Re-Assessing TOD index in Jakarta Metropolitan Region (JMR)

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Received: May 20, 2017
Accepted: June 6, 2017
Published: June 10, 2017

Abstract

Transit Oriented Development (TOD) is believed to be able to overcome the issues of urban transport. However, in practice, the current TOD in Jakarta Metropolitan Region (JMR) is still a deficiency in accommodating the needs of transportation movement and not in facilitating services in terms of TOD function. The objective of this paper was to re-assess the service quality of actual TOD in 54 commuter railway stations. The paper performed criteria-indicators and measured a composite TOD index by using Analytical Hierarchy Process (AHP)-multicriteria model, statistics test, and Geographical Information System (GIS) application. TOD index was found that urban areas have a high TOD index. On the other hand, the suburban areas have a low TOD-index. The statistical test showed that there was a strong correlation between different criteria. This paper concluded that most of the stations which were located in the suburban area had a low index thus need improvement. Consequently, the station areas needed to have a policy relevance.

Keywords: Re-Assessing, Transit Oriented Development (TOD), TOD index, Geographical Information System (GIS), Analytical Hierarchy Process (AHP), Jakarta Metropolitan Region (JMR).

1. Introduction

Dynamics discourse of modern cities has occurred in many countries in the world where the dispute discuss the comparison which is better between the city of car-based and public-based (Blumenauer, 2002; Miller et al., 2016; United Nation, 2005). In the various paradigms, that gave rise to different periods in the pattern of the relationship between the city and transit activities (Olaru et al., 2011).

The problem of a metropolitan region in many countries like Jakarta Metropolitan Region (JMR) is the occurrence of a vigorous migration between urban and suburban areas where it is known by the phenomenon of urban sprawl (Sunarto, 2009). Transportation is sometimes not able to support this condition with an optimal service. One example is the station where its function becomes less able to accommodate the needs of the population movement as well as it has not been in accordance with the policy action (Marshall, 2013). Thus, it is needed a reassessment of station function to accommodate the mobility of a population between regions through the provision of the mass public transport services in transit nodes (Fard, 2013).

This can be done by applying the concept of Transit Oriented Development (TOD). According to (Feudo, 2014), TOD emerged not in spite of historical development patterns of the metropolitan region consists of urban, suburban and connection with public transportation such as trains or buses. TOD was introduced in America in the late 19th century in which mode of transportation serving the growth pole; (Cervero et al., 2002; Evans & Pratt, 2007; Jarboui., 2012). This phase marked the existence of a separate settlement zone patterns of work zones linked by mass transportation with the facilities such as stations, rail and modes made to cater to each zone (Arrington & Cervero, 2008; Olaru et al., 2011; Loo et al., 2010; Nasri & Zhang, 2014; Kwon, 2015).

The zoning area between urban and suburban development process happens where land use and transportation in particular relic transit zoning has been motivating this paper to reassess TOD uses the multicriteria evaluation (Malczewski, 2006). Thus, Singh (2015) noted that assessing TOD becomes important because it is expected to improve the TOD level of success.
The main objective of this research is to provide an alternative solution to the problem of the growth of the metropolitan region that tends to develop towards auto pattern oriented by encouraging residents to use the facilities of public transport rather than private cars (Taki et al., 2017). Thus, it can solve problems sprawling (Renne & Wells, 2005).

Previous TOD research for JMR has been conducted by H. S. Hasibuan et al., (2014) by assessing the most potential stations for TOD using the analysis of land uses proportion around transit stations. Nevertheless, the assessment is still general, therefore, this study enhanced previous research by reassessing TOD using index accompanied by more complete criteria and indicator generated from the experts. This paper began with an introduction, the literature reviewed relating to composite TOD index later explanation of how to reassess it based on existing condition. The next part contained information of the study area, details about data and methods, and the results of each. This paper concluded with a discussion of the main findings of research and implications.

1.1. The case of Jakarta Metropolitan Region (JMR)

This study examined the commuter railway transportation system in the metropolitan region of Jakarta. The layout of Jakarta according to the study of (H. Hasibuan & Soemardi, 2014) is a strategic because of Jakarta is not only the capital city of Indonesia but also it is a planned region for the adopted concept of TOD.

The JMR cover urban and suburban area, they are Jakarta City, Bogor City, Depok City, Tangerang City and Bekasi City (Figure 1). It is known as Jabodetabek, it has a network of commuter rail serving residents to travel from the suburbs to the urban (city centre) and vice versa.

![Fig. 1. Administrative boundaries of study area](image1)

![Fig. 2. The commuter rail route of JMR](image2)

2. Materials and Methods

2.1 Data collection

Required data is a variety of spatial as well as non-spatial data. The required data was collected from the ministry and agency. Administrative boundaries, railway network, station locations, land use data were all available as spatial data layers in vector format.

| No | Type                          | Year | Source                                      |
|----|-------------------------------|------|---------------------------------------------|
| 1  | Shapefile of administrative boundaries of JMR (Jabodetabek) | 2015 | Geospatial Information Agency               |
| 2  | Shapefile of land use type (residential, commercial, open space, parking area) | 2014 | Geospatial Information Agency               |
| 3  | Railway network GIS shapefile | 2015 | Ministry of Transport                      |
| 4  | Railway station location      | 2015 | Ministry of Transport                      |
2.2 Chosen criteria

Chosen criteria of TOD based on the 3-D major concept of TOD consisting of Density (development), Diversity (mixing land uses) and Design (pedestrian-friendly) (Cervero & Kockelman, 1997). Economic development criteria is also an important part of the TOD concept as in the study (Fard, 2013). At that point, this study makes this concept as a measurement and the basis for selection of criteria and indicators.

Density, Higgins & Kanaroglou (2016) noted density as describing how the interactions that occur within the station area which it has two meanings, namely the ability to transact internally travel in stations such as walking, bicycles and the second is the ability to travel into a transit network system. The indicators used in this criterion are a mixed-ness for residential, commercial, open space, parking area, and a density for residential, commercial, school and hospital.

Diversity or a diversity index is a quantitative measure that informs the number of specific types (in terms of land use i.e. certain types of land use such as residential, commercial, etc.) and can also be useful to illustrate how evenly certain types of land use are distributed among the other types (Higgins & Kanaroglou, 2016). There are various kinds of diversity calculation, especially in calculating land use diversity. There are two popular indexes used: Simpson index and Shannon Index. In this study using the Simpson index to calculate the proportion of certain primary land use in each area around the station.

Economic referred to this study that is the current degree of economic performance in the station area. The measurements of these criteria are calculated in diverse sizes, such as numbers of jobs (Atkinson et al., 2011), the percentage of employment (Prasertsubpakj & Nitivattananon, 2012), the number of business establishments (Fard, 2013). In the analysis of this paper, we use population density, the ratio of Building Coverage Ratio (BCR) and Floor Area Ratio (FAR).

2.3 Description of indicators

The indicators of TOD are selected from previous research by looking at the trend of a growing research (Sung & Oh, 2011; Mu & de Jong, 2012; Binglei & Chuan, 2013; Singh, 2015; Higgins & Kanaroglou, 2016) hence generated the selected criteria as in Table 2 below.

Table 2. The selected criteria and indicators from previous studies.

| No | Criteria | Indicators | Sung & Oh (2011) | Mu & de Jong (2012) | Binglei & Chuan (2013) | Singh (2015) | Higgins & Kanaroglou (2016) | Jakarta, Indonesia (2015) |
|----|----------|------------|-----------------|-------------------|----------------------|-------------|----------------------------|--------------------------|
| 1  | Population density | Data of population density (inhabitants/sqkm) from Statistics Indonesia in 2015 (http://data.jakarta.go.id/, 2016) |
| 2  | Commercial, school and hospital density | It is calculated using GIS by adopting formula from Nasri & Zhang (2014) |
|    |   | \( D_C = \frac{\text{Commercial or building area}}{\text{total area (sqkm)}} \) |
| 3  | Residential, open space and parking area mix | Measuring all of this indicators with the following formula, as adapted from Zhang & Guidon (2008): |
|    |   | \( MI(i) = \frac{\sum_i n_i S_c}{\sum_i (S_c+S_r)} \quad \forall i \) |
|    |   | \( MI(i) \) means the ‘Mixed-ness Index’, \( S_r \) shows the sum of total area under residential land use within \( i \), \( S_c \) is the sum of the total area non-residential urban land uses. |
| 4  | Land use diversity | The concept of diversity is derived from the Simpson index and Kamruzzaman & Baker (2014) used land use diversity in their research related to TOD with a formula: |
|    |   | \( \text{Land use diversity} = 1 - \sum (a/A)^2 \) |
|    |   | Where \( a \) is the total area of a specific land use category (e.g. commercial) within the buffer of a TOD, and \( A \) is the total area of all land use categories within the buffer. |
| 5  | Building Coverage Ratio (BCR) | Land use zones restrict the use of buildings in each categorised zone; BCR controls the volume of buildings in each zone. The ratio of the building area divided by the land (site) area. Building area means the floor space of a building when looking down at it from the sky. In this study, there are some categories of BCR such as (20 - 40) %, (41 - 60) %, (61 - 80) %, < 20%, and > 80%. For this study, the category of (61 - 80) % is taken because the building conditions in there are so dense that the building area almost covers the total area of available land. Another category, < 20% is identified as nonresidential area, > 80% is slum area. |
Floor Area Ration (FAR).
FAR controls the height of buildings in each zone (Binglei & Chuan, 2013). The ratio of total floor area divided by land (site) area. Total floor area means the total of all the floor space in a building. The data of FAR in this study are divided into 4 categories, those are the 1st, 2nd, 3rd and 4th floor. This research will take the area above > 1 with the explanation that shows the 1st floor is the normal house, 2nd floor is the flat house, 3rd floor is the maximum floor, and 4th is the basement.

Station area analysis
The TOD area is the area of influence of the railway station in its urban and suburban context, which is different on metropolitan and city scale. To include influences from a higher scale on the city scale station areas the railway route is examined on the regional or metropolitan scale, the scale of the whole railway, as an activity corridor, an activity centre, and a transport corridor. At this scale, the influence radius of 800 meters around each station of the railway is used to understand the structure of the line as a whole. Within this radius, important networks and issues can be recognised that are influencing the direct surroundings of the station in an 800-meter radius.

The TOD area is the walkable area around transit stations, an area of 800-meter radius from the station, called the station area. Within this radius urban transformations have a direct influence on the use of the train and the direct station areas as activity centres. Some of these station areas have better chances and more opportunities to develop, because of their well-accessible location and already existing attractions.

Methodological framework in research
The objective of this study is described in figure 4 below as the analytical framework for reassessing actual TOD and analyzing the development of metropolitan region along railway network in urban and suburban areas.

2.6 Weights calculation using Analytic Hierarchy Process (AHP)

The calculation of weights with techniques of analytic hierarchy process (AHP) is done by running the paired comparisons of some expert in their field, the expert provides expertise in accordance with the assessment against criteria and indicators are proposed on a Saaty scale (Bunruamkaew & Murayam, 2011).

This technique assesses the relative significance of the proposed criteria and indicator by assigning weight to those criteria and indicators according to the priority in the form of a hierarchical order.

To maintain the credibility of the relative significance, AHP provides a way to determine the inconsistency of judgments in the form of mathematical equations according to the formula below.

$$c_r = \frac{c_i}{r_i}$$

Where $c_r$ is the consistency ratio, $c_i$ shows the consistency index, $r_i$ is random index.

The consistency index ($c_i$) is derived using the following formula:

$$C_i = \frac{\lambda_{max} - n}{n - 1}$$

$\lambda_{max}$ means the maximum value of eigenvector and $n$ is the criteria or indicator number.

Further information from Saaty (1990) with respect to the above formula is that the consistency level is quite acceptable if $C_r$ is less than 10% (0.1), and vice versa, there is inconsistency in the evaluation process if $C_r$ is greater than 10% (0.1), this means the results of AHP calculations do not produce results which mean.

3. Result

3.1 AHP weighting

The calculation of weights with the analytic hierarchy process (AHP) is performed by running the paired comparisons of 12 experts in their field, such as professional (urban planners, policy-makers, researchers, etc.) and work experience which they have worked on the project of TOD. The following table is the results of the weights calculation.
Weighting
0.27
0.22
Hospital
0.32
0.27
1
The formula is:

\[ R_i = \sum_k W_k f_{ik} \] (7)

Where the composite TOD index \( (R_i) \) for each station \( i \), \( W_k \) is the multiplication result of the weights of all indicator or criterion and \( f_{ik} \) the standardized value of station area in the map of the indicator or criterion \( k \).

3.4 Actual TOD index ranking
The actual TOD index for 54 stations in the JMR as in Table 5 contains the difference values of criteria and indicator. Based on this data, Indonesian University station has the lowest index 0.27 and the Duri station has the highest index 0.58.

Table 5. Actual TOD index for all 54 stations

| Station          | Commercial | Residential | School | Parking | Open space | Hospital | Population | FAR     | BCR     | Diversity |
|------------------|------------|-------------|--------|---------|------------|----------|------------|---------|---------|-----------|
| Universitas      | Indonesia  |             |        |         |            |          | 0.13       | 0.57    | 0.22    | 0.51      |
| Duri             |            |             |        |         |            |          | 0.51       | 0.27    | 0.32    | 0.46      |

Fig. 5. Comparing the indicators with highest and least.
3.5 The composite TOD map

The result of the composite of actual TOD index is visualised into the map using GIS application. The used software is ArcGIS. This map shows the distribution of index spread per station and divided into 3 categories; (category 0.26-0.35), category (0.36-0.43) and category (0.44-0.58).

![Fig. 6. The actual TOD index map](image)

4. Discussion

4.1 Statistical analysis

Statistical analysis was performed to describe the distribution of the data and to find correlations between variables and find out whether there are significant differences between variable and corridors. The analysis is performed using descriptive statistics, and Pearson correlation method.

Table 5. Descriptive statistics of criteria

| Criteria      | Number of station | Minimum | Maximum | Mean  | Std. Deviation |
|---------------|-------------------|---------|---------|-------|----------------|
| Density       | 54                | 0.15    | 0.40    | 0.27  | 0.05           |
| Economic      | 54                | 0.22    | 0.75    | 0.39  | 0.10           |
| Diversity     | 54                | 0.23    | 1.00    | 0.77  | 0.19           |
| TOD Index     | 54                | 0.27    | 0.58    | 0.42  | 0.07           |

Based on the Table 5 above, the total number of stations is 54. The highest mean is found in the diversity 0.77 and the lowest mean of 0.27 in density indicator. The highest standard deviation is found in the criteria of diversity that is 0.19 and the lowest is found on the criteria of density 0.05.

Table 6. Pearson correlation amongst TOD criteria

| TOD indicators | Density | Economic | Diversity |
|----------------|---------|----------|-----------|
| Density        | -       | 0.007**  | 0.230     |
| Economic       | -       | 0.051*   |           |
| Diversity      | -       |          |           |

** Correlation is significant at the 0.01 level (2-tailed).

Correlation amongst TOD criteria indicates there is a strong positive correlation between density and economic criterion with the value 0.07 also economic and diversity with the value 0.051. Correlation of density with diversity has a correlation that is not significant because it valued 0.230.

Table 7. Descriptive statistics of TOD index in corridors

| Corridor      | Number of station | Min | Max | Mean   | Std. Deviation |
|---------------|-------------------|-----|-----|--------|----------------|
| Bekasi        | 13                | 0.33| 0.54| 0.2822 | 0.0470         |
| Bogor         | 26                | 0.27| 0.51| 0.2686 | 0.0535         |
| Serpong       | 7                 | 0.29| 0.47| 0.2686 | 0.0387         |
| Tangerang     | 8                 | 0.27| 0.58| 0.2598 | 0.0772         |

Based on Table 7 above that the minimum index is found in the corridors of the Bogor and Bekasi with a value of 0.23, while the maximum index found in the Tangerang corridors is 0.58. The best standard deviation is the lowest value found in the Bekasi Corridor which is 0.0470.

4.2 Improvement actual TOD based on corridor

4.2.1. Bekasi Corridor

There are 13 stations in the Bekasi Corridor, most of the stations have a good index. However, there is potential for improvement in Bekasi and Kranji Station.

Table 8. The ranking of TOD index in Bekasi Corridor

| Number | Station       | Corridor | Density | Economic | Diversity | TOD Index |
|--------|---------------|----------|---------|----------|-----------|-----------|
| 1      | Bekasi        | Bekasi   | 0.26    | 0.32     | 0.54      | 0.33      |
| 2      | Kranji        | Bekasi   | 0.26    | 0.39     | 0.46      | 0.34      |
| 3      | Cakung        | Bekasi   | 0.25    | 0.31     | 0.77      | 0.38      |
| 4      | Klender Baru  | Bekasi   | 0.25    | 0.45     | 0.69      | 0.40      |
| 5      | Kramat        | Bekasi   | 0.27    | 0.40     | 0.77      | 0.41      |
| 6      | Buaran        | Bekasi   | 0.25    | 0.46     | 0.77      | 0.42      |
| 7      | Jatinegara    | Bekasi   | 0.25    | 0.43     | 0.85      | 0.43      |
| 8      | Klender       | Bekasi   | 0.28    | 0.43     | 0.85      | 0.45      |
| 9      | Pasar Senen   | Bekasi   | 0.37    | 0.35     | 0.77      | 0.45      |
| 10     | Rajawali      | Bekasi   | 0.29    | 0.38     | 0.92      | 0.46      |
| 11     | Pondok Jati   | Bekasi   | 0.29    | 0.51     | 0.85      | 0.47      |
| 12     | Kemayoran     | Bekasi   | 0.25    | 0.60     | 0.92      | 0.49      |
| 13     | Gang Sentiong | Bekasi   | 0.40    | 0.61     | 0.77      | 0.54      |
4.2.2. Bogor Corridor

Bogor is a corridor with the most number of stations, namely 26 stations. Most of the stations are potential (red colour) for improvements, mainly located in the suburban area.

Table 9. The ranking of TOD index in Bogor Corridor.

| Number | Station         | Corridor | Density | Economic | Diversity | TOD Index |
|--------|-----------------|----------|---------|----------|-----------|-----------|
| 1      | Univ Indonesia  | Bogor    | 0.15    | 0.22     | 0.62      | 0.27      |
| 2      | Pd Cina         | Bogor    | 0.17    | 0.31     | 0.46      | 0.27      |
| 3      | Cilebut         | Bogor    | 0.23    | 0.38     | 0.38      | 0.31      |
| 4      | Depok           | Bogor    | 0.29    | 0.26     | 0.46      | 0.32      |
| 5      | Bojonggede      | Bogor    | 0.28    | 0.53     | 0.23      | 0.34      |
| 6      | Citayam         | Bogor    | 0.25    | 0.42     | 0.46      | 0.34      |
| 7      | Univ Pancasila  | Bogor    | 0.22    | 0.32     | 0.77      | 0.37      |
| 8      | Tanjung Barat   | Bogor    | 0.27    | 0.34     | 0.69      | 0.38      |
| 9      | Pasar Minggu    | Bogor    | 0.26    | 0.31     | 0.77      | 0.38      |
| 10     | Juanda          | Bogor    | 0.22    | 0.34     | 0.85      | 0.39      |
| 11     | Duren Kalibata  | Bogor    | 0.20    | 0.37     | 0.92      | 0.40      |
| 12     | Depok Baru      | Bogor    | 0.27    | 0.31     | 0.85      | 0.41      |
| 13     | Lenteng Agung   | Bogor    | 0.27    | 0.39     | 0.77      | 0.41      |
| 14     | Jakarta Kota    | Bogor    | 0.28    | 0.37     | 0.85      | 0.43      |
| 15     | Bogor           | Bogor    | 0.35    | 0.42     | 0.62      | 0.43      |
| 16     | Karet           | Bogor    | 0.22    | 0.43     | 0.92      | 0.43      |
| 17     | Sawah Besar     | Bogor    | 0.34    | 0.33     | 0.77      | 0.43      |
| 18     | Dukuh           | Bogor    | 0.36    | 0.34     | 0.77      | 0.45      |
| 19     | Gondangdia      | Bogor    | 0.30    | 0.44     | 0.85      | 0.46      |
| 20     | Mampong         | Bogor    | 0.36    | 0.41     | 0.77      | 0.46      |
| 21     | Jayakarta       | Bogor    | 0.31    | 0.45     | 0.85      | 0.47      |
| 22     | Manggarai       | Bogor    | 0.28    | 0.54     | 0.85      | 0.47      |
| 23     | Cawang          | Bogor    | 0.25    | 0.50     | 1.00      | 0.48      |
| 24     | Cikini          | Bogor    | 0.30    | 0.52     | 0.85      | 0.48      |
| 25     | Tebet           | Bogor    | 0.28    | 0.52     | 0.92      | 0.48      |
| 26     | Mangga Besar    | Bogor    | 0.27    | 0.75     | 0.77      | 0.51      |

4.2.3. Serpong Corridor

Serpong is the smallest corridor with the number of 7 stations. Same as to the other corridors, most of the stations which are potential (red colour) for improvements are mainly located in the suburb.
4.3 The reassessment of actual TOD index by theory and policy relevance

4.3.1. Theory relevance

The relevance of the city planning policy through reassessment actual TOD is conducted by looking at the whole and relating to various urban development theories that can be described briefly as follows.

Beginning of the 19th century about Garden City Movement is a theory that emphasises the balance between residential areas, industrial and open spaces in urban areas bounded by the existence of green belts.

Concentric theory of the Central Business District (CBD) is the center of the city located right in the middle of the city and is the center of social, economic, cultural and political life, and is the zone with the highest accessibility in a city.

The concept of sustainable development (1970) is the theory that encourages balance in the implementation of development, especially the economic, socio-cultural and environmental aspects. The concept of integrated spatial and municipal space arrangement (early 1980s) encourages the provision of adequate open spaces and balance of space for occupancy and work activities, including the preservation of old towns and rebuilding of old warehousing areas.

The Transit-Oriented-Development (TOD) (1990s) theory of mixed residential and commercial zones with ease of pedestrian accesses to freight (developed at locations along the railway or bus route), each TOD on the city has its own character in accordance with the environment. The 2000s emerges the concept of smart city with one of its policies is the provision of guidelines for green public transport planning. This concept offers an enhancement the quality of life.

Based on the theory above and associated with the development of the JMR, it can be seen the development that occurred in this area is as follows.

The rapid development of urban areas, especially in capital city of Jakarta led to the expansion of development areas to the suburban areas along with improved infrastructure. The city area reignited with development areas to the suburban areas along with the development of the JMR, it can be seen the achievement of criteria and indicator. Especially the management of transit area, like TOD achievement of criteria and indicator.

The station in JMR is a very important thing in determining the treatment increasing the area to the ideal TOD. Therefore, the reassessment of the actual railway station in JMR is a very important thing in determining the TOD characteristics through index. This method distinguishes between stations to facilitate the treatment increasing the area to the ideal TOD.

4.3.2. Policy relevance

Based on the overall TOD reassessment, it is found that high TOD with index 0.44-0.58 is in urban area (Jakarta City) and low TOD with index of 0.26-0.35 located in suburban area (Tangerang, Serpong, Bekasi, Bogor) for that need an increase to TOD with low index by various policies as follows.

Improvement of low TOD areas need to pay attention to the main indicators of density, economy and diversity, but not limited to those indicators that can be expanded by considering the area that combines green, growth and job.

Density indicator is the main indicator based on expert judgment, the emphasis on special policy on demography and the strategy of developing new settlement centers.

The quality of life of the population within the TOD area is enhanced by special arrangements in the utilization of locations for public interest such as residential, commercial, business, education, health.

Making community-based on participatory planning considering the role of the private sector and the community are the main actors of urban development. The engagement process starts from planning, utilization and control. In the context of cooperation, effective coordination mechanisms are developed.

5. Conclusion

The range of TOD index values of 54 stations in JMR is ranging from 0.26 to 0.58 with the details as follows, 6 stations (range 0.26-0.35) scattered in the transition area of suburban and urban, last 37 stations (range 0.37-0.58) dispersed in urban areas or city centre. It can be concluded that a high index value of stations tends to be in the urban areas, and, vice-versa, the station with low index value located in the suburb. This is because of the difference of acquisition in criteria and indicator of each the station. Therefore, the recommended stations eligible for improvement should apply the concept of TOD well. The level of improvement in each of these stations is adjusted to the value of the achievement of criteria and indicator.

The provision of a good public transport, especially the management of transit area, like TOD is critical to the city management due to the nature of the public mass and providing physically as well as non-physical fulfilment for the satisfaction of its inhabitants. Planning for good TOD that meets the needs of the community regarding effective transportation and efficient travel service-based paradigm consequently reduce and even overcome the problems of everyday life of the city such as road congestion, air pollution and traffic safety.
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