

Proceeding Paper

Analysis of Mode Reliability Factors among Off-Campus Students Using Structural Equation Modeling in Dhaka City †

Md. Mushtaque Tahmid ^{1,*}, Fuad Al Mahmud ^{1,*}, Oyshee Chowdhury ¹ and Md Asif Raihan ²

¹ Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh; 2oyshee3@gmail.com

² Accident Research Institute, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh; raihan@ari.buet.ac.bd

* Correspondence: sayeemss21@gmail.com (M.M.T.); raiyan.khan.fuad@gmail.com (F.A.M.)

† Presented at the 4th International Electronic Conference on Applied Sciences, 27 October–10 November 2023; Available online: <https://asec2023.sciforum.net/>.

‡ These authors contributed equally to this work.

Abstract: Determining the mode choice for movement in developing cities like Dhaka is beset with multifaceted challenges and intricacies, rendering it an arduous undertaking. Numerous factors contribute to the complexity, thereby impeding the selection of an optimal transportation mode. Bangladesh University of Engineering and Technology (BUET) attracts students from various regions and cultures in Dhaka city. Examining users' perceptions of preferred mode choice is the primary objective of this study. Transportation performance of buses and institutional buses was considered as most of the off-campus students are highly dependent on these two modes. Structural equation modeling (SEM) was implemented to create two distinct empirical models to investigate the correlations between key factors that impact public transportation mode choice. Models were calibrated using data from 1664 respondents who were formally surveyed about their expectations, experiences, and opinions regarding their usual means of transportation. There were 20 attributes of travel experience including safety, comfort, cost, travel time, waiting time, convenience, reliability, availability, environment friendliness, driver behavior, overtaking tendency, vehicle speed, obeying the law, accident probability, weather, punctuality of arrival and departure, etc. Policy implications have been analyzed in the context of a developing country such as Bangladesh from the perceived ratings on mode choice so that by providing reliable, efficient, and student-friendly transportation options, educational institutions, planners, and transportation authorities can support the success and overall well-being of off-campus students.

Keywords: modal analysis; structural equation modeling; mode choice



Citation: Tahmid, M.M.; Al Mahmud, F.; Chowdhury, O.; Raihan, M.A.

Analysis of Mode Reliability Factors among Off-Campus Students Using Structural Equation Modeling in

Dhaka City. *Eng. Proc.* **2023**, *56*, 259.

<https://doi.org/10.3390/ASEC2023-15872>

ASEC2023-15872

Academic Editor: Letizia De maria

Published: 7 November 2023



Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

A relatively specialized area of transportation study, analysis of student travel behavior examines how students commute to and from institutions as well as for other objectives such as extracurricular activities, employment, and social engagements. Educational institutions are in a prime position to lead in the sustainable transportation sector [1]. Off-campus students are highly dependent on either public buses or institutional buses for their day-to-day commute. The STP (2005) stated that the modal share of trips on public transport in the capital of Bangladesh, Dhaka, is about 44%. Dhaka has announced its intentions to introduce route clusters to enhance the reliability of its bus services. Despite numerous plans and initiatives, the city continues to grapple with the challenge of achieving a dependable bus service [2]. Hence, assessing reliability and mode preferences is vital at this stage. To design policies and infrastructure that can assist in lessening congestion and shortening travel time, transportation planners can obtain insight into the special mobility needs of this demographic by examining the mode preferences of students.

Individual mode preferences vary according to numerous reasons. Students, especially university students, are more versatile than others in mode choice. Since they are independent on campus and make their own daily decisions, they have complicated and diverse travel behavior. They live, study, and socialize with different types of students and so their preferences of mode frequently are influenced by others [3]. At McMaster University, Canada, students' mode choice depends on factors like cost, environment, and attitude; longer travel times reduce car and bicycle preference [4]. In Sylhet, Bangladesh, 43% of university students choose walking/cycling (active mode), while 57% opt for motorized/non-motorized vehicles (passive mode) for travel [5]. Another study examines mode choices for school travel among university members in New Delhi, revealing differences in vehicle ownership based on residence; parents' higher education discourages walking/bicycling; and, regardless of safety perception, private vehicles are preferred, particularly by mothers [6]. In another study of Abbottabad, Pakistan, gender-based mode choice preferences are analyzed [7]. One study in Los Angeles shows university students' multimodal behavior; discounted transit passes decrease car use, while factors like commute distance, gender, and social proximity influence commuting choices [8]. Key findings from a study of six universities in Vietnam show that characteristics of students such as age, gender, and income have a significant impact on their mode choice decision [9].

A mode choice behavior study of students at the University of Asia Pacific, Dhaka, found that for education purposes, a significant percentage of students use public buses [10]. A study from the University of Central Florida, USA, conducted by DeFrancisco et al. employed structural equation models (SEM) to identify the primary factors impacting the choice to carpool when commuting to a university campus [11].

Therefore, insufficient research on barriers and preferences except for socio-demographic factors of students in choosing sustainable transportation modes (public and institutional buses simultaneously), in congested and polluted cities like Dhaka can be acknowledged. This SEM study compares public and institutional bus transportation services for off-campus students to identify reliability variables and barriers, with policy implications for promoting sustainable modal shift, reducing carbon emissions and congestion, and improving the quality of student life.

2. Methodology

2.1. Data Collection and Demographic of Respondents'

The data collection method was mainly an offline questionnaire survey. We tried to sort out constraints by giving brief descriptions to the respondents and incorporating translations into Bangla (native language) for better interpretation. After filtering and eliminating anomalies, 1664 sets of data were selected for analysis. The rating of each observed variable was arranged according to Table 1. Moreover, socio-demographic data on age, gender, payment method, and arrival time were also amalgamated.

Table 1. Variable considered for survey with qualitative scale for parameters.

Variable Name ¹	Qualitative Scale	Variable Name ¹	Qualitative Scale
Vehicle Quality	Very bad quality to very good quality	Vehicle Speed	Lowest speed to highest speed
Arrival Punctuality	Very low to very high punctuality	Availability	Never to very frequently available
Driver Behavior	Very bad to very good behavior	Travel Cost	Highest cost to lowest cost
Departure Punctuality	Very low to very high punctuality	Waiting Time	Highest time to lowest time
Safety	Least safe to highly safe	Travel Time	Highest time to lowest time
Driving Skill	Very poor skill to very good skill	Overtaking	High tendency to low tendency
Obeying Law	Never obeying to always obeying law	Travel Distance	Shortest to largest distance
Comfort	Least to highly comfortable	Accident Proneness	Highest accident to least accident
Convenience	Least to highly convenient	Weather	High effect of weather to no effect of weather
Env. Friendliness	Least to highest friendliness		

¹ Numerical scale for all variables is 1 to 5.

The percentage of male participants is 68.4% and the percentage of female participants is 31.6%. This disparity is attributed to the higher participation and representation of male students at engineering universities in the context of a developing country like Bangladesh.

2.2. SEM Model

SEM (Structural Equation Modeling) was implemented to develop the structural relationship between observed and latent variables. This method combines confirmatory factor analysis and path analysis with appropriateness for determining latent constructs from observed questionnaire variables and assessment of the association between unobserved and target variables. SEM, however, performs well when the sample size exceeds 200 [12]. A general rule of thumb is that the ratio of sample size to the number of observed parameters might range from 5 to 1 [13] to 20 to 1 [14]. Considered sample sizes for each model satisfied all the above requirements. The model consists of 20 observed variables and 2 latent variables and, among the 20 observed variables, reliability is considered to be the target variable. The observed variables are vehicle quality, arrival punctuality, driving behavior, departure punctuality, safety, driving skill, obeying of law, comfort, convenience, environment friendliness, vehicle speed, availability, travel cost, waiting time, travel time, overtaking, travel distance, accident proneness, and weather. The two latent variables are overall transportation experience and travel hassle. Principal Component Analysis was carried out with VARIMAX rotation using SPSS 16.0 package. After the factor analysis, insignificant precursor for determining reliability of bus modes “Travel Cost” was eliminated. It may be because of the very lower rate of cost for students in both institutional and public bus services. Additionally, institutional buses receive subsidies from either educational institutions or the government. Therefore, it was proved as an insignificant precursor for determining reliability of bus modes.

However, the factor analysis can be considered acceptable according to the Kaiser–Meyer–Olkin (KMO) measure and Bartlett’s Sphericity Test. This factor analysis can be considered appropriate according to the KMO value (Table 2) and Bartlett’s Sphericity test was also found significant (Table 2). KMO values are classified as “Great” between 0.8 to 0.9 and factor analysis is significant when $p < 0.05$ [15]. Later, structuring SEM models with the target variable “Reliability”, along with other observed variables, was completed on STATA13, and models were run for the results. Results for both models are illustrated in Figures 1 and 2, Tables 3 and 4. Models were used to determine the associations between the target variable and other latent and observable variables. The two-tailed t-test with a 95% confidence interval was employed to verify the significance of a parameter. The models underwent a goodness-of-fit test as well; the results are displayed in Table 5. The values were in line with the accepted values.

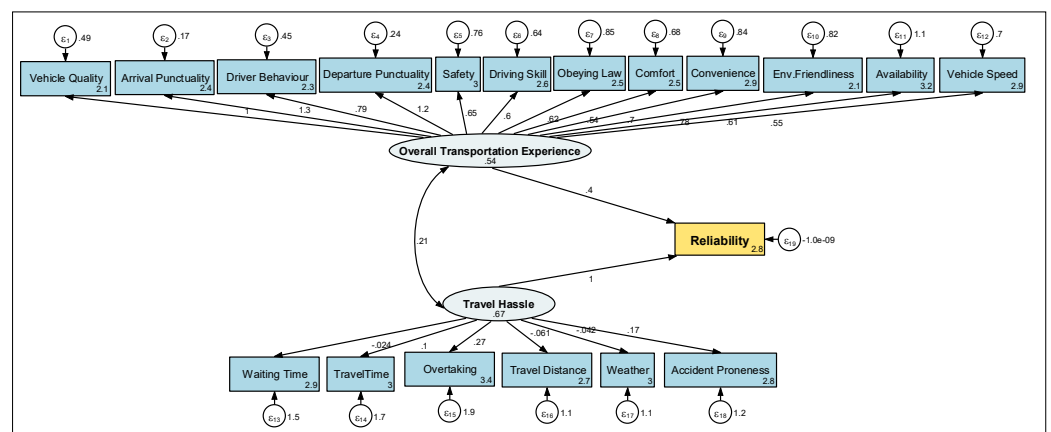


Figure 1. Reliability model for public bus.

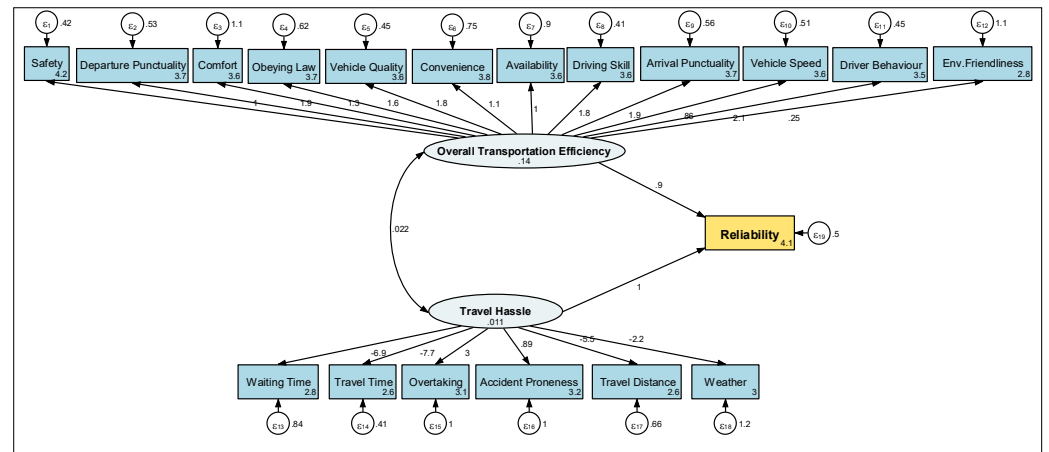


Figure 2. Reliability model for institutional bus.

Table 2. KMO and Bartlett’s Test.

Measures	Analysis Values	[15] Standard
Kaiser–Meyer–Olkin Measure of Sampling Adequacy.	0.826	0.8–0.9
Bartlett’s Test of Sphericity Approx. Chi-Square	0.0002	<0.05

Table 3. Model outputs (public bus).

Latent Variables	Observed Variables	Parameters Estimated from Model			Rank
		Coefficient	z-Value	p-Value	
Overall Transportation Experience	Vehicle Quality	1.000	-	-	3
	Arrival Punctuality	1.304	26.85	0.000	1
	Driver Behavior	0.791	19.54	0.000	4
	Departure Punctuality	1.214	25.44	0.000	2
	Safety	0.652	13.29	0.000	7
	Driving Skill	0.600	13.82	0.000	10
	Obeying Law	0.619	12.71	0.000	8
	Comfort	0.544	12.45	0.000	12
	Convenience	0.699	13.83	0.000	6
	Env. Friendliness	0.777	15.56	0.000	5
	Vehicle Speed	0.554	12.56	0.000	11
	Availability	0.605	10.76	0.000	9
Travel Hassle	Waiting Time	-0.024	-0.44	0.662	6
	Travel Time	0.105	1.49	0.135	4
	Overtaking	0.272	3.25	0.001	2
	Travel Distance	-0.614	-1.33	0.183	1
	Accident Proneness	0.167	3.27	0.001	3
	Weather	-0.042	-0.88	0.381	5
Observed Variables	Latent Variables	Coefficient	z-value	p-value	Rank
Reliability	Overall Transportation Experience	0.401	2.51	0.012	2
	Travel Hassle	1.000	-	-	1

Table 4. Model outputs (institutional bus).

Latent Variables	Observed Variables	Parameters Estimated from Model			Rank
		Coefficient	z-Value	p-Value	
Overall Transportation Experience	Safety	1.000	-	-	11
	Departure Punctuality	1.850	12.97	0.000	2
	Comfort	1.331	10.23	0.000	8
	Obeying Law	1.600	12.40	0.000	7
	Vehicle Quality	1.795	13.47	0.000	6
	Convenience	1.111	10.14	0.000	9
	Availability	1.033	9.11	0.000	10
	Driving Skill	1.843	13.75	0.000	5
	Arrival Punctuality	1.883	13.02	0.000	3
	Vehicle Speed	0.865	9.56	0.000	4
	Driver Behavior	2.053	13.80	0.000	1
Env. Friendliness	0.254	2.46	0.014	12	
Travel Hassle	Waiting Time	-6.858	-2.66	0.008	2
	Travel Time	-7.686	-2.64	0.008	1
	Overtaking	3.019	2.54	0.011	4
	Accident Proneness	0.890	1.73	0.084	6
	Travel Distance	-5.483	-2.59	0.010	3
	Weather	-2.225	-2.31	0.021	5
Observed Variables	Latent Variables	Coefficient	z-value	p-value	Rank
Reliability	Overall Transportation Experience	0.903	8.24	0.000	2
	Travel Hassle	1	-	-	1

Table 5. Goodness of fit.

Fit Indices	Public Bus	Inst. Bus	Standard
Absolute Fit Index			
Root Mean Squared Error of Approximation (RMSEA)	0.065	0.070	0.05–0.08
Standardized Root Mean Square Residual (SRMR)	0.101	0.050	<0.1
Incremental Fit Index			
Comparative Fit Index (CFI)	0.825	0.833	0.95
Tucker–Lewis Fit Index (TLI)	0.784	0.810	0.95

3. Results and Discussion

3.1. Factor Analysis

Confirmatory factor analysis (CFA) was used to reduce the twenty observed variables into smaller sets of factors. Two factors were extracted from the factor analysis. The findings showed that 45.983% of the variation could be explained. After factor analysis, observed variables were clustered into two latent attributes: “Overall Transportation Experience” and “Travel Hassle”.

3.2. Model Interpretation

In the SEM model of the public bus (Figure 1, Table 3), waiting time ($p = 0.662$), travel time ($p = 0.135$), travel distance ($p = 0.183$), and weather ($p = 0.381$) emerged as insignificant precursors for predicting reliability. However, in the SEM model of the institutional bus (Figure 2, Table 4), only accident proneness ($p = 0.084$) was found to be an insignificant precursor. Waiting times and travel times have little bearing on public bus network reliability because, as a developing nation, Bangladesh struggles to maintain an effective transportation infrastructure. In addition, bus schedules are impacted by poor road conditions, high urban densities, mechanical issues, rising population densities, and traffic congestion, and, thus, a general perception among students has been formed that these issues are common and far beyond the control of the administration. Therefore, due

to tolerance, lower expectations than in developed countries, and limited affordability to use other modes, waiting and travel time are not a striking indicator for predicting the reliability of public buses. Moreover, travel distance is also an insignificant precursor for the reliability of public buses because, in developing countries like Bangladesh, bus routes are relatively shorter having less variability in travel distance. In addition, bus systems operate on fixed routes and between frequent predetermined stops. As in Bangladesh, weather conditions are not extreme and there are better adaptive systems of buses, weather is perceived as an insignificant indicator of reliability. However, waiting time, travel time, travel distance, and weather are significant indicators for the model of institutional bus (Figure 2) because there are more expectations of students from institutional bus services regarding these issues. Accident proneness was proved to be insignificant for the model of institutional bus services because there is ingrained reliability among students from the institutional bus services to be accident free.

In the models of public buses (Figure 1, Table 3) and institutional buses (Figure 2, Table 4), latent variable travel hassle impacts reliability more than transportation experience. Overtaking (Coeff. 0.272, Table 3) and accident proneness (Coeff. 0.167, Table 3) were the influencing precursors of travel hassle impacting reliability in the model for public buses. Less accident proneness and overtaking tendency enhance the reliability of using bus services. In Bangladesh, bus accidents are severe where there are lack of police control and median [16]. In terms of the lack of law enforcement, accident probability increases, and overtaking, speeding also appear in road networks, resulting in the loss of reliability. Arrival punctuality (Coeff. 1.304), departure punctuality (Coeff. 1.214), and vehicle quality (Coeff. 1.000) were the top three (Table 3) striking factors of reliability under the latent variable "overall transportation experience". Punctuality is seen as an important factor in student life and reliability perception is increased among them if the transportation service is punctual. Students are also more concerned about the vehicle quality of public buses for better perception and consciousness.

In the institutional bus model (Figure 2), waiting time, travel time, and travel distance negatively affect reliability because students can access institutional bus services from different remote routes and reach their remote destination from the university. Under the latent variable of overall transportation experience driver behavior, departure punctuality, and arrival punctuality were influencing reliability more than other observed variables. Vehicle quality was perceived as a mid-ranked influencing factor of reliability. As safety and availability can be ensured properly by the university, the influence was lesser from those factors. It was also noticeable that there was a proclivity of lesser environmental concern from the administration in public bus services than in institutional bus services. There was more expectation of vehicle speed, driving skill, and comfort in institutional bus services than in public bus services, according to the models.

3.3. Model Fit

The models have undergone a goodness-of-fit test, and the obtained value indices are presented in Table 5. These values confirm that the model exhibits reasonably favorable fit indices [17].

4. Conclusions

Based on the findings of this research, it is evident that users of both public buses and institutional buses are primarily concerned with issues related to travel inconvenience. To enhance the reliability of these modes of transportation, it is imperative to prioritize factors such as optimizing routes, improving the efficiency of boarding and alighting, minimizing travel time and distance in public services, and effectively managing driver behavior and attitude. Developing efficient and well-planned routes, implementing measures to streamline boarding and disembarking, introducing dedicated lanes for public transportation, minimizing unnecessary detours and distances for users, enforcing strict training, monitoring protocols for drivers to ensure safe and customer-oriented behavior, and prioritizing

facilities according to the convenience of the students from the survey can be accomplished by policymakers and urban planners to introduce a reliable and sustainable transportation mode for students in a developing country like Bangladesh.

Author Contributions: Conceptualization, M.M.T. and F.A.M.; methodology, M.M.T. and F.A.M.; software, M.M.T. and F.A.M.; validation, M.M.T., F.A.M. and O.C.; formal analysis, M.M.T., F.A.M., O.C. and M.A.R.; investigation, M.M.T., F.A.M., O.C. and M.A.R.; resources, O.C.; data curation, O.C.; writing—original draft preparation, M.M.T. and F.A.M.; writing—review and editing, M.M.T. and F.A.M.; visualization, M.M.T. and F.A.M.; supervision, M.A.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

References

- Balsas, C.J.L. Sustainable Transportation Planning on College Campuses. *Transp. Policy* **2003**, *10*, 35–49. [CrossRef]
- Plan after Plan, a Reliable Bus Service Still Eludes Dhaka | The Business Standard. Available online: <https://www.tbsnews.net/bangladesh/plan-after-plan-reliable-bus-service-still-eludes-dhaka-629094> (accessed on 14 September 2023).
- Limanond, T.; Butsingkorn, T.; Chermkhunthod, C. Travel Behavior of University Students Who Live on Campus: A Case Study of a Rural University in Asia. *Transp. Policy* **2011**, *18*, 163–171. [CrossRef]
- Whalen, K.E.; Páez, A.; Carrasco, J.A. Mode Choice of University Students Commuting to School and the Role of Active Travel. *J. Transp. Geogr.* **2013**, *31*, 132–142. [CrossRef]
- Urmi, U.F.; Rahman, K.; Uddin, M.J.; Hasan, M.N. The Prevalence of Active Commuting to School and the Factors Influencing Mode Choice: A Study of University Students in a Secondary City of Bangladesh. *Sustainability* **2022**, *14*, 16949. [CrossRef]
- Sarangi, P.; Manoj, M. Escorting and Mode Choice Decisions of Members of an Urban University in New Delhi, India. *Case Stud. Transp. Policy* **2020**, *8*, 1440–1450. [CrossRef]
- Lodhi, R.H.; Rana, I.A.; Waheed, A. Gendered Mode Choice Preferences and Characteristics for Educational Trips in Abbottabad, Pakistan: An Empirical Investigation. *Case Stud. Transp. Policy* **2022**, *10*, 2102–2110. [CrossRef]
- Zhou, J. Sustainable Commute in a Car-Dominant City: Factors Affecting Alternative Mode Choices among University Students. *Transp. Res. Part A Policy Pract.* **2012**, *46*, 1013–1029. [CrossRef]
- Nguyen-Phuoc, D.Q.; Amoh-Gyimah, R.; Tran, A.T.P.; Phan, C.T. Mode Choice among University Students to School in Danang, Vietnam. *Travel Behav. Soc.* **2018**, *13*, 1–10. [CrossRef]
- Nasrin, S. Private University Students' Mode Choice Behaviour for Travel to University: Analysis in the Context of Dhaka City. In *Proceedings of the Transportation Research*; Mathew, T.V., Joshi, G.J., Velaga, N.R., Arkatkar, S., Eds.; Springer: Singapore, 2020; pp. 299–310.
- DeFrancisco, J.; Harb, R.; Radwan, E. Evaluation of a Carpooling Program in a University Setting Using a Stated Preference Survey. In *Proceedings of the Transportation Research Board 93rd Annual Meeting*, Washington, DC, USA, 12–16 January 2014.
- Lei, P.-W.; Wu, Q. Introduction to Structural Equation Modeling: Issues and Practical Considerations. *Educ. Meas. Issues Pract.* **2007**, *26*, 33–43. [CrossRef]
- Bentler, P.M.; Chou, C.-P. Practical Issues in Structural Modeling. *Sociol. Methods Res.* **1987**, *16*, 78–117. [CrossRef]
- “How Big Is Big Enough?": Sample Size and Goodness of Fit in Structural Equation Models with Latent Variables. Available online: <https://psycnet.apa.org/record/1987-17621-001> (accessed on 15 September 2023).
- The Multivariate Social Scientist. Available online: <https://uk.sagepub.com/en-gb/eur/the-multivariate-social-scientist/book205684> (accessed on 15 September 2023).
- Barua, U.; Tay, R. Severity of Urban Transit Bus Crashes in Bangladesh. *J. Adv. Transp.* **2010**, *44*, 34–41. [CrossRef]
- Hu, L.; Bentler, P.M. Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria versus New Alternatives. *Struct. Equ. Model. Multidiscip. J.* **1999**, *6*, 1–55. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.