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MobilityCoins - First Empirical Findings on the User-Oriented System Design for Tradable Credit Schemes

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ABSTRACT

Tradable Credit Schemes recently gained more popularity in the literature on travel demand and congestion management. The basic principle of TCS is a cap-and-trade system that incorporates the rationing of infrastructure use rights to internalize the external costs of transportation. However, there is a lack of empirical research regarding user behavior and user preferences in such schemes. This paper builds on the idea to use TCS not only as an alternative for congestion charging, but also for providing incentives for sustainable transportation choices. In this paper, we present first empirical findings on the user-oriented system design of such a scheme, the MobilityCoin system. These findings are based on fifteen expert interviews and pre-test results of a stated preference survey on mode choice and trading behavior. We specifically look at system elements in which user preferences and user characteristics may play a role in making such a scheme a success: credit allocation, market regulation, trading behavior (willingess-to-sell, willingess-to-pay) and user effort caused by the system. Our findings are that experts support the concept of MobilityCoins and of individual credit allocation based on different user-related parameters, but appeal to put emphasis on the right implementation, low user effort and a fair TCS market regulation. Survey respondents understand the system idea, clearly react to stimuli by showing a mode shift compared to the status quo and would trade MobilityCoins reasonably.

Keywords: tradable credit schemes; user behavior; sustainable mobility; cap-and-trade; stated-preference; expert interviews

INTRODUCTION

As many of our cities follow a car-centric design, driving a private vehicle is, in many cases, convenient, fast and relatively cheap in our society. However, motorized traffic produces high rates of negative externalities on users of the urban space and the environment (e.g. unequal space distribution, air pollution) (*1, 2*). To reduce these externalities in cities, one can implement push and pull measures on the demand and supply side in the transportation system (*3, 4*). On the one hand, a city or region might provide incentives for more sustainable transportation modes, for example through subsidies or better cycle- and public transportation networks (pull-factors). On the other hand, one might reduce the attractiveness of private car travel, e.g. by removing and redesigning the current car-centric traffic infrastructure, implementing car-free zones and speed limits, or by decreasing the individual demand for motorized trips through economic measures (*5, 6*). The latter are considered promising (*7*) and already proved successful (*5*), while recently described as having failed using their fullest potential (*8*). Among these economic instruments are tradable credit schemes (TCS). They have been proposed as an alternative to road pricing for traffic management to reduce congestion and emissions (*9, 10*), and offer the advantage that financial flows happen between the users and not between user and authority - and that users can financially benefit from traveling sustainably (*11*). The basic principle of TCS is a cap-and-trade system that incorporates the rationing of transportation infrastructure use rights to internalize the external costs of transportation (emissions, public space consumption) (*12*).

Cap-and-trade-systems have their origin in the economic theory of pollution control: Coase (*13*) introduced the idea of making property rights explicit and transferable, while giving the market the task to value and circulate these rights, to allocate them optimally. TCS have been first proposed by Verhoef et al. (*9*) for transportation applications and by Goddard (*14*) to control vehicle emissions and congestion. The key design parameters of a TCS system are the initial allocation of credits to eligible receivers, the charging scheme of credits for mobility, and the trading rules (e.g., system boundaries, price limits, transaction costs, trading channels, validity period of credits). The economic mechanism is that a traveler gets charged according to the polluter pays principle (*15*), e.g., for using public space and producing external costs. On the resulting "transportation market" (*16*) users can trade their credits, while the agency controls the quantity of credits on the market that is usually linked to trips, emission levels or infrastructure use (*11*). Trading on this market emerges if the initial endowment of credits is not sufficient to meet a user's travel demand. Then, one can buy credits from the market - either from other users, or the agency, or both. Contrary, users whose initial endowment exceeds their travel needs can sell credits for money to users with a higher credit demand.

Initially conceived for car traffic management only, the idea of TCS has been discussed in a multi-modal context as well. Balzer and Leclercq (*17*), e.g., integrated buses and Bogenberger et al. (*18*) integrated all urban transportation modes into a TCS scheme, called MobilityCoins. In this paper, we build on the latter. The trip charge can be dynamic and depend on, e.g., mode and drive-train type, time of day, trip distance, external costs, or any other objective set by the government (*19*). Here, a car trip might be more costly than a public transportation (PT) trip, e.g., due to higher emissions and space consumption. Additionally, in the MobilityCoin system users can (marginally) earn credits with bicycle trips as an incentive (e.g., in times of high congestion).

In some aspects, TCS is similar to other economic instruments such as road pricing and parking management, where a charge, toll, fee or levy is raised to reduce demand. However, in contrast to conventional economic measures, TCS can also directly financially incentivize sustainable transportation modes through the "trading" aspect of the system (*19*).

The current literature is, so far, mostly focusing on modeling TCS, e.g., modeling of the market equilibrium (*20, 21*), the pricing scheme (*22–24*), or applying TCS to different network topologies, to homogeneous and heterogeneous users and different system boundaries. A general overview is given in (*25–27*). Research has also concentrated on the social acceptance and equity aspects of TCS (*23, 28–30*). The approaches have to make assumptions about user preferences and user behavior in a TCS system, for which so far a lack of empirical evidence exists. Recent work in this domain explores the public acceptance of TCS using focus groups (*31*), and the feasibility of TCS using expert interviews from policymakers and transportation researchers (*32*). Krabbenborg et al. investigated whether the public would vote for the implementation of such a scheme based on a stated preference experiment (*29*). Among the few studies that investigated user behavior is Brands et al., who conducted a lab-in-the field experiment on user behavior of a TCS for parking permits (*10*). However, the literature so far does not present much empirical findings on the user behavior. Until now, to the best of our knowledge, no stated-preference surveys on mode choice and trading behavior exist in this field.

To address this gap, we developed a two-step methodology that combines expert interviews with a stated-preference survey, that specifically focuses on the user perspective. We conducted in the first step expert interviews to explore the user-oriented solution space of the TCS design parameters (e.g., initial endowment of credits, market regulation, system boundaries) and used this information in the second step to develop a stated preference survey on user behavior (mode choice, trading and budget preferences). This paper consequently contributes with the first large-scale empirical findings on user behavior (mode choice and trading behavior) under a TCS scheme (the MobilityCoin System) in a real-world metropolitan area, Munich, Germany. In addition, this paper contributes methodologically with the development of a stated-preference survey for TCS systems.

This paper is organized as follows. The next section discusses the two-step study design and methods used to explore the user-oriented system design parameters. Subsequently, the results are presented for the first step of the study (expert interviews) and the second step (stated-preference survey). This paper ends with a discussion of the results and the directions for future research.

STUDY DESIGN AND METHODOLOGY

In this section, we will discuss the two-step process of this research: the expert interviews on the general system design and the stated-preference survey on user behavior in the MobilityCoin system. The overall methodological process is displayed in Figure 1.

Expert Interviews

We chose the method of expert interviews as a first step of the research process as it provides an exploratory approach to analyze the general assumptions and system elements of MobilityCoins. This allows us to rethink the basic assumptions and simplifications of current modeling approaches, and to reflect on TCS from an implementation and society-based perspective.

Expert interviews have been recommended to investigate on new research fields, for example to get access to privileged information, and to understand (social) challenges of a specific topic (*33, 34*). Experts are considered as persons in charge of developing, implementing or deciding on systems, strategies or goods. Therewith, their high level of professional, subject-specific and systemic knowledge, but also their experience (*35*), is often considered valuable in first research

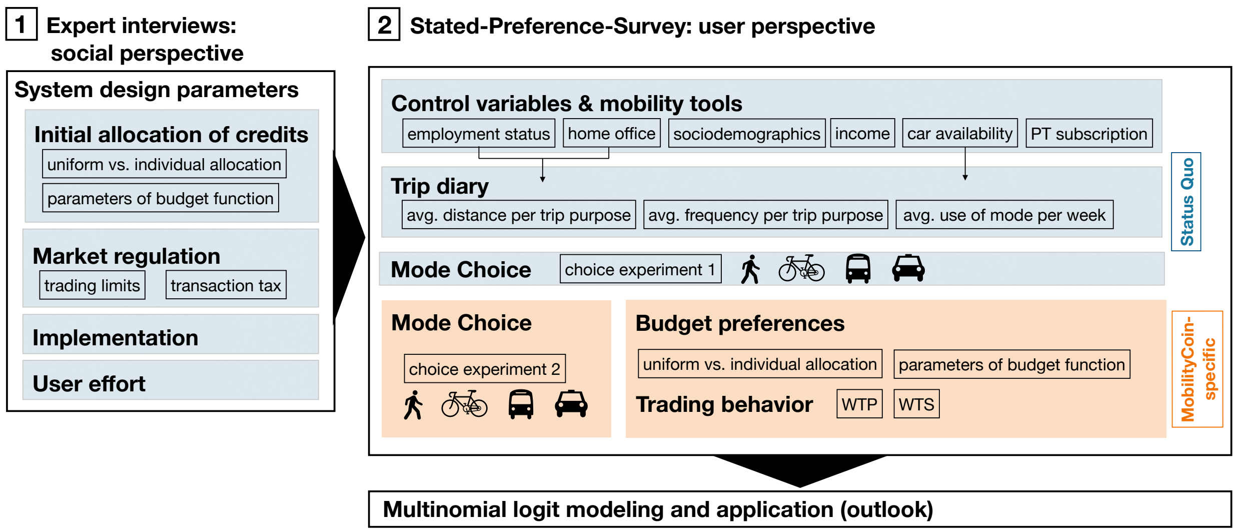

FIGURE 1 : Two-step methodological process.

steps, as this knowledge is otherwise hard to access.

In our study, we interviewed 15 experts, mostly from the city of Munich, Germany, in guided interviews of 60 to 80 minutes. First aggregated results on the critical aspects for social acceptance, the spatial and temporal system boundaries, the target achievement and the initial budget allocation can be found in (*36*). The different expert fields are summarized in table 1. In order to associate statements with individual experts in the results section, we assigned an alphabetic character to each expert. The experts were selected to represent a wide range of relevant stakeholders in the Munich area. We contacted the highest position in the institution that was related to the field of mobility (see reached positions in brackets in the table). The interviews were conducted either in person or in an online meeting.

TABLE 1 : Overview of expert fields

Expert field (number of experts, position)	Assigned letter
Local and regional public transportation (2, CEOs)	A,B
Traffic and mobility science (2, PhD, Professor)	C,D
Transportation technology companies (2, CEO, Professor)	E,F
Disabled people (1, spokesperson)	G
Environment (1, consultant)	H
Economy (1, head of institute)	I
Car club, bike club, car industry (3, spokespersons, executive)	J,K,L
Administration (3, city, metropolitan region, federal state)	M,N,O

Stated-Preference Survey

The expert interviews provide first insights on how to design a user-oriented MobilityCoin system. To get extensive insights on the user behavior, we are currently conducting a stated-preference (SP)

You travel for the following purpose: Work/Education.
Your average trip distance is 0.1 to 2.99 km.

It's day 15 of the month and you have a remaining budget of 75 % .
The weather is sunny.

Scenario 6	Option 1: Car	Option 2: PT	Option 3: Walk	Option 4: Bicycle
Travel time	10 min	5 min	27 min	10 min
Access & egress time		8 min		
Frequency		every 5 min		
Transfers		2 x		
Travel cost	2,2 €	2,25 €		
MobilityCoin expense	9,75 €	3,1 €		
MobilityCoin revenue				0,3 €
Quality of cycle lane				very good

FIGURE 2 : A choice situation in the MobilityCoin experiment. In this case, the respondent is shown trip purpose "work/education" and the lowest distance class. The attributes "MobilityCoin expense" and "MobilityCoin revenue" are only displayed in the MobilityCoin experiment, not in the status quo experiment.

survey in Munich. As this data collection is ongoing, we provide first results of the pre-test.

SP surveys are frequently used in travel behavior research to predict mode choices in situations that cannot be easily revealed (*37*). The core of SP surveys are hypothetical preference experiments in which a set of alternatives, each connected to a set of varying attributes, is presented to a respondent. In the most basic case, the respondent is asked to choose one of these alternatives (first-preference choice task).

In the full survey, we will contact a representative sample of 9500 inhabitants in Munich, Germany, between 18 and 80 years. In the pre-test, we contacted 500 inhabitants, bringing the total of the representative sample to 10 000. To increase sample size for the pre-test, we also distributed the survey bilaterally. The postal addresses were made available by Munich's registry office. Based on experience gained from surveys with similar response burden (*38*) and based on the pre-test's results (14,6% response rate), we aim for a sample size of n > 1000 for the full survey. The survey is conducted online and an incentive of 15 EUR is paid for complete participation. Each respondent receives a letter with a personal invitation code.

The survey contains the following elements. Their sequence is displayed in Figure 1.

1. **Socio-economic and demographic information**: Control variables.
2. **Mobility tool ownership**: Driving license, car availability and type of PT subscription. Driving license and car availability are required for the "car" option to be displayed in the travel diary.
3. **Travel diary**: Respondents are asked to give information on the average trip distance for three trip purposes (work, leisure, errand), about the frequency of mode usage (car, PT,

bike, walk), and the frequency of trips per trip purpose. Only car users, i.e. respondents with a car use that is equal or higher than once a week, are shown the willingness-to-pay (WTP) questions on trading behavior. Car users are asked how much they would pay for additional car trips if their budget is depleted. Only cyclists, i.e. respondents that cycle at least 2 to 3 days a week, are shown the willingness-to-sell (WTS) questions on trading behavior (as cyclists are more likely to have more budget left on average). Cyclists are asked if they would (partially) sell their remaining budget.

4. **Preferences on the initial credit allocation**: Respondents are asked to indicate their preference over individual or uniform credit allocation and if they chose the former, to rank different individual attributes according to their importance. In contrast to the expert interviews, the selection of attributes was slightly modified: we added the attribute "care work" to the selection to put more focus on social aspects and removed the attributes "job-relatedness", as this was partly covered by the "distance to work" attribute.
5. **Credit trading behavior**: The respondents are asked to indicate their willingness to pay and sell credits on the market given the conditions mentioned in step 3.
6. **SP experiments on mode choice without and with TCS**: There are a total of 12 choice situations for each respondent, 6 in the status quo experiment, and 6 in the MobilityCoin experiment. The trip distance and trip purpose are fixed for each respondent over both experiments. Attributes such as travel time and trip cost are pivoted around specific reference levels. The attributes are evenly randomly distributed. Figure 2 shows a choice situation of the MobilityCoin experiment, with additional MobilityCoin-specific attributes.

RESULTS

Expert Interviews

In this section, we discuss the results of the expert interviews, covering a selection of topics: (i) the initial credit allocation (uniform versus individual budget and the allocation parameters), (ii) implementation issues, (iii) market regulation, and (iv) user effort.

Expert opinion: Initial Credit Allocation

All experts except M and F agree that an individual mobility budget is more favorable to a uniform allocation. Primarily because of increased user acceptance, as the amount of allocated MobilityCoins would account for individual circumstances. However, M argues that a uniform budget would encourage trading on the credit market and simplify the budget's handling. F argues that a fair allocation of credits would automatically emerge through trading. In the following, we present the experts' arguments regarding individual attributes for a possible budget allocation function.

Parameter: Rural vs. urban area. Eight experts argue that the budget should be larger in rural areas than in cities (A,D,G,J,K,L,N,O). I, on the other hand, argues that spatial factors such as residence location should not be included in the budget function as this would negatively affect residence and workplace decisions. For example, German residents that have a high commuting distance receive a tax commuting allowance, which may encourage people to live further away from their workplace, making them more car-dependent. However, A, C, H, J and L consider workplace location important for the budget allocation. C appeals on the importance of residence location, as it is often dependent on more than one person (because of family members etc.) and cannot easily changed as the work location.

Parameter: Income. The experts do not agree on the parameter income. 6 experts state that incorporating income into the budget function would be reasonable (A,B,D,E,I,O). 3 experts are against that approach (H,J,L). J argues that it would not be fair to let wealthy people pay more for the same good (credits). H argues that poor people should not be encouraged to drive more, just because they receive more coins than they need. She argues that factors such as transit availability or the mobility impairment bonus already include many relevant factors in the budget function; thus, the socioeconomic status would not provide additional information regarding the required budget. A, contrarily, supports the idea of allocating more credits to poorer households, as it would be related to climate justice. B agrees and states that if lower income is not accounted for, this would lead to dissatisfaction of some societal groups. D and L also emphasize on the importance of the employment status in the budget function.

Parameter: Trip frequency and length D and B would not integrate trip frequency and length into the budget function, as these parameters should be adjusted by the MobilityCoin system. L proposes to either include the factor job-relatedness or trip frequency and length, as these would correlate. Expert O proposes a compromise by grouping people into "activity levels" ranging from "not active" to "very active" and that incorporating different trip purposes such as work, leisure and grocery shopping. People would then get their mobility budget according to their activity level and trip purpose.

Parameter: Availability of transportation modes. Most experts agree that the number and level-of-service of transportation modes around the resident's location play a central role in the budget size. J points out that well-connected citizens should not be overly advantaged by the system. As already mentioned, the budget function could, in general, provide additional coins for living outside urban areas and therefore low accessibility. More precisely, the budget function could include the time-to-walk to different transportation services of specific street segments or neighborhoods. E, G and M plead to first develop PT services in rural areas before implementing a TCS - this would reduce the need to allocate higher budgets to residents in rural areas. B and I are against including PT availability into the budget function as this would, as a consequence, influence the decision on residential location and should rather be solved by improving PT services in rural areas.

Parameter: Mobility impairment. All respondents agree that either the MobilityCoin fare or the basic budget must consider whether a person has a disability. N states that it should also be taken into account whether a person is involved in care work, which requires extra trips, often by car. D argues that for disabled people, the car should not cost more than PT services. G proposes to link the budget increase or fare decrease to the disability status: Depending on the disability's severity, the fare is reduced accordingly. However, he argues that also disabled people should make an effort to reduce the traffic load and is therefore against the idea of providing an unlimited budget to disabled people. I argues that including social parameters into the budget calculations would be crucial for social acceptance, although they would not be necessary for the functioning of the system.

C argues that the system should not only account for disabilities, but for age, health and fitness level in general. He argues that there are considerable differences in physical fitness levels, so that cycling or using PT would not be equally accessible for all, causing equity issues. He worries that some groups can generate income with the proposed system while others are marginalized - therefore, he suggests accounting for this factor in the budget function

Overall parameter ranking: The experts ranked the parameters as follows: mobility impairment, supply of PT services, walking distance to PT, job-relatedness, location of work place, socioeconomic status, average trip length and frequency.

Expert opinion: Practical Implementation and Validity Period.
Most of the experts (A,B,C,E,F,I,K,M,O) are optimistic when it comes to the implementation of the system, but they name challenges: I estimates that such a system could be implemented by 2025, M states that this would take 5 to 10 years. C argues that data security and need for tracking would be the most severe issue to solve. He proposes to use blockchain technology to decentralize the recorded data. Also, he points out that the technological requirements would already be fulfilled - the system implementation would therefore not fail. Four experts express more concerns (D,G,J,L). L, for example, does not support the idea of MobilityCoins for everyone. He could imagine having it as a social compensation for low-income households in combination with a congestion charge or parking fees. He considers it as unnecessarily complicated to manage mobility holistically. I argues that there would be a need for extensive public persuasion on the benefits of such a system. In Munich, it would be up to the municipalities to implement it, as they are most likely to have traffic problems. At the moment, however, they lack the legal means: the municipality is not entitled to implement a congestion charge, set up parking fees or city-wide lower speed limits.

Regarding the validity period, some experts favor a monthly rhythm. This allows for easier planning and forecasting of expenses and revenues (same rhythm as salary) and it could lead to a higher trading activity compared to a yearly rhythm. We followed these arguments and set the validity period in the SP survey to one month.

Expert opinion: Market regulation
In the MobilityCoin system, the agency can regulate the quantity of coins circulating in the market, to manage the market price. However, there is the risk that wealthy people start hoarding, which can deter the market price and undermine equity. Therefore, the experts were asked if the number of coins that can be bought from the market should be regulated. The experts show disagreement on this topic. Some are completely against it, especially the experts from the automotive and economic sector (I,D,K,C,L). C argues, that a limitation of coin purchases would interfere with the right to move, a constitutional right. I and D argue that the quantity of coins and market price would already regulate supply and demand. A second group of experts (H,J,N,O) suggests increasing the price of coin purchases progressively (comparable to a progressive tax system), to increase system acceptance. The third group of experts is in favor of a limit on coin purchases (A,F,G,M). A and M argue that a missing limitation could lead to over-buying and therefore to a lack of market liquidity.

Another market regulation instrument in the MobilityCoin system is the transaction tax, so that with each market transaction the agency can generate revenue. O proposes to connect the transaction tax to the income group or the person's travel behavior - persons with higher income or emission-intensive trips would be charged with a higher transaction tax. As an economist, expert I does not support this idea, arguing that a transaction tax would decrease the amount of executed useful transactions, which would lead to less trading and therefore less market liquidity. L argues that the implementing municipality should not rely too much on a transaction tax, as it would be difficult to forecast if it would generate sufficient funds.

Expert opinion: User Effort
Many experts (H,J,L,M,N) agree that the user effort should be kept as low as possible. Optimally, there should be a smartphone application that runs in the background, automatically keeps track of trips and calculates the new credit balance. L argues that users would have much more tasks than they have today, which makes the implementation challenging. D criticizes that not every resident will own a smartphone, and that there is no legal obligation to own a smartphone in Germany. C and D state that users without smartphone also may lose track of their current budget, and the tracking might not work in each vehicle. H emphasizes the importance of giving the user assistance in how to easily manage expenses and revenues. N points out that it would be necessary to share a certain amount of information with the agency, i.e. the mode of transportation used and the location of residence and workplace. Furthermore, he emphasizes the difficulty of matching a mode to the tracking data, as the software has to differentiate between, e.g., sitting alone in a private vehicle and pooled rides.

Stated preference survey
In June 2022, we completed the pre-test of the full study. The data collection for the full study started in the last week of July 2022. In the pre-test, we obtained a sample size of n=132 respondents. 56,2% were recruited through the postal letter channel (mailing group), which is a representative sample; 36,2% through social media and a small number (7,7%) through distribution in a university seminar. Overall, the pre-test proved to be successful: we obtained a response rate of 14,6% for the mailing group (500 contacted, 73 complete responses). For the full survey, we can expect a similar response rate (n = 0.146 * 9500 = 1387), as the monetary reward stays the same. We also know through the pre-test, that the respondents answer in a time span of two weeks after receiving of the letter. This information is helpful for the full survey organization. We will discuss the findings from the pre-test in the following.

Socio-demographic and socioeconomic data
The gender distribution is balanced (49,4% men, 48,2% women, 2,4% diverse). The sample shows a slight over-representation of younger age groups (average year of birth is 1982) and well-educated people (63,9% with bachelor or master degree). 94% of the respondents own a driver's license. 55,5% regularly have access to a car which is representative when comparing to the study "Mobilität in Deutschland (MID)" (*39*) that analyzed the mobility behavior of Munich citizens. Regarding PT subscriptions, most of the respondents who are subscribed use a yearly pass or a semester ticket (students). 44,6% do not have a PT subscription (a little bit less compared to the 53% stated in (*39*)), and 13% do not have one now, but had one in the last three years. 89,2% of the respondents bought the 9€ ticket for public transportation, that the German government introduced for three months in the months of June to August 2022. This ticket enables the Germany-wide usage of PT services for a total price of 9€ per month (*40*).

User behavior: Initial Credit Allocation
Similarly to the expert, users prefer a budget allocation that is based on individual attributes (76,2% approve, compared to 87% of the experts). If we control for the socio-demographic influence, we see that low income classes (up to 1600€ per month) do favor individual budgets more than middle income classes. Regarding education and car usage, we do not have enough data yet in the lower education groups/car usage levels to derive statements. Having children does not affect the opinion

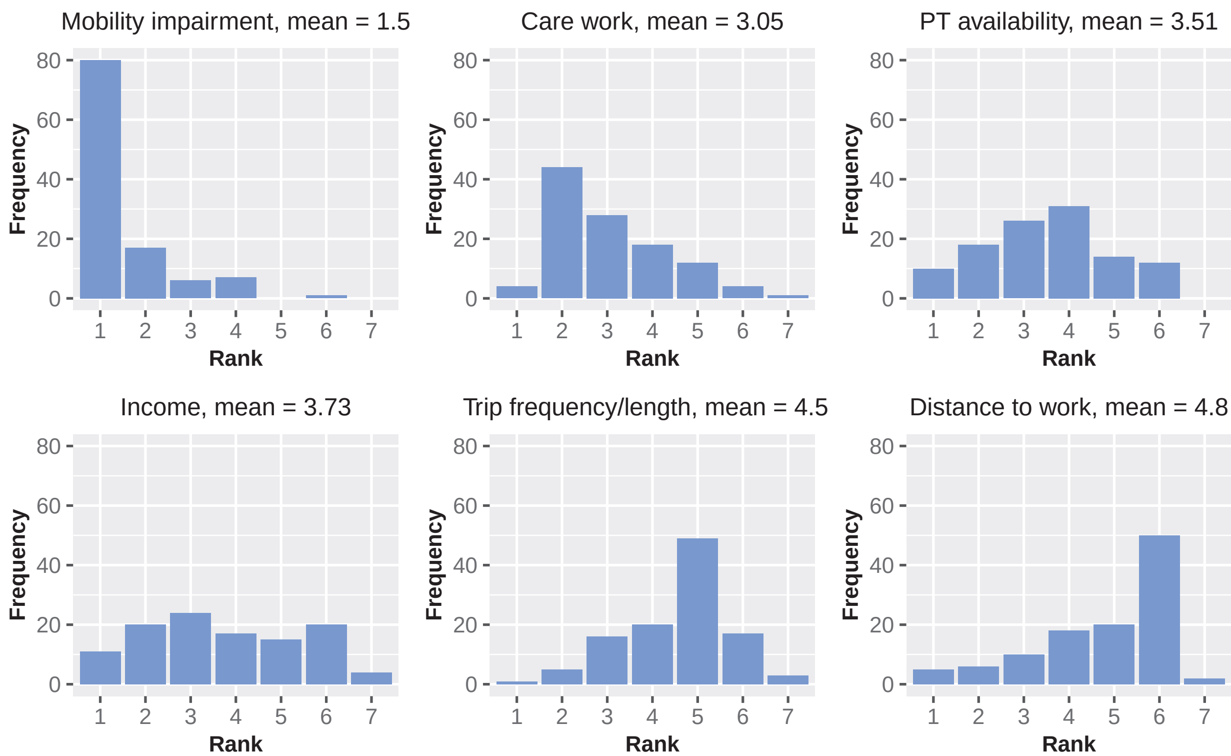

FIGURE 3 : Ranking position of parameters according to perceived importance for an individual budget function

on individual budgets. Here, we would have expected parents to be more in favor of individual budgets compared to non-parents, as parents might want to be accounted for extra trips they have to do for their kids. Students, trainees and unemployed people tend to favor individual budgets more than employed people.

The group of respondents who are in favor of an individual mobility budget were then asked to rank individual attributes according to their importance for a budget allocation function. The attributes, frequency and mean of ranking positions are displayed in Figure 3.

Personal disability and care work are considered the most important parameters and should lead to a higher budget allocation - these results match with the expert interview. The attribute “mobility impairment” is ranked first and shows a rather small standard deviation value whereas care work is ranked second and shows a slightly higher standard deviation. PT availability is considered the third most important attribute; however, we see a moderate standard deviation for this parameter, which shows that the respondents are rather divided on that topic. Most of the respondents ranked income fourth place, which is interesting in comparison to the expert interviews, where the socioeconomic status was ranked almost last place and considered less important. However, income is also the attribute with the highest standard deviation, so similar to the experts the respondents disagree on the importance of this attribute. The attributes trip frequency and length were ranked fifth place, which is more similar to the expert interview results. The distance to work was ranked sixth place.

TABLE 2 : Willingness-to-pay for MobilityCoins for one additional kilometer with the car, given that the budget is depleted and given a reference price for public transport (in €/km)

Reference price PT	WTP Work	WTP Errands	WTP Leisure	Mean
0.25€	0.23€; sd=0.2	0.38€; sd=0.56	0.54€; sd=0.8	0.38€
0.5€	0.58€; sd=0.39	0.8€; sd=0.49	0.72€; sd=0.64	0.7€
0.75€	0.61€; sd=0.58	0.49€; sd=0.49	0.77€; sd=0.84	0.62€
Mean	0.47€	0.56€	0.68€	

TABLE 3 : Willingness-to-sell MobilityCoins after 15 and 25 days, given different remaining budget levels

Time of month	WTS with 50% left (50€)	WTS with 75% left (75€)	Mean
After 15 days	24.14€ (48%); sd=16.87	41.55€ (55%); sd=16.2	32.84€
After 25 days	38.82€ (78%); sd=11.09	52.85€ (70%); sd=19.96	45.84€
Mean	31.48€ (63.0%)	47.2€ (62.9%)	

User behavior: Trading

Regarding the trading behavior, respondents were asked to indicate their (1) willingness to buy new coins, given that their budget is depleted, and their (2) willingness to sell coins, given that they have remaining budget.

In Situation 1 (WTP), the respondents are asked to indicate how much they would pay for each additional kilometer with the car, given that their MobilityCoin budget is depleted and given that each additional kilometer with PT would cost them in comparison either x $\in \{0.25, 0.5, 0.75\}$ Euros, with x being set randomly for each respondent. We see that respondents have the highest WTP for leisure trips (sports, culture), followed by the WTP for errands. The trip purpose work has the lowest WTP. As we only have limited sample sizes for each PT reference value group in the pre-test, we cannot yet explain why respondents sometimes tend to spend less euros per kilometer on car trips than on PT trips. One explanation could be that the WTP for trips in general is lower than the assumed PT reference price. We will carefully validate and enrich these results with higher sample sizes when analyzing the full survey.

In Situation 2 (WTS), the respondents are asked to indicate how much they would sell of their current budget, given that they have either 75% (75€) or 50% (50€) budget remaining on either day 15 or day 25 of the month. Both parameters are randomly set for each respondent.

We see that there is a general willingness to make use of the financial incentive to sell excess credits. Considering that a market needs liquidity and credit trading to function, this is a positive result. As expected, respondents tend to sell more of their budget at the end of the month. Respondents with 75% of the budget remaining tend to sell slightly more of it after 15 days (55%) than people with 50% of their budget remaining (48%). However, after 25 days, the group with 50€ of their budget remaining tends to sell more of it than the 75€ group (78% compared to 70%). Nonetheless, the standard deviation is rather high for the latter case (sd = 19.96). As we have only limited sample sizes for each case, these numbers should be carefully interpreted when comparing

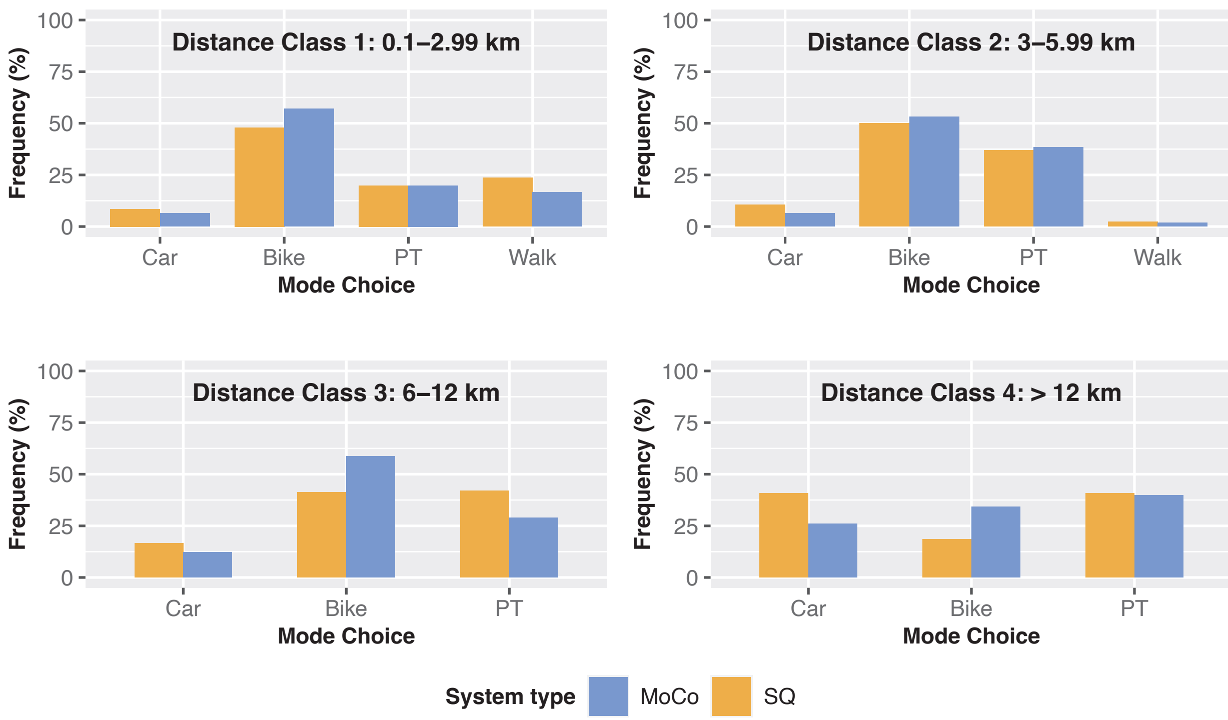

FIGURE 4 : Comparison of mode choice in the status quo vs.in the MobilityCoin system, filtered for each distance class that was shown in the scenarios

them to each other. At this point in time, we can observe that after half of the month, people tend to sell half of their budget (if having at least 50€ of budget remaining). After 25 days, people tend to sell three-quarters of their budget, when they have at least 50€ remaining.

So far, we cannot assess sociodemographic and socioeconomic influences and the impact of mobility behavior on WTP and WTS, as the sample size in each randomized group is too small.

User behavior: Mode Choice

As these are preliminary results based on the pre-test, we highlight descriptive findings that already indicate a shift in mode choice preferences induced by the proposed system. In the MobilityCoin scenario people chose bike more frequently compared to the status quo (see Figure 4), especially for trips in higher distance classes. This clearly indicates that travelers are motivated to also travel larger distances with more sustainable modes. As such, the introduction of a MobilityCoin system seems to be helpful in order to induce a shift from car to more active transportation modes. If we look at the effect of different remaining budget levels on mode choice (see Figure 5), we can observe that persons tend to use the bike more when they have less budget remaining. Unexpectedly, car and public transport are used less frequently in the 75% remaining budget scenario compared to the 50% remaining budget scenario. We will be able to analyze this in more detail with a higher sample size in the full survey.

Figure 6, which is taken from the travel diary part of the survey, shows that most errand trips are in distance class 1 (up to 2.99km) whereas most leisure trips and work trips are in distance class 2 (up to 5.99km). This distribution is representative for Munich when comparing to the findings of

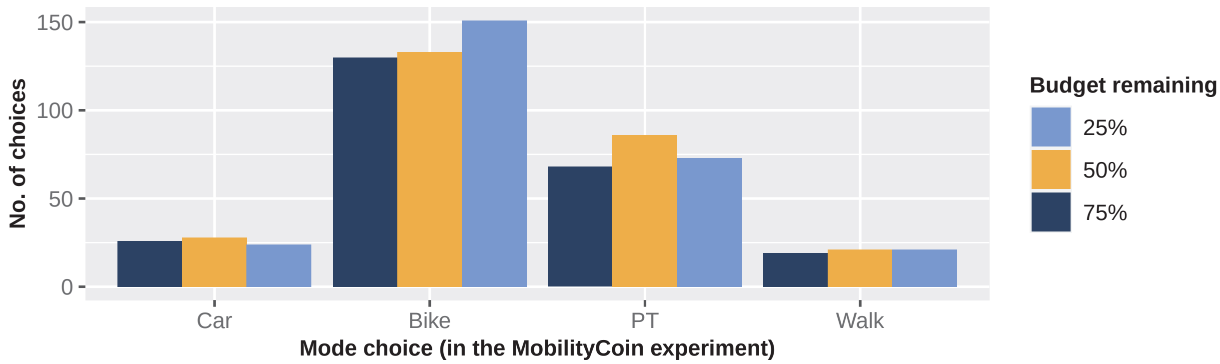

FIGURE 5 : Mode Choice in the MobilityCoin system given different remaining budget levels

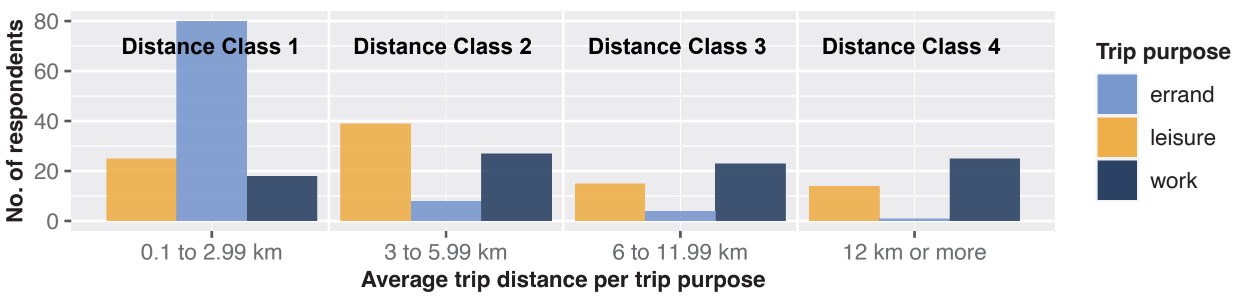

FIGURE 6 : Average distances for work, leisure and errand trips

the MID study (*39*) that analyzed the mobility behavior of all Munich citizens. The travel distances of the mode choice scenarios shown to the respondents in the SP survey were adapted from the travel diary of the users. Due to the fact that errand trips are over-represented in the lowest distance class, we obtained too many trips in this distance class. In order to retrieve a evenly balanced number of trips for each purpose and distance class, we will control for that in the main phase of the survey. This is not only important for the experimental design, but also from a modeling perspective at a later stage. Proper sample weighting will ensure sample representativeness.

CONCLUSIONS

In this paper, we empirically analyzed the MobilityCoin system, an integrated and multi-modal tradable credit scheme (TCS). The MobilityCoin system is a cap-and-trade system that incorporates the rationing of infrastructure use rights to internalize the external costs of transportation while at the same time incentivizing sustainable transportation choices (*18*). So far, few studies empirically assessed the system design parameters, user behavior and user preferences within TCS, a research gap filled by this study. We combined two research methods, focusing on the Munich metropolitan area, Germany: first, we conducted expert interviews to explore and refine the user-oriented solution space of the system design parameters. Second, we used these insights to develop a stated preference (SP) survey on user preferences and user behavior within a MobilityCoin system. While both methods examined possible parameters for the initial allocation of the MobilityCoin budget, each had an individual focus: The expert interviews focused on market regulation and system boundaries, whereas the SP survey concentrated on trading preferences and mode choice.

Concerning the most important results, both experts and users prefer an individual initial allocation of MobilityCoins based on user characteristics and prerequisites. Mobility impairment and care work are considered the most important parameters, whereas disagreement could be discovered for the parameter income within and across both groups. The experts agreed upon the realistic implementation of the system with a few challenges like data security being mentioned. They also agreed on keeping the user effort as low as possible but there was no consensus on the necessity of market regulation and transaction tax. Based on the SP survey, we could identify that users will trade on the MobilityCoin market. Car users are willing to pay for additional car trips in case of budget depletion, whereas users with remaining budget are willing to sell a specific share of the budget. Considering that a market needs liquidity and credit trading to function, this is a very positive result. Most importantly, the MobilityCoin system causes a mode shift effect to the bike compared to the status quo and thus proves to be a very promising economic instrument for promoting more sustainable and space-efficient modes. Based on the experience gained through the pre-test, we expect a similar response rate of 15% for the full survey that already started with a representative sample of 9500 inhabitants of the city of Munich. Within future research, we will develop a more comprehensive mode choice model (multinomial logit model) and will extend and validate the presented results on a larger scale.

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AUTHOR CONTRIBUTIONS

The authors confirm contribution to the paper as follows: study conception and design: L. Hamm, S. Weikl, A. Loder, K. Bogenberger, T. Schatzmann, K. Axhausen; data collection: L. Hamm, T. Schatzmann; analysis and interpretation of results: L. Hamm, S. Weikl; draft manuscript preparation: L. Hamm, S. Weikl, A. Loder, K. Bogenberger. All authors reviewed the results and approved the final version of the manuscript.

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