Australasian Transport Research Forum 2017 Proceedings
27 – 29 November 2017, Auckland, New Zealand
Publication website: http://www.atrf.info

Beyond the cost/income ratio: new approaches to measuring transport affordability in three Indonesian metropolitan regions[1]

Yulia Dewita[2], Barbara T.H. Yen[2], Matthew Burke[2]

Email for correspondence: yulia.dewita@griffithuni.edu.au

Abstract

Transport related disadvantages, including unaffordable transport may lead to social exclusion and economic difficulties. In many cases, households choose to live in the city core and spend more on housing to lower their transport costs. Understanding how the affordability of transport is measured and distributed across cities is important to support the formulation of transport policies. This paper aims to examine the link between transport affordability and urban form by exploring household transport expenditures in twenty-two municipalities within Jakarta, Bandung, and Medan metropolitan areas in Indonesia. National household expenditure survey data are used to measure fuel, engine oil, minor repairs and maintenance, and public transport and other costs. In addition to the widely applied cost-to-income ratio method, this research proposes an alternative way to measure the affordability by using the data envelopment analysis (DEA) method. This method provides a more straightforward result that allows each municipality being observed to be ranked based on their affordability performance. The results suggest that transport affordability is affected not only by spatial structure and travel pattern, but also the choice and availability of transport modes. This research sheds new light on transport affordability in the developing cities context, and has implications for policy in the urban and transport sectors in Indonesia.

1. Introduction

Urban sprawl has characterised the development pattern of many cities, including in Indonesia. The urbanised areas expand towards the peripheries; people with lower income often have to live further away from the core area with inadequate facilities and infrastructure, including transport (Cervero 2013; Herwangi et al. 2015). On the other hand, compact development pattern is deemed to encourage more active travel and public transit use, less travel, and better access to services and facilities (Burton 2000, p.19). As in many countries in the Australasia and Asia region, Indonesia has adopted the compact city concept in its urban policies to curb the undesirable impact of sprawl. Yet a clear understanding of the consequences, particularly of the social equity issue such as transport affordability, is subject for further research.

In the Western literature (Bertaud 2004; Dodson et al. 2004; Glaeser et al. 2008; Mattioli, Lucas & Marsden 2016) a relationship exists between transport and urban structure where the city core has an advantage over peri-urban areas in terms of accessibility and transport affordability. However, much less is known about the developing cities context, including in Indonesia. Different transport systems characteristics and the particular role of large motorcycle and paratransit mode shares, as well as large and dispersed metropolitan regions create a transport geography quite different to European, Australian, and North American cities (Cervero 2013).

[1] This is an abridged version of the paper originally submitted for ATRF 2017. The full version is being submitted elsewhere. For further information about this research please contact the authors.

[2] Cities Research Institute, Griffith University, 170 Kessels Road, Nathan, Brisbane, QLD 4111, Australia.

The affordability threshold concept is often used in measuring the affordability. This sets a proportion of household income required to meet transport needs, relative to a benchmark value (Dodson et al., 2004, p.27). Despite the benefit of comparison across regions, defining and using a single benchmark of what is considered affordable is rather subjective (Gomez-Lobo 2011; Venter & Behrens 2005). There are research gaps in terms of how to link the affordability indicator with an appropriate benchmark, as well as in how it is distributed across Indonesian cities.

This paper aims to add the literature on the relationship between transport and urban form, particularly in term of affordability in developing cities context, in three metropolitan regions in Indonesia. Moreover, we propose an alternative method of examining transport affordability using the data envelopment analysis (DEA) method. The paper shows that the DEA method offers a more straightforward affordability measurement, and that 'centre and periphery' assumptions in regard to transport affordability do not necessarily apply in Indonesian cities. This research provides new insights on transport affordability in the developing cities context that might apply to those in the Australasia region, and has important implications for policy in the urban and transport sectors in Indonesia.

2. Methods

2.1. Study Area

Three metropolises with different population size were selected as the case studies: Jakarta Metropolitan Area (JMA), Bandung Metropolitan Area (BMA) and Medan Metropolitan Area (MMA), as displayed in Table 1. The high rate of population and economic activities has produced rapid development and expansion in both the JMA and BMA, with the MMA also expanding at a slower pace. The urban form of the three metropolises are characterised by Indonesia's version of sprawl where urban activities expand from the core area towards the adjacent municipalities to form a wide metropolitan area. A more recent trend is towards more mixed land-uses and higher density development not only in the city centre but also in suburban and outer areas, particularly in the JMA and BMA. This is creating a more polycentric metropolitan region (Winarso 2011, p.186). Transport mode shares in Indonesian major cities including these three metropolises are characterised by a large proportion of private vehicles–especially motorcycles– and paratransit.

Table 1. Population and area of the JMA, BMA and MMA

Metropolitan Area	Area (km^2)	Population (in 2010)	Density/km^2 (in 2010)
Jakarta (JMA)	6,427.51	27,936,112	4,346
Bandung (BMA)	3,477.65	7,974,630	2,293
Medan (MMA)	4,692.87	4,485,155	956

Source: Census of Population (BPS, 2010)

2.2 Data and Variables

Data to explore transport affordability was obtained from the 2014 National Social Economic Survey (SUSENAS) published by the Indonesian Bureau of Statistics (BPS). The SUSENAS is an annual household consumption survey that gathers information on households' expenditure for two categories: food and non-food, including transport. In this paper, household-level data are aggregated at the area unit level (municipality). A total of 22 municipalities within the JMA, BMA and MMA were observed. Two variables were defined to measure the transport affordability: transport costs and household income.

2.2.1. Transport Costs

Transport costs in this paper refer to monthly households' expenses on transport. In this study, we selected four variables to represent necessary transport costs: 1) fuel cost, 2) engine oil, 3) maintenance and minor repairs, and, 4) public transport and other transport costs. The last item covers expenses from public transport fares (bus, train, airplane, ship/ferry and paratransit mode), parking fees, road tolls, and other costs. This aggregation has made it impossible to exclude long-trip and non-daily travel, and separate the private and public transport costs. Average values are used to cover all costs within the included variables, particularly the public transport and other transport costs variable.

2.2.2. Household Income (Total Expenditure)

With household income data not provided, we used total households' expenditure as a measure of income and the benchmark against which to compare the transport expenditure. In the SUSENAS this variable covers food and non-food consumption, including taxes and insurances, but not savings. Socio-spatial variation in households' total expenditure patterns and levels occurs across cities and regions. Thus, median rather than mean values are used to avoid the skewing of data by outliers. The median total expenditure data used in the study was calculated for each municipality within the three metropolitan areas.

2.3 Method of Analysis

2.3.1 Transport Affordability Index

A transport affordability index was calculated as the percentage of transport cost in household total expenditure. This model can be expressed by:

Transport Affordability Index (TA Index) = $\frac{Total\ Transport\ Costs\ (TC)}{Total\ Household\ Expenditures\ (HE)}\ x\ 100\%$, where:

TC = mean monthly household total transport costs (fuel cost + engine oil cost + minor repair and maintenance cost + public transport/other cost)

HE = median monthly household total expenditure.

2.3.2 DEA Transport Affordability

Data Envelopment Analysis (DEA) is a non-parametric efficiency measurement method originally designed to evaluate the relative efficiency of a decision-making unit (DMU) in an organisation, or between organisations in the same industry performing similar tasks (Chiou et al. 2012, p.2). The model proposed in this paper treats each municipality as DMUs and the efficiency measure as affordability. The evaluation results will then indicate which location is "efficient" or in this case, affordable.

The first widely applied DEA model, the Charnes, Cooper, and Rhodes (CCR) version, which had an input orientation and assumed constant return to scale, is used. This model can be expressed by:

$$\text{[CCR]} \quad \underset{u,v}{Max}\ h_q = \sum_{r=1}^{R} u_r y_{qr} \tag{1}$$

$$s.t. \quad \sum_{r=1}^{R} u_r y_{ir} - \sum_{j=1}^{J} v_j x_{ij} \le 0\ ,\ i = 1,2,\cdots,I \tag{2}$$

$$\sum_{j=1}^{J} v_j x_{sq} = 1 \tag{3}$$

$$v_j \ge 0\ ,\ j = 1,2,\cdots,J \tag{4}$$

$$u_r \geq 0,\ r = 1,2,\cdots,R \tag{5}$$

where h_q is the affordability score of location q. I is the total number of locations to be evaluated, each of which has J types of inputs and R kinds of outputs. u_r and v_j are the multipliers corresponding to output r and input j of location q, respectively. From the above CCR model, the optimal input/output multipliers can be determined.

The model calculated transport affordability with four input variables (fuel cost, engine oil cost, minor repair and maintenance cost, public transport and other cost) and one output variable (household total expenditure). The ratio of the output variable over all input variables is calculated to find such values for u and v such that the affordability measure of i-th location is maximised, subject to constraints that the efficiency or affordability value would be between 0 and 1.

3. Results and Discussions

3.1. The Pattern of Transport Affordability

Table 2 shows that households in the three metropolitan areas generally spent around 10–15% for transport from their total expenditure. Households in only two out of 22 municipalities spent relatively low proportions on transport expenses, the West Bandung Regency in the BMA (7.9%) and Bekasi Regency in the JMA (8.8%). Transport expenses as a share of total household expenditure between households living in the core and periphery areas are relatively similar.

The pattern becomes more nuanced when one applies the DEA method. Five municipalities (all located in the JMA) were considered as efficient or affordable with a score of 1.00. The DEA affordability scores show that transport is generally more affordable in Jakarta, the capital city and the largest metropolitan region in Indonesia, than in Bandung and Medan metropolitan areas. In the BMA and MMA, the central zone is more affordable than the outer zone, which is not necessarily the case in the JMA. Table 2 also shows that the bottom three of the least affordable municipalities are all located in the periphery of BMA, which also have the lowest median income of all.

It has been suggested in the transport literatures that in a city or metropolitan region, the costs of transport in the core area is more affordable due to the broader options of public transport services and its mixed land-use that encourage walking and biking that shorten the daily trips while the peri-urban areas are on the contrary. This study found that the results are varied based on the spatial structure of the cities.

The DEA affordability scores in the BMA and MMA conform to the ‘centre and periphery’ hypothesis. It can be seen that the city of Bandung, Cimahi and Medan as the core areas of the BMA and MMA are considerably more affordable than the peripheries. These results are likely to be related to the dominantly monocentric structure of these metropolitan areas, where jobs, education and shopping centres are still highly concentrated in the city core, so people travel from the periphery to the city centre. However, the JMA delivers DEA affordability scores which are inconsistent with the Western literature. This related to the JMA having a higher degree of polycentricity. For example, Bekasi Regency is one of the employment centres in the region with its industrial estates and ‘self-contained’ new towns, where commuting trips to the core area are reduced. Such new towns have turned into suburban centres within the periphery of JMA that diverted the pull-factor of Jakarta and reduced the number of daily commuters to the core of JMA (Winarso et al. 2015, p.227). Unlike the dominantly monocentric cities, the pattern of daily trips in a polycentric metropolitan area is randomly distributed across the region. Those municipalities that become the suburban centres are most likely to have more local than radial travel pattern, therefore more ‘transport affordable’.

Table 2. Transport affordability index and DEA transport affordability

Metropolitan Area		Municipalities	Transport Affordability Index	DEA Transport Affordability Scores	DEA Transport Affordability Ranking
JMA	**Core**	South Jakarta	14.9%	0.808	6
		East Jakarta	12.6%	0.754	8
		Central Jakarta	10.0%	1.000	1
		West Jakarta	14.0%	1.000	1
		North Jakarta	13.3%	0.721	13
	Periphery	Tangerang Regency	12.0%	1.000	1
		Tangerang City	13.2%	0.817	5
		South Tangerang	13.5%	1.000	1
		Bogor Regency	11.6%	0.702	14
		Bekasi Regency	8.8%	1.000	1
		Bogor City	11.2%	0.726	11
		Bekasi City	12.0%	0.836	4
		Depok City	14.3%	0.941	2
BMA	**Core**	Bandung City	11.3%	0.720	12
		Cimahi City	10.6%	0.740	9
	Periphery	Bandung Regency	10.9%	0.341	18
		West Bandung	7.9%	0.593	16
		Sumedang Regency	9.7%	0.545	17
MMA	**Core**	Medan City	11.9%	0.869	3
	Periphery	Binjai City	12.6%	0.693	15
		Deli Serdang	13.4%	0.733	10
		Karo Regency	9.7%	0.770	7

These findings may help us to understand how transport affordability distributed across different locational settings and its important implication for urban and transport policies in Indonesia. The concentrated decentralisation concept, which creates polycentric urban form with multiple growth centres, might be a suitable strategy for compact city policies in Indonesian metropolises. The containment aspect must be followed by the suburban centres to reduce dependency to the core area. The urban transport policy should focus on developing a comprehensive strategy on integrated and affordable public transport network that connects all centres within the metropolitan region to avoid urban fragmentation.

3.2 DEA as an Alternative Approach to Measure Affordability

This study proposes the DEA method as an alternative way to examine transport affordability. We argued that this method might address the problem raised by defining and applying a single benchmark in the cost/income ratio method. Spending 10% of income on transport may be considered as affordable in a certain region, while it is unaffordable for other regions. Venter and Behrens (2005) suggested a monotonic relationship between the transport cost/income ratio and citizen’s welfare measures must be present for the benchmark method to perform. Households, who spend more on transport expenditure, must have decreasing or constant welfare, and vice versa. The DEA method may assist by providing the range of value from 0 (unaffordable) to 1 (affordable) that would have similar meaning everywhere, and is thus easier to interpret in order to rank the municipalities. In the calculation, each DMU (municipality) is being compared to each other to measure the relative efficiency. Thus, the efficient DMUs are the most affordable municipalities relative to other municipalities included in the observation. From Table 2, it can be seen that Central

Jakarta, West Jakarta, Tangerang Regency, South Tangerang City, and Bekasi Regency in the JMA, with the score of 1.00, are ‘transport affordable’ municipalities, while the other municipalities in the JMA, BMA and MMA are less affordable.

The affordability index shows that households with a higher income level tend to spend relatively higher proportions of their income on transport, while the DEA affordability score suggests that a higher transport cost does not necessarily result in lower affordability (see Table 2). This inconsistency may be due to the presence of a non-monotonic relationship in the cost/income ratio method; while the DEA method has incorporated the difference of municipalities being observed represented by the values of both output and input variables.

There are some cases where both methods deliver similar results. One example is Bekasi Regency, which has a transport affordability index of 8.8% and a DEA affordability score of 1.00. As one of the largest concentrations of manufacturing in the JMA, this municipality is home to seven major industrial estate companies (Hudalah et al. 2013, p.44). Three of these companies have created “new self-contained towns” to accommodate the workers (Hudalah et al. 2013, p.45). This development trend has turned Bekasi Regency into a suburban centre, reducing its dependency for employment on the Jakarta Special Region more centrally within JMA. Therefore, most of the trips made by Bekasi Regency’s residents are local and shorter-distance, and thus more affordable.

The DEA outcomes also suggest that municipalities in the JMA are generally more affordable in terms of transport costs than those in the BMA and MMA. Apart from higher level of incomes, this result may be explained by the fact that transport system in the JMA is more advanced than those of the BMA and MMA. In both of these regions, transport services are dominated by paratransit modes such as minivans (*angkot*), taxi and motorcycle taxis (*ojek)*, which fares are inconsistent and higher. The DEA transport affordability results suggest it is necessary to accelerate the provision of higher-order transit systems in the BMA and MMA.

Moreover, the DEA method provides further information on the sources of inefficiency or in this case, unaffordability, by computing slack values for each of the input variables. All municipalities with an affordability score of less than 1.00 are considered as inefficient with at least one input slack value, because of having higher costs variable values. These slack values indicate which input variables that is inefficient (e.g. fuel cost), thus need an improvement strategy.

4. Conclusion

This paper’s methodological contributions were in presenting an alternative measure for transport affordability using the DEA model. The widely applied cost-to-income ratio method requires a strict monotonic relationship between income and transport expenditure which is violated in many real-world situations. The DEA method may assist by providing a range from 0 to 1 for the affordability level, which has similar meaning across the cities in the sample. Moreover, this method enables further analysis of each transport costs component to identify strategies for improvement, which is essential from a policy perspective.

The applied contributions were in providing DEA results that revealed differences in transport affordability across three metropolises in Indonesia. The more monocentric and moderate-sized metropolitan areas (MMA and BMA) further support the argument that the transport burden of households living in the city core is less than in the peri-urban areas. However, this does not apply to the very large and more dispersed and polycentric megalopolis of the JMA. Key transport destinations and especially workplaces are less concentrated in the centre and growing sub centres have created more local transport and reduced commuting trips.

This study has many limitations. Aggregate figures used in this study prevent further examination of the affordability impact on key sub groups which is hidden by the data. The three case study represent key industrial and administrative cities, not a more tourist-oriented cities, such as the Denpasar metropolitan area in Bali, which might have quite different outcomes. Extensive research on affordability that combines transport and housing components should be developed, as both are interrelated. Further enquiry incorporating recent trends of 'mobility as a service' in Indonesian cities with the rise of *gojek*, the motorcycle version of 'uber', may also offer further understandings.

Bertaud, A 2004, 'The spatial organization of cities: Deliberate outcome or unforeseen consequence?', *IURD Working Paper Series*, viewed 16 June 2017, http://escholarship.org/uc/item/5vb4w9wb

Biro Pusat Statistik Indonesia (BPS) 2010, *Census of Population,* viewed 6 February 2015, http://www.bps.go.id

Burton, E 2000, 'The potential of the compact city for promoting social equity. In E Burton, M Jenks & K Williams (eds.), *Achieving Sustainable Urban Form*', Spon Press, London UK, pp.19-29.

Cervero, Robert 2013, 'Linking urban transport and land use in developing countries', The Journal of Transport and Land Use, vol. 6, no.1, pp.7-24, http://dx.doi.org/10.5198/jtlu.v1.425

Chiou, YC, Lan, LW & Yen, BT 2012, 'Route-based data envelopment analysis models', *Transportation Research Part E: Logistics and Transportation Review,* vol. 48**,** pp. 415-425, https://doi.org/10.1016/j.tre.2011.10.006.

Dodson, J, Gleeson, B & Sipe, NG 2004, '*Transport disavantage and social status: a review of literature and methods',* Urban Policy Program, Griffith University Australia.

Glaeser, EL, Kahn, ME & Rappaport, J 2008, 'Why do the poor live in cities? The role of public transportation', *Journal of urban Economics,*vol. 63, no. 1, pp. 1-24, https://doi.org/10.1016/j.jue.2006.12.004.

Gomez-Lobo, A 2011, 'Affordability of public transport: A methodological clarification', Journal of Transport Economics and Policy, vol. 45, no. 3, pp. 437-456, viewed 2 June 2017, (online Ingenta Connect).

Herwangi, Y, Pradono, Syabri, I & Kustiwan, I 2015, 'Making the Connection between Transport Disadvantage and Motorcycle Usage of Low –Income People in Yogyakarta Urbanized Area, Indonesia', *Journal of the Eastern Asia Society for Transportation Studies*, vol. 11, pp.90-109, viewed at 12 September 2017

Hudalah, D, Viantari, D, Firman, T & Woltjer, J 2013, 'Industrial land development and manufacturing deconcentration in Greater Jakarta', *Urban Geography,* vol. 34**,** pp. 950-971, http://dx.doi.org/10.1080/02723638.2013.783281.

Mattioli, G, Lucas, K & Marsden, G 2016, 'The affordability of household transport costs: quantifying the incidence of car-related economic stress in Great Britain' in Universities' Transport Study Group, *48th Annual Universities' Transport Study Group*, 6-8 January, Bristol, doi:10.13140/RG.2.1.1613.7045

Venter, C & Behrens, R 2005, 'Transport Expenditure: Is the 10% Policy Benchmark Appropriate?' paper presented at the 24th Southern African Transport Conference (SATC 2005), 11-13 July, South Africa, viewed 21 October 2016.

Winarso, H 2011, 'Urban Dualism in the Jakarta Metropolitan Area', *In:* Sorensen, A & Okata, J (eds.) *Megacities: Urban Form, Governance, and Sustainability.* Tokyo: Springer Japan, doi: 10.1007/978-4-431-99267-7_8.

Winarso, H, Hudalah, D & Firman, T 2015, 'Peri-urban transformation in the Jakarta metropolitan area', *Habitat International,* vol. 49, pp. 221-229, doi: https://doi.org/10.1016/j.habitatint.2015.05.024