Confirmatory Factor Analysis of Comprehensive Traffic State Assessment: A Case Study Approach Towards an Integrated LGU Transportation Planning and Traffic Management Model

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Abstract

The swiftly metamorphosing networks of the Philippine transportation system greatly encourage movement all around the country. The capacity of the country's major roads in comparison with the opportunities and exigencies that demand the people to travel is frequently misaligned— metropolises are now enabled to cater more road networks and the main road segments have become more congested. This impacts neighboring developing cities like Meycauayan. This study aimed to conceive a CTSA (Comprehensive Traffic State Assessment) model by using the road segment of Iba-Malhacan as a case study. The study employed confirmatory factor analysis for the testing of hypotheses and verification of the model's integrity involving a sample size of 204 Meycauayan residents; all the established hypotheses were sufficiently proven and the model also indicated an overall good fit. The study also employed a simplified road and traffic analysis for the delineation of the road segment's general traffic state. The study determined that the gradual worsening of the traffic state was mainly because of the immense aggregate average daily volumes of standard passenger cars, four-wheeled PUVs (public utility vehicles), as well as large trucks and other heavy vehicles both capital-bound and homeward— a CTSA-based objectives tree was engendered as a recommendation.

Keywords: Transportation planning, traffic management, confirmatory factor analysis

1. Introduction

It is quite fair to state that the capacity of the country's major roads in comparison with the opportunities and exigencies that demand the people to travel are frequently misaligned— the impacts of the rapid industrialization, urbanization, and the infrastructure boom crawl with haste to neighboring cities within the close vicinity of Mega Manila, and a particular one is the City of Meycauayan. Meycauayan is a rapidly developing city which acts as a gateway for the National Capital Region into the rural parts of Central Luzon. In recent years, Meycauayan has been highly industrialized due to it being once abundant in land and vicinity to the nation's capital— industrial parks were gradually erected in the city; a consequence of that is the emergence of small to heavy industry trucks and their subsequent contribution to the traffic composition. Currently, Meycauayan suffers from daily traffic congestion covering most of the main roads; the jams would put the cars into a standstill especially at peak hours. The road segments that frequently suffer from this plight are the ones that are connected to major intersections of the city, a particular road segment that bears the greatest brunt is the span of Iba-Malhacan— which covers the great majority of travels both in the secondary and tertiary roads. In relation to all these, constructing a model for transport planning and traffic management that shall take into consideration the expeditious growth of locales, together with the rate of urbanization and industrialization, as well as taking into account the various elements that bring about significant impacts is highly imperative as also once emphasized by Lidasan, Espada, & De Leon (2010).
The overture of this case study encompassed the necessity of formulating a comprehensive model for the integrated LGU (local government unit) transportation planning and traffic management model, as well as the supposed benefits of conducting research pertaining to the said subject. The main component of the research was the formulation of the comprehensive LGU transportation planning and traffic management model by utilizing the road segment of Iba-

Malhacan in the City of Meycauayan, Bulacan as a case study. The focus of the study was the determination of the significant considerations comprising the systematic approach to municipal-scale transportation planning and traffic management.

2. Methodologies

2.1. Conceptual Framework

The focal interest of this case study was the construction of an integrated LGU transportation planning and traffic management model by being able to quantifiably evaluate a certain city's traffic state, as well as by being able to establish a general traffic predicament diagnosis, and thereafter engender action plans which uphold citizen-centric and sustainable ideals. In alignment with that, the research aspired to establish the modeling by conducting a simplified traffic and road analysis as well as by defining traffic state as a coalescence of three faculties: the faculty of traffic management systems, the faculty of service, and the faculty of transport sustainability. In this model, the stated faculties describe a certain LGU's transportation planning and traffic management capabilities with regards to the equipoise of the local travel demand and nominal transport infrastructure capacities, the impacts of traffic to the locale and the environment, as well as the service quality in terms of transportation LOS (level of service). The approach was systematic as per the review of Flores, Mújica, & Hernández (2015). The framework presented in Figure 1 served as the basis in the prosecutions of this study.

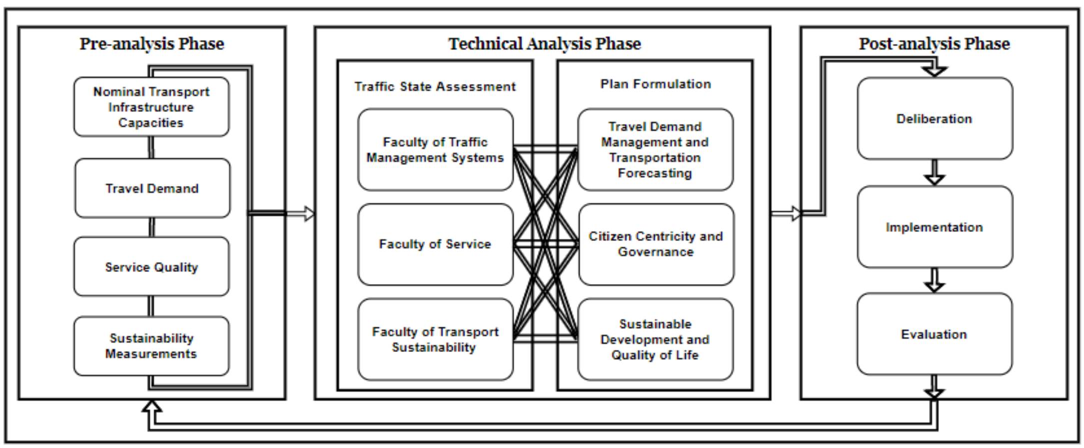

Figure 1. Conceptual Framework

In this model, the pre-analysis phase entails the identification of the significant elements involved in the conceptualization of the traffic planning model aligned with the established goals and objectives in consideration of the environment primarily affecting the system. It comprises four integrants, namely: Nominal Transport Infrastructure Capacities, Travel Demand, Service Quality, and Sustainability Measurement. The succeeding phase, which is essentially composed of the undertakings that enable the evaluation of then identified elements in a quantifiable manner as well as convert them into actionable information; the technical analysis phase includes two sub-phases: the traffic state assessment, which will take into account all the particulars of the three faculties coalescing in order to define the traffic state— and the plan formulation, which entails the development of the detailed outlining of the transportation and traffic management action plan with regards to citizen-centricity and quality of life. This phase was synthesized through the findings of Zhang et al. (2017), Shewmake, (2012), Watling et al. (2012), Hidayati et. al. (2019), Salini et al. (2016), Cascetta & Cartenì (2013), Van Ryzin (2004), Nigro (2012), Koval et al. (2018), Kamaruddin & Noor (2017), Griškevičiūtė-Gečienė & Griškevičienė (2016), Popova (2017), Todd (2014), Mosaberpanah, & Khales (2012), Singh (2016), as well as Rafiemanzelat et al. (2017) in all of their studies pertaining to the stated elements and discussed subjects regarding transportation planning and traffic management. Lastly, the post-analysis phase, which is aligned with the upholding of citizen-centric ideals in governance through unending furtherance and refinement. It comprises three iterative steps, namely: Deliberation, Implementation, and Evaluation.

Having stated all of these, the following hypotheses were also established:
H1: There is a discerned correlation between traffic management systems and service quality

H2: There is an ascertained correlation between transport sustainability and service quality
H3: There is a distinguished correlation between traffic management systems and transport sustainability

2.2. Confirmatory Factor Analysis

For the proving of the hypotheses established for the integrated LGU comprehensive LGU transportation planning and traffic management model, the research utilized the CFA (confirmatory factor analysis) method through IBM SPSS Statistics and AMOS in order to ascertain the conclusiveness of the model. According to Dragan and Topolšek (2014), the CFA multivariate statistical technique is essentially utilized considering the predetermined abstractions substantiated by theoretical research is already present— as it was the case for this study, the said factor analysis method was utilized in order to determine the significant relationship described by the model between the manifest and the latent variables, the correlational associations among latent variables themselves, the degree to which the data is explained by the model, as well as other model fit indices commonly referred in CFA. Presented in Figure 2 and were the AMOS-yielded CFA model.

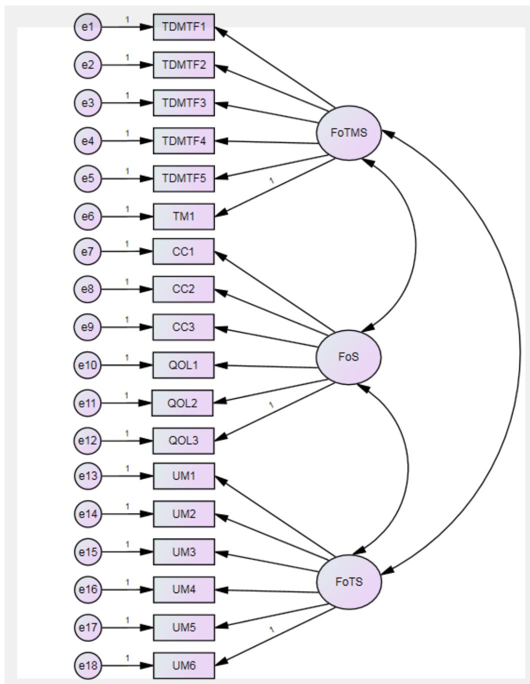

Figure 2. IBM SPSS AMOS-yielded CFA model

In this case study, the CFA method was utilized in order to prove the stated hypotheses and also validate the integrity of the postulated model through the associations and indices established as academic standards, presented in Table 1.

Table 1. CFA utilization rationale and definitions

Element	Definition
Correlation (Latent Variables)	The measure which exhibits the associative relationship between latent variables
Standardized Regression Weights (Manifest Variables)	The measure which exhibits the overall influence of each manifest variable/s on the latent variable/s
Absolute Fit Indices	The measure which brings forth the basal substantiation of the proposed model relative to the gathered data
Incremental Fit Indices	The measure which compares the proposed model to a null one

Parsimony Index	The measure which indicates the simplicity of the proposed model
Convergent Validity and Reliability	The measure which exhibits the factual associations of proposed related constructs

2.3. Simplified Road and Traffic Observation

The case study also employed a structured observation approach in the data gathering for the simplified traffic flow analysis in order to approximate Meycauayan City's annual average demand flow rate and thereupon be able to assess the general state of traffic through the principles of CTSA. A cumulative amount of 10 weeks— which then yielded 35 days worth of raw traffic data— were allotted for the structured observation in order to achieve a rigid baseline for the traffic data analysis. A fundamental analysis of the road characteristics was executed in order to determine the road segment capacity— highly complex road and traffic analysis were not explored extensively. The simplified road and traffic analysis also employed a traffic survey exclusively for Meycauayan residents which delineates a sample's general travel inclinations, commuting preferences, and the such; the survey only focused on the fundamentals and did not delve deeper into the study of driver and pedestrian behavior in the highest degree. The Iba-Malhacan road segment was divided into four main sections namely: road sections A, B, C, D, and each of these sections was further divided into four more subsections for the purpose of conducting a precise traffic observation primarily through manual means. The vehicles were also classified accordingly presented in Table 2.

Table 2. Established vehicle classification

Vehicle Type		Average Dimensions		Projected Static Operational Area (m²)
		Length (m)	Width (m)	
2W-B	Two-wheeled Class 1	2.3000	1.3750	3.1625
2W-M1	Two-wheeled Class 2 Type 1	2.0327	1.2367	2.5137
2W-M2	Two-wheeled Class 2 Type 2	2.4670	1.3377	3.3000
3W-T1	Three-wheeled Class 1	2.1000	1.8250	3.8325
3W-T2	Three-wheeled Class 2	3.3650	1.8650	6.2757
4W-PC1	Four-wheeled Class 1	4.9783	2.4050	11.9729
4W-PC2	Four-wheeled Class 2	7.5000	2.7417	20.5625
THIV1	Trucks and other Heavy/ Industry Vehicles Class 1	8.9833	3.1417	28.2226
THIV2	Trucks and other Heavy/ Industry Vehicles Class 2	12.9000	3.1250	40.3125
THIV3	Trucks and other Heavy/ Industry Vehicles Class 3	15.5333	3.1250	48.5417

The adaptation of the methodologies and formulae of the FHWA-USDOT (Federal Highway Administration of U.S. Department of Transportation), the AASHTO (American Association of State Highways and Transportation Organization), and the DPWH (Department of Public Works and Highways) enabled the calculations pertaining to road capacity, traffic volume, and composition, as well as the transportation LOS through the establishment of a PCU value and volume-demand ratio. This simplified road and traffic flow analysis aimed to approximate the annual average daily traffic using the data collected in the whole span of the structured traffic observation. Presented in Table 3 were the established PCU per road subsection.

Table 3. Calculated PCU per road section

Road Section	2-wheeled Vehicles			3-wheeled Vehicles		4-wheeled Passenger Vehicles		Trucks and Other Heavy Vehicles		
	2W-B	2W-M1	2W-M2	3W-T1	3W-T2	4W-PC1	4W-PC2	THIV1	THIV2	THIV3

A	A.1	0.4402	0.2100	0.2756	0.4001	0.6552	1.0000	1.7174	2.9465	4.2087	5.0679
	A.2	0.5283	0.2100	0.2756	0.4801	0.2641	1.0000	1.7174	2.8287	4.0404	4.8652
	A.3	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	A.4	0.5283	0.2100	0.2756	0.4801	0.2641	1.0000	1.7174	2.8287	4.0404	4.8652
B	B.1	0.5283	0.2100	0.2756	0.4801	0.2641	1.0000	1.7174	2.8287	4.0404	4.8652
	B.2	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	B.3	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	B.4	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
C	C.1	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	C.2	0.7924	0.2100	0.2756	0.4801	0.2641	1.0000	1.7174	2.8287	4.0404	4.8652
	C.3	0.5283	0.2100	0.2756	0.3201	0.2641	1.0000	1.7174	3.1429	4.4893	5.4057
	C.4	0.5283	0.2100	0.2756	0.3201	0.2641	1.0000	1.7174	3.1429	4.4893	5.4057
D	D.1	0.5283	0.2100	0.2756	0.3201	0.2641	1.0000	1.7174	3.1429	4.4893	5.4057
	D.2	0.6603	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	D.3	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679
	D.4	0.4402	0.2100	0.2756	0.4001	0.2641	1.0000	1.7174	2.9465	4.2087	5.0679

3. Results and Discussion

3.1. Confirmatory Factor Analysis Outcomes

The employed estimation method was maximum likelihood, as it is the most logical parametric given that the model was postulated factually. Presented in Table 4 is the overall acceptable CFA yielded results; the primary outcome pertinent to the case study's realization, which was the correlations among the latent variables, were all identified to be within the fairly strong positive relationship spectrum— all the three correlations yielded considerable values above the acceptable threshold thus the three established hypotheses were sufficiently proven. The uncorrelated low error variances also indicated that the measurements used were generally reliable. Moreover, the factor loadings were also identified to be generally within the minimum acceptable ranges as per Dragan and Topolšek (2014) excluding three, namely: TDMTF2, TDMTF3, and UM2— this implied that these three manifest variables did not particularly offer a scale of measure which is significant in comparison with the other factors. These assessments of factor loadings essentially reflect the convergent validity among variables with respect to the sample size of the data; this, therefore, indicated that the relatively low factor loadings of the three stated variables does not exactly solely signify discrimination, but more so a possible insufficiency in the a priori determination of statistical power. Nevertheless, 15 manifest variables were retained as significant factor loadings were engendered.

Table 4. Factor loadings and correlation of latent variables

Latent Variables	Correlation	Significant Correlation	Verdict
FoTMS - FoS	1	> 0.7	Significant
FoS - FoTS	0.842		Significant
FoTS - FoTMS	0.880		Significant
Manifest Variables	Standardized Regression Weights	Significant Factor Loading for n=200	Verdict
TDMTF1	0.693	> 0.4	Significant
TDMTF2	0.178		Insignificant
TDMTF3	0.233		Insignificant
TDMTF4	0.424		Significant
TDMTF5	0.507		Significant
TM1	0.47		Significant
CC1	0.661		Significant
CC2	0.649		Significant
CC3	0.566		Significant
QOL1	0.663		Significant
QOL2	0.827		Significant
QOL3	0.838		Significant
UM1	0.757		Significant
UM2	0.329		Insignificant
UM3	0.763		Significant
UM4	0.664		Significant
UM5	0.642		Significant
UM6	0.557		Significant

Presented in Table 5, the model yielded an overall good fit as per the standard thresholds; advancing to the absolute fit indices, CMIN/DF, GFI, RMSEA, and SRMR values were within acceptable and good ranges— this implied that the model fits the sample data well and further validated the integrity of the case study's hypotheses. Incremental fit indices such as the TLI and the CFI essentially compare performances between the proposed model and a null one; engendering values within the acceptable range indicates how the model of interest surmounts the null model in improving the overall fit. The PNFI was also reported to be within good range and what this essentially pertains to is the parsimoniousness of the hypotheses. Lastly, the AVE and CR were calculated with regards to the dismissal of the three manifest variables with low factor loadings and it was initially identified that the AVE was inadequate as it barely neared the cut-off value; but then as the CR exceeded its respective threshold, the model retained adequacy in its convergent validity as per Fornell & Larcker (1981).

Table 5. Model fitness

Fitness Indices	Acceptable Values	Model Fitness	Verdict
CMIN/DF	< 3	2.244	Good
GFI	≥ 0.85	0.847	Acceptable
TLI	≥ 0.80	0.860	Acceptable
CFI	≥ 0.90	0.879	Acceptable
RMSEA	< 0.07	0.078	Good
SRMR	> 0.5	0.0674	Good
PNFI	> 0.5	0.693	Good
AVE	> 0.5	0.431	Acceptable, due to CR
CR	> 0.6	0.916	Good

3.2. Simplified Road and Traffic Observation Outcomes

The traffic observation that was conducted in the span of the Iba-Malhacan road segment focused primarily on the fundamental measurements. All of the data gathered in the structured traffic observation enabled the determination of the road segment traffic data metrics presented in Table 6.

Table 6. Iba-Malhacan road segment traffic data

Metric	Observed	Historical Data			
	2020	2019	2018	2017	2016
Approximate Annual Average Daily Traffic	27,317	25,601	21,052	20,151	20,194
Change Rate	1.0670	1.2161	1.0446	0.9979	-
Average Change Rate	1.0814				

Average Hourly Traffic Composition for the Iba-Malhacan Road Segment

Vehicle Type	Approximate Hourly Volume		Approximate Roadway Occupancy (km)	Approximate Vehicle Occupancy (person)
	(Vehicles)	(PCU)		
2W-B	227	116	522	227
2W-M1	237	50	483	356
2W-M2	326	90	804	489
3W-T1	267	108	560	666
3W-T2	198	57	667	496
4W-PC1	281	281	1398	983
4W-PC2	254	435	1901	887
THIV1	58	172	522	
THIV2	54	227	694	-
THIV3	49	249	760	
Total	1951	1784	8.312	4105
Nominal Capacity of the Iba-Malhacan Road		1461	8	-

The road segment of Iba-Malhacan on most hours of a day, as presented in Table 7, garnered an average LOS rating of F or saturated; the volume-capacity ratios exceeded the value of one and that essentially indicates that there is a recognizable misalignment between the nominal infrastructure capacity and the travel demand. This entails that the entire span of Iba-Malhacan experiences lockstep situations quotidianly and at most times of the day. The section that was identified to be relatively performing better compared to the rest of the road segment was section C2 as it's the sole section that has four lanes and thus was able to cater the immense volume less worstly— in the other hand, section D1 naturally performed the worst as it had the smallest nominal capacity.

Table 7. Approximate average LOS of the Iba-Malhacan road segment

Road Section	Volume-Capacity Ratio	Approximate Average LOS

Road Section A	1.2144	F	Saturated
Road Section B	1.2428	F	Saturated
Road Section C	1.1393	F	Saturated
Road Section D	1.3854	F	Saturated

These results exhibit that in the holistic perspective, the road segment of Iba-Malhacan in the City of Meycauayan suffers mainly from too great of a burden primarily caused by the gross demand flow rate of standard vehicles, PUVs, as well as large trucks and other heavy vehicles— as elaborated in the prior chapters, the misalignment of the travel opportunities and exigencies with the current nominal capacity of transport infrastructures create this state of oversaturation that just ceases movement in certain sections of the road in various hours of the day. Obtaining a consistent LOS rating of F profoundly indicates a below-par service-providing capacity from the perspective of an average traveler; this firmly suggests that an average individual who inevitably passes this road segment in a routinary manner has to tolerate this average traffic state in the same frequency. Attributing all the established notions discussed in the chapter prior, these kinds of outcomes can be associated with a relatively deprived well being and quality of life— having such a low approximate average transportation level of service indicates the frequency in which the discussed standstills and lockstep traffic situations occur; this accordingly translates to human and environmental stress altogether. As identified in the CFA, the manifest variables QOL2 and QOL3 engendered the highest factor loading; these variables pertained to the significance of a certain locale's traffic state to one's perceived general well being as well as the effects brought about by the asserted traffic state to the general air quality of the respective locale. Ascribing and incorporating the examined results of the traffic survey in the outcomes of the road and traffic analysis, a well-grounded association between the predominant destinations of routinary travels and excessive volumes of PUVs can be established; the average Meycauayan resident is either a public commuter habitually utilizing three to four modes of public transit before reaching their destination or a private one availing themselves of their respective vehicles— traveling both intrazonal and interzonal, but primarily the former. All in all, these were the elaborations for the principal outcomes of the case study. The interpretation of the results is based on the grand synthesis of concepts established by the modeling and formulation of the CTSA, hence a CTSA-based traffic problem tree was engendered for the City of Meycauayan, as presented in Figure 3. The problem tree was essentially constituted by four parts— the leaves which were in the uppermost portion, the truck which was situated in the middle, and the roots together with the bedrock way below the entangled bottom area. In the CTSA-based problem tree, the trunk represented the core problem of the Iba-Malhacan road segment, the leaves signified the immediate negative effects that the core problem induced, the roots in turn were the primary and secondary causes, and the bedrock manifests the insufficiency in the subject locale's faculties.

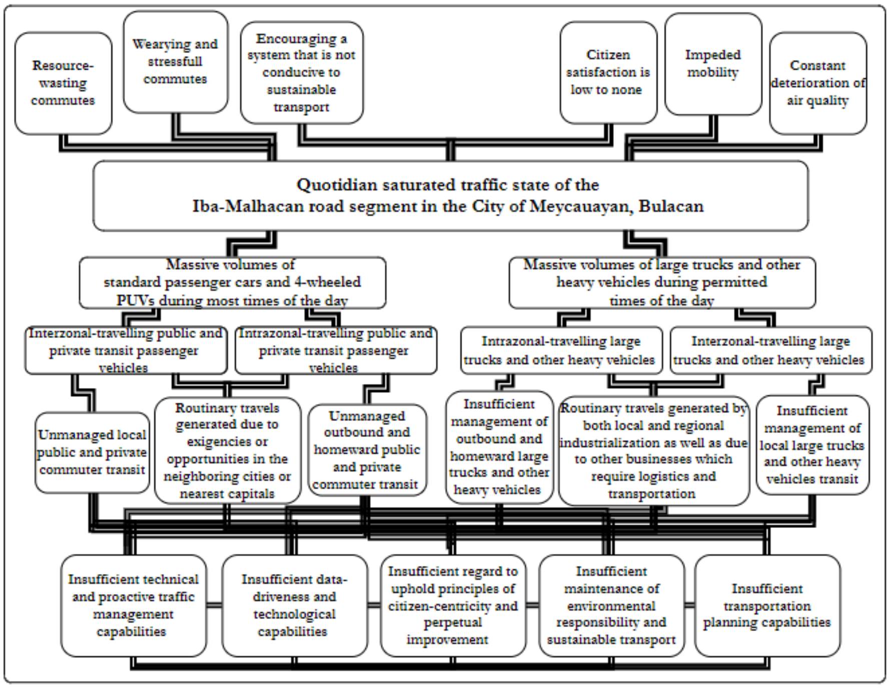

Figure 3. CTSA-based problem tree of the Iba-Malhacan road segment

4. Conclusion

Transportation planning and traffic management— as consistently emphasized in this research— both not only bear great importance in the organization and logistics concerning all aspects pertaining to the various sorts of traveling and just mobility in general but also contribute substantially to the overall perception of the citizens towards its governing body as the travel demand ceaselessly increase as time progresses. Integrating the ideologies advocated by various pertinent sciences with transportation through contemporary conceptualization attributed to the principles of measuring the quality of service might be one of the few possible key resolutions to the predicament that a great number of highly developing cities undergo due to rapid urbanization and industrialization. In the case of Meycauayan City, the gradual worsening of the traffic state was mainly due to the fact that a large quantity of the daily traffic volume consists of four-wheeled passenger cars, PUVs, as well as heavy vehicles bound to both of the nearest capitals— namely Manila and Malolos— as well as homeward ones coming from all over. The immense bulk is by reason of accumulated macro and micro causes intertwining one another; the disparity in infrastructure capacity and travel exigency, as well as the ongoing infrastructure boom being a few of the main determinants. The integrity of this model was determined through the CFA method and the case study's hypotheses were sufficiently proven— the fitness indices of the postulated model were all within acceptable thresholds; even though three variables were dismissed due to relatively low factor loadings, the essence of the model was retained due to its validity. It is important to note that although acceptable results were achieved, the overall structure of the model does not competently evince capacity for immediate replication.

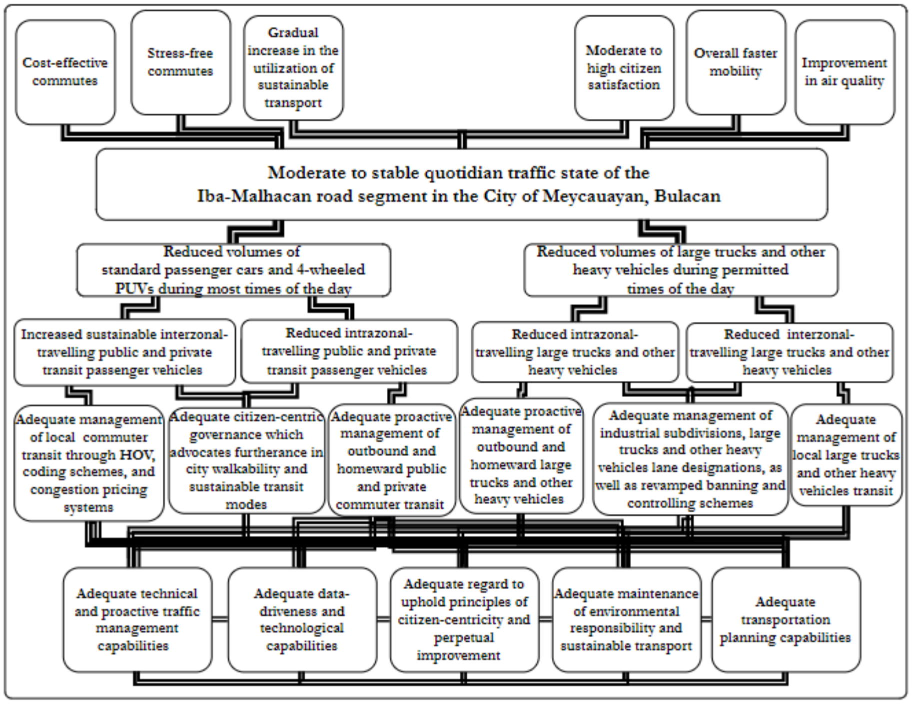

Figure 4. CTSA-based objectives tree for the Iba-Malhacan road segment

The CTSA-based traffic objectives tree, as presented in Figure 4 above, is essentially a contrast of the problem tree—the trunk denotes the core end goal, the leaves represent the immediate positive effects, the roots exhibit the primary and secondary action plans, and the bedrock indicates the inverse of the insufficiencies diagnosed in the problem tree. Furthermore, the greater characterization of attributes pertaining to various elements and variables which encompass the transportation planning and traffic management aspects of the CTSA model were presented in Figure 5.

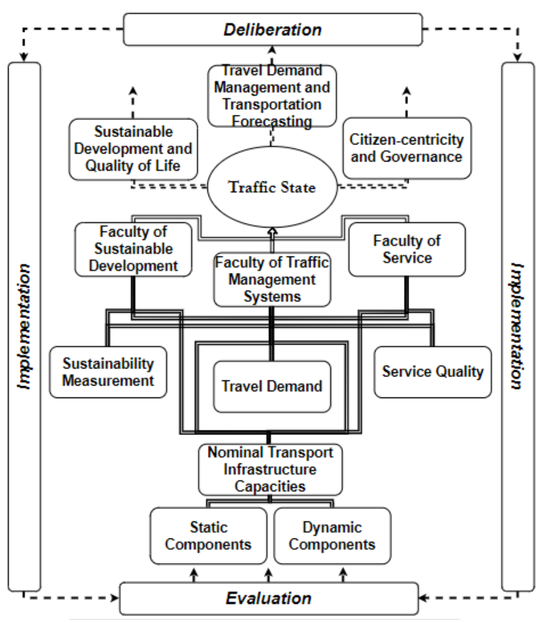

Figure 5. The CTSA model prototype

This case study is not only for the sole benefit of Meycauayan City; moreover, it aimed to engender a substantial contribution to the longstanding traffic predicament of the Philippines by striving to design an integrated comprehensive LGU transportation planning and traffic management model through a systematic approach which acknowledges an extensive array of variables in order to aid not only fellow researchers with kindred spirits but also public servants wearing their hearts on their sleeves. All in all, the outcomes of this case study of the Iba-Malhacan road segment of the City of Meycauayan contribute significantly not only to the furtherance of the CTSA model to its possible actualization— but also to the discipline of transportation planning and traffic management in the Philippine context.

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