Perceived risk of urban water consumption: Scale development, validation and characterisation in Spain

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ABSTRACT

The objective is to develop a measure of perceived risk underlying urban water consumption (UWC) that is applicable in situations of drought and strong rainfall. First, we analyse existing scales and the dimensions involved in perceived risk related to UWC. Second, we test our proposed scale using two studies. Study 1 was carried out in Spain in 2012 (n = 701) during a period of heavy rains. Study 2 was performed in 2014 in the semi-arid area of Spain (n = 477) during a long drought period. The proposed scale has three dimensions (impact, time-related and control) and high reliabilities (0.86–0.89), validities (convergent, discriminant, construct) and is invariant between both rainy and dry periods. UWC Perceived Risk Scale fits into a Pearson 'Type VI distribution', which can serve scholars and technicians in measuring urban water perceived risk in their researches and urban water management projects.

1. Introduction

Increasingly urban populations, levels of consumption higher than the speed of replenishment and climate change, are adversely affecting the availability of water for urban uses and consumption. These problems, together with the rapid expansion of cities and the current periods of drought and flooding have made water scarcity a major urban problem in the early 21st Century (Miller 2006).

Unlike many natural risks, the ones related to urban water consumption can be regarded as unbound and invisible (Wachinger and Renn 2010) affecting individuals, their quality of life and surrounding territory. In most countries, residents consume water from distribution networks under public and private management. The general public believes that water is readily available and is unconcerned about water supply issues and the process of getting water to its faucets (Solomon et al. 2014). However, the public also perceives latent risks in its own levels of consumption and the uses of available water (Domènech et al. 2010).

It is important to quantify and characterise this risk perception because depending on how risks are perceived (low/high), individuals will be more or less likely to (a) collaborate with hazard reduction (McCaffrey 2004) and (b) demand that distribution managers take steps to ensure supply. Therefore, understanding public perception of the risk related to urban water consumption (and the ways in which water is consumed) can help improve water management (Kiriscioglu 2010). Additionally, the gap between the perceptions of the residents and the decisions taken by the water managers could be reduced (Dobbie and Brown 2014). Similarly, to conduct adequate communication actions, policy-makers must have information on how the public perceives the risks (Willis et al. 2004). Finally, it has been argued that citizen participation is necessary to design and implement public policies on water concerns and that the different evaluations of real and perceived risks must converge.

However, we have not found any instrument that measures the public’s perception of the risk underlying urban water consumption. Additionally, we have not found a characterisation of citizens grounded on declared perceived risk. Therefore, the objective of this study is to develop an instrument to measure this perception. We also aim to design an instrument that is easy to implement in questionnaires, commonly used by municipalities, other institutions and in a wide range of water research projects.

To achieve our objectives this research starts by defining what hazards and risks are, and analysing their dimensions. We present two studies in two different contexts within the same country (Spain). The first one was conducted in 2012 in a strong rainfall period while the second one in 2014 in a drought period. This allows us to check the invariance assumption of the proposed scale confirming that our scale is not sensitive to climate context (rainy vs. dry period). We describe the method used: participants, the method of contacting them and how the materials and questionnaire were constructed. We then present the results, the goodness of fit, reliability and validities of the proposed scale. Finally, we discuss the findings and the utility of the proposed scale for perceived risk analyses.
2. Background

2.1. Definitions

Urban water consumption comprises the 8–11% of worldwide water that is used for domestic and urban uses, in contrast to the 19–22% used by industry and the 70% used in agriculture (FAO 2015). However, this 8–11% is very important because it is the water that directly reaches citizens, which they use for personal health, sanitation, leisure, household cleaning and feeding. At the same time this water requires exhaustive treatment to achieve sufficient quality for consumption. Additionally, ‘hazard’ can be defined as the ‘intrinsic ability of an agent or situation to cause adverse effects to a target such as people, environment, etc.’ (Scheer et al. 2014, p. 2) while ‘risk’ as a function of the likelihood of an event actually occurring, its intensity, the extent of the damage it causes and the vulnerability of the people it affects (Godfrey and Howard 2005). Therefore, ‘hazard’ exists by itself as a contingency or source of (real or potential) damage, whereas, ‘risk’ refers to the potential for this source to cause real damage (Kaplan and Garrick 1981).

Although ‘hazard’ and ‘risk’ are two different concepts, they are often misused interchangeably (Scheer et al., 2014). Literature has also shown that the public does not differentiate between them because they do not understand the concept of probability (Lofstedt 2011), the language they use is non-technical and non-discriminatory, or they associate the concept of hazard with the ‘impact’ it may produce (Wiedemann et al. 2010).

2.2. Water consumption hazards in urban environment

Hazards can be classified as natural (floods, droughts), technological (mainly related to the quality of drinking water and the use of recycled water) or mixed (e.g. ‘scarce’ because it combines drought with infrastructures – as technological). There are, however, two issues that are less visible to the public but that generate significant problems like water shortage: water consumption levels and the use of available water (McDonald et al. 2014). This scarcity is increased by the effects of climate change on coastal cities (e.g. McGranahan et al. 2007) and because of changes in urban models, which have promoted an increase in water consumption. For example, Southern Europe and North African countries have switched from a traditional compact urban model to a more dispersed urban model with higher water consumption (Kasanko et al. 2006). This situation, combined with a more and more reduced availability, increases the water stress hazard, posing greater problems for water management and quality of life.

2.3. Risk perception and its measurement

There are two major approaches to study and measure risk: the objective and subjective approaches. The first one assumes that risk is the most likely variation based on actual experiences, and is determined by measurable physical facts (Hansson 2010). The second one maintains that a risk represents an uncertainty based on each individual’s vision. Therefore, objective or expert (scientific) measurements are insufficient for evaluating it properly (Slovic 1999). It has been affirmed that what matters is the perception of risk rather than the statistical probability or ‘expected technical impact’. This is because such perception may better help understand human behaviour (Renn 2008).

Lazo et al. (2000) showed that the public generally perceives greater ecological risk than experts. Slimak and Dietz (2006) found that experts are more concerned about high-impact long-term ecological risks, whereas the public is more concerned about risks that produce serious consequences, although the likelihood of them actually occurring is low. In turn, the public tends to underestimate high-risk events and to overestimate small-risk ones.

In their study, Kiriscioglu et al. (2013) found no differences between experts’ and the public’s urban water consumption risk assessments. Nevertheless, other researchers found divergent viewpoints between the public and experts (policymakers and scientists) regarding risks in potable water safety, and water demand supply at regional level – the public’s perceived risk was higher (Larson et al. 2009). In this regard, Po et al. (2003) affirmed that the public’s risk perception of water reuse is generally higher despite the treatment guarantees given by experts and authorities.

The question of how the public perceives risks has generated discussion in the literature. Thus, Starr’s (1969) seminal work suggested that it is not sufficient to just calculate the number of fatalities to analyse the risk of a particular hazard. It was Fischhoff et al. (1978) who initially used the psychometric paradigm to identify the factors/dimensions influencing perceived risk. In these early investigations, respondents were presented with a long list of potential hazards which they had to evaluate according to various attributes.

Since the nineties, several studies have included water hazards as part of potential ecological hazards (e.g. McDaniels et al. 1995, Lazo et al., 2000). Subsequently, hazards and risks were restricted to ‘specific topic areas’, which has reduced the list of attributes analysed and introduced new attributes to improve risk characterisation [in supplementary materials Table A shows some scales used to measure perceived risks including water-related hazards]. These scales are based on the two main approaches used in the literature to measure risk perception: the psychometric and the socio-cultural. The first one assumes the characteristics of risk influence the individuals’ judgments of risk. It uses psychophysical scaling methods and multivariate analysis to create quantitative representations of the attitudes and perceptions of risk based on its attributes at individual level. However, the socio-cultural approach suggests that perception of risk is formed in the context of a range of social, cultural and political factors (Bickerstaff 2004).

2.4. Dimensions of urban water consumption perceived risk

Perceived risk is not a one-dimensional construct. Its dimensions vary depending on the phenomenon or event. The literature highlights six dimensions: social, financial, psychological, performance, time-related and physical (e.g. Hoyer and MacInnis 2008). However, this list increases or decreases according to the product, type of risk and consumption situation.

We have found few studies analysing perceived risks in environmental and water topics. McDaniels et al. (1995) characterised ecological risks using a sample of students (n = 68). Sixty five ecological risks (both natural and man-made) were presented and assessed using 30 scales or tests¹ (e.g. certainty, scope of impacts,
destructiveness, etc.) all of them seven point ranged. They found that the ‘ecological risk’ construct had five dimensions (hidden factors not directly measurable and observable), where the dimensions ‘impact of the hazard’ and ‘availability’ almost explained two thirds of the total information contained in the construct measured – variance. Among all the statements that describe the ‘ecological risk’ construct, they only introduced two related to water in urban environment: urban water uses and housing. Subsequently, Lazo et al. (2000) compared expert perceptions (n = 26) and public perceptions (n = 24), using 13 hazards from McDaniels et al.’s (1995) study. They found four latent variables or dimensions that explained 95.4% of the total information contained in the obtained scores – variance. In this study the dimensions of ‘impact’ and ‘avoidability/control’ are also very important. Additionally, this study did not introduce any water-related hazards.

Previously, McDaniels et al. (1997) analysed the perception of ecological risk to water environments using a sample of 183 people. They found four factors where the impact dimension (including immediacy of impacts) explained more than 50% of the original information of the perceived risk variable and controllability 10% approximately. Recently, Kiriscioglu et al. (2013) conducted a study with a sample of 115 people. They found three dimensions: ecological impact (including immediacy of impacts), benefits and controllability of hazards, which explain 57.2% of the total variance.

2.5. Evaluation of previous instruments

The described instruments in Section 2.4 analyse a wide variety of hazards, involving long lists of attributes to provide a minimal characterisation of each one. The problem with extensive risk lists is that it is not clear if respondents actually know about the risks they are evaluating (Weyman and Kelly 1999). Moreover, Axelrod et al. (1999) introduced rest periods while questionnaires were being completed, although it is known that lengthy lists are fatiguing, produce rejection and missing data. Additionally, long lists do not guarantee better results as their length can be reduced without reducing the predictive validity (Burisch 1997).

For the above reasons we decided to develop a new instrument to measure the public’s perception of the risk underlying urban water consumption.

3. Method

Two studies have been performed. Study 1 was conducted during November 2012, but this month was one of the rainiest months of the past 30 years (more than double the averages for the more drought prone areas of the south and southeast). Then, a Study 2 was conducted in May 2014, during a drought period, to avoid possible systematic bias in the responses of Study 1. From January to May 2014 rainfall was 25% of what is usual for that period in Southeastern area.

3.1. Country and context

Both studies were conducted in Spain, a country with the lowest water resources per capita and the largest Water Exploitation Indices2 (30.2 in 2010) in Europe. A significant part of Spanish territory has high water stress, which will increase in the coming decades. It also has very severe environmental problems produced by the overexploitation of aquifers, uncontrolled urban construction, and highly politicised water management that has promoted conflicts between citizens from different regions. However, Spanish citizens do assume the problems derived from water scarcity, resulting in low litres per capita per day consumption (LCD) compared to other countries. Madrid, Barcelona and Valencia (major cities in Spain) consume 131, 110 and 113 LCD respectively, while other European cities such as London, Stockholm or Oslo consume 158, 178 and 197 LCD, respectively (IWA 2010).

3.2. Dimensions under consideration

To characterise the perceived risk of urban water consumption, we have taken into account three dimensions that are consistent throughout the risk perception literature:

(1) Impact of the hazard, determined by the subjective importance of consequences for individuals. As the severity and duration of the impact on individuals or their social groups (low availability and quality of the resource) increases, so does perception of the hazard (Hoekstra et al. 2012). Previous literature on perceived ecological risks (e.g. McDaniels et al., 1997) has shown that impact is the most important factor when evaluating this construct. Therefore, in risk situations where individuals could directly experience negative consequences, as in the case of hazards associated with urban water practices, the perceived importance of the risk exceeds the information they can obtain from other people, organisations or the media (Takács-Sánta 2007).

(2) Immediacy of negative impacts. This is a time-related dimension of the consequences and refers to the perceived proximity of the negative consequences of hazards related to urban water consumption. In the case of environmental hazards, this dimension typically has a high level of uncertainty, and its consequences are perceived as very distant in time (Gattig and Hendrickx 2007). This situation suggests that hazards that seem distant are perceived as less serious, while their negative consequences increase as they are perceived as more present (see Vlek and Keren 1992).

(3) Avoidability/controllability of impacts or perceived capacity for controlling a hazard, ensuring that it does not generate problems. In the case of urban water, this refers to the public’s belief that (a) their actions can help prevent the problem and (b) water managers will be able to prevent the hazards (O’Connor et al. 1999). There is an inverse relationship between perceived control and perceived risk. In the case of natural hazards, this control is not only perceived individually, but is also related to trust in the perceived ability to manage the resulting risk (Weyman and Kelly 1999).

3.3. Item and scale development

We considered the three factors explained in Section 3.2. Researchers created a list of eight adjectives for each factor with
their corresponding antonyms. Two focus groups discussed the three lists to discard the adjectives that were likely not to be understood within the context of ‘risk relating to urban water consumption’. Each focus group had six individuals: Group 1 consisted of people in the 18–25 age range, and group 2 consisted of seniors (60-older).

The question and initial items were developed in Spanish. To fully ensure that the full text presented in this paper evokes the same semantic fields in both Spanish and English, the terms used have been transcribed with the back translation system. The researchers translated the Spanish terms into English and then a bilingual professor translated them back from English to Spanish, proving the term meanings remained the same. Following we present the accepted items in the Spanish language with their equivalent in English:

**Question:** How would you qualify the risk associated with current water consumption (in Spain)? Semantic differential scale from 1 to 7 is used.

**Factor 1 (Impact):**

- **F1a.** Non-important vs. very important (No importantes vs. importantes).
- **F1b.** Non-dangerous vs. very dangerous (No peligrosos vs. peligrosos).
- **F1c.** Inoffensive vs. hazardous (Benignos vs. graves).

**Factor 2 (Time-related):**

- **F2a.** Long term vs. short term (Largo plazo vs. corto plazo).
- **F2b.** Distant vs. close (Lejanos vs. inminentes).
- **F2c.** Non-urgent vs. very urgent (No urgentes vs. urgentes).

**Factor 3 (Control and management):**

- **F3a.** Manageable vs. non-manageable (Gestionables vs. imposibles de gestionar).
- **F3b.** Governable vs. non-governable (Manejables vs. inmanejables).
- **F3c.** Easily surmountable vs. non-surmountable (Fácilmente superables vs. no superables).

### 3.4. Participants

For Study 1 target population comprises Spanish citizens aged 18 or over. We obtained 701 participants: 298 men (42.5%) and 403 women (57.3%), ranging from 18 to 73 years of age. The average age was 32.6 years (SD = 12.7): 34.8 for men (SD = 13.3) and 38.4 years for women (SD = 13.3). 51.1% of respondents had a high school education or lower, and 20.1% are university graduates. For Study 2, the target population comprises all residents aged 18 or over in the provinces of Murcia and Alicante, where the drought was more intense in the period studied. We obtained valid and accurate responses from 477 participants from 44 towns: 243 men (50.9%) and 234 women (49.1%), all between the ages of 18 and 60. The overall average age is 38.3 years (SD = 13.1). The average for men is 38.2 years (SD = 12.9) and 38.4 years for women (SD = 13.3). 79.9% of respondents have a high school education or lower, and 20.1% are university graduates.

### 3.5. Fieldworks

For Study 1 we used two survey methods. First, a Web questionnaire was disseminated on social networks and via email. Second, because the Spanish population over the age of 60 has limited access to the Internet, we used traditional paper-and-pencil survey with this segment. For Study 2, to minimize self-selection bias, we designed a unique traditional paper-and-pencil questionnaire conducted by interviewers in face-to-face interviews. Participants were approached in public places using a systematic random procedure.

### 4. Results

#### 4.1. Model measurements

For Study 1 confirmatory factor analysis (CFA) for three-factor structure was used applying robust methods for the assumption of non-standard estimator corrections. The result reveals a poor fit for the CFA model (Satorra-Bentler chi-squared or SBχ² = 156.89 with 24 degrees of freedom (df), Incremental Fit Index or IFI = 0.94, Comparative Fit Index or CFI = 0.94, Standardised Root Mean-Square Residual or SRMR = 0.06, Root Mean-Square Error of Approximation or RMSEA = 0.09). The loading factor obtained for the item ‘Non- vs. very-urgent’ recommended its elimination, because its factor loading is 0.56 < 0.70 and compromises the instrument’s convergent validity. After removing item F2c, goodness of fit is good (SBχ² = 59.75 with df = 17 p < 0.01, normed chi-squared = 3.51, IFI = 0.98, CFI = 0.98, SRMR = 0.04, RMSEA = 0.06, 90% confidence interval of RMSEA ranges from 0.04 to 0.08). Table 1 shows the results.

Convergent validity is tested using the factor loadings, which are over 0.7 and significant in all cases. We confirmed discriminant validity using Average Variance Extracted (AVE) and correlation coefficients between factors. Our analyses confirm that each factor retains over 50% of the AVE (information) and none of the

#### Table 1. Validities and reliabilities for Studies 1 and 2.

| Factors                  | Items descriptors | Study 1                      | Study 2                      |
|--------------------------|-------------------|------------------------------|------------------------------|
|                          |                   | FL | CR | AVE | Correlations F2 F3 | FL | CR | AVE | Correlations F2 F3 |
| Impact (F1)              | Important         | 0.75 | 0.83 | 0.63 | 0.43 0.20 (0.04) (0.04) | 0.68 | 0.84 | 0.64 | 0.46 0.18 (0.04) (0.04) |
|                          | Dangerous         | 0.81 |               |     |                   | 0.88 |               |     |                   |
|                          | Hazardous         | 0.82 |               |     |                   | 0.82 |               |     |                   |
| Time–related (F2)        | Short term        | 0.82 | 0.89 | 0.80 | 0.27 (0.04)       | 0.82 | 0.89 | 0.77 | 0.09               |
|                          | Close             | 0.96 |               |     |                   | 0.93 |               |     |                   |
| Control & Management(F3) | Manageable        | 0.80 | 0.81 | 0.60 |                   | 0.83 | 0.86 | 0.66 |                   |
|                          | Governable        | 0.71 |               |     |                   | 0.76 |               |     |                   |
|                          | Surmountable      | 0.79 |               |     |                   | 0.85 |               |     |                   |

FL = Factor loadings, CR = Composite reliability, VE = Variance extracted, in brackets standard error of correlations.
Invariance is especially important when the instrument is based on self-reported responses, and when it is developed as a multi-factorial scale with several items per factor. In fact, a lack of invariance may prevent proper measurement and correct interpretation of the data. In our research we analyse two types of invariance: Configural invariance, and metric invariance. We do not analyse scalar invariance because it is not our goal to compare mean levels of latent variables or factors, given the two very different situations in which the fieldwork was conducted.

Configural invariance states that the number of factors and items that load on each factor must be equal in the groups where the instrument is applied. In empirical studies it is common to use individual CFAs for each group (in our case, for 2012 – a period of strong rainfall, and 2014 – a period of drought). Metric invariance makes the restriction that the factor loadings for both periods must be equal or very similar. This would mean that each item contributes similar information in the two periods considered, and therefore, the factor loadings would not depend on when the study was conducted.

For configural invariance, although the $\chi^2$ statistic is significant, the fit of the model is good, the error indices are <0.08, and the fit indicators are >0.90 (RMSEA = 0.06, SRMR = 0.06, CFI = 0.98). In the case of metric invariance the results are good ($SB\chi^2 = 146.97$ with $df = 42 p < 0.01$, normed chi-squared = 3.5, Incremental $\chi^2 = 35.12$ with $df = 8$, $CFI = 0.94$, $SRMR = 0.01$, $RMSEA = 0.06$, the 90% confidence interval for RMSEA ranges from 0.05 to 0.07). In addition, it is observed that the resulting model worsens because the increase in robust chi-square is significant (Co = 1.92; C1 = 1.81; Cd = 1.38; TRd = 35.12), after using Satorra and Bentler’s correction, where the corrected chi-square is distributed with 8 degrees of freedom. However, upon a slight reduction of goodness of fit indicators, the error indicators remain within the recommended levels. We therefore conclude that metric invariance is supported.

### 4.3. Statistic behaviour

Prior to the analyses, all the factors were normed using the Hsu and Chen (2007) method that converts the original range of the different factors into a new 0–1 homogeneous range. After testing the invariances, we proceed to create the Urban Water Consumption Perceived Risk Scale (UWPR), which is a Type II reflective first-order and formative second-order factor model. In these type of models, Impact, Time-Related, and Control factors are considered to be reflective, but their relationship with the global construct is formative. Thus, the factors do not act as a representative sample of perceived risk factors, but are relevant based on the analysis of specific water-related literature (see Section 2.4). To keep the UWPR within the 0–1 range, the formula to apply is:

\[
UWPR = 0.36F_{\text{Impact}} + 0.28F_{\text{TimeRelated}} + 0.36F_{\text{Control}} (0 \leq UWPR \leq 1)
\]

In this formula the weight of each factor comes from their ‘explained variances’ because the higher the percentage of explained variance, the greater the importance of this factor (de Grujter and van der Kamp 2007). As the three factors have formative nature and they should explain 100% of the total information, factor weights are calculated using each explained variance divided by total explained variance. Table 2 shows the descriptive statistics for the 2014 sample, which has been used as an evaluation sample. Factor Impact has the highest score and factor Control has the lowest. The first of them is strongly asymmetric towards the right (high scores). Factor control can be understood as symmetrical as the population interval contains a zero (perfect symmetry). UWPR has a mean significantly different to the median (Me = 0.50) because $t = 15.92$, $p = 0.00$, and 95%. Confidence Interval for the difference between the empirical mean and the theoretical median is CI = 0.09–0.12. Applying 1000 bootstrap samples we obtain mean differences $DM = 0.11$, bias = 0.00, $SE = 0.01$, $p = 0.00$.

We finally estimate if UWPR follows a statistical distribution applying EasyFit 5.5 software. The empirical data fits into a Pearson 'Type VI distribution', with parameters $a1 = 145.04$, $a2 = 0.03542$, and $\beta = 0.0037$. The Anderson-Darling test $AD = –20.49$
The perceived risk associated with urban water consumption. Orr et al. (2011) warned that one of the great hazards facing humanity is that water will be an increasingly scarce resource. To reduce consumption and adopt more strongly conservationist behaviours, the public should perceive the risk of higher and higher levels of consumption. This perception of risk can help to guide behaviour (Slovic and Weber 2002).

Our UWPR scale presents several advantages over existing scales in the literature. First, while the research we previously described uses a range of 5 to 65 simultaneous hazards, our scale focuses on a single problem (‘urban water consumption’). Additionally, the number of attributes or items has been reduced from between 14 to 30 to only 8, whilst maintaining high levels of reliability and validity. This permits more parsimonious measurement of the construct to be assessed, is easy to administer and can also be used together with other scales within one single questionnaire. Second, we have used two large samples (a test sample and a validation sample), which allow the proportional representation of different population groups (by gender, habitat, age, income and education). Third, we have taken into account the situational context of the study (a period of strong rainfall, 2012 and a period of drought, 2014). In this sense, because the UWPR test is invariant, comparisons can be made knowing that the scores obtained come from a test that is not affected by variations in perception of situational context of water scarcity. UWPR, as a perceived risk construct, maintains the same structure and metric (not score) in scarcity vs. non-scarcity situations. Finally, derived from invariance, the UWPR scale provides equivalent scores in those situations, minimizing the influence of acquiescence bias.

The UWPR distribution fits into a statistical distribution that suggests perceived risk phenomenon requires a multi-parameter distribution. Its highly asymmetric function not only involves the existence of non-normal behaviour; future research should also take into account the importance of unconventional sampling. This Pearson distribution, a well-known distribution, has been used to model different phenomena (e.g. environmental extreme events). Therefore, assuming that perceived risk measurement can be adjusted to this distribution, it is possible to make inferences about the population, reduce the bias that occurs when variables are added, facilitate the understanding of phenomenon and calculate probabilities.

Finally, studies based on the psychometric approach to the measurement of risk perception only take into account the characteristics of the risk rather than the processes underlying its perception (Sjöberg 2002). This limitation opens a potential new research stream into how risk perceptions are created and developed and how, in turn, they influence behaviour.

Notes
1. A scale/test is a set of statements that describes and allows developing reliable and accurate measurement of a phenomenon under study.
2. The Water Exploitation Index (WEI) describes how total water use puts pressure on water long-term resources. WEI < 20% means no water stress, 40% < WEI < 20% means water stress and WEI > 40% means severe water stress.

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