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Can Multimodal Real-Time Information Systems Induce a More Sustainable Mobility?

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Interest in advanced traveler information systems (ATIS) is increasing in modern cities, and more attention is given to real-time multimodal information. Through those systems, decision makers hope to achieve a shift from the car to alternative, environmentally friendly modes of travel. Few comprehensive assessments have been undertaken to verify the actual contribution of ATIS to such modal shift. In this paper, the effects on travel behavior of Optimod'Lyon, a multimodal real-time information navigator for the smartphone developed in Lyon, France, in 2013 and launched in May 2015, are assessed. To this end, a mixed method was adopted. A questionnaire was administered and focus groups were organized before and after the test of the application. A stratified sample of 50 people living in the metropolitan area of Lyon was also involved. The theory of planned behavior was used as the framework for the questionnaire design, which investigated attitudes, subjective norms, and perceived behavioral control. To evaluate behavioral change, data were analyzed through the use of parametric and nonparametric tests, factor analysis, and binary logistic regression. Survey participants were initially interested in Optimod'Lyon and showed a positive attitude toward its use. Before the test, they evaluated the travel planner positively but this lessened over time. After the test, use of the various travel modes remained stable. Consistency with regard to the most used mode and to behavioral patterns and attitudes was shown, strongly related to habits and to the frequency of past behavior.

Transport of goods and people is an important driver of global economic growth and prosperity. It fosters trading, accessibility, and connectivity. In 2012, the transport sector in Europe was responsible for 31.8% of final energy consumption and 1,173.3 million tonnes of carbon dioxide–equivalent greenhouse gases, and continuous escalation of these figures is envisaged (*1*). One favored solution for offsetting such an unsustainable trend is based on advanced traveler information systems (ATIS). ATIS are data integration systems delivering accurate, reliable, and timely information to travelers (*2*). The systems help travelers plan their route, estimate their travel time, and make informed decisions on the basis of real-time information (*3*). ATIS are viewed as encouraging travelers to make the best use of available transport modes and as supporting an integrated, sustainable transport system.

The impact and effectiveness of ATIS depend on travelers' responses to these systems, on the typology of supplied information, and on the way the information is used by travelers. Abdel-Aty stated that definition and quantification of ATIS impacts are not easy because of the lack of actual situations in which travelers' behavior can be observed under the influence of ATIS (*4*). The potential of ATIS to affect mobility behavior has rarely been researched (*5, 6*). However, many attempts have been made to assess ATIS benefits by gathering data from various sources, predominantly from surveys but also from field observations and simulations (*7*). Most of the surveys for estimating user satisfaction and the effects of ATIS operation concerned the effects of traffic information on car drivers, mainly commuters (*6, 8, 9*). Only a few studies have explored the consequences of information for public transport ridership, notwithstanding the potential role of information in increasing ridership and improving customer satisfaction (*10, 11*). The effects of multimodal real-time navigators have received even less analysis. Despite the increasing importance of multimodal journey planners, real-time navigators and research into their effect on travel behavior are still in their infancy. The project Optimod'Lyon (2012 to 2015) pioneered in developing a real-time navigator for the smartphone. All transport modes (car, public transport, bicycle, bikesharing, foot, carsharing, and carpooling) were included in an integrated way. This paper presents the results of a test on a panel of users.

Real-time information was a novelty introduced by SmartWay, one of the first smartphone applications for public transport when it was developed in 2010–2011. Today, more real-time applications, such as those developed for Zurich, Switzerland; Vienna, Austria; and London, are available (*11*). However, an application that allowed travel to a destination through a multimodal trip chain suggested on the basis of real-time information did not exist before the development of Optimod'Lyon. It was followed by the European Union project OPTICITIES, which developed similar apps in Torino, Italy; Gothenburg, Sweden; and Madrid, Spain (www.opticities.com).

Information is a key factor in mobility today. It has a high potential for optimizing travelers' choices. Abdel-Aty noted that accurate, high-quality information is decisive for using public transport (*4*).

Whether systems like these affect modal choice and how any such effect occurs depend on how they are utilized. Obviously, this is not only a technological but also a social process requiring technology assessment (*5*). Farag and Lyons showed how travel behavior, travel attitudes, and sociodemographic features have the strongest effect on pretrip public transport information use for both business and leisure trips (*12*). It was also argued that past behavior and habits are not always good predictors of future behavior (*13*).

Complex human behavior is cognitively regulated. Despite existing bylaws, it should be subjected to at least some degree of monitoring. As a consequence, the new information provided by ATIS,

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if relevant and convincing, could produce changes in attitudes, subjective norms, and perceptions of behavioral control that would affect intentions and likely influence subsequent behavior (*13*).

The objective of this research is to bridge the gap of knowledge in the literature by analyzing the effects on travel behavior of the real-time multimodal information provided by the smartphone application developed within the Optimod'Lyon project. The effectiveness of multimodal real-time information systems is assessed. Limitations before their use are described, and changes induced in travel behavior are recorded.

METHODS: SURVEY AND DATA ANALYSIS

The Lyon, France, Metropolitan Area, under the Grand Lyon authority, covers an area of 512 km^2 (58 municipalities) with a population of about 1.3 million people. Lyon is an important center of economic development and is France's second-largest metropolitan area, after Paris.

Participants in the survey were selected according to a stratified sampling plan on the basis of gender, age, education, occupation, income, presence of children in the household, and travel pattern (travel time, scope, mode, and origin and destination). Fifty people were recruited for the sample by a specialized agency. The sample was designed not to represent the local or national population but to include various users' profiles to provide a better test of all possible behaviors and reactions to the use of the application.

The survey administered to the sample followed a quali-quantitative approach based on two tools, the web questionnaire and the focus group, which were meant to work in an integrated way.

The web questionnaire, created with the Google form platform, was addressed to the participants in two stages: in February 2013 (ex ante) and, 5 months after the application was tested (from June to October), in October 2013 (ex post). Just a few days after the administration of the ex ante questionnaire, the focus groups were organized to investigate the issues contained in the questionnaire. This allowed both a cross-reference with the topics discussed and a double check of the results of the questionnaire. All 50 individuals participated in the first stage; four dropped the survey and did not participate in the second stage. During the test of the application, an ongoing survey was undertaken to check its functionalities. To involve the panel throughout the survey period, a smartphone (Samsung Galaxy S3 Mini) was presented as an incentive.

The ex ante and ex post questionnaires consisted of five sections: travel habits, attitudes toward mobility, environmental issues, familiarity with and interest in technological tools, and Optimod'Lyon application. The focus group followed a similar pattern: personality traits, attitudes toward technology, perceptions about real-time information, expectations about Optimod'Lyon application, willingness to pay, and barriers to using the app were investigated.

In designing the questionnaire and the focus group, attention was paid to attitudes and behaviors related to the most frequent trip made by respondents; purpose and people's occupation (workers, students, retired people, housewives, and so forth) were disregarded. The most frequent trip is, arguably, the best known to users in terms of time and general constraints. The most frequent trip could induce a specific mobility behavior, regardless of a person's characteristics (employed or unemployed) and trip purpose (work, shopping, and so forth): it is more related to habits, and, hence, less likely to be changed (*14*). The survey design is underpinned by the theory of planned behavior (TPB), which is largely applied to understand the link between intention and behavior. It has shown positive results in many fields and has become a powerful predictive model for explaining human reactions (*15*). Questions concerning several issues (such as travel behavior of users, their opinions about private and public transport and about technological tools) were rated according to a five-point Likert scale, since this represented a good compromise in terms of overload for the respondent (*16*). That scale was chosen for consistency throughout the questionnaire as well as to avoid reporting errors (*17*).

Since the total number of participants was 50, use of the central limit theorem and the Shapiro–Wilk test to guarantee the normal distribution of the variables was not possible. On the assumption that data would never be precisely normally distributed, in accordance with Brown (*18*) and Fife-Schaw (*19*), the variables were considered relatively normal if skewness and kurtosis values ranged between –1.5 and +1.5. Descriptive analysis, parametric and nonparametric tests, factor analysis, and binary logistic regression were used to analyze the collected data and to assess the effectiveness of the application. Software from BMDP Statistical Software was used for the analyses (*20*).

To identify the TPB factors structure, a principal component analysis with quartimax rotation was conducted on 10 questionnaire items. For samples with fewer than 60 participants, items can only be acceptable if communalities amount at least to 0.60 (*21*). Therefore, two items were removed in the first analysis. In the second analysis, sampling adequacy (Kaiser–Meyer–Olkin) indicated a mediocre compact of correlations (.608), and the analysis of sphericity displayed a strong relationship between the items (degrees of freedom = 28, $p < .001$), both of which indicated that factor analysis is appropriate for this measure. Factors were extracted on the basis of the eigenvalue being greater than 1, percentage of variance accounted for, percentage of variance explained by each factor, number of items with significant factor loadings, and factor interpretability (*22*).

RESULTS

Participants were evenly balanced by gender (25 women and 25 men). Their ages ranged from 23 to 68. With regard to education, 32% held a university degree, 68% had not attended university, and two (4%) had no diploma.

Average gross household income was €3,000 to €5,000 per month for 34% of participants and €1,500 to €3,000 per month for 48% of participants (€1 = $1.36 in February 2013). Only 8% received less than €1,500 per month. With regard to household composition, 38% lived as a couple, 22% lived alone, and 28% had a larger family (of four or fewer people). People living with children were 44% of the sample.

Almost all respondents had a driver's license (90%), and the overall car availability of their households was high: 44% owned one car and 42% owned two cars. However, 10% did not have access to any car within the household.

With regard to travel habits—daily travels and most frequent trip—the most favored mode was the car as driver (52% in autumn–winter, 36% in spring–summer); 32% used public transport, with a strong decrease in summertime. Use of soft modes (bicycling and walking) in connection with public transport was indicated by 10% of respondents. Since most of the participants were employed, for 74% of them the most frequent trip was to work. Five participants traveled for leisure and four to pick up somebody.

This paper focuses on the quantitative analysis. Only the results of the questionnaires are presented, which are confirmed by the

TABLE 1 Rotated Matrix Principal Component Analysis Structure

Item	TPB	SN	ATT	PBC
I expect that my family and friends put me under pressure to reduce the environmental impacts of my travels	SN	**.898**	—	—
I expect that my family and friends incite me to use Optimod'Lyon	SN	**.762**	—	—
I expect that policy makers incite me to use Optimod'Lyon	SN	**.754**	—	—
I expect that policy makers put me under pressure to limit the environmental impacts of my travels	SN	**.753**	—	.346
I don't like driving for most frequent trips	ATT	—	**.883**	—
I don't like traveling by car	ATT	—	**.882**	—
I would use public transport more often if I had real-time information	PBC	—	—	**.809**
I would use Vélo'v (bikesharing) more if real-time information was available	PBC	—	—	**.784**
Eigenvalues		2.713	1.795	1.286
Percentage variance explained		33.908	22.436	16.078

NOTE: All factor loadings > .300 (or < .300) are shown. — = smaller loadings. Loadings of items used to identify each factor are in bold. SN = subjective norms; ATT = attitudes toward the behavior; PBC = perceived behavioral control.

focus group outcomes. The two subsections below give the results of the ex ante and ex post stages of the tests. The first shows potential barriers for using the app and evaluates the constructs of the TPB. The second presents the effects of the app on travel behavior. The answers provided by the panel to the two-stage questionnaire are compared.

Ex Ante Results: Barriers to Use and Behavioral Constructs

Most participants (41 out of 50) owned a smartphone. They indicated that they were skilled users of technology and showed a high level of interest in technological devices. In choosing a route to an occasional place, they mainly used websites (e.g., Mappy, Via Michelin) to get the information (44 participants); the second most used tool was the GPS navigator (31 participants); the third was apps like Google Maps (28 participants).

More than half of the participants (27) considered that apps help them in their daily life, and 31 found that use of some apps is enjoyable. Twenty-two participants liked to discover new apps.

The principal component analysis allowed for detection of three main factors, matching the TPB. Table 1 shows the rotated matrix and includes all loadings greater than 0.30. The loadings of the items used to identify each factor are shown in bold in the table. Factors were identified as representing attitudes toward the behavior (ATT), perceived behavioral control (PBC), and subjective norms (SN). The number of factors was chosen through the scree test, which was used jointly with the Kaiser criterion of computing the eigenvalues for the correlation matrix to avoid distortions in the results (*23*). The three factors explained a total of 72.422% of the variability of the original eight variables. Parallel analysis was also used to check whether the number of factors for this number of observations was significantly different from a parallel random process (*24*), confirming the number of latent constructs. Therefore, the complexity of the data set can be considerably reduced by using these components, with 27.578% loss of information.

The value of mean communality was 0.724, greater than the threshold (0.70), and all items presented a loading factor greater than 0.60 (*25*). The high loadings on two different items related to PBC and ATT made the factors meaningful and well in conformance with the theory even though loaded by only two variables.

Cronbach's α was computed for the items used in identifying each factor (SN, $\alpha = .802$; ATT, $\alpha = .739$; PBC, $\alpha = .532$), and all values complied with the threshold (0.70) except for PBC. The PBC construct showed a poor value for internal consistency (although it was still acceptable). Nevertheless, it was decided to use the PBC construct in the analysis because small sample size can deflate the Cronbach's α value (*26*). Respondents' scores on the scales were calculated by considering the mean value on items in each scale (from 1 to 5). For all TPB constructs, the mean values of the 50 participants were near the midpoint of the scale (3). Pearson correlation and Spearman's rho did not show any significant correlation among the three constructs, which indicates that they are independent.

A scale of 1 to 5 was used to inquire about the intention to change transport mode, with 1 and 2 expressing the least willingness to change travel behavior and 4 and 5 expressing the opposite. People responding with 3 were considered undecided and thus were left out. Table 2 shows descriptive statistics for people who expressed the intention to

TABLE 2 Descriptive Statistics for TPB Variables for Different Intentions

Intention	Constructs	Mean	Minimum	Maximum	SD	Variance	*n*
Keeping travel behavior	ATT	3.259	1.00	5.00	1.259	1.584	27
(12 using car and	SN	2.704	1.00	5.00	1.070	1.144	27
15 using PT + soft modes)	PBC	2.685	1.00	5.00	1.257	1.580	27
Changing travel behavior	ATT	2.0000	1.00	4.50	1.275	1.625	9
(6 using car and 3 using	SN	2.7500	1.75	4.00	.791	.625	9
PT + soft modes)	PBC	3.2778	1.50	4.00	.833	.694	9

NOTE: PT = public transport.

keep or change their travel behavior (hereafter referred to as "keepers" and "changers," respectively). The higher value shown by PBC changers is consistent with the theory, as is the lower value for ATT.

Mann–Whitney *U*-tests did not indicate significant differences between keepers and changers with regard to SN ($U = 121$, $p = .985$) or PBC ($U = 82.5$, $p = .149$), but significant differences ($p < .05$) were recorded for ATT ($U = 56$, $p = .016$). Thus, it can be argued that the keepers are the majority with regard to both the car and the sustainable modes. This indicates the strong influence of habits on daily travels.

Spearman's rho correlations among variables were calculated, and the three constructs did not show any significant correlation. Thus, multicollinearity would not be a problem in regressions using these variables as predictors (*21*).

A logistic regression was used to understand the ability of the TPB model to explain the modal change intention. SN, ATT, and PBC were entered simultaneously in the regression where the ATT and PBC constructs were significant ($p < .05$) and the SN construct was not. Then, a model using the forward stepwise method was built. ATT were added to the model (Table 3). SN were excluded at the first step because they had significance values larger than .05. Finally, even though PBC had a significant value, it was left out in the last step because it did not contribute to improving the model fit. For a logistic model, when the intercept is zero, the logit (or log odds) is zero, which implies that the event probability is .5. This is a strong assumption that sometimes is reasonable, but more often it is not. Therefore, a highly significant intercept in this model is generally not a problem (*27*).

As a further check, the backward stepwise method was used. The above results were not changed, which increases confidence in the reliability of the model. The Hosmer–Lemeshow test and the C.C. Brown test indicate that the model adequately fits the data, since the values are higher than .05.

The model is reported in Equation 1:

$$\Pr(\text{maintain}) = \frac{e^{-1.068+.835\text{ATT}}}{1+e^{-1.068+.835\text{ATT}}} \tag{1}$$

where the odds of maintaining the used mode increase by a multiplicative factor of 2.31 [the value of exp(ATT coefficient), with the coefficient being equal to 0.835] for each absolute increment of the ATT score. Globally, 80.6% of the cases are correctly classified.

Evaluation of Effects of Application on Travel Behavior

As indicated in the methodological section, the analysis carried out after the test involved 46 persons (four participants left the experiment). However, the figures of the initial sample have been retained.

Comparison of the stated and revealed potential benefits of the application as declared by the individuals indicates that the number of people with a positive view decreased to a statistically significant extent from the ex ante to the ex post surveys. Likewise, the intention of changing travel behavior as a result of the application significantly differed between the two surveys (Table 4).

Table 4 shows that the only significant statistical difference thanks to real-time information was related to car use: the number of participants who admitted using the car more decreased strongly from 16 (ex ante) to four (ex post).

With regard to the most frequent trip, an overall change toward a more sustainable mobility was not evident. Some participants moved from car to other modes, while others switched from more sustainable modes to car. The number of people using polluting modes slightly increased after the test, which contradicts theoretical expectations. The introduction of Optimod'Lyon did not produce any change in the use of car, motorcycles, bicycles, or Vélo'v (bikesharing) in autumn–winter, in spring–summer, or on weekends.

The intention of using the app to plan occasional and daily trips showed significant changes after the test. It decreased in both cases ($Z = -4.564$, $p < .001$ for occasional trips; $Z = -4.347$, $p < .001$ for daily trips).

Three decision-making scenarios—pretrip planning, en route, and reroute—were tested in the ex post survey: 15 people used Optimod'Lyon for pretrip planning, 10 for en route information, and 20 for reroute information.

Another aspect analyzed in the ex post questionnaire was the usefulness of the app in discovering new routes. Even though a neutral viewpoint is noticeable ($M = 2.93$, SD = 1.526), 16 participants reported that they found new routes by using Optimod'Lyon. Furthermore, 14 participants stated that the app allowed them to save time during their trips; 11 persons both found new routes and saved time. Finding new routes and saving time during the travel thanks to the app showed a significant and positive correlation (Spearman's rho = .652, $p < .001$).

An important issue in understanding the potential success of Optimod'Lyon is assessment of willingness to pay for using the application. After the test, willingness to pay was significantly lower than previously stated ($Z = -2.062$, $p = .039$).

The ergonomics of Optimod'Lyon was evaluated through three criteria: easiness of use, problems using the app, and time losses in searching for information. There is a statistical difference between the ex ante and ex post surveys ($Z = -4.682$, $p < .001$ for ease of use; $Z = -3.062$, $p = .002$ for facing problems) indicating that people faced more difficulties than expected in using Optimod'Lyon. The statement "I did not lose a lot of time using Optimod'Lyon" was only present in the ex post questionnaire. The number of participants agreeing that they did not lose time using the application was 21; 10 disagreed.

TABLE 3 TPB Model

						95% Confidence Interval exp(ATT coefficient)	
Predictor	Coefficient	SE	Coefficient/SE	*p*-Value	exp(ATT coefficient)	Lower Bound	Upper Bound
ATT	.835	.373	2.24	.043*	2.31	1.08	4.92
Constant	−1.068	.954	−1.12	.302	.344	.050	3.29

*Significant at the .05 level.

TABLE 4 Stated and Revealed Benefits and Intentions: Statistical Differences Between Ex Ante and Ex Post Surveys

Stated and Revealed Benefits	Ex Ante (number of people who agreed to the statement)	Ex Post (number of people who agreed to the statement)	Paired t-Test	p-Value	Wilcoxon Test	p-Value
Optimod'Lyon as a facilitator toward a mobility behavior change	19	3	3.64	<.001*	–5.35	<.001*
Optimod'Lyon as an incentive to change mobility behavior	17	9	9.12	<.001*	–3.20	<.001*
Gain time, thanks to Optimod'Lyon[a]	42	14	6.84	<.001*	–4.89	<.001
Optimod'Lyon as a tool that helps to reduce the environmental impact of travel	29	6	8.42	<.001*	–5,37	<.001*
I intend to change my travel habits	8	3	2.00	.051	1.86	.068
I would use public transport more often if I had real-time information on timetables and passes	24	16	1.77	.083	–1.74	.082
I would use Vélo'v (bikesharing) more often if I had real-time information on availability of Vélo'v and occupation sites	13	10	na	na	–1.74	.082
I would use my car more often if I had real-time traffic information	16	4	na	na	–2.55	.011*
I would carpool more often if I had real-time information on its availability	18	14	na	na	–1.21	.226

NOTE: na = not applicable.
[a]In the ex ante survey, there were three questions assessing Optimod'Lyon's influence on limiting travel environmental impacts. The three questions showed an excellent Cronbach's α (.911), and their mean value was used as a new variable.
*Significant at the .05 level.

Before the test, a principal component analysis, using the statements from the ex ante questionnaire, was used to identify the TPB constructs: ATT, PBC, and SN. The same statements were used in the ex post questionnaire, and the Cronbach's α was computed for the items used for each factor to determine whether these constructs continued to be valid after the test. ATT ($\alpha = .671$) and PBC ($\alpha = .674$) constructs in the ex post did not reach the threshold but showed an acceptable value for internal consistency (*26*). SN ($\alpha = .745$) showed a good internal consistency. Participants' scores on reliable scales were computed by taking their mean on items included in each scale, so that scores ranged from 1 to 5. Paired *t*-tests and Wilcoxon signed rank tests were performed to verify whether there were significant differences in how participants scored the TPB constructs between the two questionnaires.

ATT and PBC did not show any significant difference between the two questionnaires; on the contrary, the SN construct presented a significant decrease between the ex ante (2.75) and the ex post surveys (1.25). These results confirmed what was found earlier concerning the lack of predictive power of the TPB constructs and will be discussed in the next section.

DISCUSSION AND CONCLUSIONS

The results indicate that there were no constraints on use of Optimod'Lyon as long as participants are familiar with the technology and with the use of smartphone applications (e.g., Google Maps), GPS navigators, and websites in obtaining travel information. A sample including people of different ages, educational levels, and professions showed how the use of technology largely cuts across socioeconomic characteristics, as proved by the wide market penetration of information and communication technology (ICT) tools. The rise in the popularity of mobile devices and the ubiquitous web are changing the way of living. For example, social media have performed better than traditional systems in providing information during emergency situations (*28*). Ninety percent of American adults have a cell phone and 64% have a smartphone; sensors in mobile devices collect data that can be harvested for multiple uses (*29*).

Such a revolution, fostered by ICT, has led decision makers to believe that technological devices could change travel behavior and encourage the use of more sustainable transport modes, thanks to the better information such devices provide.

To this end the Optimod'Lyon project was funded to develop a so-far nonexistent tool. The tool would include all transport modes in one application and provide real-time intermodal routing information. The panel selected for the test was monitored before, during, and after use of the application to assess its effects on mobility patterns of the participants.

At the onset of the test, travelers' assessments of the travel planner were slightly positive, but this waned over time. Use of the various modes remained stable after the test, although a small increase in use of the car for the most frequent trip was observed. Although 17 participants changed the mode used for the most frequent trip, their change was driven not by the search for greater sustainability but by factors such as changing job location, finding a better route, and meteorological conditions.

The negative ex post evaluation of Optimod'Lyon could be due in part to the application itself, since it was not easy to use during the daily commute. Furthermore, during the test, the app was updated three times. Small changes were made in terms of content and user interface that could cause some bias in the results. The evaluation showed that Optimod'Lyon did not yet meet all the technical preconditions demanded by travelers for inducing a change in mobility behavior. Fayish and Jovanis had already observed that user-friendly systems providing accurate information and pleasant graphical design would encourage the use of ATIS (*30*).

In addition, the results of the test were consistent with those of previous studies: few people used the app on a daily basis or for planning daily commuting; it was most often used for planning occasional trips (*31, 32*).

The facts indicate that the app alone had no influence on modal shift and that users' expectations with regard to its use were not met.

The reasons for such a mismatch are several. Arguably, the real-time feature of Optimod'Lyon did not match the expectations of the participants: 42 people wanted to save time and only 14 actually did so, and ATIS should allow for time saving (*32*).

Furthermore, there is evidence that the information is not effective for daily trips since the user is unlikely to consult it. The habitual nature of such a trip makes the information redundant over time. Skoglund and Karlsson, in a study carried out in Stockholm, Sweden, observed changes in respondents' assessment of the planner and the provided service over 9 months (*33*). The planner was rated as less useful, less effective, less amenable, and less stimulating than initially expected. Those researchers also showed that the information provided by the travel planner was relied on but that the perceived value of the service dwindled over time. The service had been reused by fewer than 40% of the respondents.

Willingness to pay for use also lessened after the test. This is apparently related to the lack of time saving allowed by the app. Lack of willingness to pay for such applications has been found in previous studies (*11, 34, 35*).

The Expert Group on Intelligent Transportation Systems for Urban Areas concluded that implementation of the multimodal information system was the most economical method for reducing carbon dioxide emissions by 24,000 tons/year in Lyon, equivalent to 1% of modal shift from cars to bicycles or public transport (*36*). The results of this research call into question the capacity of those systems, by themselves, to achieve a modal shift of 1%. Those systems must be part of a wider strategy for achieving sustainable urban mobility, including more investments in public transport, in pedestrian and bicycle routes, and in measures to decrease car use.

Participants stated that this app did not help them to reduce environmental impacts to the extent that they expected. Despite the strong awareness of environmental problems, a low intention to reduce car use has been found (*37*). It is confirmed in the sample described in this paper, where the intention to use more sustainable modes (public transport, bikesharing, carpooling) if real-time information is available decreased after the test, as also shown by the lack of fit of the TPB model.

Intention is the best predictor of future behavior unless strong habits prevail with regard to the target behavior. However, if there is no intention of changing a travel habit, the use of a journey planner does not provide any additional information, as confirmed by the literature:

- There is no correlation between respondents' assessment of the travel planner and their reported change of travel mode (e.g., more travel by public transport and less by car) as a consequence of access to the travel planner (*33*).
- There is little evidence to suggest that the provision of information has been effective in promoting modal shift (*33*).
- Realizing changes in people's travel behavior is difficult (*38*). Several cooperating factors determine how the individual perceives his or her "action space" and the choices that are considered possible. Among the factors are not only the design of the transport system but also the household socioeconomic situation; accessibility to services; motives; attitudes; knowledge; and, not least, habit. Routine habits, such as commuter journeys, are most often undertaken without further thought or reflection (*13, 39*).

As the results of the test showed, the model proposed by the TPB was unable to predict intentions with regard to modal shift. The intentions to change mode slightly came from the personal assessment of shifting modes (ATT); the other two constructs, SN and PBC, did not play a role in explaining intentions.

ATT, PBC, and intentions did not change significantly. The stability of intentions and of PBC could explain the stability of the observed behavior. Those factors presumably determined the behavior in the past and, since this remained unchanged, prompted the corresponding behavior in the future (*13*). The observed lack of fit of the TPB can be related to the participants' high frequency of past behavior, which leads to mobility habits strongly influencing the process of modal choice. Hence, the behavior under consideration, rather than being completely reasoned, is partly under the direct control of the stimulus situation, that is, the repetition of the habitual performance (*13*).

Aarts et al. found that systematic travels limit the effects that information can have on modal shift because people automatically behave without consulting the available information (*40*). If routines are disregarded, human social behavior is always regulated at a certain (even if low) level of cognitive effort. Therefore, to induce a particular multimodal behavior, the use of information should contribute to disruption of the routine behavior and to the initiation of reasoned action (*41*).

Mobility habits are a constraint in the process of modal choice. Information can play a role in shifting modes only if it provides users with significant reasons to break away from their routine and thus change the cognitive foundation of intentions and behavior.

Individuals most inclined to use Optimod'Lyon are middle-aged car owners who have a high educational level and familiarity with technology. However, a motivated use of information through travel planners is challenging and, hence, unlikely to change the travel behavior of individuals unless benefits are perceived. Only three of the eight persons who declared their intention to change their behavior before the test have retained that intention.

The conclusions of this study should be considered with caution because of the sample size (ex ante = 50; ex post = 46). Nevertheless, they are confirmed by the results of the focus groups, and they match the outcomes of other studies well. However, these conclusions cannot be generalized. It was impossible to have a control group, since all participants got a smartphone. This limitation is not uncommon in field studies, but it raises the possibility that events other than the introduction of the multimodal app produced the observed effects (*13*).

Nonetheless, the research provides insights into the impacts that ATIS can have on mobility and may be a starting point for future studies.

Even though multimodal traveler information systems are a recent concept—albeit nowadays globally used—there is a need for assessment of their impacts. Substantial funds are being dedicated to their development without a real understanding of their effectiveness.

In this research the TPB model was applied to predict modal shift when real-time information is used. It can be concluded that, with the available data, the model did not fit the expected behavior. Thus, research is continuing within the OPTICITIES project. The theory is being applied to a larger sample, and the findings of the research will be used for factor constructions. Then, in the OPTICITIES project, other behavioral models will be tested to understand whether they work better in predicting modal shift in the case of multimodal real-time information. A mix of models or a new model eventually will be constructed to describe and predict this complex behavior.

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