

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(-)
	Category 2 - Ecological garbage handling	
6	I put dead batteries in the garbage	R1(-)
7	I sort glass wastes for recycling	R5
	Category 3 - Water and power saving	
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(-)
	Category 4 - Ecologically aware consumerism	
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
	Category 5 - Garbage inhibition	
18	I re-use plastic bag from the groceries	RR1
19	I sometimes buy beverage in cans	RR2(-)
	Category 6 - Environmental activism	
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
	Category 7 - Transport	
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 27th of October 2017 to the 24th 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 Torino¹. 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

¹https://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 ≤ 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 ≥ 0.64 , slight to moderate DIF when size CUMLOR is ≥ 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

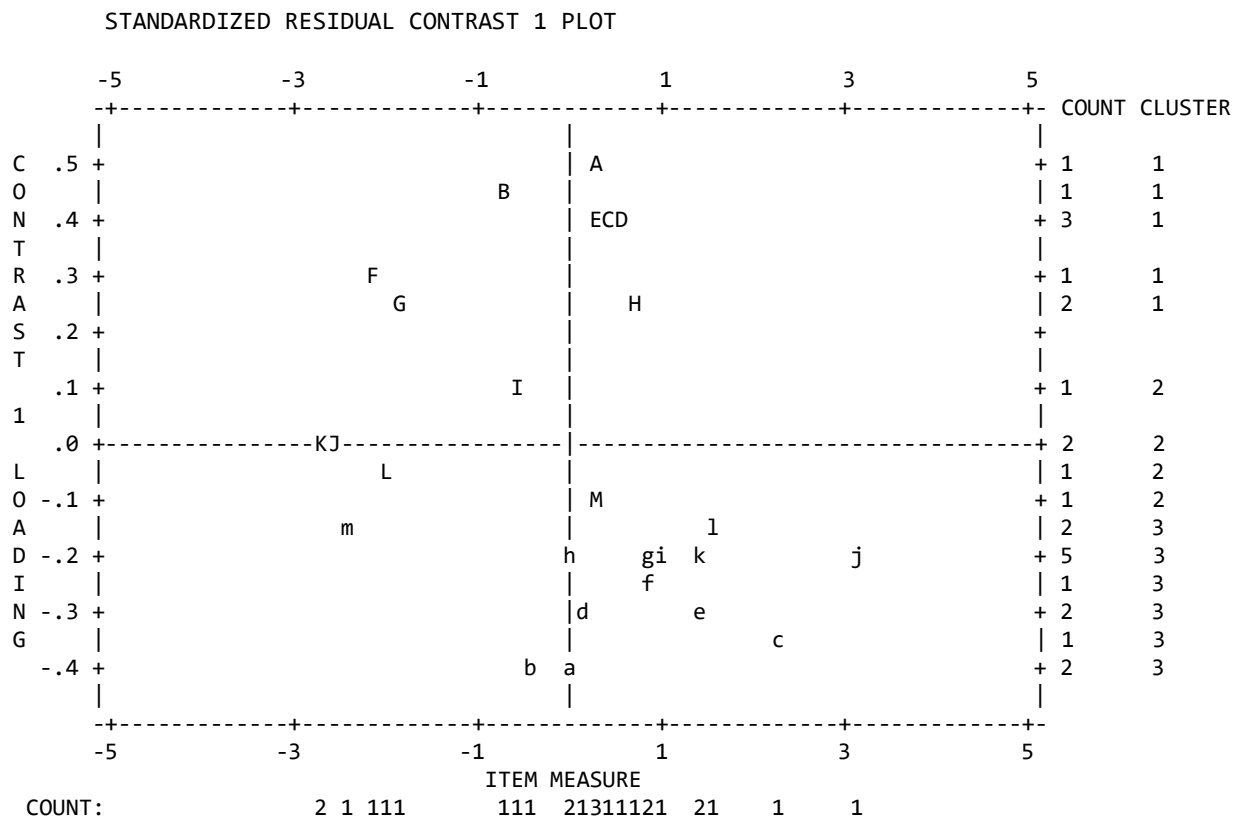


FIGURE 1 Item loadings on the first contrast

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 guidelines² 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).

² 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

15 • The most difficult item is V2 followed by item V4; both belong to the category of
 16 environmental activism;

17 • The easiest items are R5 and RR1, followed by CS3. These three items are not targeting to
 18 any person; some persons above and below these items are less inclined to GEB, so these items
 19 are not useful to the GEB measurement but still fall within the user's ability range;

20 • Items CS1 and V5 measure similar portions of the trait and therefore, from a measurement
 21 perspective, are redundant. This is also the case of items CE6, CS2, T2; CE1_REVC, T1; CE15,
 22 CS4, RR2_REVC; CE14, V3; AE4, CE9; AE5, CS6_REVC; and R5, RR1. Within groups of items,
 23 individual items can be removed losing a small precision of the measurement;

24 • We do not see the gap between items more than a logit, but there is a need to fill the
 25 measurement gaps, between V4 and CS1, and between items AE6_REVC and R1_REVC. This
 26 explains the relatively poor value of the individual separation reliability.
 27

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

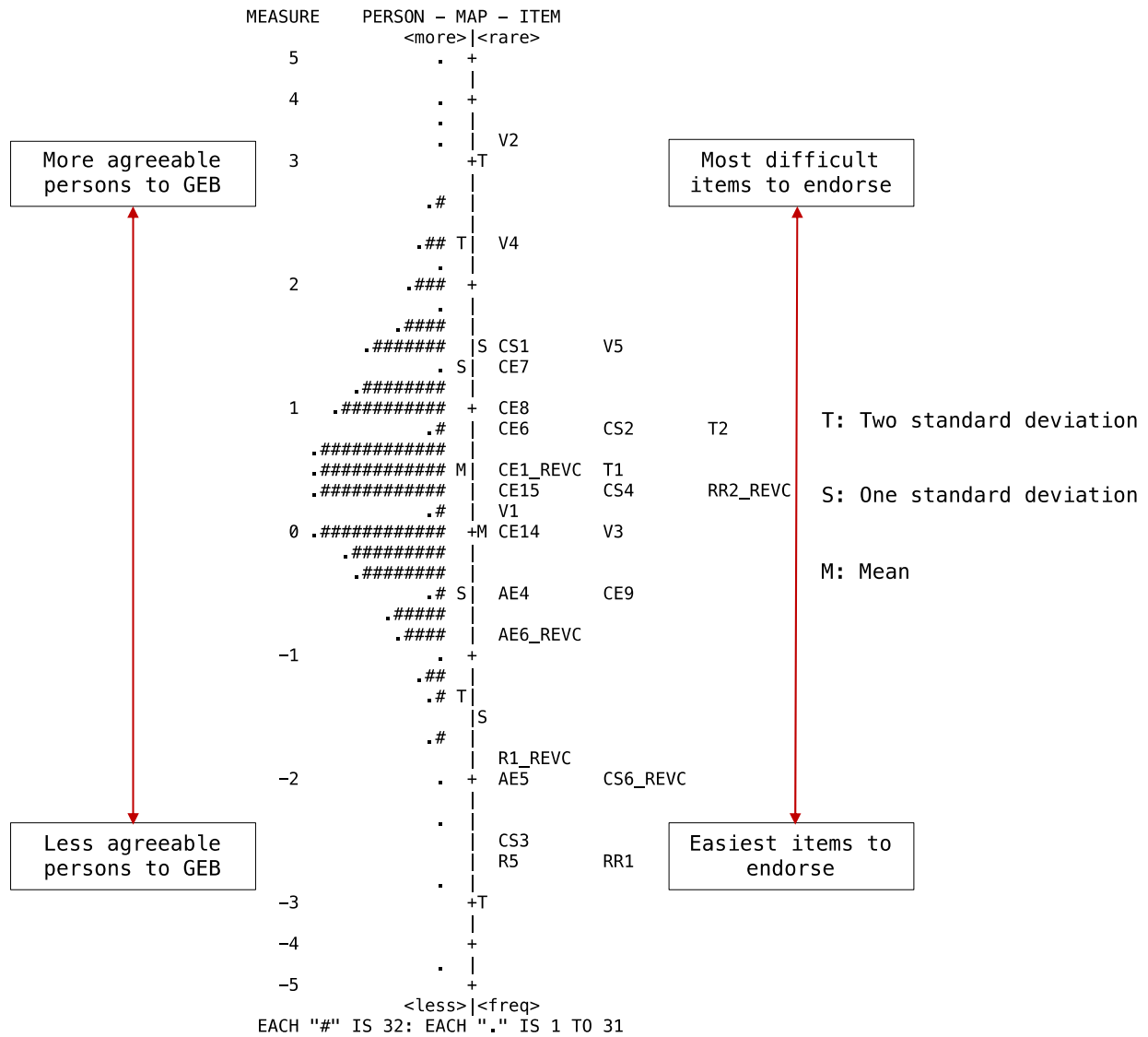


FIGURE 2 Write map

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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 Linacre³, 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

³ <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.

10

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