Perceived Mobility Need Satisfaction across Transport Modes: First Validation of the PMNS and Its Predictive Value for Mode Use and Willingness to Pay

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SHORT SUMMARY

This study provides a first psychometric examination of the Perceived Mobility Need Satisfaction (PMNS) scale across multiple transport modes and tests its predictive validity for transport use and willingness to pay. Using data from an online mobility survey at the University of the Bundeswehr Munich, 143 respondents with complete PMNS ratings across five transport modes contributed 715 mode-specific evaluations. Depending on the degree of between-person dependency, subsets of PMNS items were analysed using CFA or MCFA. The results indicate that the original PMNS structure required minor refinements, but yielded interpretable and psychometrically acceptable measurement models. Safety and comfort showed meaningful within- and between-person variance, whereas autonomy, competence, and money primarily reflected mode-specific evaluations. PMNS-derived factors further predicted cumulative travel distance and willingness to pay. Overall, the findings support the feasibility of assessing perceived mobility need satisfaction across transport modes and underline its relevance for understanding use and acceptance beyond behavioural indicators alone.

Keywords: Confirmatory factor analysis; Mobility behaviour; Multi-modal transport; Psychological needs; Public transport; Shared mobility

1. INTRODUCTION

Mobility decisions cannot be understood solely as the outcome of instrumental cost-benefit considerations, such as travel time, monetary costs, or accessibility. From the perspective of the Campbell paradigm, individuals may bridge such cost differences through motivation. Higher motivation is associated with a greater willingness to accept temporal or monetary costs and may therefore lead people to choose comparatively costly options (Kaiser, Byrka and Hartig, 2010; Taube et al., 2018).

From a need-satisfaction perspective, such motivation is shaped in part by the extent to which psychological needs are fulfilled (Ryan and Deci, 2000; Sheldon et al., 2001). The Perceived Mobility Need Satisfaction (PMNS) scale operationalises this perspective for the mobility domain (Schrills et al., 2024). Across 20 items, it assesses the extent to which a given transport mode satisfies autonomy, competence, relatedness, safety, financial concerns, physical well-being, and pleasure. In doing so, it provides a framework for examining whether differences in perceived

need satisfaction across transport modes are associated with behavioural indicators of transport use and with willingness to pay for mobility-related services.

This perspective is relevant because transport modes are unlikely to satisfy the same needs to the same degree. Prior research has shown that mobility choices are shaped not only by instrumental considerations, but also by affective and symbolic motives (Steg, 2004). More broadly, transport-related need satisfaction has been linked to well-being and behaviour (Vella-Brodrick and Stanley, 2013), and recent work suggests that mobility-related needs may also matter for the use and acceptance of specific mobility services (Gruner et al., 2024; Martín et al., 2024). In this sense, the PMNS offers a way of capturing the motivational quality of transport experiences rather than merely their functional efficiency.

At the same time, the PMNS has so far been examined primarily in more specific mobility contexts. Its broader psychometric applicability across several transport modes within the same sample remains unclear. This is an important limitation because the scale is explicitly intended to be used across different mobility options. A first validation in a multi-mode design is therefore needed to determine whether the proposed dimensions can be recovered across transport modes and whether the resulting factors are meaningfully related to behavioural outcomes.

The present study addresses this gap by providing a first psychometric examination of the PMNS in a multi-mode design including walking, cycling, public transport, private car, and campus micromobility sharing. In addition, it tests the predictive validity of the PMNS with regard to two classes of outcomes: first, indicators of transport mode use, and second, willingness to pay for a concrete potential mobility service, the BikeService, comprising free access to tools, repair services at fair prices, and bicycle purchase and resale options. The central expectation is that need satisfaction should not merely describe transport experiences, but should also explain variance in use and acceptance that is not captured by behavioural indicators alone.

2. METHODOLOGY

The study is based on an online survey conducted on the campus of the University of the Bundeswehr Munich. The full survey sample comprised 369 respondents. For the present analyses, only respondents with complete PMNS ratings for all five transport modes were retained. The analytic dataset therefore comprised 715 evaluations nested within 143 respondents who provided complete ratings across the five transport modes walking, cycling, public transport, private car, and MORE Sharing.

Demographic information comprised age, gender, net household income per month, household size, and highest educational attainment. Mobility behaviour was assessed retrospectively for the previous week for five transport modes: walking, cycling, private car, public transport, and MORE Sharing, the university's micromobility fleet. For each mode, participants reported cumulative travel distance and use frequency, that is, the total distance travelled and the total number of trips made during the previous week.

Perceived mobility need satisfaction was measured using the original German version of the Perceived Mobility Need Satisfaction (PMNS) scale (Schrills et al., 2024). The PMNS comprises 20 items intended to capture autonomy, competence, relatedness, safety, financial considerations, physical well-being, and enjoyment. All items were rated separately for each of the five transport modes on a six-point Likert scale ranging from complete disagreement to complete agreement, thereby allowing a mode-specific assessment of perceived need satisfaction.

Willingness to pay was assessed in relation to a proposed campus bicycle service (BikeService), comprising free access to tools, repair services at fair prices, and bicycle purchase and resale options. In the present study, willingness to pay was operationalised as a dichotomous indicator of whether respondents were willing to make a financial contribution to this bicycle-related service.

To examine the dimensional structure of the PMNS across transport modes, repeated mode-specific evaluations were analysed in a multilevel framework reflecting their nesting within respondents. Depending on the degree of between-person dependency indicated by the intraclass correlations (ICCs), subsets of items were modelled using either conventional confirmatory factor analysis (CFA) or multilevel confirmatory factor analysis (MCFA). Predictive validity was examined by regressing cumulative travel distance and willingness to pay on the PMNS-derived factors. For the regression analyses, all available observations without missing values on the respective outcome and predictors were used.

3. RESULTS AND DISCUSSION

The analytic sample consisted of 143 participants with a mean age of 31.53 years (SD = 12.34, range: 18–65). Of these respondents, 32.3% identified as female, 67.3% as male, and 0.3% as diverse. The sample was socio-demographically heterogeneous with respect to household composition, income, and education.

Regarding mobility behaviour in the previous week, walking was the most frequently used mode, with a mean of 20.75 trips, followed by cycling (3.30), car use (3.44), public transport (3.45), and MORE Sharing (0.93). In terms of cumulative travel distance, the largest values were reported for public transport (M = 290.74 km, SD = 447.76) and private car use (M = 246.51 km, SD = 1417.79), whereas walking (M = 25.22 km, SD = 23.24), cycling (M = 16.01 km, SD = 31.38), and MORE Sharing (M = 2.30 km, SD = 6.41) accounted for substantially shorter distances.

Figure 1 displays the PMNS response distributions across the five transport modes. The item profiles reveal marked differences between modes, indicating that perceived need satisfaction varied systematically with the transport option under evaluation.

ICC values for the autonomy, relatedness, competence, and money indicators were close to zero (ranging from .002 to .071), except for Item 7 (.273), indicating little between-person dependency and supporting the use of a conventional CFA (Hox, 2013). The initial model, including these four dimensions and their indicators except for Item 7, showed poor fit, $\chi^2(49) = 486.68$, $p < .001$, Robust TLI = .876, Robust CFI = .908, SRMR = .114, Robust RMSEA = .144. Based on modification indices, Item 8 was reassigned to the money factor, which is theoretically defensible if money is conceived as a resource. Given the weak and conceptually inconsistent performance of the relatedness indicators across modes, Items 5 and 6, together with the relatedness dimension, were removed, resulting in a substantially improved model fit, $\chi^2(32) = 118.739$, $p < .001$, Robust TLI = .968, Robust CFI = .977, SRMR = .033, Robust RMSEA = .078. Allowing residual covariance between Items 9 and 10 further improved fit, $\Delta\chi^2(1) = 26.03$, $p < .001$. Because both items refer to destination accessibility, unlike Item 11, this covariance was retained in the final measurement model (Figure 2), $\chi^2(31) = 90.128$, $p < .001$, Robust TLI = .977, Robust CFI = .984, SRMR = .027, Robust RMSEA = .066.

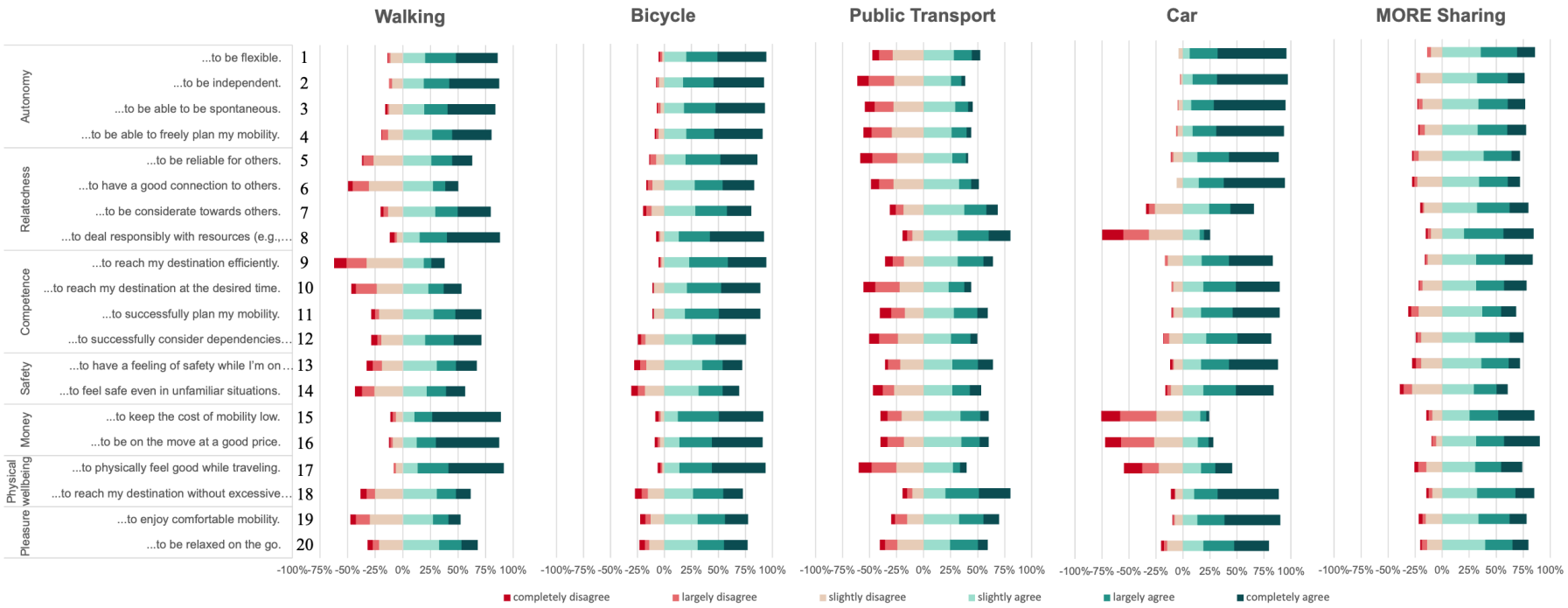


Figure 1: Descriptive Statistics of the PMNS

Compared with these indicators, those reflecting safety, physical well-being, and pleasure showed larger ICCs (.136 to .309), except for Item 17 (.028), indicating substantial between-person variance and supporting the use of MCFA (Muthén, 1994; Hox, 2013). After removing Item 17, Items 18, 19, and 20 loaded on a common factor that is most appropriately interpreted as comfort. A two-factor structure comprising safety and comfort fitted the data well at both within- and between-person levels, $\chi^2(9) = 36.360$, $p < .001$, Robust TLI = .960, Robust CFI = .982, SRMR_within = .032, SRMR_between = .019, Robust RMSEA = .075,

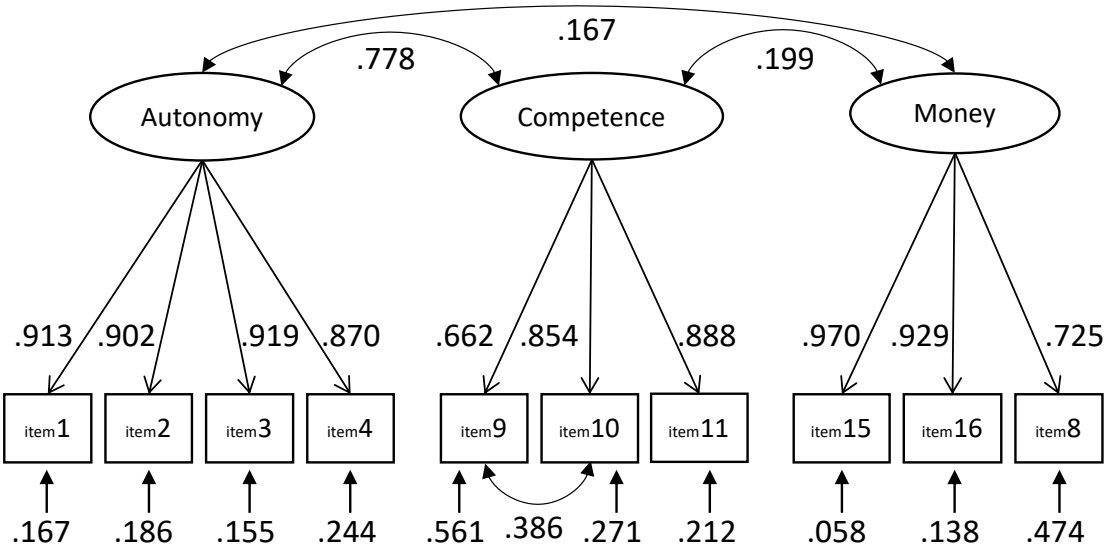


Figure 2: CFA Model

BIC = 10161.349. Constraining unstandardised factor loadings to equality across levels worsened model fit only slightly, $\Delta\chi^2(3) = 8.49$, $p = .037$, and was therefore retained in the final model (Figure 3), $\chi^2(12) = 44.363$, $p < .001$, Robust TLI = .963, Robust CFI = .978, SRMR_within = .033, SRMR_between = .081, Robust RMSEA = .073, BIC = 10155.150. The unstandardised between-level residual variance of Item 19 was fixed to .005 because the initial estimate was slightly negative (-.009, SE = .023). Given this small inadmissible variance estimate, the parameter was fixed conservatively in the final model (Kolenikov and Bollen, 2012).

Cross-level measurement invariance allows the between-level constructs to be interpreted as the person-level average of their corresponding within-level constructs across transport modes (Stapleton, Yang and Hancock, 2016; Jak, 2019). Accordingly, the between-level factors represent individual needs for safety and comfort, whereas the within-level factors represent the extent to which a given transport mode satisfies these needs. By contrast, autonomy, competence, and money showed negligible between-person variance and are therefore better interpreted as mode-specific evaluations rather than stable person-level attributes.

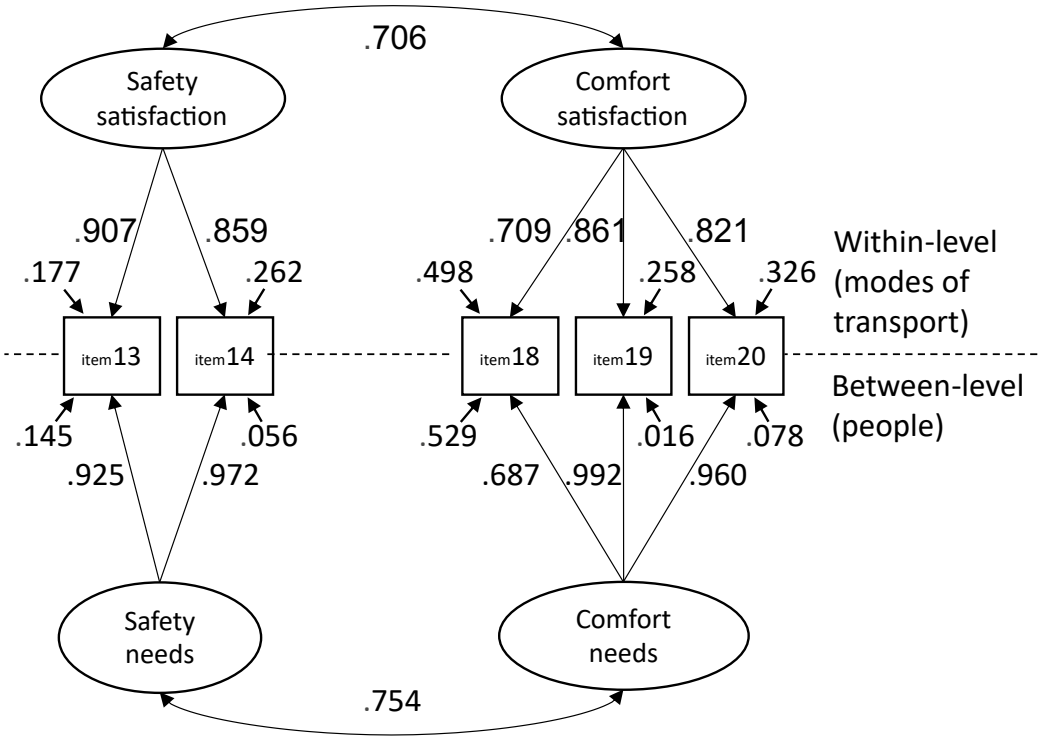


Figure 3: MCFA Model

The predictive analyses indicate that the psychometrically refined PMNS factors are behaviourally meaningful. To predict cumulative travel distance, a baseline model including transport mode only explained a modest proportion of variance, $F(4,626) = 24.12$, $p < .001$, $R^2 = .128$. Several PMNS factors were examined together with their interactions with transport mode. In the final model, only interactions involving safety and autonomy reached or approached conventional levels of statistical significance, increasing explained variance, $F(14,616) = 9.69$, $p < .001$, $R^2 = .162$. The predictive effects were not invariant across transport modes. Among the tested interactions, only the interaction between public transport and autonomy reached statistical significance, indicating that greater autonomy satisfaction was associated with greater distance travelled by public transport ($B = 76.05$, $p = .042$). No robust general effect of safety emerged; among the tested safety interactions, only the interaction with car use approached significance ($B = 68.11$, $p = .073$), suggesting a possible tendency towards greater car distance at higher levels of safety satisfaction. Interactions involving the remaining PMNS factors were also examined, but none reached statistical significance and are therefore not reported in detail. Taken together, these findings suggest that the behavioural relevance of need satisfaction is mode-specific rather than general. In particular, autonomy appears to matter for public transport use, which is noteworthy because public transport is often perceived as comparatively constrained.

Additional evidence for predictive validity was obtained for willingness to pay. Willingness to make a financial contribution to the BikeService was modelled as a function of physical comfort, bicycle use frequency, and their interaction. The model was significant, $\chi^2(3) = 37.34$, $p < .001$, with McFadden's $R^2 = .087$. Physical comfort was a significant positive predictor, $B = 0.800$, $OR = 2.226$, 95% CI [1.288, 3.846], $p = .004$, whereas bicycle use frequency as a main effect was not significant, $B = -0.126$, $OR = 0.882$, $p = .640$. The interaction between comfort and bicycle use frequency was significant, $B = 1.046$, $OR = 2.846$, 95% CI [1.150, 7.042], $p = .024$, indicating that more frequent bicycle use was associated with a higher likelihood of willingness to pay only

when bicycle use was accompanied by comparatively higher comfort satisfaction. Thus, willingness to pay for the BikeService was not explained sufficiently by behavioural exposure alone, but depended in part on need-related evaluations, particularly comfort.

4. CONCLUSIONS

Mobility needs and their satisfaction by different transport modes could be modelled successfully using CFA and MCFA after minor refinements of the original PMNS structure. These refinements should be considered in future revisions of the scale. At the same time, the successful modelling of the core dimensions supports the feasibility of assessing perceived mobility need satisfaction across transport modes and the relevance of the underlying constructs.

Initial evidence for predictive validity was also obtained. After separating mode-specific evaluations from more stable person-level differences, PMNS-derived factors predicted both travel distance and willingness to pay. In particular, autonomy satisfaction was positively associated with public transport distance, suggesting that public transport use may depend in part on whether the mode is experienced as enabling flexible and self-directed travel. Likewise, willingness to pay for the BikeService was not explained sufficiently by use frequency alone, but depended in part on comfort-related need satisfaction.

Taken together, the findings suggest that mobility services may benefit from being designed not only to improve instrumental performance, but also to satisfy users' psychological needs. For public transport especially, services that enhance perceived autonomy, for example through greater flexibility or improved intermodal options, may increase user acceptance and use from a need-satisfaction perspective.

ACKNOWLEDGEMENTS

This research is funded by dtec.bw - Digitalization and Technology Research Center of the Bundeswehr. dtec.bw is funded by the European Union - NextGenerationEU.

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