

Validating Italian General Ecological Behaviour Questionnaire of Travellers using Dichotomous Rasch Model

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1 **Validating Italian General Ecological Behaviour Questionnaire of**  
2 **Travellers using Dichotomous Rasch Model**

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1 **ABSTRACT**

2 Ecological behaviour and the impact on environment are subjects of public concern and  
3 understanding individual behavioural measures to induce sustainable lifestyles is of extreme  
4 importance for policy makers to assess and promote sustainable mobility. To this end, a  
5 questionnaire with highly reliable items, evaluation of determinants and accurate measurement of  
6 ecological behaviour is a precondition for understanding the levers for a behavioural change. This  
7 paper aims at understanding whether the dichotomous Rasch model provides a legitimate  
8 measurement of General Ecological Behaviour (GEB) using a 26 items questionnaire as a valid  
9 tool to assess pro-environment behaviour of a large sample of users. A web questionnaire was  
10 administered using the snowball sampling plan in the Piedmont region (Italy) reaching out a  
11 sample of 4473 respondents. Results suggest that using the dichotomous Rasch model, proposed  
12 questionnaire is able to effectively measure pro-environment behaviour of travellers.  
13 Unidimensionality, perfect level of item reliability of 1, very high item separation of 34.22,  
14 absence of larger differential item functioning, and local independence are all good indicators of a  
15 valid model. This research shows how a good, validated, and reliable measurement of ecological  
16 behaviour would support public bodies to plan environment focused transport policies thanks to  
17 the knowledge of which variables determine the pro-environment behaviour. In addition, the  
18 proposed approach allows also to measure the efficacy of the adopted policies.

19  
20 *Keywords:* General Ecological Behaviour, Pro-environment Travel Behaviour, Dichotomous  
21 Rasch Model

## 1 INTRODUCTION

2 Ecological behaviour and the impact of human activities on the natural environment are subjects  
3 of public concern and have been largely studied in the psychological research that underlined the  
4 importance of adopting more ecological behaviours or lifestyles (1, 2). The ecological behaviour  
5 means the actions which contribute towards environmental preservation and conservation (3, 4).  
6 It seems, albeit, that what people choose to do to reduce their environmental impact often does not  
7 correspond well with what research suggests they should do (5, 6). This apparent lack of  
8 correspondence has called into question the criterion validity of behavioural measures of  
9 ecological lifestyles (7, 8). In this regard, the proper measurement of General Ecological  
10 Behaviour (GEB) of users can serve as a powerful tool for policy makers to implement and,  
11 particularly, to assess more user-focused policies supporting people in adopting daily ecological  
12 habits. For that a well-designed GEB questionnaire with proper items, that match the real lifestyle  
13 habits of users is also a precondition and require attention, considering different cultural and  
14 geographical contexts.

15 Therefore, various studies in literature used GEB to assess sustainable behaviour. Arnold  
16 et al. (9) assessed electricity consumption of German adults; Kaiser and Wilson (10) used sample  
17 of two transport associations: one aims to promote a transport system that has as little negative  
18 impact on humans and nature, the other represents automobile drivers' interests, such as proper  
19 road maintenance, allowing higher speed limits on freeways, and fighting gasoline-tax increases.  
20 Hergesell (11) examined differences in choosing the transport mode during the holidays through  
21 general level of environmental commitment across lifestyle domains and found that train users  
22 tend to be more environmentally committed compared to car users. Two versions of GEB  
23 questionnaire were proposed to assess pro-environment travel behaviour in an Italian region. A  
24 first version was proposed by Gaborieau and Pronello (12) based on Kaiser and Wilson (10),  
25 which we call GEB-40 (40 dichotomous items); the second version was proposed by (13) as an  
26 extended version of GEB-40, which we call GEB-51 (51 dichotomous items). One of the  
27 weaknesses of previous two Italian GEB versions (GEB-40 and GEB-51) was the inclusion of  
28 irrelevant and redundant items that were excluded in this study.

29 At best of our knowledge, the studies measuring GEB questionnaire using the Rasch model  
30 (14), whether in different cultural contexts or in a single area, used limited and small sample size.  
31 Kaiser and Biel (15) compared ecological behaviour of 247 Swedish and 445 Swiss people; Kaiser  
32 and Wilson (10) compared 686 Californian students and 445 Swiss participants; Gaborieau and  
33 Pronello (12) compare 131 Italian, 445 Swiss, and 247 Swedish participants; Hergesell (16) based  
34 on a sample of 349 German citizens, although the sample size is still within acceptable boundaries,  
35 according to Linacre (17). Nevertheless, replication in a larger sample of population is highly  
36 desirable and the use of small samples was reported as one of the limitations of previous researches  
37 (9, 12).

38 The current research focused to obtain high item reliability, good separation indexes, and  
39 well-functioning items with a larger sample size. In addition, to reduce the fatigue of respondents,  
40 it has been paid attention to use comparatively few (26) and highly reliable items to assess the  
41 GEB. The paper has three main objectives:

- 42
- 43 • To determine whether the dichotomous Rasch model could provide a legitimate measure  
44 of the chosen 26 items in the polytomous GEB questionnaire as a valid tool to assess the pro-  
45 environment behaviour of users in Piedmont region, Italy;

1 • To check the validity of dichotomous scale measurement instead of original polytomous  
 2 questionnaire, with a larger sample size, to allow a comparison with the previous two versions of  
 3 GEB questionnaires (GEB-40 and GEB-51) in the Italian context;

4 • To understand if the obtained GEB Rasch person measure has some impact on travel  
 5 behaviour – mode choice – to assess if the people behaving more ecologically effectively chose  
 6 sustainable modes or people behaving less ecologically chose unsustainable transport modes.  
 7

8 The paper is organised as follows: the following section will present the methodology used  
 9 to design and administer the questionnaire, the sampling plan, and the requirements to assess the  
 10 dichotomous Rasch model. Section 3 presents the obtained results. Then, section 4 discusses the  
 11 appropriateness of the dichotomous scale and questionnaire items, the inclusion or exclusion of  
 12 items, and some aspects related to questionnaire design. Finally, the discussion and conclusions  
 13 are presented.  
 14

## 15 **METHODOLOGY**

16 The research was conducted in the Piedmont region (Italy), with focus on the metropolitan area of  
 17 Torino. A web questionnaire has been designed to get in depth information related to opinions,  
 18 preferences, attitudes, lifestyles, and mobility patterns of users with the aim of studying the pro-  
 19 environmental behaviour of the sample and understanding whether a general pro-environment  
 20 attitude may legitimately be assessed using the Rasch model. A four-step methodology comprised:  
 21 (1) survey design; (2) survey administration and sample selection; (3) data base construction; (4)  
 22 model estimation and testing of GEB.  
 23

### 24 **Survey Design**

25 A survey has been designed, named “Come ci muoviamo? ... ma soprattutto come vorremmo  
 26 muoverci?”. The survey is composed by two different web-questionnaires. The first part includes  
 27 questions well established in literature, which can ensure well-grounded comparison, and it is  
 28 composed by six sections: mobility in a standard week; travel diary related to the most important  
 29 trip; integrated mobility; Mobility as a Service; attitudes and preferences – including GEB; and  
 30 socio-economic data. The second part is composed by new questions, derived from recent results  
 31 from behavioural theories to overcome some gaps observed in previous researches by (12, 13) and  
 32 it is composed by two sections: information about the most important trip; and attitudes and  
 33 preferences related to this trip. This paper mainly focuses on analysing the general attitudes  
 34 towards the environment and its ecological behaviour using the section of the questionnaire related  
 35 to GEB.

36 The GEB questionnaire is based on GEB-40 and GEB-51 but includes only 26 items  
 37 (GEB-26) reported in Table 1, resulting from deleting redundant and problematic items found in  
 38 GEB-40 and GEB-51. The questionnaire has been designed to collect polytomous data based on a  
 39 6-point Likert scale where 1 was “completely disagree” and 6 “completely agree”.  
 40

41 **TABLE 1 Structure of GEB-26 Questionnaire**  
 42

No.	Item description	Code
<i>Category 1 - Pro-social behaviour</i>		
1	Sometimes I give money to panhandlers	CS1
2	From time to time, I give money to charity	CS2
3	If an elderly or disabled person enters a crowded PT vehicle, I offer him/her my seat	CS3

4	If I were an employer, I would not hesitate to hire a person previously convicted of crime	CS4
5	Sometimes I ride public transport without paying a fare	CS6(-)
<b>Category 2 - Ecological garbage handling</b>		
6	I put dead batteries in the garbage	R1(-)
7	I sort glass wastes for recycling	R5
<b>Category 3 - Water and power saving</b>		
8	I turn off the heat at night	AE4
9	I wait until I have a full load before doing my laundry	AE5
10	In winter, I leave the windows wide open for long periods of time to let in fresh air	AE6(-)
<b>Category 4 - Ecologically aware consumerism</b>		
11	I use fabric softener with my laundry	CE1(-)
12	I always look to buy vegetables from biological agriculture	CE6
13	Sometimes, I sell goods I don't use anymore	CE7
14	Sometimes, I buy second hand goods	CE8
15	Sometimes, I offer goods I don't use anymore	CE9
16	Sometimes, I rent for free to someone, goods I occasionally use	CE14
17	I eat less meat than years ago	CE15
<b>Category 5 - Garbage inhibition</b>		
18	I re-use plastic bag from the groceries	RR1
19	I sometimes buy beverage in cans	RR2(-)
<b>Category 6 - Environmental activism</b>		
20	I often talk with friends about problems related to the environment	V1
21	I am a member of an environmental organization	V2
22	In the past, I have pointed out to someone his or her un-ecological behaviour	V3
23	I sometimes contribute financially to environmental organizations	V4
24	I boycott companies using OGM or pesticides	V5
<b>Category 7 - Transport</b>		
25	Usually, I do not drive my automobile in the city	T1
26	I usually drive on freeways at speeds lower than 100km/h	T2

Note: (-) items positively formulated as environmentally damaging, recoded.

### Survey Administration and Sample Selection

The survey was administered to the population living in the Piedmont region, with focus on metropolitan area of Torino. The citizens were reached through different channels: email, flyers, notice on the websites of municipalities and transport companies, formal notice to employees in Rail Infrastructure Managers, direct contact with major cultural and sport associations, newspapers, and local radio and Twitter including the survey in traffic bulletin. The link to the survey and QR code were available through the above channels and respondents filled in the questionnaire using the Computer Assisted Web Interviewing (CAWI), developed using the software Lime Survey.

Such wide dissemination was possible thanks to the support from the Local Public Bodies – Piedmont Region, City of Torino, main universities (Politecnico di Torino and Università degli Studi di Torino), the transport authority Agenzia Mobilita Piemontese and some transport operators as Gruppo Torinese Transporti and Sadem and the Rete Ferroviaria Italiana. Answers were collected in the period from the 27<sup>th</sup> of October 2017 to the 24<sup>th</sup> of April 2018, based on the snowball sampling plan, reaching out a random sample of 4473 respondents.

### Database Construction

1 The initial sample of 4473 records was resized to 4212 units excluding the persons whose  
 2 destination was outside both Italy and the region. The 4212 records have been used in Rasch model  
 3 estimation. The residential locations are classified in three areas, urban (metropolitan area of  
 4 Torino), suburban (municipalities around Torino-first belt) and rural (rest of the territory-second  
 5 belt). The Piedmont Territorial Demographic Observatory identifies a "first" and a "second" belt  
 6 of municipalities surrounding Torino<sup>1</sup>. The majority of respondents come from urban area and the  
 7 distribution of the three residential locations is: 2154 (51.14%) urban, 740 (17.57%) suburban, and  
 8 1318 (31.29%) rural.

9 The next step for constructing the data base was the check of missing values. Two  
 10 variables, T1 and T2 related to category 7 "transport" (Table 1), have, respectively, 437 and 572  
 11 not applicable responses. These are not missing at random, but they are a choice from respondents,  
 12 and they were considered as missing during the analysis to avoid any imputation, having a large  
 13 database. The software Winsteps, used for the Rasch model, does not require complete data in  
 14 order to make estimates, because it uses Joint Maximum Likelihood Estimation (JMLE) that is  
 15 very flexible as regards estimable data structures. Waterbury (18) reports that Rasch model can  
 16 handle varying amounts of missing data, provided that the missing responses are not missing not  
 17 at random. Hence, the missing records without any imputation were used whereas other variables  
 18 have complete data for corresponding records. Finally, the dataset is converted from polytomous  
 19 scale to dichotomous scale by converting the first three categories, from 1 (completely disagree)  
 20 to 3, to 1 "No"; and second three categories, from 4 to 6 (completely agree), to 2 "Yes".

## 21 22 **Rasch Model as a Measure of General Ecological Behaviour**

23 The general attitude towards the environment, based on the data collected by the GEB  
 24 questionnaire, was analysed using Rasch Model for scale measurement. Rasch analysis describes  
 25 procedures that use a particular model with outstanding mathematical properties developed by  
 26 Georg Rasch (14) for the analysis of data from tests and questionnaires. The mathematical theory  
 27 underlying Rasch models is a special case of Item Response Theory (IRT) and, more generally, a  
 28 special case of a generalized linear model. The statistical calculations employed by the Rasch  
 29 model to locate and order persons and item difficulty is based on Guttman Scaling and it can be  
 30 used with both dichotomous and polytomous data sets (19). This study explores the potential of  
 31 using the dichotomous Rasch model to analyse polytomous items for GEB attitude measure.

32 The Dichotomous Rasch model (DRM) (14) is the simplest model in the Rasch family of  
 33 models. It was designed for use with ordinal data that are scored in two categories. The DRM uses  
 34 sum scores from these ordinal responses to calculate interval-level estimates that represent person  
 35 locations and item locations on a linear scale that represents the latent variable. The difference  
 36 between person and item locations can be used to calculate the probability for a correct or positive  
 37 response ( $x = 1$ ), rather than an incorrect or negative response ( $x = 0$ ). The equation for the DRM  
 38 is reported in eq. 1:

$$39 \quad B_n - D_i = \ln(P_{ni}/P_{ni}) \quad (1)$$

40  
41 where

42  $B_n$  = ability of a specific person  $n$ ;  
43

---

<sup>1</sup>[https://web.archive.org/web/20140727134854/http://www.demos.piemonte.it/site/images/stories/caricafil e/territori/E\\_area\\_metropolitana.pdf](https://web.archive.org/web/20140727134854/http://www.demos.piemonte.it/site/images/stories/caricafil e/territori/E_area_metropolitana.pdf).

1  $D_i$  = difficulty of a specific item  $i$ ;  
2  $P_{ni}$  = probability of person  $n$  correctly answering item  $i$ ; and  
3  $\ln$  = “log-odds units” (logits), which is a natural logarithm.

4 The DRM specifies the probability,  $P$ , that the person  $n$  with ability  $B_n$  succeeds on item  $i$   
5 of difficulty  $D_i$ .

6 The key Rasch model requirements are unidimensionality, local independence, persons-  
7 invariant item estimates/person parameter separability, and item-invariant person estimates/item  
8 parameter separability.

9 For the parameter estimation for DRM, Winsteps Rasch Analysis program was used.  
10 Winsteps implements two methods of estimating Rasch parameters from ordered qualitative  
11 observations: JMLE also known as UCON (Unconditional Maximum Likelihood Estimation) (20)  
12 and PROX (Normal Approximation Algorithm) devised by Cohen (21).

#### 14 *Rasch Measures and Model fit*

15 Rasch model fits are used to examine the unidimensionality of the latent trait to measure attitude  
16 towards GEB. Unidimensionality is evaluated using: 1) point-biserial correlation 2) fit statistics,  
17 3) Principal Component Analysis of Residuals, and 4) local independence.

18  
19 **Point-biserial Correlation** Point-biserial correlation is a useful diagnostic indicator of data  
20 miscoding or item mis-keying: negative or zero values indicate items or persons with response  
21 strings that contradict the variable. Li et al. (22) suggests that point-measure correlation larger than  
22 .3 indicate that items are measuring the same construct.

23  
24 **Fit Statistics** Rasch model provides two indicators of misfit: INFIT and OUTFIT. Since the ZSTD  
25 value is based on the MNSQ, as reported by Boone et al. (23), we first examine the MNSQ for  
26 evaluating fit. If the MNSQ value lies within an acceptable range, we ignore the ZSTD value.  
27 According to Boone et al. (23), INFIT and OUTFIT mean-square fit statistics between 0.5-1.5  
28 represents productive items. For mathematical formulation of point-biserial correlation, INFIT,  
29 OUTFIT, and ZSTD refer to (12).

30  
31 **Principle Component Analysis of Residuals (PCAR)** Unidimensionality was checked through  
32 PCAR. According to Reckase (24) unidimensionality is hold if: a) the amount of variance  
33 explained by measures is  $> 20\%$ ; b) unexplained variance of the eigenvalue for the first contrast is  
34  $< 3$ ; and unexplained variance accounted by first contrast is  $< 5\%$ .

35  
36 **Local Independence** Local independence means that after the contribution of the latent trait(s) to  
37 the data is removed, all that is left is random noise (25). A correlation of  $r=0.40$  among items is  
38 low dependency.

39 Besides these, Rasch model assumptions include assessing *reliability and separation* of  
40 measures, *differential item functioning*, evaluation of item difficulty using *Write map* to evaluate  
41 construct validity.

42  
43 **Reliability** It ranges from 0 to 1 and the higher is better (26). Bond and Fox (27) suggested value  
44 between 0.6-0.8 is acceptable.

45



1 *Separation index* Separation index of 1.50 represents an acceptable level, 2 represent a good level  
2 according to Miller and Dishon (28) and 3 represents an excellent level as reported by Duncan et  
3 al. (29).

4  
5 *Differential Item Functioning (DIF)* DIF is used to determine whether the individual items on a  
6 test function in the same way for two or more groups (30). Mantel-Haenszel (MH) (31) test for  
7 dichotomies is used. Items are flagged as DIF when the MH probability value is  $\leq 0.05$  and then  
8 the DIF size is assessed according the criteria by Zwick et al. (32). Moderate to large DIF when  
9 size CUMLOR is  $\geq 0.64$ , slight to moderate DIF when size CUMLOR is  $\geq 0.43$ , negligible when  
10 size CUMLOR  $< 0.43$ . We investigated DIF by two criteria: 1) gender and 2) residential location.

## 11 **RESULTS**

12 This section presents the results by following the various steps described in the methodology.

### 13 **Point-biserial Correlations**

14 All items' correlations are positive and pointing in the same direction. However, three small  
15 positive correlations are observed and analysed hereafter:

16  
17

- 18 • *Item AE6\_REVC* has a low correlation (.05) close to zero. When assessing closely this item,  
19 74.17% users agree, and 25.83% disagree, showing that this is one of the easiest behaviours to  
20 engage into (Measure=-0.76);

21  
22

- 23 • *Item CS6\_REVC* has a low correlation (.09) close to 0.1. When closely assessing this item,  
24 90.38% users agree, and 9.62% disagree; similar to the previous item, this is also one of the easiest  
25 behaviours to engage into (Measure=-2.08). Almost most of the users agreed to using public  
26 transport without tickets, which may cause the low correlation;

27

- 28 • *Item CS4* has a low correlation (.08) near to 0.1. Analysing this, no big difference among  
29 the answered categories of the respondents (46.77% disagree and 53.23% agree) was found. This  
30 item seems to have medium difficulty across all respondents (Measure = 0.31).

### 31 **Fit statistics**

32 Item AE6\_REVC has the highest mean-square outfit (1.55). The small difference of .05 over the  
33 threshold might not degrade the measurement. We found that all other items are within acceptable  
34 ranges of MNSQ, hence we are not investigating ZSTD.

### 35 **Principle Component Analysis of Residuals**

36 First, the amount of variance explained by measures is 34.2% (11.5% of raw variance explained  
37 by persons and 22.7% of raw variance explained by items) which is larger than the requirement of  
38 20% according to Reckase (24). Second, the unexplained variance by first contrast is 5.4%, which  
39 is slightly greater than 5%, but the eigenvalue of first contrast is 2.14 ( $< 3$ ). The results suggest  
40 that the unidimensionality is hold across the whole test.

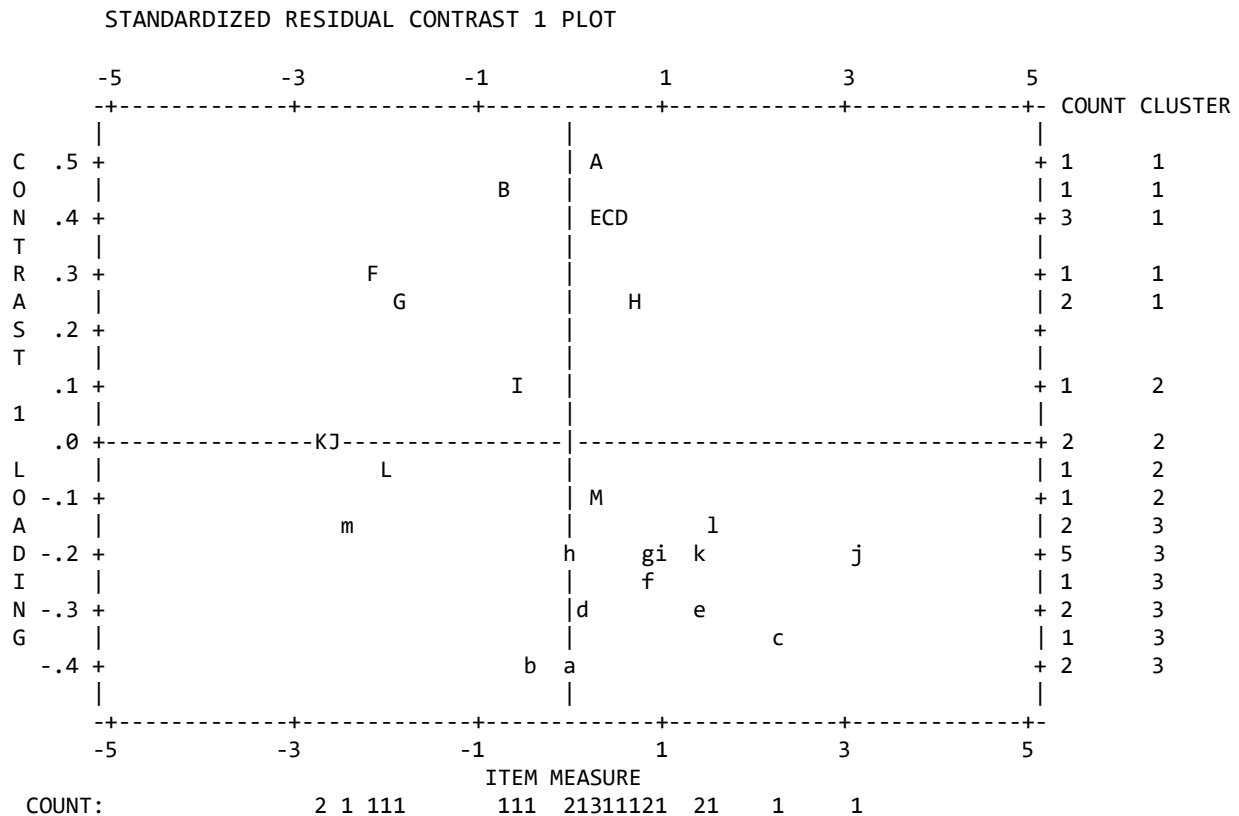
41 The loading of items on the first contrast of the residual based PCA are shown in Figure  
42 1, showing that this possible sub-dimension is formed by two items, A (AE6\_REVC), and B  
43 (CS6\_REVC). Items A and B have the largest loadings, quite far away from the general cluster  
44 created by the other items, and the eigenvalue of first contrast is 2.14 (~2 items). To see the items  
45 corresponding to the letter of alphabet represented in Figure 1, refer to Table 2.

1  
2

**TABLE 2 Estimates of Item Parameters, Infit, Outfit, and Point-biserial Correlations**

Entry No.	Total Score	Measure	Model S.E.	Infit		Outfit		Point-bis. Corr.		Exact Match (%)		Item
				MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.	OBS%	EXP%	
10	7336	-.76	.04	1.24	9.90	1.55	9.90	A .05	.33	70.9	75.7	AE6_REVC
5	8019	-2.08	.05	1.10	2.54	1.48	6.48	B .09	.24	90.4	90.4	CS6_REVC
4	6454	.31	.03	1.27	9.90	1.43	9.90	C .08	.38	53.0	65.8	CS4
6	7938	-1.86	.05	1.08	2.17	1.31	4.87	D .15	.26	88.0	88.5	R1_REVC
19	6418	.35	.03	1.20	9.90	1.29	9.90	E .16	.38	56.6	65.8	RR2_REVC
25	5712	.46	.04	1.15	9.90	1.24	9.90	F .20	.37	58.6	65.5	T1
11	6248	.53	.03	1.14	9.90	1.22	9.90	G .23	.38	59.8	65.8	CE1_REVC
26	5285	.78	.04	1.09	7.13	1.12	6.22	H .28	.38	61.4	66.6	T2
8	7203	-.58	.04	.99	-.72	.99	-.26	I .35	.34	73.9	73.3	AE4
13	5535	1.37	.04	.97	-1.91	.95	-2.17	J .40	.37	72.7	72.5	CE7
1	5491	1.43	.04	.96	-2.25	.94	-2.33	K .41	.37	74.1	73.1	CS1
14	5812	1.03	.03	.96	-3.36	.93	-3.66	L .42	.38	70.1	68.8	CE8
18	8185	-2.69	.07	.94	-1.15	.87	-1.55	M .26	.19	94.4	94.3	RR1
2	5949	.87	.03	.93	-5.96	.91	-5.22	m .45	.38	70.8	67.5	CS2
7	8176	-2.64	.07	.93	-1.22	.76	-2.93	l .27	.20	94.1	94.1	R5
3	8136	-2.48	.06	.92	-1.62	.76	-3.29	k .30	.21	93.2	93.2	CS3
9	7985	-1.98	.05	.92	-2.03	.85	-2.45	j .32	.25	90.2	89.6	AE5
16	6673	.06	.03	.91	-7.93	.88	-7.00	i .47	.37	70.6	66.8	CE14
17	6441	.32	.03	.91	-8.75	.86	-8.55	h .48	.38	70.7	65.8	CE15
12	5911	.92	.03	.90	-8.18	.87	-7.59	g .48	.38	72.5	67.8	CE6
21	4586	3.13	.06	.90	-2.48	.72	-4.61	f .38	.27	91.5	91.3	V2
22	6715	.01	.03	.90	-8.58	.87	-7.08	e .47	.37	72.2	67.2	V3
15	7134	-.49	.04	.89	-7.71	.83	-6.86	d .47	.35	76.3	72.2	CE9
20	6625	.11	.03	.88	-9.90	.83	-9.90	c .50	.37	72.4	66.6	V1
24	5391	1.56	.04	.88	-6.88	.83	-6.85	b .48	.36	78.2	74.8	V5
23	4912	2.33	.04	.83	-6.48	.66	-8.91	a .50	.32	84.9	84.0	V4
Mean	6548.8	.00	.04	.99	-1.0	1.00	-.9	-	-	75.4	75.7	-
P.SD	1059.6	1.50	.01	.12	6.	.24	6.7	-	-	12.0	10.6	-

3



**FIGURE 1 Item loadings on the first contrast**

The correlations of the person measures computed with each cluster of items were as follows: Cluster 1 and 2:  $r = 1.0$ ; Cluster 1 and 3:  $r = 0.0587$ ; Cluster 2 and 3:  $r = 1.0$ . Having cluster 1 and 3 low correlation, the sub-dimension might be due to the items in cluster 1, as discussed above for items A and B.

### Local independence

According to the Linacre guidelines<sup>2</sup> all items correlation is  $< 0.4$ , hence no item residuals are correlated, respecting the local independence assumptions of Rasch analysis.

*Person measure reliability* is .67 and *item measure reliability* is 1 (perfect), acceptable with the less variability of the measurement attributed to measurement error. The *person separation*, equal to 1.44, shows that this test can distinguish between high and low performers (1.44, ~2 levels) and represent good level of separation according to Miller and Dishon (28).

*Item separation* is very high, equal to 34.22, and represent excellent level of separation (29). With this large person sample, the item difficulties are estimated exceedingly precisely and validating the GEB construct validity ( $> 3$ ).

<sup>2</sup> [https://www.winsteps.com/winman/table23\\_99.htm](https://www.winsteps.com/winman/table23_99.htm).

1 *DIF* is assessed using MH test, based on gender (Female, Male) and residential location (Urban,  
 2 Suburban, Rural), and it is conducted by comparing a reference group (the majority group) with a  
 3 focal group (the minority group) (33). The reference group for gender and for residential location  
 4 are respectively, female and urban while the other are the focal groups.

5 Considering gender, two items report *DIF* of slight to moderate size: CE9 with p value .00  
 6 and *DIF* size .63; and V1 with p value .00 and *DIF* Size -.47. Looking at residential location, two  
 7 items, R5 and T1, show moderate to large *DIF*. R5 with p value .00 and *DIF* size .90 for urban and  
 8 rural; p value .00 and *DIF* size 1.12 for urban and suburban. T1 with p value .00 and *DIF* Size .44.  
 9

## 10 Write map

11 Figure 2 depicts the person measures (left) and the item measures (right). Persons at the top had  
 12 the least difficulty endorsing items, while persons at the very bottom had the most difficulty  
 13 endorsing items. We can observe that:

- 14 • The most difficult item is V2 followed by item V4; both belong to the category of  
 15 environmental activism;
- 16 • The easiest items are R5 and RR1, followed by CS3. These three items are not targeting to  
 17 any person; some persons above and below these items are less inclined to GEB, so these items  
 18 are not useful to the GEB measurement but still fall within the user's ability range;
- 19 • Items CS1 and V5 measure similar portions of the trait and therefore, from a measurement  
 20 perspective, are redundant. This is also the case of items CE6, CS2, T2; CE1\_REVC, T1; CE15,  
 21 CS4, RR2\_REVC; CE14, V3; AE4, CE9; AE5, CS6\_REVC; and R5, RR1. Within groups of items,  
 22 individual items can be removed losing a small precision of the measurement;
- 23 • We do not see the gap between items more than a logit, but there is a need to fill the  
 24 measurement gaps, between V4 and CS1, and between items AE6\_REVC and R1\_REVC. This  
 25 explains the relatively poor value of the individual separation reliability.  
 26  
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## 28 DISCUSSION AND CONCLUSIONS

29 The purpose of this research was to scrutinize psychometric properties of the GEB-26  
 30 questionnaire using a DRM approach to validate and compare the scale with those used in previous  
 31 research and to understand if this has some impact on travel behaviour, notably on mode choice.

32 Unidimensionality has been evaluated utilizing Rasch fit statistics, as well as PCAR and  
 33 point-biserial correlations. Notably, all these tests of the measure's dimensionality suggest the  
 34 items lie on one trait as hypothesized during survey design. Therefore, it can be recommended to  
 35 use the GEB-26 as a unidimensional scale. Model fit indicators suggest that the scale contains one  
 36 particularly misfitting item, AE6\_REVC, with only slightly high outfit MNSQ value (0.05), that  
 37 is not threatening the validity of the scale, so that it is not suggested to delete it. The fact that item  
 38 AE6\_REVC was the only item with poor fit warrants further investigations as it offers potential  
 39 insights into the structure of GEB. It is well known that negatively coded items, especially if there  
 40 are only a few and located at the end of the questionnaire, may be confusing for the respondents  
 41 (34). However, it is also possible that the item did not confuse the respondents, but not behaving  
 42 ecologically may actually not be seen as an inverse conceptualization of ecological behaviour, but  
 43 rather a (partly) different construct in its own right. Moreover, local independence, reliability, and  
 44 separation indexes assumptions were confirmed with good Rasch measures validity.  
 45

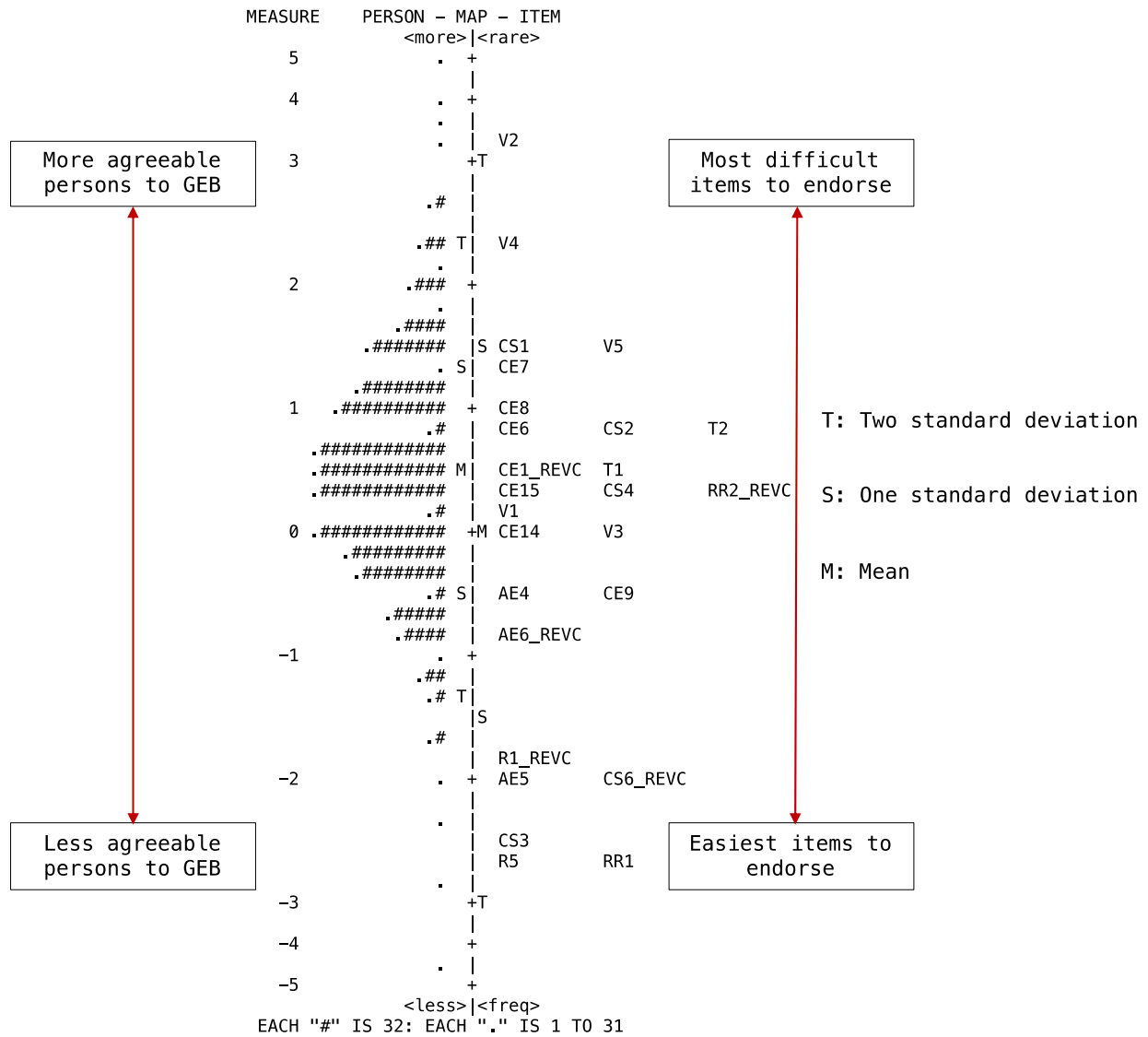


FIGURE 2 Write map

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We have obtained perfect level of reliability of 1, separation of 34.22 for items, and sufficient level of person separation and reliability. Although, person (test) reliability mainly depends on the variance of sample ability and on the number of categories per item. If we have more categories, then we might achieve higher person reliability. So, in this study we first validated the questionnaire by converting polytomous scale to dichotomous scale to compare the results from the previous studies (GEB-40 and GEB-51) and to verify how the selected test performs with larger sample size as also person separation and reliability are sample dependent. The most important aspect is to validate the questionnaire items that have been selected, to revise them, if necessary, for designing the next survey.

Observing DIF analysis, item CE9 is more difficult for females and V1 is more difficult for males. This shows the cultural, societal, and attitudinal difference as determinant factors to engage in a certain behaviour. The DIF size for these two items was slight to moderate, hence we are not considering excluding these items for the next questionnaire. This aspect is also part of

1 Campbell's paradigm (35) of attitude, which states that some behaviour may be more difficult in  
2 certain contexts than in others. This applies also to the residential location (R5) and the related  
3 land use; the results show how a well shared habit of sorting glass for recycling is easier for people  
4 living in rural areas due to the different organisation of collection points of glass located at single  
5 homes, differently from the scattered patterns of collection points in the cities. The way of living  
6 in rural areas makes also people less used to drive in congested urban traffic (T1), reason why  
7 urban citizens are more used and, thus, inclined to use car to travel inside the cities; differently,  
8 those living outside prefer travelling to the city by train or suburban bus to avoid traffic and parking  
9 problems. So, what stated by Arnold et al. (9) holds true, showing the importance of surroundings  
10 and contextual elements in the daily routine. The DIF size for R5 is moderate to large, which  
11 requires some attention to consider in further analysis; instead, item T1 has slight to moderate DIF,  
12 not necessarily indicated for deletion.

13 Observing the results, GEB-26 shows good psychometric properties when using DRM to  
14 validate the scale; some further analysis can be useful to verify the three items that are slightly  
15 borderline.

16 The second aspect that was investigated, concerning the validity of GEB in influencing the  
17 modal choice, is key in the current debate on climate change that calls for major changes in  
18 people's daily lifestyles (2). A frequent question arising is: do what people report to protect the  
19 environment converge with their environmental impact? If, theoretically speaking, this could hold  
20 true, under an empirical observation our results show the opposite. We observed that out of  
21 selected sample of 4212 respondents, for the most important trip (that with longest distance), 1368  
22 (32.48%) use trip chain followed by 1156 (27.45%) using car, 729 (17.31%) using public transport,  
23 330 (7.83%) walking, and 310 (7.36%) cycling. Looking into trip chain, car as driver is used by  
24 the highest percentage of respondents, 1333 (31.65%), followed by 1096 people (26.02%) using  
25 public transport, 667 travelling by train, 401 walking, and 322 cycling. This finding shows how  
26 people do not do what they intent/say to do. Hence, behavioural measures of ecological lifestyles  
27 may reflect actual environmental impact in some other contexts such as in electricity consumption,  
28 as reported by Arnold et al. (9), but they do not apply in transport sector by looking at results and  
29 as shown in previous studies (36). This is referred as attitude-behaviour gap (37) or behaviour  
30 intention gap (38), demonstrating the volatility of the concepts of attitude or intention (39). The  
31 results obtained in this research also contradict what found in (12), where the high GEB score was  
32 correspondent to those users who use soft modes (walking or bike) for their most frequent trip,  
33 followed by public transport (regional train, bus, tram or metro) and, then, private motorised  
34 vehicles (car or motorbike). One reason of this contradiction might be that the trip chain was  
35 excluded by Gaborieau and Pronello (12) and the sample was smaller (108 users). This discrepancy  
36 will be further investigated in the continuation of the research.

37 It should also be recalled that the sample sizes in previous studies – in Italian context (GEB-  
38 40 and GEB-51), in Swedish and Swiss context (15), and in Californian context (10) – were  
39 comparatively too small, although still within acceptable boundaries, according to Linacre (17).  
40 Nevertheless, replication in a larger sample is highly desirable as suggested in current research.  
41 Regarding the generalizability of the results, it must be noted that the composition of samples of  
42 previous studies was formed thanks to a stratified sampling plan. Thus, different results may be  
43 observed when the sample follows the snowball sampling approach and the participants are, as in  
44 this case, younger and/or with a bit lower educational level. Finally, it needs to be emphasized that  
45 even excellent internal validity is no assurance that a given scale will also exert good external  
46 validity.

1           One of the limitations of these studies assessing ecological and environmental behaviour  
2 is that people may not be aware about their environmental impacts and/or the damage they cause  
3 to the environment. As reported by Hamidi and Zhao (40), the individuals who have greater  
4 environmental awareness are more likely to travel by public transport or cycling if the physical  
5 conditions facilitate using these modes. Hence, the proper environmental and mobility education  
6 is needed to educate people as also suggested by Gaborieau and Pronello (12); and Pronello and  
7 Camusso (36).

8           Further research is needed to deepen our understanding of the GEB and to devise  
9 appropriate measurement instruments. There was no evidence that individuals with diverging  
10 sociodemographic characteristics, such as age, had a different understanding of the items. The item  
11 which is difficult could be answered by respondents with high capability, whilst easy items could  
12 be answered by respondents with high and low ability. Overlapping items measure different  
13 elements with different levels of difficulty (41), hence we do not suggest to exclude items to design  
14 a new survey by looking only at redundancy of items in write map. Some recommendations are  
15 worthy to be given for improving the scale. Firstly, more items could be selected with high or low  
16 difficulties so that the scale will be able to measure individuals outside an intermediate level of  
17 ecological behaviour, particularly to fill in the gaps identified in the study in write map analysis.  
18 This is important because limited differentiation capabilities may attenuate existing effects of  
19 measuring ecological behaviour. The GEB-26 might not be capable of detecting strong effects  
20 potentially attributable to interventions based on ecological behaviour in terms of larger person  
21 ability range due to weakness of questionnaire design; in fact, we obtained person measure  
22 reliability equal to .67 and person separation equal to 1.44, which is acceptable but not excellent.  
23 Hence, GEB researchers would profit from more sensitive measurement instruments capable of  
24 detecting differences between individuals who are high and low in ecological behaviour.  
25 Furthermore, we do not suggest excluding any item by looking only at the dichotomous scale  
26 measurement. The item exclusion will be further decided after measuring the original 6 scale  
27 polytomous questionnaire using Rasch rating scale model, which is the next step of our research,  
28 continuing to validate and select the appropriate measurement scale to measure GEB of users. As  
29 suggested by Linacre<sup>3</sup>, the scale with more categories is expected to give better and higher person  
30 reliability and separation. Future research may also investigate by testing the GEB questionnaire  
31 in different cultural and territorial contexts such as different regions, cities, and metropolitan areas  
32 of Italy, and different European countries to validate the appropriate GEB questionnaire.

33           In summary, we can conclude that GEB-26 shows acceptable approximation to Rasch  
34 requirements. Improvements, as outlined above, are strongly warranted, and may yield a reliable  
35 and internally valid measurement device for the measurement of GEB.

36           The final aim is to propose proper public targeted policies to induce people to sustainable  
37 travel choices. For that, a well-planned and environment-focused transport education policy can  
38 play a role to educate people and make them aware about their environmental footprints and  
39 motivate them to behave ecologically and sustainably. In this regard, the transport policies together  
40 with the idea of giving incentives to people when they use the sustainable modes could trigger  
41 them towards more sustainable behaviour as reported by Pronello and Kumawat (42). Technology  
42 can also play a role for giving incentives to promote sustainable mobility or engaging them in pro-  
43 environment ecological behaviour with the help of smartphone apps, as these days the apps are  
44 becoming part of daily life of people and the trend is exponentially increasing (42). To this end, a

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<sup>3</sup> <https://www.winsteps.com/winman/reliability.htm>.

1 good, validated, and reliable measurement of ecological behaviour would let public bodies to  
2 measure the efficacy of adopted policies.

3

4 **AUTHOR CONTRIBUTION STATEMENT**

5 The authors confirm contribution to the paper as follows: study conception and design: Cristina  
6 Pronello; data collection: Cristina Pronello; analysis of results: Pinky Kumawat; interpretation of  
7 results: Pinky Kumawat and Cristina Pronello; draft manuscript preparation: Pinky Kumawat and  
8 Cristina Pronello.

9 All authors reviewed the results and approved the final version of the manuscript.

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