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# THE BENEFIT OF AN INNOVATIVE URBAN INFORMATION INFRASTRUCTURE: THE CHOICE EXPERIMENT METHOD APPLIED TO THE "TOTEMS" OF EU PROJECT SINFONIA

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## ABSTRACT

The diffusion and integration of the information and communication technologies (ICT) in the urban environment is a pillar of the current smart city development approach. Sensors, monitors, and portable devices allow acquisition, exchanging and querying of data (or even big data) in real time. However, the technological and digital innovation in our cities should be considered not the final goal, as the application *per se* of all the available technologies. On the contrary, this should be done as the most efficient and cost-effective way to improve citizens' quality of life. In designing and construction of an innovative urban information infrastructure, enabling the users interaction and communication, it plays a prominent role to understand how and if the project meets users expectations.

By recording the stated preferences of users is possible to determine the value of a service offered for the first time by the Municipality. Thus, a Choice Experiment valuation method (CE) is here applied to estimate the economic value of an innovative infrastructure, as a non-market good. According to the CE rules, the interviewer presents in a face to face surveys specific hypothetical scenarios, describing the offered services and costs, asking for the best and worst option. The survey involves a sample representative of the whole potential users, including citizens, commuters, and tourists. The case study analysis is developed within the European smart city project SINFONIA. In this context, CE allows researchers to estimate the perceived benefits of forthcoming smart points, called "totems", in the Italian city of Bolzano, and to provide designers with insights on additional attributes.

The suggested method allows designers and decision makers to clear understand citizens' priorities and expectation toward an innovative urban infrastructure. The purpose of this paper is also to contribute to a better understanding of the socio-economic aspects connected to the implementation of smart devices in the urban environment. It shows a high replicability potential in other similar contexts, undertaking the smart city development approach.

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## 1. Introduction

All over the word, urban settlements are embracing the so-called “smart city” development approach. Basically, it means ensuring a better quality of life for citizens, by making a full use of information and communication technologies (ICT), in compliance with the sustainable development principles (Mosannenzadeh et al., 2016). Currently, there is a sort of environmental-technological nexus, where ever more people is confident with the internet and mobile devices (see the high market penetration of smartphones) and at the same time aims to “live greener”. Consumers preferring organic products to large scale agri-food industry goods, or drinking tap water instead of bottled, are asking to urban public authorities and service companies to support local agri-food markets, to install drinking water facilities in public spaces and to promote eco-friendly happenings. Similarly, environmental issues as local air pollution, call for tangible measures aiming at reducing emissions; for example, by encouraging people to use electric vehicles in urban commuting instead of traditional cars. In this context wireless connections, interactive communication tools and innovative devices are essential components to involve citizens in tackling urban challenges and to make useful the huge amount of information, also called “big data”, continuously harvested by sensors and stored in servers. New public infrastructures are expected to increase the quality of life of the residents, meeting their needs and satisfying expectations. In a context of scarcity of public budgets, investments should be done carefully, without following the “smart city” fascination uncritically. In some cases, a merge between innovation and traditional solutions, well designed for the specific context, allows the best result.

Starting from these premises, and in view of a public funding for an innovative urban information infrastructure in the city of Bolzano, some specific questions rise: (i) do people prefer to have only information or do they need additional services? (ii) What services mostly increase the perceived benefits? (iii) Is there any kind of willingness to pay for them? We decided to investigate these points by using the Choice Experiment method, as face to face questionnaire surveys are usually adopted as a major instrument for eliciting citizens or tourists’ preferences for non-market goods, as changes in landscape quality, environmental resources quantity, and availability of new green features in buildings (Chau, Tse and Chung, 2010).

In this paper, a brief description of the study area and data collection method is presented, together with a general overview ion the methodology and assumptions. Then, results from the testing phase (involving citizens, urban commuters, and tourists in Bolzano) are presented and insights gained commented, in order to fix bugs and improve the statistical efficiency of the forthcoming major survey.

## 2. Methods

### *2. 1. Study area and data collection*

The study has been carried out in the city of Bolzano, which is a city in the northern part of Italy. Bolzano, with approximately 100,000 inhabitants, is the main city of South Tyrol, a mountainous province in the Alps. The city itself and the surrounding alpine territory are a well-known holiday destination, appreciated for a high environmental quality and hospitality. Efficient public services (especially transportation) and a green tourist-oriented marketing also contribute to promoting the image of Bolzano as well organized territory inland and abroad. At the country level, the city often ranks on the top of yearly charts comparing the quality of life in different contexts. In 2015 it was first-ever and under the “free time” category for presences at cultural events, sports, and expenditures from foreign tourists (Sole24Ore, 2015).For historical and cultural reasons, Bolzano is characterized by strong liaisons to the neighboring Austria, it is, in fact, bilingual and both Italian and German are official languages. The economy of the region, and similarly of the city, is based on services and a good industrial sector, which allowed Bolzano to be one of the richest Italian city. At the same time, the municipality committed to making out of Bolzano a smart and technological city, in order to increase inhabitants’ well-being.

In mid-2014 the municipality of Bolzano joined a five years smart cities and communities project, funded by the European Union. The so-called “SINFONIA project”, whose acronym stands for “Smart INitiative of cities Fully cOmmitted to iNvest In Advanced large-scaled energy solutions”, is going to develop some different smart measures within the city. The main benefit for single users will be a deep energy retrofit of selected dwellings in public owned residential buildings, while the most relevant result for the community will be the implementation of an innovative urban information infrastructure. Such infrastructure will interact with users through some smart points, called “totems”, to be located in the most strategic areas of the city.

In this framework, the present research undertakes the issue of what could be the most appreciated services for citizens, urban commuters, and tourists in Bolzano. Data collection was made by means of a semi-structured questionnaire, structured as the typical CE survey (Carson et al., 1994; Adamowicz et al., 1998), personally administrated to the local inhabitants during month July 2016. Two interviewers were recruited for the data collection. This paper discusses the result of the pre-test, which is conducted with the aim of receiving feedbacks from the present version of the questionnaire and collect priors for increasing the design efficiency for the major survey (Johnson et al., 2013). The present version of the questionnaire contains 4 sections, for a total of 29 questions. The first section contains introductory and “warm-up” questions, with the main objective of presenting the topic and let respondent be familiar with it. The second section includes attitudinal questions, to assess the degree of knowledge and feeling of the respondent with technology in general and informative points in particular. The third section contains the choice tasks and lastly, the fourth section contained socio-demographic questions to collect information about the sample. The CE exercise was designed according to the guidelines available in the literature (Hoyos, 2010; Riera et al., 2012). Relevant attributes and attribute levels included in the choice tasks are summarized in table 1. Attributes were chosen from a list of candidate services that was discussed with representatives of the municipality of Bolzano. In particular, possible solutions involve the inclusion of SOS points, water supply, hotspot for Wi-Fi connections, some level of information about the city (in particular information about weather conditions, tourist attractions and for residents), electricity supply (for tablet and smartphones, electric bicycles and electric cars) and information about mobility (parking area availability, free charging areas and traffic information). Finally, the last attribute is the cost associated with each alternative, in the form of a monthly ticket to be paid to access those services. The status quo situation (SQ) is a situation with a basic level of services, still hypothetical because these infrastructures have to be built. In particular, the SQ foresees a basic level of totems with no SOS, no water supply, and no Wi-Fi connection. The only available services are: charging points for smartphones, information about weather conditions and, concerning mobility, information about available parking spaces.

*Table 1 – Attributes and levels for the experiment*

| **Attribute** | **Description** | **Levels** |
|---|---|---|
| SOS | Emergency call service | Yes (SOS)<br>No (SQ) |
| WATER | Drinking water | Yes (WATER)<br>No (SQ) |
| WI-FI | Hotspot for Wi-Fi connection | Yes (WI-FI)<br>No (SQ) |
| ELECTRICITY | Charging station | Devices (tablet + smartphone) (SQ)<br>Electric bicycle (BICYCLE)<br>Electric vehicle (AUTO) |
| INFO | Information about the city | Weather and environmental conditions (SQ)<br>Touristic and cultural (TOURISTS)<br>For residents (RESIDENTS) |

| | | |
|---|---|---|
| MOBILITY | Information about mobility | Availability of charging points for vehicles (SQ)<br>Traffic conditions and public transports (TRAFFIC)<br>Availability of parking spaces (PARKING) |
| COST | Monthly cost of the option (€) | 0 (SQ),<br>0.50<br>1.00<br>1.50<br>2.00<br>2.50<br>3.00 |

*Source: Author's own elaboration*

In order to allocate attributes in the alternatives, a rotation orthogonal design with 36 choice tasks was created, subsequently arranged in 3 blocks, using the software "R" and in particular the function called "rotation.design" in the package support "CEs" (Vecchiato and Tempesta, 2015). Each respondent was required to complete 12 choice tasks, composed by 2 alternatives and the SQ option (which is the current situation with the infrastructure designed to provide a basic level of information services). An example of a choice task is given in figure 1. After the pre-test, prior values for the parameters will be estimated, so that the experimental design could be modified in order to increase its statistical efficiency, following a procedure described by Huber and Zwerina (Huber and Zwerina, 1996). The efficiency of the new design will be evaluated based on the D-error criterion, as explained by Rose et al. (2008).

*Figure 1 – Example of choice task*

| SERVICES | OPTION 1 | OPTION 2 | OPTION 3 |
|---|---|---|---|
| SOS | NO | YES | NO |
| WATER | YES | NO | NO |
| WI-FI | YES | NO | NO |
| ELECTRICITY | • TABLET or SMARTPHONES | • TABLET or SMARTPHONES<br>• ELECTRIC BICYCLES | • TABLET or SMARTPHONES |
| INFO | • WEATHER and ENVIRONM. CONDITIONS | • WEATHER and ENVIRONM. CONDITIONS<br>• TOURISTIC and CULTURAL | • WEATHER and ENVIRONM. CONDITIONS |
| MOBILITY | • FREE PARKING SPACES<br>• FREE CHARGING POINTS | • FREE PARKING SPACES<br>• FREE CHARGING POINTS<br>• TRAFFIC CONDITIONS and PUBLIC TRANSPORTS | • FREE PARKING SPACES |
| COST | 2.00 € | 2.50 € | 0 € |
| **BEST OPTION** | | | |
| **WORST OPTION** | | | |

*Source: Author's own elaboration (translated from the Italian questionnaire)*

### *3. 1. Econometric modeling*

The CE methodology is embedded in McFadden´s Random Utility theory (RUM), stating that individual choices are observable with a certain degree of uncertainty (Manski, 1977). According to RUM, the utility that people derive from a certain purchasing option is given by:

$$U_{int} = V_{int} + \varepsilon_{int}$$

Where $U_{int}$ is the global utility obtained by individual I, from alternative n in the choice situation t, $V_{int}$ is the observable (deterministic) component of the utility, while $\varepsilon_{int}$ is a random unobservable disturbance. The analyst is able to evaluate the deterministic component of the utility that, according to Lancaster´s attribute theory (Lancaster, 1966), is given by the sum of the utility provided by each attribute of the option:

$$V_{nt} = \beta_t X'_{tn}$$

Where $X'_t$ represents the vector of attribute of the option n in the choice situation t and $\beta_t$a vector of parameters, indicating the effect of each attribute in the composition of the observed utility. In order to evaluate $V_{nt}$ with a statistical model, it is necessary to make assumptions about the distribution of $\varepsilon_{int}$ (Henser, Rose and Greene, 2005). The most common way to do that is to assume a Generalized Extreme Value distribution type I, allowing the computation of choice probabilities through a Multinomial Logit Model (MNL). Under the assumption of Independently and Identically Distributed (IID) random terms and the Independent from Irrelevant Alternatives (IIA), the MNL model restitutes one point estimate for each parameter. For this reason, is not capable to capture preference heterogeneity across respondents. When preferences across respondents is supposed to matter, a common statistical specification to relax the assumption of preference homogeneity is to implement a mixed logit model (MXL). MXL assume a random distribution of the parameters, thus it is possible to compute individual parameters. In the MXL model, choice probabilities take the form (Train, 2003):

$$P_{ni} = \int \frac{e^{\beta'_n x_{ni}}}{\sum_j e^{\beta'_n x_{ni}}} \varphi(\beta | b, \Omega) d\beta$$

In which $\frac{e^{\beta'_n x_{ni}}}{\sum_j e^{\beta'_n x_{ni}}}$ is the logit formula, $\varphi(\beta | b, \Omega)$ is the density function of the distribution of the coefficients. A common practice in empirical evaluations is to assume normally distributed parameters, to a lesser extent analysists make use of triangular or uniform distributions. The cost attribute is assumed to be constant; this is not likely to be verified in reality because people may react differently to price changes, but it is done for computation reasons. The calculation of willingness to pay (WTP) for each single attribute is given by the negative of the ratio between coefficients, formally:

$$WTP_b = -\frac{\beta_b}{\beta_{cost}}$$

From this equation, it is possible to see that, assuming a normally distributed cost coefficient, the computation of WTP would be given by a ratio between two normal distributions. Such an operation restitutes a Cauchy distribution that doesn´t have central finite moments and it is not desirable (Giergiczny *et al.*, 2012). Thus, a constant price attribute is preferred. In this paper we make use of the standard MNL and of the MXL to model information point choices (Greene, Hensher and Rose, 2006), all the computations were done in R statistical software (R Core Team, 2013).

## 3. Results and Discussions of the testing phase

As already mentioned, this paper discusses the preliminary result of the study, i.e. the pre-test that was completed with the main objective of collecting priors for the parameters. Priors are useful to increase the efficiency of the design, which will be modified for the main survey. During the pre-test it was possible to

collect 37 questionnaires, out of which only 29 were compiled enough to be useful for the analyses. Given that we had 12 choice tasks per respondents and each choice task had to be filled with the best and worst alternative, it was possible to collect 24 observations per individual, thus leading to 696 total observations. In Table 2 results of the MNL and MXL models are provided. It is possible to see that, even if the sample is rather small, several variables are significant at least at 10% of confidence level. This might be considered a good result, because from the literature it is well-known that orthogonal designs require much bigger sample sizes for the variables to be significant, compared to efficient designs (Rose *et al.*, 2008; Rose and Bliemer, 2009; Greiner, Bliemer and Ballweg, 2014).

*Table 2 – Results of the MLN and MXL models*

| | MNL | | | MXL | | |
|---|---|---|---|---|---|---|
| **Attribute** | **β** | **St. err.** | | **β** | **St. err.** | |
| | | | | **Fixed Parameter** | | |
| COST | - 0.3197 | 0.1057 | ** | - 0.535 | 0.125 | *** |
| | | | | **Random Parameter** | | |
| SOS | 0.2547 | 0.1291 | * | 0.495 | 0.209 | * |
| WATER | 0.3909 | 0.1316 | ** | 0.429 | 0.201 | * |
| WI-FI | 0.8167 | 0.1317 | *** | 2.362 | 0.356 | *** |
| BICYCLE | 0.2883 | 0.1944 | | 0.490 | 0.278 | . |
| AUTO | 0.4452 | 0.1721 | ** | 0.785 | 0.223 | *** |
| TOURISTS | 0.4638 | 0.1789 | ** | 0.438 | 0.227 | . |
| RESIDENTS | 0.5556 | 0.1835 | ** | 0.511 | 0.241 | * |
| TRAFFIC | - 0.1052 | 0.1863 | | - 0.144 | 0.228 | |
| PARKING | 0.2341 | 0.1749 | | 0.590 | 0.235 | * |
| SQ | - 0.5446 | 0.3243 | . | - 0.556 | 0.408 | |
| SCALE | 0 | 0 | | 2.761 | 0.663 | *** |
| | | | | | | |
| Sd_SOS | | | | 1.623 | 0.252 | *** |
| Sd_WATER | | | | 0.877 | 0.211 | *** |
| Sd_WI-FI | | | | 1.850 | 0.279 | *** |
| Sd_BICYCLE | | | | 0.000 | 0.248 | |
| Sd_AUTO | | | | 0.119 | 0.291 | |
| Sd_TOURISTS | | | | 0.277 | 0.237 | |
| Sd_RESIDENTS | | | | 0.828 | 0.222 | *** |
| Sd_TRAFFIC | | | | 0.571 | 0.274 | * |
| Sd_PARKING | | | | 0.209 | 0.180 | |
| Sd_SQ | | | | 2.561 | 0.297 | *** |
| LL | - 533.63 | | | - 428.22 | | |
| AIC | 1090.78 | | | 898.43 | | |
| BIC | 1145.33 | | | 993.88 | | |
| N | 696 | | | 696 | | |
| **Respondents** | 29 | | | 29 | | |

.,*,** and *** indicate significance levels of 10%, 5%, 1% and 0.1%, respectively

*Source: Author's own elaboration*

Concerning attributes, the coefficient for the COST of the alternatives is negative and statistically significant at 1% of confidence level. This is usually the most important result in a CE application, because it proves that paying money reduces the perceived utility of any alternative. With regard to the other attributes,

it is be shown that people are willing to pay positive figures for many of them. In particular, the coefficient for SOS is positive and statistically significant, as well as coefficients for WATER and WI-FI. These are dummy variables, so including such features in the final design of the totems contributes to a higher appreciation of this foreseen infrastructure. On the other hand, BICYCLE is still positive but not statistically different from zero, which means that people are indifferent to having electricity points for bicycles, compared to the basic level that provides power for tablet and smartphone. This might be for several reasons. For example, not many people have electric bicycles, thus such attribute might be less important for many. Although in fact these achieved in the last years a quite satisfactory local market penetration and are used by daily commuting within the city by students and workers. Moreover, electric bicycles are currently offered to guests by several hotels or rented to tourists. Probably the result relates to the fact that electric bicycles do not require constant charging, and their autonomy in most of the cases matches the current daily needs of users. Thus it could be irrelevant for many to have such an additional feature outside their home or accommodation place. The coefficient for AUTO is positive and statistically significant. This result is in a way surprising if jointly read with BICYCLE, because people seems not willing to pay for electric bicycles only, but they are for having the possibility to charge both bikes and cars, the latter being not much common in Italy. This result could be seen may be as anticipating a further development in the electric vehicles (EV) sector. Availability and wide territorial coverage of charging stations are fundamental requirements for an increase in public acceptance and trust toward EVs (Zubaryeva *et al.*, 2012), those are beneficial for decreasing polluting emissions in transport and reducing dependence on fossil fuels. Concerning INFO, the level is positive for both coefficients: additional levels of information provided (for tourists and local inhabitants) contribute to increasing the perceived benefit. Conversely, the attributes for MOBILITY are not significant, thus such attribute levels seem not to be relevant in the computation of individual preferences. Finally, the SQ is negative and significant. A negative coefficient for the SQ is an indication that people tend to prefer alternative solutions, compared to the present situation (in this case a basic solution of an informative panel). For this reason, additional characteristics of the totems seem to be reasonable to increase the benefit of the users. The last parameter called SCALE, is the scale parameter connected with the second-best choice and it is usually included to assess whether the variance of answers vary when the number of alternatives decreases (Goodman, 2005; Scarpa and Notaro, 2009). In this case, the scale is very close to 0, meaning that variance is constant between the best and worst choice.

Looking at the MXL model results it is possible to notice that parameters are slightly different in the magnitude, while almost all of them are coherent in the sign. The SQ becomes non-significant. This result, jointly read with the significance of the standard deviation of the SQ, indicates that, when taking into account preference heterogeneity, the current situation is on average nonimportant for respondents, but with many differences across the sample. In general, the MXL model considerably increases the level of log-likelihood, meaning that it is probably a better model for the data. In particular, having the log-likelihood closest to zero (it goes up to -428 from -533, as in MNL), indicates a considerable improvement in a fitting curve to observations. The significance of many parameters variance is an indication that preference heterogeneity matters. Concerning point estimates of the parameters, it has to be noticed that the WI-FI parameter sharply grows from around 0.8 up to about 2.3, while the others remain very similar. In this model, the scale parameter is also important and statistically significant (with a value of about 2.7).

Table 3 shows the computation of WTP for each attribute. From this table it can be seen that the higher level of WTP is for having a WI-FI connection (2.55 €/month). This figure increases up to 4.4 €/month in the MXL model. WTP for information is high as well, assessed to be 1.45 €/month for including tourist information and 1.74 €/month for including also information to citizens. These figures reduce if calculated with a MXL model to 0.82 and 0.96 €/month, respectively.

*Table 3 – WTP for each attribute*

| | WTP (€/month) | |
|---|---|---|
| **Basic level (SQ)** | **MNL** | **MXL** |
| Digital information panel and charging station only for devices (tablet + smartphone) | - 1.70 | - 1.04 |
| **Additional attributes** | **MNL** | **MXL** |
| Emergency call service (SOS) | 0.80 | 0.93 |
| Drinking water | 1.22 | 0.80 |
| Hotspot for Wi-Fi connection | 2.55 | 4.41 |
| Charging station for electric bicycles | 0.90 | 0.92 |
| Charging station for electric bicycles and vehicles | 1.39 | 1.47 |
| Cultural and tourists information | 1.45 | 0.82 |
| Cultural and tourists information, and interaction with municipal information office | 1.74 | 0.96 |
| Information about traffic conditions and public transports | - 0.33 | - 0.27 |
| Information about traffic conditions, public transports and availability of parking spaces | 0.73 | 1.10 |

*Source: Author's own elaboration*

Subsequently, WTP for electricity supply for vehicles and emergency call are positive as well but with a lower magnitude, while WTP for mobility information is quite low compared to other attributes. The WTP for SQ is negative, indicating disutility coming from having a basic level of information points, without innovative services.

This study is just a pre-test, implemented for a better tailoring of the major survey, so results can change after the administration of more questionnaires and the fine tuning of the experimental design. Still, it is important to notice that these data, although coming from a small sample, provide interesting insights about people´s preferences. For example, it is possible to see that probably, the inclusion of Wi-Fi and several types of information within the final version of the totems might be preferred by citizens, because of their high coefficients and significance levels. In addition, it is possible to notice that preference heterogeneity seems to be an important issue in this case. The superiority of the MXL model is not only given by the performance of the parameters, which are on average more significant, but also by the standard measures of goodness of fit. In particular, the AIC and BIC statistics are lower in the MXL model, indicating a better performance of this model. One might think that MXL model is, therefore, more appropriate to investigate the heterogeneity of totems' catchment area. Moreover, a further investigation of answers to attitudinal or socio-demographic questions will help to understand how different categories of users perceive the benefit of an innovative urban infrastructure with additional services.

## 4. Conclusions

The present contribution has shown the results of a pretest for a CE application, aimed at estimating individual´s preferences for smart information points in the city of Bolzano. The main objective of this pre-test was to obtain estimations of the prior distribution for the coefficients for each attribute included in the study, in order to improve statistical efficiency for the major survey. Results highlighted that most of the coefficients for policy attributes are positive, meaning that those features for totems are perceived as beneficial for the city. Conversely, the SQ situation has a negative WTP, thus indicating that the present situation (a basic level of the infrastructure) is perceived as not optimal for the city.

In stated preference studies, the main positive aspects are related to the possibility to investigate preferences of social actors that are affected by public choices, in order to obtain insights about their needs and, possibly, tailor policies or measures based on their tastes. Drawbacks of this approach are connected to the high costs of doing the survey, in terms of economic, time and human resources effort. In addition, it is well-known that stated preferences applications suffer from some bias, which is common to all questionnaire survey. Next steps for this research will include the modification of the design for the major field survey,

which will be administered face-to-face by means of recruited interviewer and translated in German. Moreover, the pre-test highlighted the need of minor modification of layout and the wordings of some questions, which will be considered for increasing the quality and clarity of the questionnaire. This step is very important in surveys, because it is rarely possible to assess *a priori* the adequacy of a questionnaire as a tool for collecting information. Pre-tests give the possibility to modify the questionnaire based on respondents reaction and, consequently, increase the quality of the data in the major survey.

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