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Article

Willingness to Pay and Public Acceptance for Hydrogen Buses: A Case Study of Perugia

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Abstract: Sustainability transportation is characterized by a positive externality on the environment, health, social security, land use and social inclusion. The increasing interest in global warming has caused attention to be paid to the introduction of the hydrogen bus (H2B). When introducing new environmental technologies, such as H2B, it is often necessary to assess the environmental benefits related to this new technology. However, such benefits are typically non-priced due to their public good nature. Therefore, we have to address this problem using the contingent valuation (CV) method. This method has been developed within environmental economics as a means to economically assess environmental changes, which are typically not traded in the market. So far, several big cities have been analyzed to evaluate the perceived benefit related to H2B introduction, but to the best of our knowledge, no one has performed a CV analysis of a historical city where smog also damages historical buildings. This paper presents the results obtained using a multi-wave survey. We have investigated user preferences to elicit their willingness to pay for H2B introduction in Perugia, taking into account all types of negative externalities due to the traffic pollution. The results confirm that residents in Perugia are willing to pay extra to support the introduction of H2B.

Keywords: hydrogen bus; acceptability; contingent valuation; stochastic payment card

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1. Introduction

Growing concern about climate change has highlighted the role of improvements in energy efficiency and engendered a shift toward new environmental technologies for reducing greenhouse gas emissions. In this context, transportation systems confirm their importance due to negative externalities such as climate change, local air emissions, noise, congestion, and accidents.

A general agreement exists on the inequality of the distribution of transportation externalities, insofar as they mainly affect low-income populations [1]. Furthermore, local governments have attempted to implement measures to restrain negative traffic externalities, even if in many cases without success. Generally, measures have been adopted only under critical situations and in haphazard ways. Moreover, these measures have affected the most economically disadvantaged citizens [2]. In Italy, the most frequently adopted measures are number plates or limited traffic zones. From a long-term and structural perspective, one possible solution to these problems is the introduction of hydrogen buses (H2B).

The introduction of H2B has at least two main challenges. First, it requires costly investments in fueling infrastructures and the public acceptance thereof, which are affected by people's anxieties due to the perceived potential dangerousness of hydrogen (H2). Second, the high costs and poor performance of the H2B compared to diesel or methane busses present major obstacles. Consequently, these obstacles have to be overcome to obtain a general public agreement on the needed, though costly, investments in H2B introduction. In this paper, we attempt to investigate the preferences of local public transport (LPT) users in the city of Perugia (Italy) by assessing both public acceptability of and related willingness to pay (WTP) for H2B. In particular, we propose a new policy scenario for large-scale H2B introduction in Perugia to interviewees to evaluate their WTP by implementing a contingent valuation (CV) survey method and using a stochastic payment card (SPC) approach.

To the best of our knowledge, this is the first study to attempt to estimate the WTP for H2B in a small historical city where environmental concerns are linked to the concern about smog damage to historic buildings. The paper is structured as follows. Section 2 provides a brief review of the literature, the case study is presented in Section 3, the method is described in Section 4, and the econometric model is presented in Section 5. Section 6 provides empirical results, and Section 7 concludes the paper.

2. Literature Review

Many studies have investigated H2 technology acceptability, rather than its applications (see, among others, Altmann and Graesel [3] and Cherryman *et al.* [4]) or knowledge and opinions about specific energy H2 projects [5,6]. Zacharian-Wolff and Hemmes [7] analyzed acceptance of both H2 technology and its different applications in the Netherlands, and O'Garra *et al.* [8] investigated the awareness determinants of H2. However, to the best of our knowledge, only a few studies [8–16] have attempted to analyze preferences for and acceptability of H2B irrespective of WTP assessment. These studies were mainly focused on major cities, such as Berlin, London or Perth, but studies on medium towns, such as Stockholm, or on small towns, such as Luxembourg or Knoxville, also exist. Finally, Heo and Yoo [17] estimated the WTP for a large-scale introduction of H2B in Korea by surveying the major Korean cities.

In the majority of studies, researchers investigated users' preferences, although a few studies focused on riders' preferences [9] or on both users and drivers [16].

It is not easy to compare the literature results due to differences in the selected samples, questionnaire designs, elicitation methods and city sizes; however, some general topics can be identified. In keeping with the aim of this paper, we only review (Table 1) studies researching the demand side by focusing on users' or potential users' attitudes and preferences.

Table 1. Literature review on contingent valuation (CV) studies on hydrogen bus (H2B)—main findings.

Study	Country	City	Data Year	Sample Size	Main Findings
Altmann and Graesel [3]	Germany	Munich	1997	n.a.	Students were not willing to pay more for H2 compared with other fuels
Maack *et al.* [18]	Iceland	Revkjavik	2004	200	Compared to the cost of oil: (i) 37% would accept paying more; (ii) 34% would pay the same; (iii) 28% would pay less.
O'Garra [19]; O'Garra *et al.* [12]; O'Garra and Mourato [13]	*5 countries* [(a)]	Capital cities and others	Ex-ante surveys [(b)]: from July 2003 to February 2004. Ex-post surveys [(c)]: from July 2004 to February 2005	Berlin (344–263) [(d);] London (414–300); Luxembourg (300–301); Perth (300–300); Oakland (302)	WTP more for H2B was high (> 75% of the total sample was willing to pay extra bus fare). WTP was quite similar across cities and did not change significantly between ex-ante and ex-post surveys.
Haraldsson *et al.* [20]	Sweden	Stockholm	2004	518	WTP more for H2B was low (20% of the total sample was willing to pay extra bus fare, but 64% were not willing to pay more for the introduction of fuel cell buses).
Heo and Yoo [17]	Korea	*7 cities* [(e)]	2007	509	Citizens were willing to pay more for environmental improvement due to H2B.

[(a)] England, Germany, Luxembourg, Australia and the U.S.; [(b)] London, Berlin, Luxembourg, Perth and Oakland. [(c)] London, Berlin, Luxembourg and Perth; [(d)] We report in the parentheses *ex-ante* and *ex-post* values. [(e)] Seoul, Pusan, Taegu, Kwangiu, Ulsan, Daejon and Incheon.

Indeed, some authors, such as Altmann and Graesel [3], Heo and Yoo [17] and Maack *et al.* [18], surveyed residents, including bus users and non-bus users. In other studies, respondents were only bus users, such as in O'Garra *et al.* [12], O'Garra and Mourato [13], and O'Garra, [19]. Finally, Haraldson *et al.* [20] interviewed not only bus users but also bus drivers. Our study takes into account only bus users.

First, the overall result is that public awareness of H2B seems to generally be low, even if some differences exist due to demographic features such as age, gender, education and environmental attitude [14]. On the contrary, Schmoyer *et al.* [5] found that age and gender do not affect public awareness, whereas O'Garra *et al.* [8] found that H2 awareness was related to gender, age, education and environmental knowledge.

Concerning attitudes, many scholars have found largely positive attitudes towards H2B [8,12,18,20]. This crucial point has been deeply discussed in the literature focusing on the link between knowledge and acceptability. Previous studies have underlined that a favorable public opinion can depend on whether the available information on H2 is commonly positive [12] and rather generally refers to fuel use [14]. Indeed, Hemmes *et al.* [21] obtained a reduced acceptability by also providing negative information to their respondents, and the same reduction characterizes studies on infrastructure rather than specific applications [14]. Moving to the CV studies, we found seven papers (Table 2) that focus on the topic of analyzing WTP for H2B.

We noticed that the results are highly heterogeneous, which is primarily due to the type of good under evaluation (e.g., H2B or an H2B introduction project rather than H2), but these results also largely depend on the nature of the information available to the respondents [14].

Table 2. Literature review—the willingness to pay (WTP) for H2B.

Study	Survey	Method	Good under Evaluation	Annual WTP [(a)]
Altmann and Graesel [3]	Face to face	Questionnaire-based survey of passengers and students.	H2B demonstration projects	n.c.
Maack *et al.* [18]	Face to face	Questionnaire-based survey of passengers and residents along the H2B route.	Fuel	n.c.
O'Garra [19]; O'Garra *et al.* [12]; O'Garra and Mourato [13]	Face to face and phone survey	Questionnaire-based survey of bus users and non-users. (Logit and Interval regression)	H2B demonstration projects	Berlin (26.72—from 10.76 to 34.07) [(b)]; London (37.67—from 20.58 to 54.59) [(b)]; Luxembourg (24.17—from 13.97 to 43.18) [(b)]; Perth (from 18.74 to 20.31) [(b)]
Haraldsson *et al.* [20]	Face to face	Questionnaire-based survey of bus users and drivers.	H2B	n.c.
Heo and Yoo [17]	Face to face	Questionnaire-based survey of heads of households. Dichotomous choice CV method	H2B trial project	WTP *per* household 3.54; from 2.93 to 4.08

[(a)] EUR 2013; n.c. not computable; figures are mean WTP. [(b)] We report in the parentheses values related to the *ex-ante* survey, from July 2003 to February 2004, and the *ex-post* survey, from July 2004 to February 2005.

3. The Case of Study

Perugia is a relatively small city with a population of approximately 170,000. It has a typical radial structure with a difference of altitude of more than 150 meters and a density of over 360 inhabitants per square kilometer. In this city, life is influenced by the presence of two universities, in which 61,000 students are enrolled. It has a typical urban employment structure, with more than 70% of its total of 61,000 employees employed in the service sector. Employment in the service sector follows a distinct pattern of concentration, with location-based services in the town center, although public sector decentralization is ongoing. All of these features make Perugia a difficult city in which to deploy public transport.

From a historical perspective, the municipality of Perugia took its first steps in the direction of alternative mobility in the 1970s. The first lift was constructed in 1973, and the first escalator was constructed in 1983, kicking off a project that now includes the LPT Company with services provided by bus, bus call, escalators and lifts, as well as MiniMetrò and Ferrovia Centrale Umbra. This last mode of transportation is the regional railroad network, which reaches the city center and is also used for urban transport.

In terms of LPT policy intervention aimed at limiting private transportation use and promoting public road transportation, several measures have been adopted. In the 1970s, a measure reform was started that aimed to expand different mobility forms. This reform and the following changes characterize Perugia, since the 1970s, as an innovative city relative to LPT. In the 1990s, a more integrated public transport system, both in terms of the tariff and the network, was implemented. At the beginning of the 2000s, a limited traffic zone was introduced in the historic center, as well as a people-mover system. Finally, in 2008, MiniMetrò began operations as part of the changes to traffic in Perugia, which improved multimodal mobility.

The trend of the demand for public transport in the city of Perugia is reported in Table 3. Analyzing the case of Perugia, we see that the increase in demand was considerable until 2001.

The result of this period confirms that reversing the negative trend in the use of LPT is possible. Of course, this would not necessarily decrease the use of private transportation, but the development of infrastructure for mobility and a reorganization of the fare system could significantly expand the number of passengers transported without compromising the total and average revenues. However, in the last years, environmental constraints have imposed a rethinking of LPT structures. In Umbria, road transportation is a significant source of emissions due to the low density of the population, and this constraint is only going to become more pressing given the new European target for CO_2 emission.

Table 3. Local public transport (LPT) passengers in Perugia.

Year	Bus	MiniMetrò	Lift and Escalators
1996	8,367,000	-	-
1997	8,770,000	-	-
1998	10,099,000	-	-
1999	10,961,000	-	-
2001	12,075,000	-	-
2002	12,771,000	-	-
2003	12,632,000	-	11,309,434
2004	12,373,000	-	11,350,940
2005	12,673,009	-	10,863,176
2006	12,548,873	-	10,776,846
2007	12,598,708	-	10,742,762
2008	12,364,689	2,769,587	10,077,471
2009	12,382,316	3,134,426	9,035,793
2010	12,438,651	3,177,243	8,917,428

Despite climate change concerns and the general social agreement for a more sustainable society, the reduction of transportation emissions in urban areas requires choices and infrastructures that have a significant impact on the urban form. Consequently, in the following paragraphs, we investigate the acceptability of and preferences for H2B by comparing the public willingness to pay for air pollution reduction with the higher cost of large-scale H2B introduction. Using the CV method, we define a scenario with a large-scale introduction of H2B to capture values of LPT users in Perugia.

4. The Method

To derive estimates of citizens' WTP, a local survey with 587 interviews was administered from the end of January to March 2013 using a representative sample of users. Authors and Ph.D. students conducted the survey using a face-to-face method. The authors also properly edited the full raw dataset to avoid recode mistakes that could affect the results.

A preliminary analysis was conducted in June 2012 by a focus group composed of transport managers, experts, and users. Their experience and knowledge permitted them to obtain the price vector, taking into account potential biases associated with the payment card method [22]. By using a focus group, we also obtained an unbiased economic valuation of H2B introduction and a more reliable WTP. We also used validity test questions to mitigate consumer confusion [23,24]. Respondents were first asked if they knew about H2B advantages and disadvantages, and then they were asked to identify the H2B-specific ones from among a set of general advantages and disadvantages. In this way, we took into account the importance of the description and understanding of the valuation scenario and how people are directly or indirectly affected by the proposed environmental change. In so doing, we followed several guidelines that suggest various ways to test for one's understanding and acceptance of the scenario proposed. One common method is to include questions whose answers should confirm each other [25]. Finally, it is well known that in CV, a divergence between stated and actual consumer behavior exists [24]. To reduce this divergence, we introduced uncertainty in the elicitation format using a multiple-bounded uncertainty approach [26].

4.1. The Questionnaire

The pros and cons of the H2B development scenario were provided by questionnaire to the respondents using a set of questions about (i) their attitudes and preferences towards private and public transport; (ii) their knowledge about world-wide H2B projects; (iii) WTP amounts to support the introduction of H2B in Perugia; and (iv) respondents' socio-economic characteristics, including environmental behaviors. The respondents were first asked whether they were aware of traffic congestion, services transport quality and pollution issues. Even if TPL services quality is an important topic [27,28], we have not dealt with this feature. We also asked if they believed that H2B could contribute to mitigating these negative externalities in Perugia. The respondents answered by choosing a value between one (awful) and seven (excellent).

- *In your opinion, what is the situation in Perugia with regard to traffic externalities?*
- *In your opinion, what is the situation in Perugia with regard to quality services of the local public transport?*
- *In your opinion, what is the situation in Perugia with regard to the tariffs level of the local public transport?*

Finally, in the first section, a personal opinion on H2B implementation was asked to each respondent:

- *Today, there is a heated debate in Perugia on the pros and cons of the local public transport development. A hydro bus could be a useful tool in this context. Are you for or against a hydro bus?*

In the next section, respondents were asked about their knowledge of H2B characteristics and benefits by answering validity test questions, which allow for investigating the accuracy of the answers provided by respondents about the scenario proposed. Specifically, we constructed a dummy variable that concerned the degree of one's knowledge of H2B. The dummy variable used to distinguish different groups is equal to one if the interviewees claimed knowledge of H2B characteristics and environmental benefits and correctly identified them in the second question. The dummy variable is zero otherwise. Afterwards, respondents were asked if they would contribute or not to H2B introduction in Perugia for environmental reasons, according to the SPC approach. In particular, respondents were informed about the new CO_2 reduction targets according to COM (15/2014) that were specified on 22 January 2014.

Finally, a reliable WTP scenario was constructed to ask respondents to state the amount of their monthly public transportation expenditure. At the end of the questionnaire, the interviewees were asked about their individual attributes, such as demographic characteristics, age and education.

4.2. Elicitation Format

The literature has underlined that the CV method is characterized by some critical points. In this research, we address two of them. First, using the SPC approach, we took into account that respondents may have had a whole-valuation distribution in mind instead of a single-point economic value. Second, we dealt with the uncertainty that typically affects CV studies.

In particular, we employed *ex-post* approaches to mitigate hypothetical bias [29] using a [26,30–33] certainty correction method to reduce overestimation risk by proposing 10 types of acceptance intensity. According to the SPC method [34–36], we used numerical likelihood information from 0% (definitively no, DN) to 100% (definitively yes, DY) in 10% increments; consequently, the respondents stated their acceptance intensity over 17 bids from 1.51 EUR to more than 4 EUR. We asked about the numerical likelihood together with the verbal likelihood because the meaning of "probably yes" (PY), "unsure" or "do not know" (DK), and "probably no" (PN) may be perceived differently among individuals if these options are provided alone. In other words, if the verbal likelihood is directly asked, an ambiguous interpretation of some responses could result. The elicitation format structure (card) used in the survey is shown in detail in Table 4. The interviewer presented the card to a respondent, who was then asked about his or her likelihood of accepting to pay for each bid on the card. Consequently, the respondents selected a number according to the probability that they associated to their WTP for each bid. Given that this procedure was repeated for each bid and for each respondent, a likelihood matrix can thus be built. In this paper, we did not use this matrix to investigate the individual probabilities of saying "yes" to referendum questions according to different bids. We only recoded the quantitative information to obtain models that would allow for treating uncertainty according to the Welsh and Poe approach (WP). Therefore, we recoded the probabilistic answers according to four models:

- "Higher bound" (HB) in which only DN (0%) = no and the others = yes;
- "Do not know" in which DN and PN (from 10% to 40%) = no and the others = yes;

- "Probably yes" in which DY (100%) and PY (from 60% to 90%) = yes and the others = no;
- "Lower bound" (LB) in which only DY = yes and the others = no.

According to the WP approach, the entire WTP interval shifts as a change in the probability statement. In this approach, each respondent's WTP lies in an interval that always includes the highest WTP, which implies that both the upper and lower bounds of the WTP interval move upwards as the accepted certainty level decreases.

For example, in the "probably yes" model, the WP intervals are [1.65–1.8] EUR, and in the "higher bound" model, the WTP intervals are [2.5–3] EUR.

Table 4. Elicitation format.

Bid (EUR)	DY		PY			DK		PN			DN
1.5	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.51	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.52	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.55	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.6	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.65	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.7	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.75	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.8	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.85	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
1.9	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
2	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
2.1	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
2.3	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
2.5	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
3	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
3.5	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
4 +	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

Instruct the respondent to circle an answer for each of 17 prices

The maximum confidence interval for WTP estimates is set by the higher and lower bound models, given that they are the "certainty models". Indeed, they use the DY and DN information that constitute the extreme values of the estimated WTP [32].

4.3. The Theoretical Model

We assume that bus users maximize bus transportation utility subject to budget constraints.

$$U = U\ (X_P, H2Bs, X_G) \tag{1}$$

The utilities function is positively related to the private goods X_P (X_{P1}, ..., X_{PN}), the composite public good X_G, and the public good H2B use services *(H2Bs)*. X_G is a composite commodity of all public goods with unit prices and values equal to the tax charged the user that maximizes Equation (1) subject to its budget constraints:

$$M = X_P P_P + X_G \quad (2)$$

where M is the nominal income and P_P is the price vector of private goods; more distant users spend all of their disposable incomes by purchasing private goods:

$$Md = M - X_G \quad (3)$$

The demand for H2B benefits and services can be obtained by modeling consumer choice within the utility maximization framework. Indeed, if we allow expenditure *(E)* to be a function of H2B benefits and allow services and private goods (X_P) and the composite of public goods (X_G) to be subject to the utility *(U)* constraint, we obtain:

$$\begin{gathered} \mathit{Min}\ E(P_P, H2Bs, X_G) \\ \mathit{sub\ to:}\ U = U(X_P, H2Bs, X_G) \end{gathered} \quad (4)$$

where P_P and P_{HBs}, are the prices of private goods and H2B environmental services, respectively. Given the utility constraint, the representative users' face expenditures for H2B use services, private goods and composite public goods; thus, the user will attempt to minimize the following expenditure function:

$$E = E(P_P, P_{H2Bs}, X_G, U) \quad (5)$$

However, given the characteristics of *H2B*, it makes sense to think of this function as a restricted demand problem where the consumer does not observe P_{H2Bs} and choose *H2Bs* but rather is offered *H2Bs* and can then choose either to pay for these services $(H2Bs^1)$ or not (HBs^0). Therefore, P_{HBs} is replaced with *H2Bs*, and the new expenditure (E^*) function (Equation (5)) can then be rewritten as follows:

$$E = E^*(P_P, H2Bs, X_G, U) \quad (6)$$

In such a restricted case, the WTP for *H2B* services use is simply the difference between two expenditure functions (with $H2Bs^1 > H2Bs^0$); the compensating surplus (CS) welfare estimate can be derived in terms of the difference:

$$CS = E^*(P_P, H2Bs^0, X_G, U) - E^*(P_P, H2Bs^1, X_G, U) \quad (7)$$

This CS is the amount that each user is willing to pay for the H2B environmental services, given that its utility level is maintained at a constant rate.

5. Econometric Model

Following the literature [37–39], we deemed it appropriate to use an interval regression method that allows for treating the data as interval data. However, we did not present the bids as intervals to the respondents. Our elicitation format allows for identifying interval values, including respondent choice. Furthermore, in our study, a limited number of respondents stated a zero bid, and a small size of intervals was used. In our analytical framework, the respondents' choices are associated with the following probability:

$$P(t_i) = P(t_{li} < WTP_i \leq t_{ui}) \quad (8)$$

Given the non-negative WTP and the skewness of the WTP distribution, we used a lognormal conditional distribution:

$$log\ WTP_i = x_i{'}\beta + \varepsilon_i \quad (9)$$

where ε_i is distributed normally with zero mean and standard deviation σ. According to Equations (8) and (9), the probability of choosing t_i can be written:

$$P(t_i) = \Phi\ ((log\ t_{ui} - x_i{'}\beta)\sigma) - \Phi\ ((log\ t_{li} - x_i{'}\beta)\sigma) \quad (10)$$

where Φ is the standard normal cumulative density function, and the corresponding log likelihood function is as follows:

$$\log L = \Sigma_i \log [\Phi\ ((\log t_{ui} - x_i{'}\beta)\sigma) - \Phi\ ((log\ t_{li} - x_i{'}\beta)\sigma)] \quad (11)$$

The optimal values of β and σ were estimated to compute the mean and median WTP according to the following equations [38]:

$$\begin{aligned} \text{median WTP} &= \exp(x_i{'}\beta) \\ \text{mean WTP} &= \exp(xi{'}\beta)/\exp\ (\sigma^2/2) \end{aligned} \quad (12)$$

Finally, we computed the confidence interval by bootstrap methods with 2000 replications.

6. Empirical Results

From Section 4 of the questionnaire, we can see that in our sample (Table 5), the average annual household income of the respondents was 25,301 EUR. Therefore, the average income of the respondents is very close to the average income of the population in Perugia.

Table 5. Characteristics of survey respondents.

Age	**Frequency**
< 18	3
18–24	35.5
25–34	13
35–44	9.5
45–54	14.5
55–64	11
> 65	13.5
Level of Education	**Frequency**
nothing/elementary	7
middle school	13.5
high school	44
Degree/Ph.D./Post doctorate	35.5

Table 5. *Cont.*

Family size (nr. of components):	Frequency
one	14.5
two	21
three	25
four	31
five	8
six or more	0.5
Income	
Mean (EUR)	25,301
c.v.	0.35

The average age of the respondents was 41.25, and the average education level in years was 16.73, indicating that the average respondent had received a college education. The average family size of the respondents (2.45) very closely approximated the average household size of the overall population.

6.1. Attitude and WTP Responses

The descriptive sample statistics of the respondents' knowledge of H2B projects are shown in Table 6. Forty-six percent of the respondents already knew that there is an ongoing class action lawsuit against urban smog and congestion in Milano, and approximately 31% recognized that the "Chic" project involves H2B introduction in Milano, Torino and Bolzano.

On the other hand, 51% of the respondents knew that in 2010, Milano began experimenting with H2B introduction. According to the answers provided by the respondents in Section 1, approximately 50% of them believe that smog and traffic congestion are critical problems. Furthermore, 68% of the respondents declared that the quality service of the local public transportation was more than satisfactory. An Urban Mobility Survey, managed by the Italian National Institute of Statistics (ISTAT) [40], also confirms this result. With regard to environmental behavior, Table 7 shows that more than 65% of the respondents were likely to leave their car at home to reduce air pollution and avert these problems.

We notice that this result is consistent with other surveys, such as O'Garra *et al.* [12] and Heo and Yoo [17]. Both surveys showed that in most cities, more than 50% of respondents are likely to avoid using their private cars for environmental reasons. Specifically, the percentage is 60% in Seoul, Luxembourg and Berlin, and it decreases to 50% in Perth and to 40% in London.

Furthermore, the willingness to limit private car usage is in line with other eco behaviors declared by respondents. Indeed, environmentally friendly behavior seems to be largely common in our sample, given that only 27% of the respondents stated that they rarely or never use LPT and more than 70% of the interviewees had adopted separate collection of rubbish. Concerning the good under evaluation, it would appear that citizens in Perugia have already reached a consensus with regard to H2B introduction and paying extra for related environmental improvements: 81% of the respondents agreed with the H2B trial in Perugia, and 88% stated their WTP for the introduction of H2B on a large-scale through an increase in bus fare. Among the people unwilling to financially support H2B introduction (Table 8), 47% declared that the local government might financially support this project (for example, by using European Funds), and 40% replied that bus fare is already too expensive.

Table 6. General knowledge questions.

Question	Yes	No
Are you aware that Codacons filed a class action against smog in Milano?	45.5%	54.5%
Are you aware that the "Chic" project includes Milano, Torino and Bolzano for Italy?	10.5%	89.5%
Are you aware that Milano, on 20 January 2010, experienced the first zero-emission H2B?	31%	69%

Table 7. Environmental behavior.

Frequency of Use of LPT:	%
almost always/always	30
sometimes	43
a few times/never	27
Differentiated Waste Collections:	
almost always/always	74
sometimes	20
a few times	4.5
never	1.5
Don't know	0
Limiting Private Car Use:	
almost always/always	36
sometimes	29.5
a few times	23.5
never	9.5
do not know	1.5

Table 8. Protest answers for H2B introduction.

Question	Yes
No, because I think they are unnecessary	13.5%
No, because tickets are already too expensive	10.5%
No, because public administration should pay the cost difference	47%
No, because I use often public transport and it would be too expensive	29%
These percentages refer to 10.6% of the sample.	

Table 9 shows the descriptive statistics of respondents' WTP for H2B introduction, expressed in terms of a single-trip bus fare (a 70-min ticket). The average WTP is 1.81 EUR, meaning that people are willing to pay an extra premium of 0.31 EUR for the environmental benefits associated with H2B implementation. This extra premium is equal to 20.7% of the cost of a single-trip ticket. It is also interesting to note that the median is much closer to the mean, meaning that few high bids were stated. We want to stress that these figures refer to the simple mean, which was computed without taking uncertainty into account. In other words, these mean and median results were calculated using only certain answers. This means that these figures are closer to the LB results; consequently, they are not the averages of the models used, as shown in Figure 1.

Details of the WTP responses are presented in Figure 1, which shows how uncertainty may affect WTP distributions. As expected, the percentage of respondents willing to pay a given amount decreases as the bid submitted increases. On the other hand, this percentage increases when weaker certainty levels are accepted. We also notice that uncertainty affects distribution, especially between 1.53 EUR and 2.3 EUR, which is also the price range that is more reliable and prevalent for a single-trip bus fare if we consider other Italian cities.

Table 9. WTP for H2B introduction and related percentage increase.

Statistical Parameters of WTP	Values EUR (%)
Minimum value	1.55 (3.3%)
Maximum value	3.50 (133.3%)
Mean	1.81 (20.7%)
Median	1.78 (18.7%)
First quartile	1.70 (13.3%)
Third quartile	1.90 (26.7%)
Standard deviation	0.22
Coefficient of variation	0.12
These values are calculated using 90.4% of the sample.	

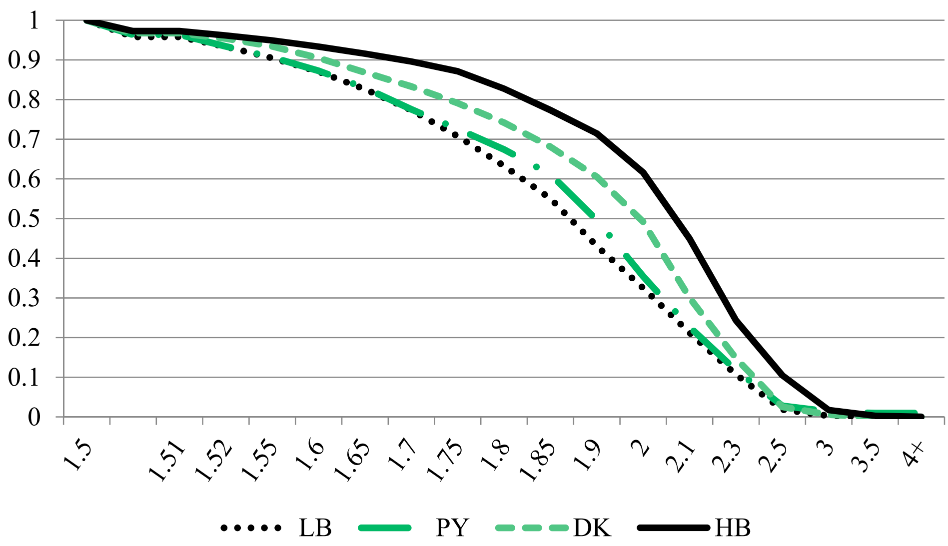

Figure 1. Survivor functions.

6.2. Estimation Results

We estimate the parameters under the assumption of log distribution (Table 10), and we compute the mean (12) and median (13) WTP following the literature, which suggests employing both measures [41,42].

The median is preferred because of its robustness, which reduces WTP overestimation risk or bias resulting from a tax price being provided to subjects in the elicitation format. Our prior expectations were confirmed by the estimated results. Indeed, the variables related to the respondents' characteristics explain the differences in respondents' WTP for H2B: age and male sex are negatively related to WTP. These results are consistent with O'Garra *et al.*'s study [12], although they contradict Heo and Yoo's study [17], which found age to be positively and significantly related to WTP. Moreover, income and education positively affect these estimates. Consequently, the results show that younger citizens are more likely to support H2B introduction, and as expected, citizens earning higher incomes, such as citizens who are more highly educated, are more likely to support the large scenario H2B introduction. Our results also show that household size is negatively related to WTP, and to the best of our knowledge, this is the first time that this variable has been found to be significant. Furthermore, concerning one's professional status, we found that the unemployed, retirees and housewives are willing to pay less when compared to persons with other statuses.

The empirical findings regarding environmental behaviors are also in line with our expectations. Indeed, users of LPT and people who adopt separate collection of rubbish exhibit a higher WTP, whereas people who are against limiting private car use for environmental purposes are willing to pay less. Finally, the results show that WTP is significantly and positively influenced by knowledge of H2B and that the dummy variable, which is a proxy for the understanding scenario, is significantly and negatively related to WTP. This means that the dummy variable reduces actual WTP estimates, confirming that a potential overestimation occurs if the proposed scenario is not fully understood by respondents. A monetary estimation of WTP shows that the median WTP lies between 2.01 EUR and 2.44 EUR for each single-trip bus fare.

A wider range of values is obtained using the mean WTP, which is more affected by high bids (the amount ranges from 2.35 EUR to 2.97 EUR). As a robustness check, we also estimated the data according to the Broberg and Brännlund [32] approach.

Preliminary results confirm that the approach used in this paper provides the following: (i) more conservative estimates; (ii) a narrower confidence interval; and (iii) more stable parameter estimates when we account for uncertainty.

The WTP estimates according to the Broberg and Brännlund [32] approach are 1.5–3.5 times lower when compared to the WTP estimates obtained using the WP approach. We underline that the median WTP lies in a range of values that is equal to an increase of 30% to 60% over the current single-trip bus fare. This is a relatively high value if compared with other literature results. A possible explanation could be found in the historical importance of the alternative mobility system in Perugia, as described in Section 3.

6.3. Policy Implications

We can now simulate the level of coverage of the costs that can be achieved, given the aggregate WTP obtained by the CV studies. To this aim, we compare the costs of modernizing the existing bus system to the total WTP of all LPT users in Perugia. The costs necessary to replace all, or part, of the current bus fleet are undoubtedly high. It should be noted that the cost of a single H2B is approximately 1.25 million EUR, on average. This cost is five times higher than a common bus fueled by diesel (*i.e.*, 250,000 EUR). Even natural gas buses, which are abundantly present in Perugia, currently cost approximately 250,000 EUR.

Considering that at the moment, there are in operation in Perugia 85 buses, of which 75 are natural gas-fueled, the cost for a total replacement of the buses currently circulating in Perugia is 85 million EUR, given that the incremental cost for each H2B equals one million EUR. For the ease of estimation, this figure does not include the additional costs required to build appropriate facilities to maintain the buses. Furthermore, we assumed that the H2B price remains constant, although innovation certainly could and likely would reduce it over time.

Using the collected data, we proceed to aggregate bus users' mean and median WTP to compute the total WTP. This computation also requires information on the number of tickets sold by the bus company over one year. We acquired this information from the Annual Reports (2008–2012) [43] of the "Umbria Mobilità" company. We then compute the aggregate WTP after dealing with three issues: the time frame for calculating the average number of tickets sold, multiple types of tickets sold, and ticket demand elasticity. Given that the policy analysis should be based on reliable and constant structural preference parameters, we began to calculate the average of tickets sold from 2008 because in this year, MiniMetrò began operating as part of the traffic reform in Perugia. Regarding the second issue, from 2008–2012, "Umbria Mobilità" sold an average of 2,180,011 single-trip tickets and 11,622 quarterly tickets. In the same period, 6473 monthly passes and 5201 annual passes were also undersigned. Therefore, we considered the following conversion coefficients: annual Card (whole network) = 1095 trips; monthly Card (whole network = 70 trips; one route = 60 trips); and three-month card (whole network = 210 trips; one route = 180 trips). We thus obtained 10,768,836 tickets sold, on average, over the reference years (2008–2012) by the company. To calculate the WTP of the citizens of Perugia, it is necessary to multiply the estimated average of the WTP for each ticket by the totality of tickets sold in a year in Perugia. We compare this figure to the estimate of the total cost needed to replace the current fleet with H2B. We interpret this as a measure of the market sustainability of *H2B* policy development. In doing so, we assumed the demand rigidity of tickets with respect to their prices. In this sense, Bigerna and Polinori [2] estimated that in Perugia, elasticity is less than one for multiple trip passes and cards, and it is slightly above one for single-trip bus fares.

In particular, calculations should be made using the extra WTP shown in Table 10. In this case, the extra WTP associated with the different models in EUR are 0.94, 0.85, 0.67, and 0.54, respectively. Using the median, the estimation of the WTP can be attributed only to 50% of the sample, so we proceeded to halve the estimated extra WTP and still attained good results. For instance, with the WP "higher bound" model, we estimated that a total replacement of the current fleet of buses should occur within 16 years. Times change further and are even more shortened if we use the average WTP instead of the median WTP. In this case, the extra WTP amounts in EUR are 1.47, 1.31, 1.07 and 0.85. The estimated time periods for a possible replacement of the bus fleet are shown in Table 11.

Table 10. Interval data regression for H2B WTP.

Variables	**Welsh and Poe Model**							
	HB Model		**DK Model**		**PY Model**		**LB Model**	
Income	0.0634		0.0621		0.0609		0.0477	
	0.0068	***	0.0056	***	0.0053	***	0.0047	***
Education	0.1795		0.1636		0.1537		0.1222	
	0.0598	***	0.0562	***	0.0401	**	0.0333	***
Family size	−0.1085		−0.1809		−0.1199		−0.0889	
	0.0501	**	0.0908	*	0.0547	**	0.0423	*
Sex	−0.3320		−0.3495		−0.3668		−0.2968	
	0.1591	*	0.1701	*	0.1607	**	0.1399	**
Use of private car [(a)]	−0.6468		−0.5546		−0.4231		−0.3628	
	0.1591	**	0.1310	**	0.1039	**	0.0948	**
Use of LPT [(b)]	0.2087		0.1896		0.1622		0.1425	
	0.0522	***	0.045	***	0.0421	***	0.0367	***
Environmental attitude [(c)]	0.2471		0.2101		0.1488		0.1340	
	0.1203	*	0.1389		0.0755	*	0.0671	*
Retired person	−0.8419		−0.8165		−0.7441		−0.5329	
	0.4099	**	0.3991	**	0.3605	**	0.2509	**
H2B knowledge [(d)]	0.8055		0.7935		0.7818		0.6562	
	0.5210	*	0.5190	*	0.5099	*	0.4110	*
Unemployed and housewives	−0.2904		−0.2815		−0.2406		−0.2012	
	0.0642	***	0.0643	***	0.0587	***	0.0449	***
Age	−0.4052		−0.3992		−0.2995		−0.2904	
	0.1979	**	0.1989	**	0.1456	**	0.1403	**
Constant	1.5273		1.4624		1.3652		0.9966	
	0.2911	***	0.2899	***	0.2598	***	0.2019	***
Lnsigma	0.5601		0.5553		0.5471		0.5305	
	0.0232	***	0.0225	***	0.0279	***	0.0262	***
Sigma	1.7508		1.7425		1.7282		1.6998	
	0.5509	***	0.0523	***	0.0502	***	0.0485	***
Obs.	587		587		587		587	
McKelvey and Zavoina's R^2	0.1325		0.1314		0.1302		0.1263	
LR $\chi^2_{(11)}$ (LR test)	186.67		183.9		152.37		117.49	
Median WTP	**2.44**		**2.35**		**2.17**		**2.01**	
[95% C.I.]	2.21	2.65	2.13	2.59	1.91	2.39	1.88	2.22
Mean WTP	**2.97**		**2.81**		**2.57**		**2.35**	
[95% C.I.]	2.68	3.25	2.55	3.03	2.36	2.8	2.17	2.46

Significant *** 1%, ** 5% and * 10%; standard error in italics. [(a)] persons against the restriction of private car use, or at most, accept very limited restrictions; [(b)] persons who almost always or always use the LPT; [(c)] persons who differentiated waste collections; [(d)] persons who knew at least one of the three proposed questions.

Table 11. Market sustainability of H2B introduction.

% Fleet Bus Replacement	(Median WTP)			
	HB model	**DK model**	**PY model**	**LB model**
100%	16 years	18.6 years	21.6 years	31 years
50%	9 years	9.2 years	11.8 years	15.4 years
10%	1.6 years	1.8 years	3.6 years	3 years
% Fleet Bus Replacement	**(Mean WTP)**			
	HB model	**DK model**	**PY model**	**LB model**
100%	5.4 years	6 years	7.4 years	9.3 years
50%	2.7 years	3 years	3.7 years	4.6 years
10%	0.5 years	0.6 years	0.7 years	0.9 years

We can see that in some cases, the time frame considered exceeds the lifespan of the H2B. This could imply that obsolete H2B remain operative, which leads to increasing maintenance costs. Nevertheless, aspects related to H2B management are outside of our current research goal. In this case, the estimated average WTP has to be used in its entirety. Very high values emerge, which would lead to a replacement of the bus fleet in a very short period of time, and this result seems to be a good starting point for future studies (at the municipal level, this result is important for helping to convince consumers to adopt lifestyles with low environmental impacts [44]), and more in-depth analyses by the city public authorities administration could be required to obtain more robust results. Finally, we can perform a simple accounting exercise to appraise the price that should be set to allow for a complete fleet replacement within an acceptable time frame. Assuming a consistent lifespan, we can see that according to the LB model, a ticket priced at 2.35 EUR would allow a complete replacement of the fleet in less than 10 years.

7. Conclusions

In this paper, we investigated LPT users and non-users' WTP to support a policy scenario for a large-scale H2B introduction in Perugia. Our survey highlights an appreciable knowledge of H2B and related experimental Italian projects. The estimated annual WTP is appreciable and allows for a full replacement of the current fleet within 5.4 to 7.4 years; these figures noticeably increase if we use the median WTP estimation. Moreover, we computed the monetary value uncertainty, which amounts to approximately 26.7% of the current company revenue by traffic. The level of coverage given by the WTP of citizens, intended as an amount in addition to the current cost of the ticket, should still be considered adequate. Indeed, given that almost all of these projects are co-financed by some public authority, the government could rely on an already positive starting point given by the citizens. Finally, the positive impact of knowledge on the WTP highlights that a further margin could exist for additional policy actions to implement appropriate education campaigns aimed at providing information to reduce the uncertainty that affects H2 technology.

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Author Contributions

Both authors contributed equally to this work. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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