.030$), and age (OR = 1.12, $p < 0.001$). The multimodality statement "We are not committed to a specific transport mode—depending on the occasion we choose the most suitable one" was negatively associated with leisure PT use (OR = 0.87, $p = 0.017$). "We cannot imagine our leisure time without a car" showed a marginal negative association (OR = 0.91, $p = 0.068$). No significant effects were found for Year 2024, Year 2025, or gender.

To analyse the number of PT leisure trips, a negative binomial regression was estimated (Table 7). The model showed adequate fit (log-likelihood = –1286.499, AIC = 2590.998). Significant predictors of trip counts included the multimodality statement (b = –0.107, $p = 0.003$), "Our child can reach leisure activities well by public transport" (b = 0.156, $p = 0.006$), and age (b = 0.084, $p < 0.001$). "Our child can move freely

Table 7 Modelling results for PT leisure trips

	Logit model (any PT use)		Negative binomial model (trip counts)	
Variable	**OR**	***p*-value**	**b**	***p*-value**
Constant	0.10	<0.001	−1.499	<0.001
(Reference: 2023) Year 2024	1.22	0.235	0.104	0.357
Year 2025	1.17	0.397	0.134	0.264
Not committed to a specific transport mode	0.87	0.017	−0.107	0.003
Cannot imagine leisure time without a car	0.91	0.068	−0.039	0.261
Child can move freely/safely by PT	1.18	0.030	0.096	0.077
Child can reach leisure well by PT	1.41	<0.001	0.156	0.006
Gender (ref. = female)	0.86	0.290	−0.059	0.532
Age	1.12	<0.001	0.084	<0.001
Model specifications and variance explanation:	Model fit: χ^2 (8) = 85.633, p = <0.001 Hosmer-Lemeshow-Test: χ^2 (8) = 19.796, p = 0.011 Cox & Snell R^2: 0.090 Nagelkerkes R^2: 0.121		Log-Likelihood:-1286.499 AIC: 2590.998	

n = 887

Table 8 Modelling results for PT accompanying trips

	Logit model (any PT use)		Negative binomial model (trip counts)	
Variable	**OR**	***p*-value**	**b**	***p*-value**
Constant	0.35	0.027	−0.836	0.021
(Reference: 2023) Year 2024	1.05	0.777	0.130	0.292
Year 2025	1.16	0.410	0.239	0.066
Not committed to a specific transport mode	0.88	0.017	−0.099	0.011
Cannot imagine leisure time without a car	0.88	0.009	−0.109	0.004
Child can move freely/safely by PT	1.13	0.118	0.053	0.341
Child can reach leisure well by PT	1.09	0.250	0.043	0.456
Gender (ref. = female)	1.00	0.993	0.006	0.952
Age	1.07	0.024	0.062	0.005
Model specifications and variance explanation:	Model fit: χ^2 (8) = 34.187, p < 0.001 Hosmer–Lemeshow χ^2 (8) = 7.243, p = 0.511 Cox & Snell R^2 = 0.038 Nagelkerke R^2 = 0.051		Log-Likelihood = −1069.522 AIC = 2157.044	

n = 887

and safely using public transport" showed a marginal association (b = 0.096, p = 0.077). No significant effects were found for Year 2024, Year 2025, "We cannot imagine our leisure time without a car", or gender.

For leisure trips, no voucher-related year effects were observed in either model, suggesting that PT use for leisure trips remained stable over time.

Accompanying trips

A logistic regression predicting the likelihood of any PT accompanying trips was statistically significant, χ^2 (8) = 34.19, p < 0.001, with good model fit according to the Hosmer–Lemeshow test, χ^2 (8) = 7.24, p = 0.511 (Table 8). The model explained between 3.8% (Cox & Snell R^2) and 5.1% (Nagelkerke R^2) of the variance. Significant predictors

Table 9 Modelling results for PT visiting trips

	Logit model (any PT use)		Negative binomial model (trip counts)	
Variable	**OR**	***p*-value**	**b**	***p*-value**
Constant	0.11	<0.001	−1.667	<0.001
(Reference: 2023) Year 2024	1.29	0.154	0.285	0.035
Year 2025	1.72	0.004	0.496	<0.001
Not committed to a specific transport mode	0.80	<0.001	−0.177	<0.001
Cannot imagine leisure time without a car	0.88	0.016	−0.060	0.144
Child can move freely/safely by PT	1.14	0.116	0.100	0.103
Child can reach leisure well by PT	1.04	0.606	0.015	0.806
Gender (ref. = female)	0.84	0.224	0.022	0.842
Age	1.18	<0.001	0.114	<0.001
Model specifications and variance explanation:	Model fit: χ^2 (8) = 79.522, $p < 0.001$ Hosmer–Lemeshow χ^2 (8) = 5.211, $p = 0.735$ Cox & Snell $R^2 = 0.086$ Nagelkerke $R^2 = 0.118$		Log-Likelihood = −956.222 AIC = 1930.443	

n = 887

included the multimodality statement "We are not committed to a specific transport mode—depending on the occasion we choose the most suitable one" (OR = 0.88, $p = 0.017$) and "We cannot imagine our leisure time without a car" (OR = 0.88, $p = 0.009$), both of which were negatively associated with PT use for accompanying trips. Age was positively associated with PT use (OR = 1.07, $p = 0.024$). No significant effects were found for Year 2024, Year 2025, gender, "Our child can move freely and safely using public transport," or "Our child can reach leisure activities well by public transport."

To analyse the number of PT accompanying trips, a negative binomial regression was estimated (Table 8). The model showed adequate fit (log-likelihood = −1069.52, AIC = 2157.04). Significant predictors of trip counts included the multimodality statement (b = −0.099, $p = 0.011$), "We cannot imagine our leisure time without a car" (b = −0.109, $p = 0.004$), and age (b = 0.062, $p = 0.005$). Year 2025 showed a marginal association with higher trip counts compared to 2023 (b = 0.239, $p = 0.066$), while Year 2024 was not significant. All other variables, including gender and both PT perception items, were not statistically significant.

For accompanying trips, PT use showed no significant changes in the likelihood of use over time, while the trip frequencies of using PT for accompanying trips shows weak evidence of an increase in 2025 ($p = 0.066$).

Visiting trips

A logistic regression predicting the likelihood of any PT visiting trips was statistically significant, χ^2 (8) = 79.52, $p < 0.001$ (Table 9). The Hosmer–Lemeshow test was non-significant, χ^2 (8) = 5.21, $p = 0.735$, indicating a good model fit. The model explained between 8.6% (Cox & Snell R^2) and 11.8% (Nagelkerke R^2) of the variance. Significant predictors included the multimodality statement "We are not committed to a specific transport mode—depending on the occasion we choose the most suitable one" (OR = 0.80, $p < 0.001$), "We cannot imagine our leisure time without a car" (OR = 0.88,

$p = 0.016$), and age (OR = 1.18, $p < 0.001$). Year effects were also observed: Year 2025 was positively associated with PT use for visiting trips (OR = 1.72, $p = 0.004$), whereas Year 2024 did not differ significantly from 2023 (OR = 1.29, $p = 0.154$). No significant effects were found for gender or the two PT perception variables.

To analyse the number of PT visiting trips, a negative binomial regression was estimated (Table 9). The model fitted the data well (log-likelihood = –956.22, AIC = 1930.44). Significant predictors of trip counts included the multimodality statement (b = –0.177, $p < 0.001$), age (b = 0.114, $p < 0.001$), and year effects: both Year 2024 (b = 0.285, $p = 0.035$) and Year 2025 (b = 0.496, $p < 0.001$) were associated with higher numbers of visiting trips compared to 2023. All other predictors, including gender, "We cannot imagine our leisure time without a car," and both PT perception variables, were not statistically significant.

For visiting trips, both the likelihood of PT use and PT trip frequencies increased significantly in 2025, while trip frequencies already show weak evidence of an increase in 2024 ($p = 0.035$).

Discussion

Effects of the PT voucher

The PT voucher introduced within the "City of Lucerne" RwL represents a co-created experiment aimed at encouraging sustainable mobility among pupils. Voucher redemption was consistently high and showed increasing acceptance. In the models, the survey year served as a proxy for voucher exposure. This design allowed for an indirect assessment of behavioural change across 2023 (before vouchers), 2024 (after voucher 1) and 2025 (after voucher 2).

Descriptive and model results indicate an increase in PT trips over time, particularly for school and visiting trips, while car, walking and cycling trips remained largely stable in their mean number of trips. No comparable year effects emerged for car, foot or bike trips (see Appendix A), underlining that temporal variation was specific to PT. Overall, PT use was stable in terms of the likelihood of occurrence of any PT trip (user share). Regarding specific purposes, the likelihood of PT use increased for visiting trips in 2025. For school trips, the logistic model indicates only a marginal increase in 2025, while the count models show clear increases in PT school-trip frequencies in both 2024 and 2025. However, the findings suggest that pupils expanded their numbers of PT trips without reducing trips by other modes. Rather than a strict modal shift, the findings point to a relative strengthening of PT within overall mobility behaviour.

In mobility research, children's travel is typically differentiated into school, leisure, accompanying and visiting trips (Mammen et al. 2012; Timperio 2004). School trips are regular and highly structured, tied to institutional schedules and parental planning (Mandic et al. 2017). The results showed the clearest effects. Logistic models indicated higher odds of PT use with age and perceived independence, and count models revealed increases in 2024 and 2025. A recurring voucher reduces costs and reinforces habits, making structured school trips particularly sensitive to intervention. Visiting trips, defined as travel to friends or relatives with family purposes (Carver, Timperio and Crawford 2013), also increased in both likelihood and counts. Vouchers appear to lower financial barriers to socially motivated, discretionary mobility, thus expanding pupils' independent social spheres.

In 2025, the probability of using PT for school trips is higher at the $p < 0.10$ level. Because school trips are largely fixed in frequency, this pattern is consistent with a change in mode choice rather than induced demand. In additional school-trip models for other modes (Appendix A, Tables A1–A4), we do not observe a corresponding decline in walking or cycling. Car-based school trips are rare and show no robust year effect in the logit model, while count-model estimates are unstable due to low counts. Thus, the reduction in other mode of transport is distributed equally without significant effects in the models (Appendix A, Tables A1–A4).

By contrast, in leisure trips consisting of recreational, voluntary travel to heterogeneous destinations (Villanueva et al. 2012), only minor changes emerged, plausibly because baseline PT use was already high, and destinations varied. Accompanying trips, which are adult-initiated obligations (Timperio 2004), showed no significant year effects. These patterns align with research emphasizing autonomy, household car-dependence and trip context as central to youth mobility (Beck et al. 2023; Duffy et al. 2024; Lee et al. 2013).

Across most models, car dependency was associated with a lower likelihood of PT use and, for some purposes, with fewer PT trips. However, for school trips, the car-dependency item was positively associated with PT school-trip counts. Age showed a clear and consistent pattern: older pupils were more likely to use PT and reported higher PT trip counts. This reflects increasing spatial autonomy and expanding activity spaces with age. In contrast, age was negatively associated with walking, indicating a modal shift from short-distance active mobility towards more independent motorised travel. Multi-modal orientation was consistently associated with *fewer* PT trips (and lower odds of PT use in several purpose models), while it was positively linked to cycling.

Taken together, the findings suggest that the PT voucher contributed to increased PT use-intensity, most notably for routine school trips and socially relevant visiting trips. It therefore supports children's and adolescents' independence by lowering the affordability barriers to using PT. Rather than a modal shift, the evidence points to a relative strengthening of PT's importance within children's and adolescents' mobility behaviour, which hints at induced demand. The results are aligned with previous work on subsidies as levers for sustainable transport behaviour (Bull, Muñoz and Silva 2021; Guzman, Cardona and Ochoa 2024), while indicating that effects vary by trip purpose.

The results indicate additive mobility growth rather than substitution: PT trip counts increased, while car, walking and cycling did not show statistically significant changes. This pattern is consistent with induced demand, i.e., newly generated trips rather than modal shifts. From a climate perspective, the net effect is therefore ambiguous: the environmental benefits depend on whether additional PT trips replace car travel or primarily increase the demand for overall mobility. From a social-participation perspective, however, induced trips can be desirable, as the voucher lowers affordability barriers and expands independent access to school- and socially relevant destinations, particularly visiting trips. From a sustainability-transitions perspective, the intervention primarily represents niche reinforcement within the existing mobility regime. It strengthens PT use within existing infrastructures without measurably reducing car dependence, suggesting that affordability-based instruments can support inclusion and behavioural change but are insufficient on their own to trigger broader regime transformation (Egermann et al. 2026; Hansen and Coenen 2015).

Results and lessons learned within the "city of Lucerne" RwL

The study demonstrates the value of the RwL approach in research on the transportation sector. By combining participatory methodology with quantitative evaluation, RwLs provide a platform for testing and refining policy tools in a real-world context. The PT voucher highlights the potential for RwLs like the City of Lucerne to act as testbeds for promoting sustainable mobility by providing policy-makers with evidence-based insights. The introduction of the PT voucher as a time-bound, politically mandated and socially co-initiated experiment is aligned with the RwL's transformative and normative aims. The collaborative development between the Children's Parliament and the City illustrates actor integration and local anchoring.

Moreover, the RwL setting in the City of Lucerne enabled adaptive learning and iterative refinement. Based on interim findings and stakeholder feedback, several adjustments were made during the experiment. For instance, preliminary results were presented to the Children's Parliament, fostering transparency and enabling feedback to be integrated. Furthermore, in response to practical challenges raised by participating families, the city administration modified the redemption process. PT vouchers could initially only be redeemed at the ticket counter, but they were later made available online. These modifications demonstrate the strength of the RwL methodology, not only as an experimental setting, but also as a dynamic and reflexive framework that facilitates continuous learning and real-time adjustments. This shows how RwLs facilitate adaptive governance processes, where feedback from participants can be translated into real-time policy adjustments.

Empirical results indicate significant increases in PT usage among children and adolescents, particularly for school and visiting trips, supporting the RwL's ability to enable and measure behavioural shifts. The integration of survey instruments, participatory elements and co-creation positions the RwL as a learning environment that informs both science and urban mobility policy (Beecroft et al. 2018; Singer-Brodowski, Beecroft and Parodi 2018). Nonetheless, challenges such as fluctuating response rates and limited institutionalization, as well as the embeddedness of meaning in the long-term structures, routines and responsibilities of the respective institutions, require continued attention in RwLs (Engels and Walz 2018; Schecke, Fichter and Tiemann 2021).

Beyond behavioural outcomes, our contextual description of the pilot shows that affordability instruments are embedded in local governance arrangements and existing transport and settlement structures. In this sense, the RwL illustrates how such policy instruments are implemented and adapted within ongoing urban transformation processes.

From a spatial sustainability-transitions perspective (Coenen, Benneworth and Truffer 2012), the effects of such instruments are also shaped by urban service densities, fare-zone boundaries, topography, school distribution, and existing mobility routines. The RwL therefore shows that transition instruments are territorially situated rather than universally transferable. Urban form has not been controlled for in the modelling due to missing information regarding pupils' places of residence. Lucerne's compact urban form, topography and integrated fare zones are likely to condition the magnitude of the observed voucher effects, limiting generalizability to more dispersed urban regions.

From a sustainability transitions perspective, the PT voucher does represent a policy instrument embedded within the existing transport network. It expands access within

infrastructures without restructuring car-dependency patterns. The intervention therefore illustrates the limits of affordability-based instruments in triggering systemic transitions. While the voucher enhances accessibility and youth autonomy, the absence of measurable reductions in car use indicates that the intervention does not fundamentally alter the dominant mobility regime. It may therefore be better understood as a social inclusion policy with sustainability co-benefits rather than as a transformative mobility intervention.

Limitations and outlook

The study has several limitations but also suggests avenues for future research.

First, the use of repeated cross-sectional representative cluster samples rather than panel data limits the ability to track individual-level changes. However, a panel design is not appropriate in this case because children undergo substantial developmental changes over a three-year period, which would confound the estimated treatment effect of the voucher if a panel design would have been applied.

Second, self-selection may be present, as families who redeemed vouchers might be more interested in participating in the study. However, random cluster-sampling and the high response rates reduce the risk of systematic bias.

Third, causality cannot be tested without individual treatment variables. While RwLs enable real-world experimentation, the absence of a control group limits causal inference. Observed effects may partly reflect broader mobility trends rather than voucher-induced change. However, the "City of Lucerne" RwL generates robust, policy-relevant evidence through longitudinal survey data measuring a large-scale experiment that, due to the strength of the intervention, supports causal interpretations.

Fourth, due to data limitations, we could not differentiate voucher effects across neighbourhoods with varying socio-economic composition or PT accessibility as measured by urban form indicators.

Furthermore, the long-term durability of behavioural changes induced by PT vouchers should be examined and explored more frequently than only every three years. In doing so, experiments could be better extended to other regions (*scalability*).

Moreover, urban transition research highlights cities as arenas of experimentation where governance actors negotiate transformative instruments (Egermann et al. 2026; Torrens et al. 2021). In Lucerne, the Children's Parliament functioned as an intermediate actor, translating youth demands into municipal policy experimentation. The subsequent proposal to extend the voucher programme for five more years indicates partial institutionalization of the experiment beyond the RwL phase. In January 2026, the City Council proposed extending the voucher program for an additional five years with a projected budget of CHF 10.5 million. This signals a transition from pilot experimentation to potential institutionalization and illustrates how RwL-generated evidence can directly inform formal political decision-making.

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Author contributions

Noah Balthasar and Timo Ohnmacht jointly conceived and designed the study. Noah Balthasar led the data collection, performed the statistical analysis, and drafted the manuscript. Timo Ohnmacht contributed to the methodological design, supported the interpretation of results, and substantively revised the manuscript. Both authors approved the

final submitted version, agree to be accountable for their respective contributions, and ensure the integrity of the work in its entirety.

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Data availability
Due to ethical restrictions related to minors' data, the dataset cannot be shared openly. A de-identified summary dataset and analysis syntax are available from the corresponding author upon reasonable request and subject to a data-use agreement.

Declarations

Competing interests
The authors declare no competing interests.

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