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Modelling the Needs of Light Rail Transit (LRT) on Transit Oriented Development Area around LRT Stations in Palembang

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Abstract. Various efforts have been made to overcome the problem of congestion in Palembang, one of them is to provide Light Rail Transit (LRT) which has been operating since July 2018. Analysis of the relationship between the needs of LRT, travel characteristics and characteristic of LRT operation is needed to evaluate the LRT level of service. Level of service of LRT can be assessed from route service, integration of LRT modes with other public transportation, travel time and cost of travel demand. Based on this, the research aims to model the need for LRT in Palembang City on the Transit Oriented Development (TOD). TOD is an area that has the potential to be developed into an integrated area between land use and transportation systems including LRT transportation mode in the area. Travel and mode choice characteristics data of respondents are collected on households in the TOD area. Structural Equation Modelling (SEM) method is used to modelling the needs of LRT. The model can be used to determine the relationship between variables the need of LRT, travel behaviour characteristic and LRT operation characteristics. The result of the study shows that there is a positive and significant relationship between the variables on TOD area around LRT stations in Palembang.

Keywords: transit oriented development, structural equation modelling (SEM), modelling the needs of LRT,

1. Introduction

Currently transportation becomes derived demand for everyone in facilitating their daily activities. In line with the pace of development and growing population growth triggered the emergence of mobility as well. One effort to solve the need of transportation problem in Palembang City is providing mass transit of Light Rail Transit (LRT) which has been operating since mid-2018. However, in order to provide mass transportation in urban areas in accordance with the requirements of community movement, it is necessary to evaluate the characteristics operational of LRT. The purpose of the evaluation is to find out whether the operational characteristics of LRT such as appropriate route, operational time, accessibility from and to the station accordingly with the travel characteristic and mode choice perception of community in Palembang City. Travel characteristics that need to be identified are the location of the origin-destination travel, the activities carried out before and after travel, travel time, the modes that are generally used and the possibility to change modes. Such information is important to know that the LRT in accordance with the daily needs of urban communities.

The purpose of this research is to evaluate the operation of LRT by modelling the need of Light Rail Transit for urban community in Palembang City. The model is used to find out the relationship between public perception about the need of LRT, travel characteristic, mode choice and operational characteristic of LRT. The method used in this study is descriptive analysis method to determine the travel characteristics and Structural Equation Modelling with second order testing of confirmatory factor



analysis was also used to form the modelling of the Light Rail Transit needs on the Transit Oriented Development (TOD) area around the LRT stations. The data required in this study are the characteristics of travel and the potential user perception of Light Rail Transit operation characteristics in Palembang City especially for people who live in the TOD area.

TOD area is mixed-use neighborhoods which are developed around a transit stop and core commercial area. The design, configuration and mix of uses provide an alternative development by emphasizing a pedestrian-oriented environment and reinforcing the use of public transportation. The development of transportation system and land use in TOD area can be conducted based on community needs of public transportation and public facilities around LRT stations. In Palembang, there are 13 LRT stations, starting from Sultan Mahmud Badarudin II station in Ilir area to DJKA station in Ulu area. TOD area has a radius 0-800 meters from stations consisting of mixed land use such as commercial, education, health and public facilities land uses. There are also many transportation infrastructure facilities around the stations such as public transport bus Trans Musi, pedestrian facilities, fly over and many other transportation infrastructures. The development of transportation system and land use in TOD area in the future can be predicted base on travel characteristic of community in TOD area.

The method used in this research is Structural Equation Modelling (SEM) was carried out with LISREL software version 8.8. The method is used for analysis the causal relationship model between public perception about the need of LRT, travel characteristic, mode choice and operational characteristic of LRT. Based on the model results it can be seen whether there is a positive and significant relationship between LRT needs and community travel characteristics, LRT operation patterns and the facilities of LRT infrastructure especially in TOD area. The research is conducted around 12 LRT stations in Palembang City. The results of this research is also explain about the development of TOD which is suitable with the travel characteristic of community, such as the provision of transit facilities in the form of integrated stations and shelters, park and ride facilities, adequate facilities for pedestrians such as sidewalks and zebra cross, mixed land use facilities, health and entertainment facilities that are connected with adequate pedestrian facilities such as the sky walk to the nearest LRT station.

2. Literature Review

2.1. Transportation System

The simple principle of the need for LRT is that one will choose the LRT mode, if the LRT will provide the greatest satisfaction for him. Someone will differ in their views in choosing the mode of transport to get to the destination. The differences in perception are influenced by the service characteristics of the mode. The concept is considered for modelling relationship between variables which is influenced the need of LRT in Palembang City is transportation system concept [1]. Transportation system consist of three components there are travel, land use and transportation infrastructure. Changes in one component will affect the other components. Increased travel demand due to changes in land use will increase the need for adequate transportation infrastructure [2].

2.2. Transit Oriented Development (TOD)

Transit Oriented Development first appeared in the 1990s which was pioneered by Calthorpe. TOD arises because of the phenomenon of urban sprawl which results in high use of private vehicles and resulting congestion. While for the formation of TOD consists of several variables, including:

1. Central commercial area, the function of mixed land use area is providing services to transit activities such as retail functions, regional scale offices, supermarkets, commercial and entertainment. The mix function area can be an attraction for diversity of destinations on the location.
2. Mixed residential areas, residential within the reach of the central commercial area and stopping on foot, with various types of occupancy (single, apartment or town house).
3. Function of public space, the area can be in the form of parks, plazas, green structures, which serve around the environment. Public spaces designed in public buildings or public facilities tailored to the needs.

4. Secondary areal, located about 1 mile from the central area and has a road network as a link to the rear area. This connector is equipped with pedestrian and bicycle lanes. This secondary area consists of low density housing, public facilities and park and ride parking spaces.
5. Mixed functions, the functions in the TOD are diverse and mixed, namely the function of the public, the commercial center and residential. Where buildings with vertical functions are the recommended type. The concept of TOD expressed by Calthrope is inseparable from the city movement system in the form of vehicles both public and private vehicles and humans who continue to move to follow the pattern of activity, and how to use an unused vacant land becomes very useful for its citizens.

Transit-based regional development movement is based on the deteriorating quality of city life which is characterized by congestion, sprawl, and non-integrated land use. TOD has the goal of creating goals that are comfortable, safe, enjoyable and sufficient for walk able environments [3]. By mixing various functions of travel activities that need to be done can be combined to be shorter and faster. These functions are the center of commercial areas, offices, retail, service, settlements with medium to high density and also public open spaces. The development of TOD is very advanced and has become a trend in big cities, especially in large new urban areas such as Tokyo in Japan, Seoul in Korea, Hong Kong, Singapore which utilizes city trains and several cities in the United States and Europe. Development of TOD-based areas has not been done in urban areas in Indonesia. The TOD plan at Manggarai Station has not been proven to date, as well as Kota and Dukuh Atas stations in Jakarta. The limited development of TOD has been done a lot, but it has no extensive impact because it is not the 4th synergy factor, namely mixed-use, high-density, non-motorized vehicle access, close to Mass Rapid Transit stations [4].

2.3 Structural Equation Modeling Methods

SEM or Structural Equation Modeling is a statistical technique that is able to analyze the pattern of relationships between latent constructs and indicators, latent constructs with each other, and measurement errors directly [5]. SEM allows direct analysis between several dependent and independent variables [6]. According to Bollen (2011) as quoted from Latan [7], 'There are sets of equations that accommodate relationships between the latent variables, observed variables and error variables'. SEM can be used to answer various research problems in a systematic and comprehensive set of analyzes.

Data analysis techniques using Structural Equation Modeling (SEM), carried out to explain thoroughly the relationships between variables in the study. SEM is used not to design a theory, but rather is intended to examine and justify a model. Therefore, the main requirement for using SEM is to build a hypothesis model consisting of structural models and measurement models in the form of path diagrams based on justification of the theory. SEM is a stronger analysis technique because it considers interaction modeling, nonlinearity, correlated independent variables, measurement errors, correlated error terms, several latent independent variables where each is measured using many indicators, and one or two latent dependent variables which are also each measured by several indicators. Thus, according to this definition, SEM can be used as a stronger alternative than using multiple regression, path analysis, factor analysis, time series analysis, and covariance analysis.

In general, SEM model can be divided into two main parts, structural and measurement models.

1. Structural model

The structural model is a set of relationships between latent variables and this relationship can be considered linear, although further development allows to include non-linear equations. In graphic form, lines with one arrow head (\rightarrow) describe the regression relationship in Greek characters written "gamma" (γ) for regression of exogenous variables to endogenous variables and Greek characters written "beta" (β) for regression of one endogenous variable to variable other endogenous, while the line with two arrow heads (\leftrightarrow) describes the correlation or covariance relationship in Greek characters written "phi" (ϕ) for correlations between exogenous variables. In this model it produces predictive validity. Examples of structural models can be seen in Figure 1.

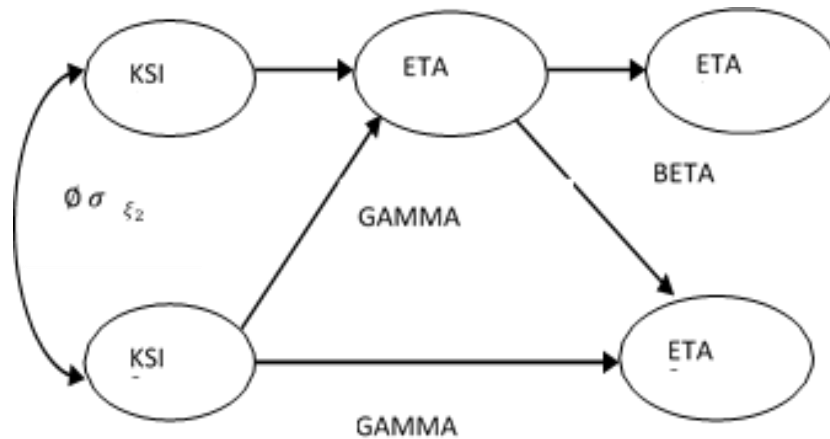


Figure 1. Structural Model

2. Measurement Model

The measurement model is part of a SEM model that is usually associated with latent variables and indicators. The relationship in this model is done by a confirmatory factor analysis (CFA) model in which there is an unmeasured covariance between each possible pair of variables. This analysis process can only be continued if the measurement model is valid. In this model it produces convergent validity. An example of a measurement model can be seen in Figure 2.

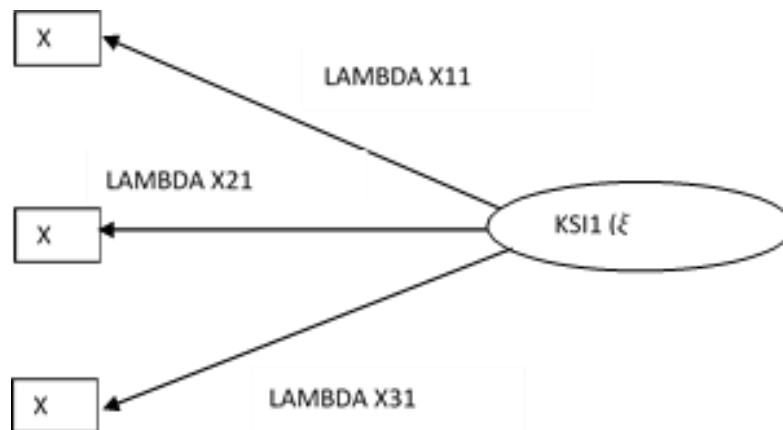


Figure 2. Measurement Model

There are two main variables in SEM, including:

1. Latent variable (latent variable) according to Joreskog 1996, latent variables are abstract psychology concepts such as attitudes, intelligence [8]. This latent variable is a key variable in SEM of concern. The behavior of latent variables can be observed indirectly and imperfectly through their influence on the indicator variable or manifest variable. There are two types of latent variables namely exogenous (independent) and endogenous (dependent) variables. Both types of variables are distinguished by position as the dependent variable or not dependent in an equation model. Exogenous variables are depicted in Greek letters with 'ksi' (ξ) and endogenous variables with eta 'eta' (η). Graphical form, exogenous variables become line targets with two arrows (\leftrightarrow) or correlation / covariant relationships while endogenous variables are targeted at least one arrow (\rightarrow) or regression relationship.
2. Observed Variables
Observed variables are abstract concepts that can be directly measured. As an example of direct

inflation can be measured by consumer price index numbers, company performance can be measured by this variable used to form latent variables that are manifested in the Likert scale question. This variable is to form an exogenous latent variable which is given the symbol X while the late endogen variable is given the symbol Y.

The validity and reliability test in the SEM model uses the Lisrel program with the measurement model performed to check whether the t-values of the observed variables in the model satisfy the good condition that is greater than the critical value of > 1.96 with $\alpha = 5\%$ [9]. Realibility analysis of measurement model is done by calculating Construct Realibility (CR) and Variance Exctrated (VE) values of standardized loading factors and error variance with equation 1 and equation 2 as follows:

$$\text{Construct Realibility (CR)} = \frac{(\sum \lambda)^2}{(\sum \lambda)^2 + \sum e_j} \quad (1)$$

$$\text{Variance Exctrated (VE)} = \frac{\sum \lambda^2}{\sum \lambda^2 + \sum e_j} \quad (2)$$

Where :

λ = Standardized Loading

e_j = Measurement Error

3. Research Metodology

The primary data taken directly through the household survey using non-probability sampling method. Respondents were chosen within a radius of 800 meters from the LRT location, as a justification for the TOD area. The example of TOD area around LRT stations are showed in Figures 3 and 4.



Figure 3. TOD area around Dishub LRT station



Figure 4. TOD area Bumi Sriwijaya LRT station

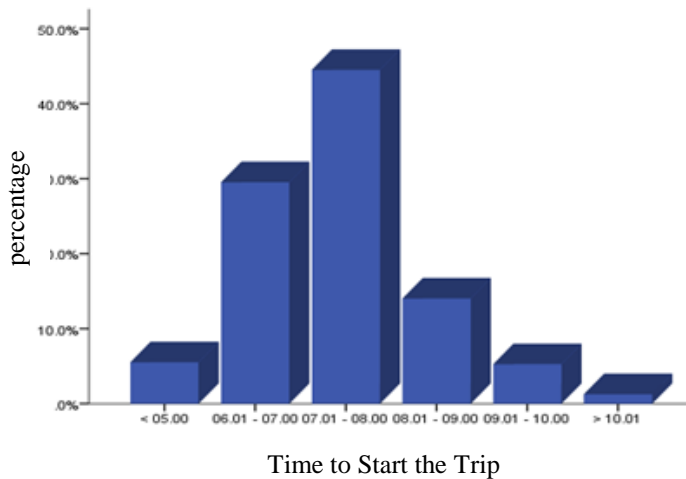
The survey was conducted at 12 LRT stations with total 400 respondents. The data obtained includes socioeconomic characteristics and travel characteristics stated in 17 variables in SEM model consisting of: work trips purpose (X_1), non work trips purpose (X_2), time allocation (X_3), travel cost (X_4), modal integration (X_5), operational time (X_6), travel time (X_7), the availability of pendentrian facilities (X_8), number of LRT rate (X_9), the availability of park and ride (X_{10}), safety (X_{11}), comfort (X_{12}), the availability of difable facilities (X_{13}), reduce private vehicle use (X_{14}), willingness to use feeder transport (X_{15}), willingness to use park and ride (X_{16}), and willingness to walk (X_{17}). These variables are assessed in the following five scales: definitely choose to use LRT; may choose to use LRT; no choice; maybe choose to use another mode; and definitely choose to use another mode. The socio-economic and travel characteristics data were analyzed using descriptive analysis method while the data on 17 indicators of modal mode variable were analyzed using Structural Equation Modeling method to obtain the most influential indicator in the needs of light rail transit modes [10].

4. Data Analysis

4.1. Descriptive Statistic Analysis of Travel Characteristic

Data analysis and discussion consisted of descriptive statistic analysis of travel characteristic to support the result of structural equation modeling analysis the needs of LRT in Palembang City. The results of travel characteristics survey from 400 respondents in TOD area around 12-point LRT stations in Palembang City are explained as follows:

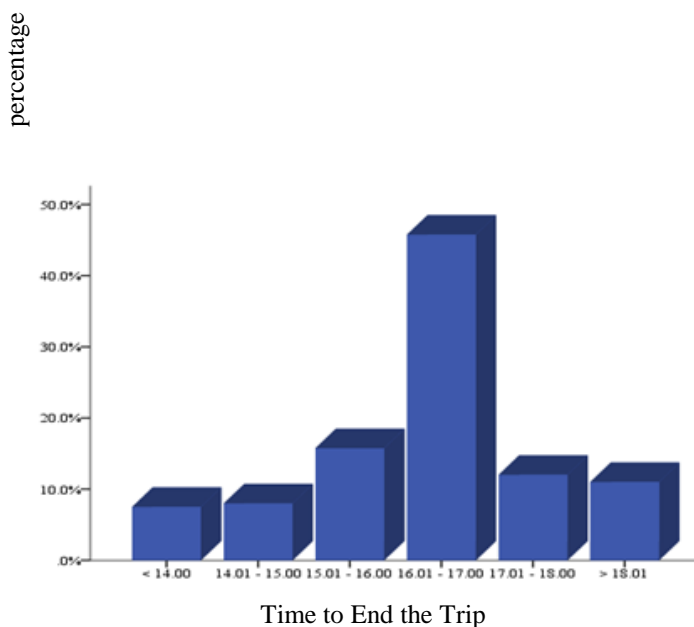
1. Travel characteristic : time to start the trip



Characteristics of the trip based on the time to start the trip (Figure 5) at 07:01 to 08:00 AM is 44.3% and the lowest proportion above 10:00 AM as much as 1.3%. This indicates that the traveller has dominance in starting the work trip from 07:00 to 08:00.

Figure 5. Percentage number of respondents based on time to start the trip

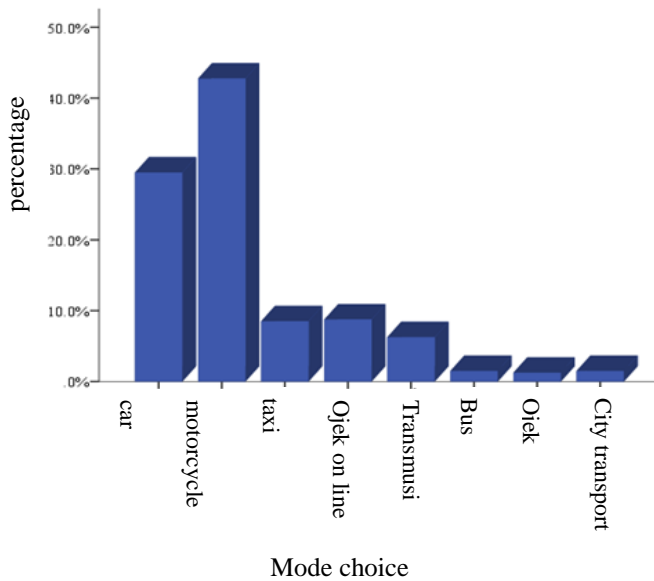
2. Travel characteristic : time to end the trip



Characteristics of travel based on the time to end the trip (Figure 6) until 17:00 afternoon is 45.8% and the lowest proportion after 14:00 as much as 7.5%. This indicates that the traveller has dominance on the way home from 16:01 to 17:00.

Figure 6. Percentage number of respondents based on time to end the trip

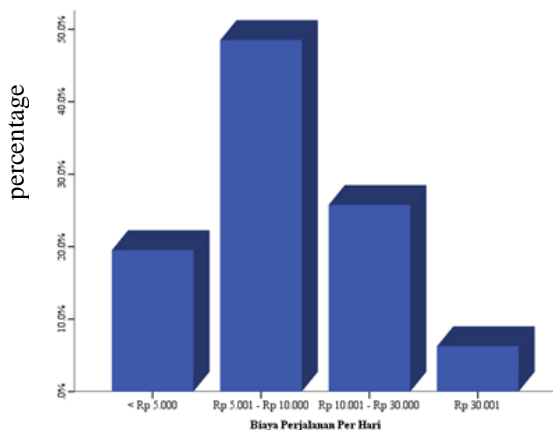
3. Travel characteristic : mode choice



The highest proportion of travel characteristics based on the type of mode choice (Figure 7): the proportion of motorcycle is 43% and the lowest proportion is the public transportation about 2%. This indicates that respondents is prefer to use motorcycle to do their activities.

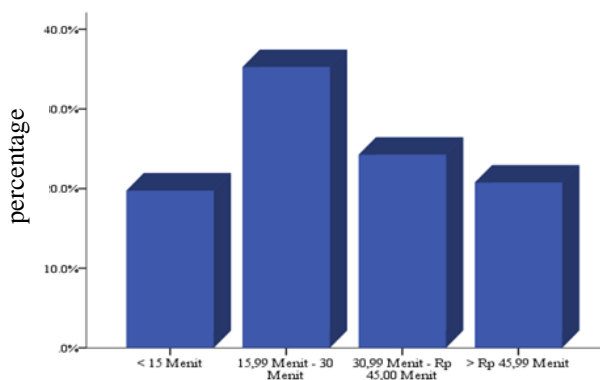
Figure 7. Percentage number of respondents based on mode choice

4. Travel characteristic : travel cost



The highest proportion of travel characteristics based on travel costs (Figure 8) to get to the workplace Rp 5,001 to Rp.10,000 is 48.4% and the lowest above Rp.30,000 is 6.3%.

Figure 8. Percentage number of respondents based on travel cost



The highest proportion of travel characteristics based on travel time (Figure 9) 15.99 minutes to 30 minutes is 35.3% and the lowest proportion under 15 minutes is 19.8%.

Figure 9. Percentage number of respondents based on travel time

4.2. Modelling The Needs for LRT Transportation Mode with the Structure Equation Modeling (SEM) Method

LRT is a mass transit that has a long line of 24 km with 13 stations, average speed 32.9 km/h and travel time 40 minutes. The feasibility of LRT operation in Palembang City can be seen from the factors that influence the needs of mode transportation. The need of mode transportation are influenced by three components of macro transportation system relationships [2]. The system forming the basic concept the needs of modes. The concept is considered for modelling relationship between variables which is influenced the need of LRT in Palembang City, shown in Figure 10.

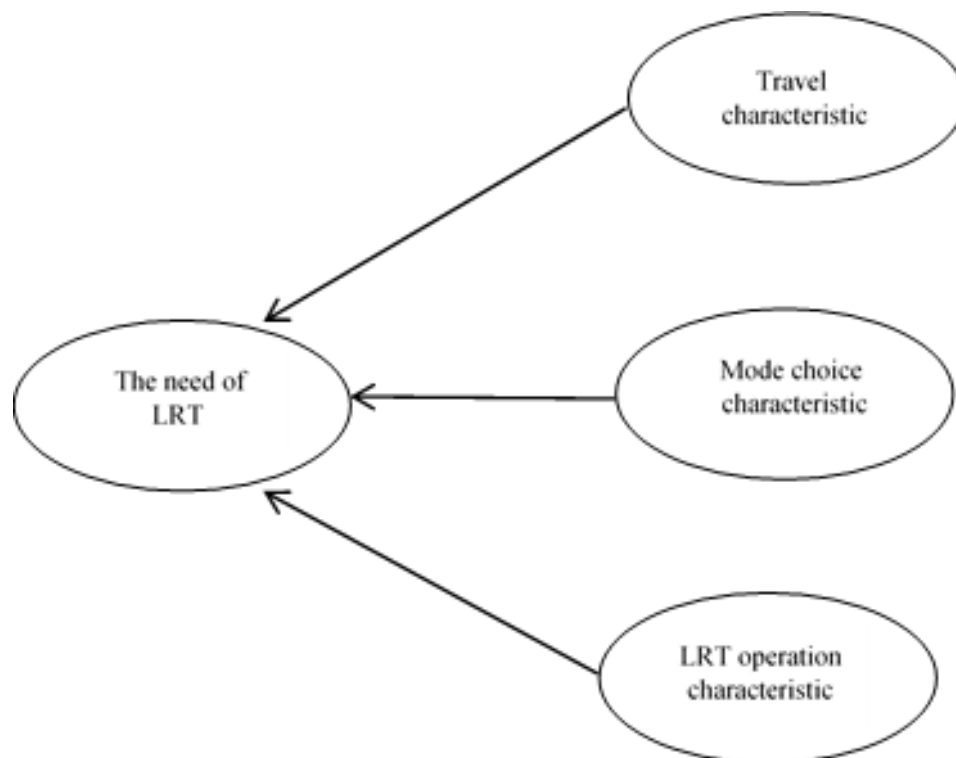


Figure 10. The concept of relationship between variables the need of LRT, travel, mode choice and LRT operation characteristics

The method used in modelling the needs of the Light Rail Transit transportation mode is the Structural Equation Modeling (SEM) Method. The purpose of the modeling is to find out how the relationship between LRT needs and travel characteristics, changes in mode choice behavior and characteristic of LRT services. By knowing this relationship, we will have the information about the actual needs of the people of Palembang City for LRT mass public transportation. Travel characteristics, mode choice behavior and operation characteristic of LRT are called latent variables. The relationship between the latent variables and the need of LRT mode can be obtained from the rating scale conducted by respondents on the indicator variables of each of these latent variables. There are 3 latent variables and 17 indicator variables contained in the model. The rating scale of indicator variables are: definitely choose the Light Rail Transit, maybe choose a Light Rail Transit, maybe choose a Light Rail Transit and another mode, maybe choose another mode, definitely choose another mode.

The analysis of causal relationships or interrelationships between variables is conducted by using SEM approach to form the causal relationship of structural travel, LRT and mode choice characteristics.

1. Specifications.

The model parameter specification uses development strategy model which means done if the structural model in stage 1 has not met statistical requirement or model fit test so that the model needs to be modified or respesifikasi.

2. Identification.

The model identification of the first structural model estimate is an over identified model because the number of known parameters is greater than the estimated number of parameters. With degree of freedom value of 82 ($df > 0$) appropriate with the standards.

3. Estimates.

The estimation method used in this research is the maximum likelihood method using software LISREL 8.8 analysis is completed in maximum iteration to 62.

4. Validity and Reliability.

The validity and reliability test in the SEM model uses the Lisrel program with the measurement model performed to check whether the t-values of the observed variables in the model satisfy the good condition that is greater than the critical value of > 1.96 with $\alpha = 5\%$. Realibility analysis of measurement model is calculated with Construct Realibility (CR) and Variance Exctrated (VE) formulas of standardized loading factors and error variance. The formulas was explained in equation 1 and equation 2. The result of validity and reliability test are explained in Table 1.

Table 1. The result of validity and reliability test

Variabel	Loading Factors	T value > 1,97	CR > 0,70	VE > 0,50	Inf.
Travel characteristic					
X ₁	0,77		0,911	0,721	
X ₂	0,80	16,31			Accept
X ₃	0,74	13,78			Accept
X ₄	0,77	13,99			Accept
LRT operation caharcteristic					
X ₅	0,77		0,984	0,870	Accept
X ₆	0,85	19,23			Accept
X ₇	0,88	19,70			Accept
X ₈	0,89	19,15			Accept
X ₉	0,90	16,37			Accept
X ₁₀	0,85	17,05			Accept
X ₁₁	0,96	17,86			Accept
X ₁₂	0,94	17,66			Accept
X ₁₃	0,91	17,24			Accept
Mode choice caharcteristic					
X ₁₄	0,76		0,907	0,711	Accept
X ₁₅	0,86	18,71			Accept
X ₁₆	0,70	12,73			Accept
X ₁₇	0,73	12,69			Accept

5. Goodness of fit in Modelling

The model fit test which includes chi square, Degree of Freedom (DF), NCP Interval, *The Root Mean Square Error of Approximation* (RMSEA), probability, Expected Cross-Validation Index (ECVI), Akaike's Information Criterion (AIC), Consistent Akaike's Information Criterion (CAIC), Normal Fit Index (NFI), *Non Normed Fit Index* (NNFI), *Comparative Fit Index* (CFI), Incremental Fit Index (IFI), Relative Fit Index (RFI), Critical N (CN), RMR, Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI) are obtained from the output of goodness of fit statics that can be seen in Table 2 and Table 3.

Table 2. The result of model fit test

Goodness of fit	Cut of Value	Analysis Result	Evaluation
Chi square	106,395	130,18	Good
Degree of Freedom	DF > 0	84	Good
NCP Interval	17.30 : 78.40	43,87	Good
RMSEA	< 0,08	0,036	Good
Probability	P value > 0,05	0,093	Good
ECVI	Approaching ECVI saturated	0,67	Good
AIC	Approaching AIC saturated	265,87	Good
CAIC	Approaching CAIC saturated	610,28	Good
NFI	> 0,90	0,99	Good
CFI	> 0,90	1	Good
IFI	> 0,90	1	Good
Critical N	> 396	369,79	Good
GFI	> 0,90	0,96	Good

The result of model respecification is the degree of freedom value of 84 (df> 0) with maximum iteration to 62. The result of t value parameter of the structural equation model can be seen in Figure 11.

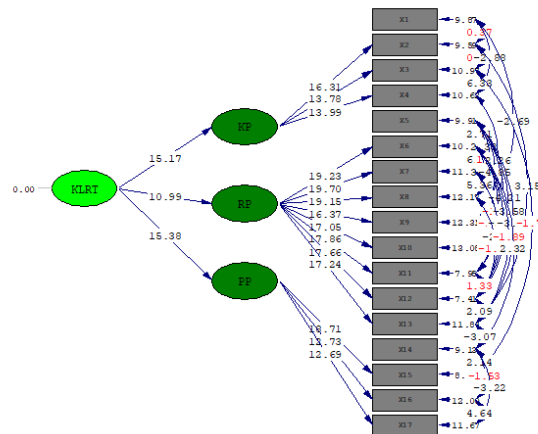


Figure 11. Results of t parameter value of Structural Equation Model

The results of the suitability test for the structural model are:

- a) The measurement model fit analysis shows that 17 indicators have meet the validation standard and then 3 latent variables also have good reliability.
- b) Analysis of reliability model which is presented by R² value shows that the effect of the indicator on each latent variable can be seen in Table 3.

Table 3. Suitable model analysis of the measurement value which is presented by R² Value

Variable	R ²	Variable	R ²
Work trip	0,59	The need of Park and Ride	0,43
Non work tip	0,64	Safety	0,92
Time Allocation	0,54	Comfort	0,89
Travel cost	0,59	Facilities Difable	0,82
Integratation Mode	0,59	Reduce Private Vehicles	0,57
Operational Time	0,72	Willingness to use feeder	0,74
Willingness to use Pendestrian	0,79	Willingness to Walk	0,54
Facilities			
LRT Rates	0,80		

- c) The analysis of reliability structural model shows that the value of the coefficient of determination

$R^2 = 0.824$. This indicates, there is 82% reability of LRT to be feasibility transportation mode in Palembang. The result shows that the community in Palembang especially who live in TOD area around the LRT stations requires LRT to be used as public transportation mode for work and non work trip.

4.3. Test of hypotheses

Test of research hypothesis on SEM (Table 4) can be seen from comparison of estimate coefficient value and its t value. If the t value is greater than the value of the critical condition then H_0 is rejected.

Table 4. Test of research hypothesis on SEM

Hypotheses	Coefficient <i>Estimate</i>	t Value	Critical Condition	Information
1	0,67	15,17	1,97	H ₁ be accepted
2	0,54	10,99	1,97	H ₂ be accepted
3	0,66	15,38	1,97	H ₃ be accepted

1. Hypothesis 1

In structural model analysis between travel characteristic variable and the need of LRT, it is known that the estimated coefficient is 0.67 and t-value of 15.17 which is greater than 1.96. This result indicates that there is significant correlation between latent variable of travel characteristic to independent variable the need of LRT mode, so this proves that hypothesis 1 is received.

2. Hypothesis 2

In structural model analysis between LRT operation characteristic and the need of LRT, it is known that the estimated coefficient is 0.54 and t-value of 10.99 is greater than 1.96. This result indicates that there is significant correlation between latent variable of LRT operation characteristic to independent variable the need of LRT mode, so this proves that hypothesis 2 is received.

3. Hypothesis 3

In structural model analysis between mode choice characteristic variable and the need of LRT, it is known that the estimated coefficient is 0.66 and t-value of 15.38 which is greater than 1.96. These results indicate that there is a significant relationship between latent variables of mode choice behavior toward independent variables the need of LRT, so this proves that hypothesis 3 is accepted.

5. Conclusion

This research show that

1. Based on the survey result travel characteristics of the time to start the trip is from 06:00 to 07:00, the time to end the trip is from 16:00 to 17:00, motorcycle is the most widely used, travel costs is Rp 5,000 to Rp 10,000 and journey time is from 15 minutes to 30 minutes.
2. The result of model analysis with structure equation modeling method of relationship between independent variables and the latent variables is 0.82. The result also show that there is a positive and significant relationship between the needs for LRT mode, travel and LRT operation characteristics on TOD area around LRT stations in Palembang.
3. Development of TOD which is suitable with the travel characteristic of community in Palembang City are the provision of transit facilities in the form of integrated stations and shelters, park and ride facilities, adequate facilities for pedestrians such as sidewalks and zebra cross, mixed land use facilities, health and entertainment facilities that are connected with adequate pedestrian facilities such as the sky walk to the nearest LRT station.

6. Acknowledgement

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