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# Quantitative and qualitative approaches in recognizing viable centres to support transit system implementation in developing countries. Case study: Makassar, Indonesia

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ABSTRACT

Implementing transit systems has been seen as one approach to better support land use development and the transport system to overcome the spatial mismatch and subsequently, the traffic congestion problems in many cities. One of the key components of transit system implementation is recognizing the viable center. However, the application of this system in practice is still limited due inadequate spatial form and mobility information, especially in cities in the developing world. This study aims to propose a spatial clustering approach to identify urban center(s) based on openly available data sources combined with expert interviews. The proposed method is intended to support local transport planning processes. Following the case study approach, the method was developed and tested in Makassar, Indonesia. Urban land use and the built environment data were used alongside data about the streets network and the distribution of facilities derived from the local authority's spatial database and OpenStreetMap (OSM). The results show that urban centers are developed outside the central business district mainly in linear form. Additional findings based on the morphological perspective show that Makassar has three types of urban fabrics, i.e., walking, car city, and transit city fabrics. Based on the urban center distribution and urban fabrics' typology, recommendations for the adjustment of transport nodes and the city network can be made, which could become a basis for transport planning in the future.

## 1. Introduction

From a planner's perspective, urban areas in the developing world have distinct challenges such as rapid population growth and urbanization, lack of appropriate transport infrastructure, and limited financial resources that lead to spatial mismatches between housing and work/activity places hence causing severe traffic congestion problems (Cervero, 2000, 2013). Additionally, high growth rates of individual motorized transport promote automobile dependency (Seum et al., 2020; Dirgahayani and Sutanto, 2020). Furthermore, the absence of strong regulations in spatial planning encourages spontaneous development and even more sprawl (Cervero, 2013). Conventional approaches in transport planning or modeling such as land use planning and transport models, which are founded on developed world cases, are often difficult to apply to cities in developing countries due to different factors such as traditional transport modes including paratransit, and two/three wheelers (Cervero, 2000, 2013). The planning stages, in which the relationship between land use and the transport system is considered, are more challenging due to lack of data.

Cities in developing countries are seeking sustainable solutions for expanding their transportation systems into already developed urban areas to solve the severe traffic congestion problems. Transit systems (Bus rapid transit, light, and heavy rail) have become a plausible solution to the traffic congestion problems. The transit system provides a framework for sustainable urban planning by creating high density, mixed land use and proximity to multi-modal public transportation neighborhoods (Calthorpe, 1993; Cervero, 1998; Ewing, 1997; Woo, 2021). Based on Bertaud (2002b), implementing a public transit system is a way to co-develop land use and the transport system. Many cities, especially in developing countries, are eager to adopt the concept. However, this concept requires large scale investments and often heavily affects the statics of the existing informal urban transport system

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(Cervero, 2000). Moreover, there remains a substantial gap in knowledge (such as planning guidelines and consideration of the potential benefit) of successful transit system implementation based on developing Asian countries (Yap et al., 2021). Therefore, they have not remained without criticism (Rizzo, 2017), and face challenges such as those arising from a transformation into hybrid systems interlinked with informal transport services (Salazar Ferro et al., 2013; Ferro and Behrens, 2015). Furthermore, due to the complex relationship between land use and transport system, an approach that can help adjust the transit system to various urban characteristics is likely to yield beneficial outcomes.

Due to the rapid population growth in developing countries, market forces drive the formation of widely dispersed mass housing clusters while the planning policy shapes the urban structure (Gwilliam, 2003; Yue and Liu, 2010). Spatial planning policy is the primary guideline in urban development and highly influences spatial configuration (Natalia and Heinrichs, 2020). The spatial planning policy aims to coordinate a variety of factors in land use and transport to promote more sustainable travel patterns (Stead and Marshall, 2001). However, cities in developing countries lack adequate planning and implementation procedures within city authorities (Gwilliam, 2003). Therefore, from a planning perspective, a study is needed to support policy making and to provide an appropriate planning guideline. The transport system has to be aligned with the urban structure (Bertaud, 2002a), and the first step is to generate a planning basis that allows practitioners and planners to integrate land use and the transport system by adjusting the transit-based public transportation system in the already developed urban areas. Identifying the transport-related urban fabrics can provide additional information for further planning actions to support the planning stage, especially in evaluating the interactions between land use and transport.

One of the key components of transit system implementation is recognizing the viable center (Newman et al., 2009). Understanding the transit center typology is the starting point for the decision-making process involved in developing integrated land use and transport systems (Woo, 2021). Moreover, identifying the urban centers' distribution is one strategy for understanding the urban spatial structure and its relation to the transport system. In this study, urban centers are defined based on the descriptions by various scholars. An urban center can be referred to as a place of employment concentration (Cervero and Wu, 1997; McMillen, 2001), or a place with a high population density (Brezzi and Veneri, 2015; Tsompanoglou and Photis, 2013; Wegener, 2013). The urban center is also called an activity center where various socio-economic activities accumulate (Rodrique et al., 2017; Yue and Liu, 2010; Anas et al., 1998; Smith, 2011; Wegener, 2013). In relation to transport infrastructure, the urban center is considered a place with good accessibility to public transport services (Anas et al., 1998; Newman and Kenworthy, 2006; McMillen, 2001; Wegener, 2013). Likewise, the urban center plays a role as an urban mobility attractor, its location influencing travel behavior (Ewing and Cervero, 2001; Rodrique et al., 2017; Schwanen et al., 2001; Zhong et al., 2013).

Various types of quantitative analysis, especially statistical-based (Brezzi and Veneri, 2015; Cervero and Wu, 1997; Giuliano and Small, 1991; Schwanen et al., 2001) and statistical-based combined with spatial analysis studies (Cai et al., 2017; Huang et al., 2015; McMillen, 2001; Riguelle et al., 2007; Yue and Liu, 2010; Zhong et al., 2013) have shed some light on the challenges posed by the unavailability of census-based data that many cities in the developing countries have to confront in the recognition of urban centers. The research gaps and challenges are thoroughly described in Natalia and Heinrichs (2020), where the authors reveal that many cities in developing countries cannot implement the quantitative approach based on cities in the developed world due to a lack of data availability. Additionally, Natalia and Heinrichs (2020) explains that the development of the GIS tool and open-source spatial data platform enables physical urban characteristics or built environment dimensions to be used as proxy indicators to identify urban centers and overcome the data gap in developing countries. The physical urban form is the result of urban lifestyles and functions (Kosonen, 2015), which can help describe urban development trends.

This study proposes a spatial cluster analysis approach that considers built environment dimensions to define urban center (s). The findings can be used as a basis for planning recommendations for Makassar's transport system.

## 2. Method

This section is divided into 1) description of the case study, 2) selection of indicators for a spatial cluster analysis and 3) an evaluation of the methodology using results from expert interviews.

### 2.1. The case study

This case study research was conducted in Makassar, Indonesia. Makassar is a metropolitan city with an area of 175.77 $km^2$ and the capital of South Sulawesi Province, located in the eastern part of Indonesia (Fig. 1). It is a fast-growing urban area with a population of ±1.45 million people. In the last ten years, Makassar experienced rapid urban expansion. As a result, Makassar suffers from problems such as urban sprawl, automobile dependence, congestion, and pollution. Similar problems have been experienced in other big cities in Indonesia, such as Jakarta, Surabaya, and Bandung. Due to support from the local experts, Makassar has been chosen case of reference for this research. Makassar can also represent other cities in Indonesia since it has similarities with Jakarta, Surabaya, and Medan as a multidistrict metropolitan area (Roberts et al., 2019). The cities also share similar typologies and problems, i.e., urban sprawl, rapid motorization, lack of appropriate public transport services, and limited funding resources.

### 2.2. Indicators for spatial cluster analysis

The primary data for this study are land use, public transport networks, street networks data derived from Makassar spatial authority in shapefile format, and street networks derived from OpenStreetMap (OSM) with SQL query. Field observation is conducted in various places within Makassar urban areas to ensure that the provided data describe the current state of Makassar land use and street networks. The field observations showed that the data is reliable. The primary streets were identified with OSM tags of key and value, i.e., highway and primary, respectively. The street networks provided by OSM offer a dataset characterized by high completeness, a dataset that can be used by even for cities in developing countries (Barrington-Leigh and Millard-Ball, 2017; Boeing, 2022). Six out of seven indicators for spatial cluster analysis are calculated into the grids using SQL query. While one indicator (Average distance from each house to the public transportation network in the given area) is calculated using the UrMo accessibility computer (Krajzewicz and Heinrichs, 2016). The calculation results of all indicators are stored in the PostgreSQL database.

This research uses indicators that represent built environment dimensions. The dimensions mainly refer to urban physical characteristics (Cervero and Kockelman, 1997; Ewing and Cervero, 2001). Various indicators of the built environment represent these features: For example, "the number of jobs in a given area" represents the density dimension; "type of land use" represents the diversity dimension; "proportion of the main road in the given area" represents the design dimension; "distance to public transport network" represents the distance to transit dimension and "number of facilities that can be reached in 30 min trip" is a representation of the destination accessibility dimension. In general, indicators that represent the built environment dimensions can be derived from open-access platforms such as OSM. For the Makassar case, the "distance to transit" dimension is represented by the "paratransit route length in the given area" since the Bus rapid transit network is still in trial operation with limited route service.

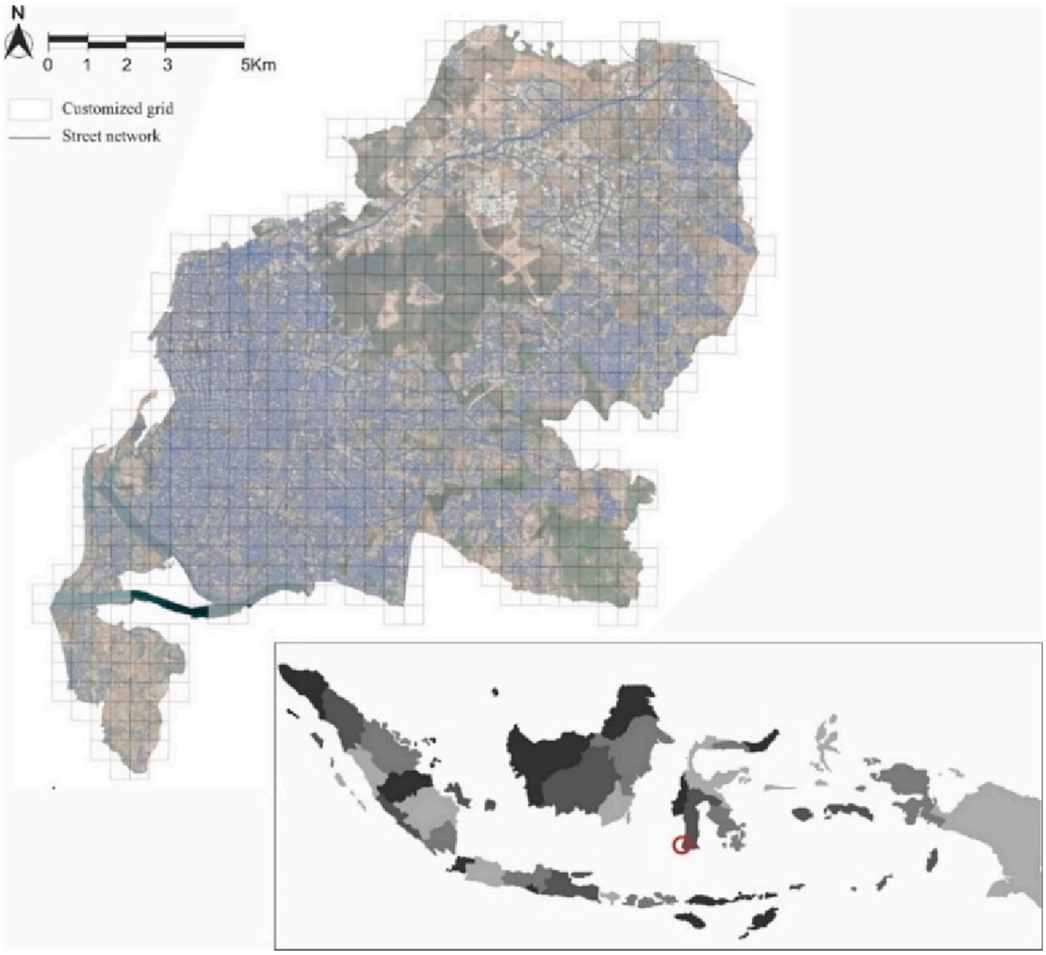



**Fig. 1.** The case study location: Makassar, Indonesia.

Paratransit is a local public transport service with a small capacity (10–12 people). According to Cervero (2000), paratransit is a mini and midi vehicle that provides last-mile connection services for a system that is mostly found in developing countries.

Density, diversity, design, distance to transit, and destination accessibility (5Ds) are the major dimensions used in studying the interaction between land use and travel characteristics within urban areas (Ewing and Cervero, 2010) but with lesser evidence for cities in developing countries (Cervero, 2013). The 5Ds strongly influence the identification of urban centers (Cervero and Wu, 1997; Giuliano and Small, 1991; McMillen and McDonald, 1998). As mentioned in the literature review section, the formation of urban centers is highly determined by the transport-related features such as good access to public transport services; the urban center is also referred to as a mobility attractor. Therefore, including indicators of distance to transit and destination accessibility as transport-related indicators in spatial cluster analysis will address most indicators that define urban center. Therefore, 5Ds can be used as the suitable proxy indicators in defining urban center(s).

The selection of indicators also considers the type of spatial shapes and resolution to be used in the analysis tool, i.e., point, line, and polygon. To help calculate the indicators with their spatial attributes, the urban area as the unit of analysis is set into a customized grid (500 × 500 m). The size of the cells is set as 500 m, which is the average walking distance threshold that has been used by some scholars (Govada et al., 2020; Keeling, 2019; Woo, 2021). The setting allows the indicators to be calculated on the same spatial resolution level.

Seven out of ten indicators were selected to avoid collinearity. This study uses the Pearson correlation coefficient to determine highly correlated indicators and exclude them from the model. Indicators that have a strong collinearity (0.8<) and those that predetermine center areas (e.g., indicators that represent destination accessibility) were taken out, leaving seven indicators (Table 1) to be analyzed in the spatial cluster analysis. A grid of uniform size can be used for all indicators within a joined computation. Indicators that have the most influence on group differentiation are shown by high $R^2$ values within the spatial cluster analysis using the k-means algorithm.

## 3. Expert interviews

From Natalia and Heinrichs (2020), studies in urban center recognition often use a quantitative approach. There are no studies conducted using a qualitative approach. However, the expert interviews for this study were conducted to obtain knowledge about Makassar's urban form and its center distribution as well as to identify indicators that can be used to recognize urban centers. Based on Bogner et al. (2009), expert interviews are an efficient and concentrated method of gathering data and information that reflects knowledge from a wider social field. The results of the expert interviews are compared to the results of the spatial cluster analysis. The result of the expert interview will also be used to cross-validate the result of the quantitative approach.

The interviews were performed as one-on-one on-site (Makassar city) interviews by one researcher, who is also the author of this paper. The interviews were conducted in January 2018 based on open and structured questions. The following criteria were applied in the selection of interviewed experts:

**Table 1**
Proposed and Selected indicators.

| Dimensions | Indicators | Proposed 1D | 2D | 3D | 4D | 5D | Selected 4D |
|---|---|---|---|---|---|---|---|
| Density | Number of firms in a given area (Cervero & Wu, 1997; Giuliano & Small, 1991; McMillen,2001; Monghadam et al., 2018; Yu, Zehng, Yu, & Wu, 2021) | ■ | ■ | ■ | ■ | ■ | √ |
| | Number of shops/services in a given area (Cervero & Wu, 1997; Giuliano & Small, 1991; Kaiser et al, 1995; McMillen, 2001) | ■ | ■ | ■ | ■ | ■ | √ |
| Diversity | Proportion of houses in the given area with commercial function (Cervero & Kockelman, 1997) | | ■ | ■ | ■ | ■ | * |
| | Mixed use level in the given area With entropy index i.e., proportion of specific function in the given area (Singh et al., 2017; Song, Merlin, Rodriguez,2013) | | ■ | ■ | ■ | ■ | √ |
| Design | Proportion of primary streets regarding all streets in the given area (Cervero & Kockelman, 1997) | | | ■ | ■ | ■ | √ |
| | Proportion of streets with intersections in the given area (UN-Habitat,2013) | | | ■ | ■ | ■ | √ |
| Distance to transit | Paratransit route length in the given area (Kenworthy & Townsend, 2002) | | | | ■ | ■ | √ |
| | Average distance from each house to public transportation network in the given area (Roth et al., 2011) | | | | ■ | ■ | √ |
| Destination accessibility | Averaged number of facilities (non-residential functions) reachable in 30 minutes from each house in the given area (Ewing, 1996; Uchida & Nelson, 2008; Van Wee & Geurs, 2016) | | | | | ■ | * |
| | Average distance from each house to CBD in the given area (McMillen & McDonald, 1998; Naess, Sandberg, & Røe, 1996) | | | | | ■ | ** |

Notes: *strong correlation; **pre-determined center.

A professional and institutional selection that represent academics, professionals, and local authorities. The selected experts are people from the university, urban planning association, and department of urban and transport planning of Makassar City.
All the experts had a working experience of more than ten years.
Good knowledge of the local city (only residents of Makassar city were selected).
Thirty interviews were planned; ten interviews represent each of the selected institutions.

Based on their diverse backgrounds and perspectives, the experts could provide enriched and relevant information about the Makassar urban area. Structured interviews were performed with questions covering three topics namely, 1) the definition of urban center (s); 2) indicators and land use characteristics that describe urban center (s); and 3) the location of the place(s) assumed to be urban center (s). According to the evidence of saturation (Spencer et al., 2003) in the interviews, the number of expert interviews was reduced. The interview phase ended after interviewing the 21st expert due to some repetitive and similar information, considered a sign of information saturation in the three main topic blocks. The information already gathered adequately represented the three targeted institutions. All the written information from the interviews was later managed through content analysis. The content analysis is performed with coding and categorization as well as supported with spatial visualization (mapping).

## 4. Results

The results of this study are divided into 1) results of individual indicator calculation, 2) results of the spatial cluster analysis and 3) results of the expert interviews.

### 4.1. Individual calculation of indicators

This section provides an overview of Makassar's urban area based on the individual calculation of the indicators. Shops and firms dominate the western part of the city (Fig. 2, map a and b). The distance to the public transport route demonstrates that, in general, Makassar's urban area is well served with paratransit networks. The patterns are demonstrated in Fig. 2 (map c). According to this map, the dominant white cells have an average of ±714 m distance to a public transport route. A significant overlap of paratransit routes appears on the primary street

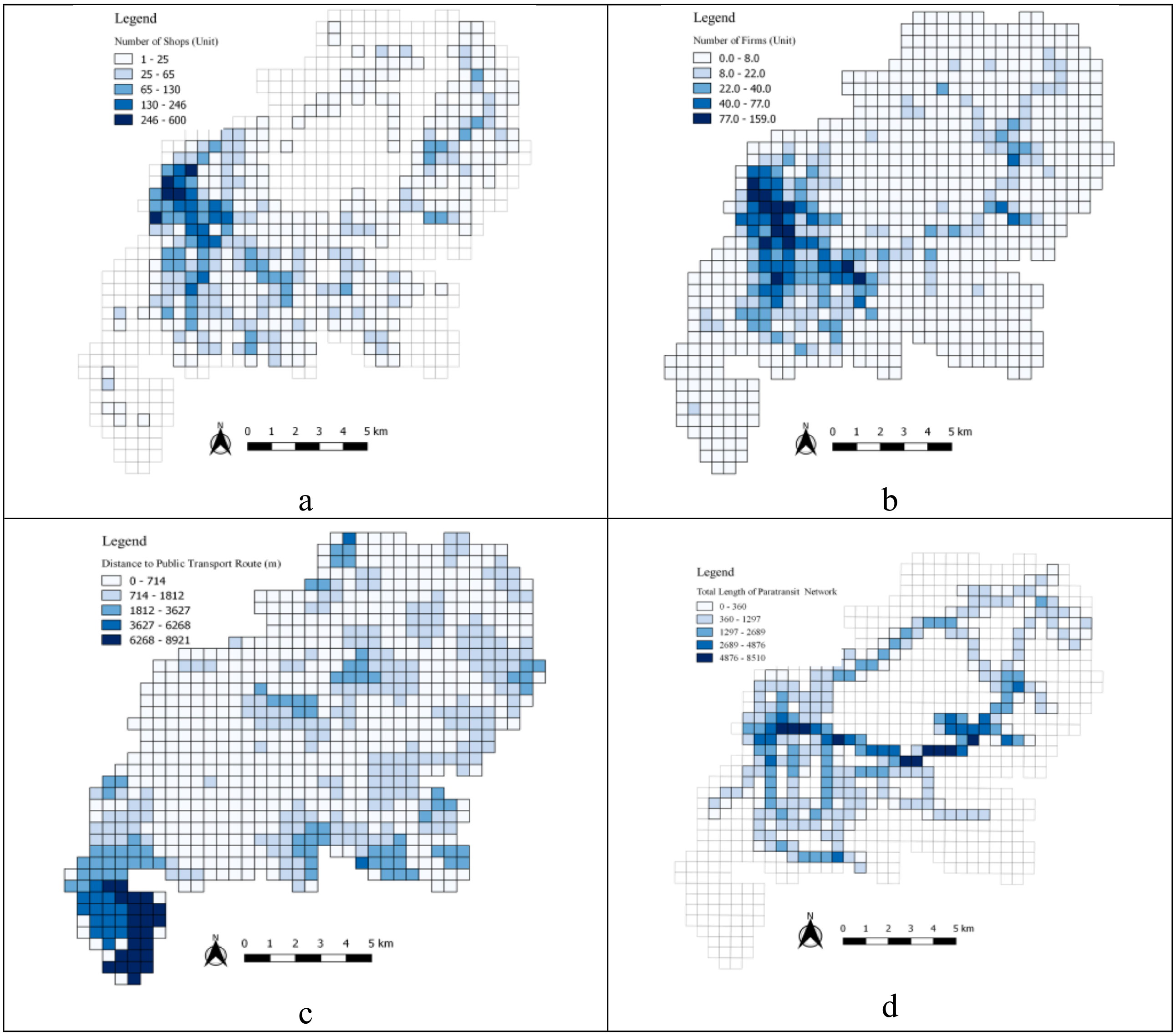



**Fig. 2.** Results of individual indicators calculations: a. number of shops; b. number of firms and c. distance to public transportation routes; d. Total length of paratransit network.

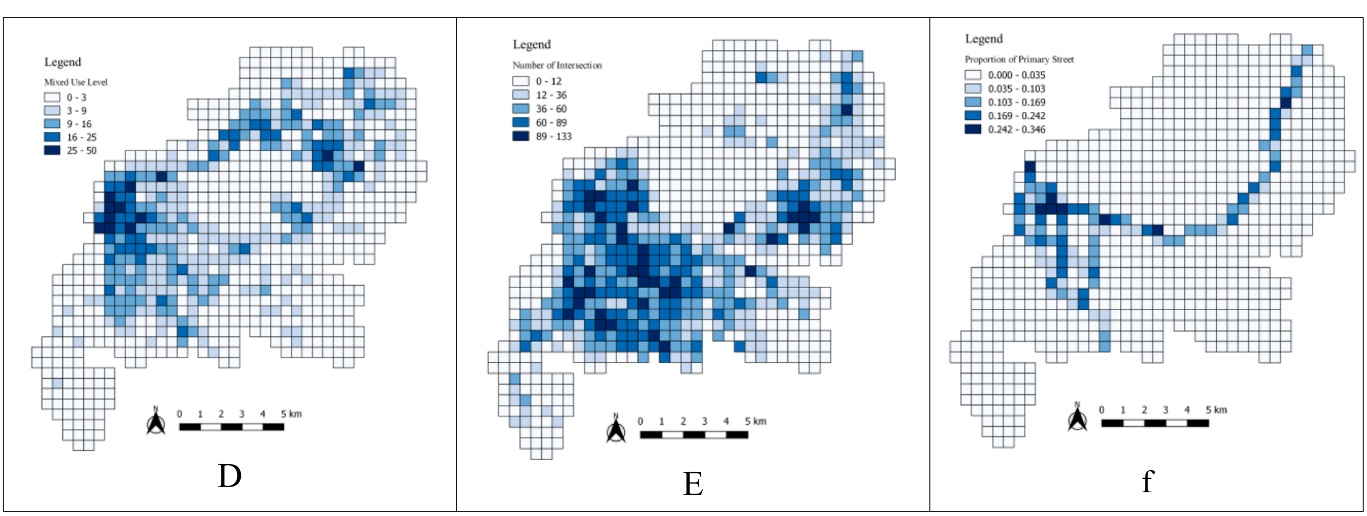



**Fig. 3.** Results of individual indicators calculations: d. mixed use level; e. number of intersections; f. proportion of primary streets.

section as the access from the west to the eastern part of the city (Fig. 2, map d).

Fig. 3 (map d) shows that Makassar's high diversity area is found in the western and eastern parts of the city. Medium diversity areas are distributed evenly across the city. The intersection density demonstrates the same distribution pattern (Fig. 3, map e). The linear pattern from the west to the eastern part of the city appears in the calculation result of the proportion of the primary street as a representation of the design dimension (Fig. 3, map f).

### *4.2. Spatial cluster analysis*

Based on the F-statistics value (Fig. 4), the best working cluster analysis is when the cluster is divided into two groups and followed by eight cluster divisions in the second rank. However, the result is too coarse and has steep differences in the values of indicators. Moreover, the value of each indicator does not clearly define an urban center. For example, the highest density area in the eight-cluster's division is the place with the lowest distance to transit. This result contradicts the definition of urban center as a high-density area with the good access to public transport service. The inconsistency could be due to missing data in the cluster analysis. Therefore, several computation steps with a different number of clusters and different combinations of indicators are performed. The computation steps yield eight computations that show interesting results, i.e., computations 1–4 with two clusters, computations 5 and 6 with three clusters, and computations 7 and 8 with four clusters. This article presents only one computation (Computation 8) result that satisfies the research purpose. Computation 8 is selected based on some criteria i.e., its level of accuracy in cluster division, and the fit between the formed clusters and the literature-based definition of an urban center. Other seven computations can be seen in the supplementary material.

For all computations, the following rules have been applied. As a start, computations 1–4 have been analyzed using two cluster differentiations and different numbers of indicators. Computation 1 has been analyzed using all seven indicators. The least influential indicator in computation 1 was taken out in computation 2; this process was repeated for each computation 1–8, continuously eliminating the indicator of least significance (lowest $R^2$ value).

As previously described, in computation 8 the area is divided into four clusters. Some indicators have been eliminated to less influential value. At this stage, computation 8 analyzes only 5 indicators that represent density, diversity, and design (3D). The analyzed indicators can be seen in Table 2 and Fig. 2. The result shows that the design dimension, i.e., "proportion of the primary streets," has the highest $R^2$ value (see Table 2, indicator list written in black). The color of each cluster presents the indicator associated with the cluster. This means the "design" indicator has the greatest influence on the center recognition. This result is different from other computations with two or three clusters whereby the density dimension had the most influential value in center recognition. Conversely, the diversity indicator is less influential in computation 8. The result also shows that indicator values in the red cluster are beyond group max compared to other indicator values in other clusters. On the contrary, the indicator values of the blue cluster are dominantly below the average level (below group median) compared to indicator values in other clusters (See Table 2, indicator list written in red and blue).

The diagram (Fig. 5) for computation 8 shows four different clusters: red, orange, green, and blue. In computation 8, the red cluster has the highest value for 4 out of 5 indicators, while the orange cluster has one indicator with the highest value, i.e., "proportion of the primary street." Three indicator values in the red cluster are outliers. A high number of intersections are also found in the red and green clusters.

In addition to tables and diagrams, the results of grouping analysis are also used for generating maps (Fig. 6). The maps show the obtained groups (clusters) as outcomes of the indicators analysis and processing process. The patterns of these clusters represent the urban centers' distribution (Fig. 6). Maps of computation 8 with four clusters are the most detailed ones. Table 2 describes the "design dimension" as the most influential indicator in cluster division. When the patterns and the indicator values are compared, the characteristics of the clusters can be divided into four ranks, i.e., the highest (red), high (orange), medium (green), and low (blue). The highest value of the "proportion of the primary streets" in the orange cluster is demonstrated in linear form on the map. Even though the green cluster has medium ranks, the value of the "number of intersections" is higher than that in the orange and blue clusters.

Besides the distribution of urban centers, the results of the spatial

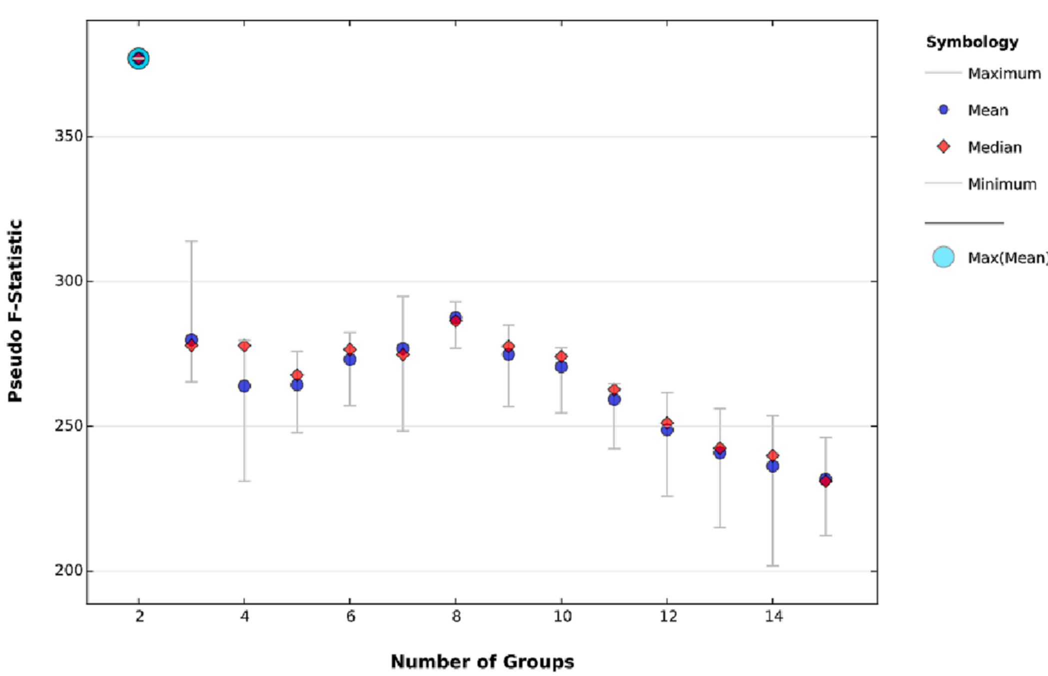



**Fig. 4.** Comparation of F-statistics value in group division.

**Table 2**
The result of spatial cluster analysis for computation 8.

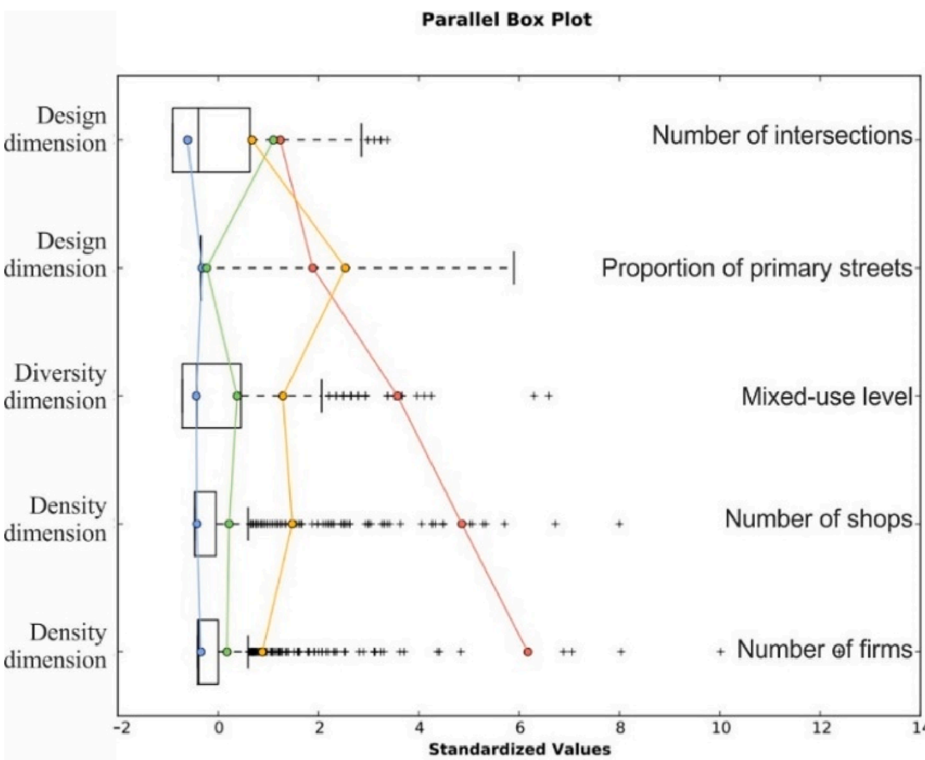




**Fig. 5.** Comparison of Indicators among clusters.

cluster analysis also yield additional findings, i.e., the morphological form of transport-related urban fabrics (Fig. 7). According to Newman et al. (2016), categorization is based on the cluster pattern and values of indicators. Further socio-demographics investigations are needed to accurately categorize the fabrics.

### *4.3. Expert interviews*

The transcripts of the expert interviews were analyzed using content analysis with the help of Atlas.ti software. Six categories were developed in the coding process based on the interview transcripts (Table 3). The experts' descriptions of the definition of centers provided detailed information regarding the indicators and land use characteristics that feature in urban centers. Forty-two indicators were categorized from the coding process (Table 3).

Makassar's urban centers were perceived to cause high traffic volume in some parts of the city. One of the experts with academic background stated that "the easy way to define Makassar's urban center is simply by looking out the area where the surrounding streets are filled with on-street parking… The utilization of the street for parking has narrowed down the traffic lane and causes traffic congestion." Another academic expert also stated that "the high use of private vehicles (especially motorcycles) that parked irregularly around the activity center is a sign that Makassar's urban center is a mobility attractor…"

Urban centers were also perceived as areas with high concentrations of various activities at higher density and intensity. One of the experts with an urban planning background stated that "Urban centers mostly have higher building density compared to other areas. Urban centers also have a higher intensity of functions… various socioeconomic activities can be found in urban centers." Another expert with a background in urban planning also stated that "Most of Makassar's urban centers are located in the proximity to the arterial or collector road to provide easy access for the visitor."

Based on the expert interviews, shopping malls accommodated

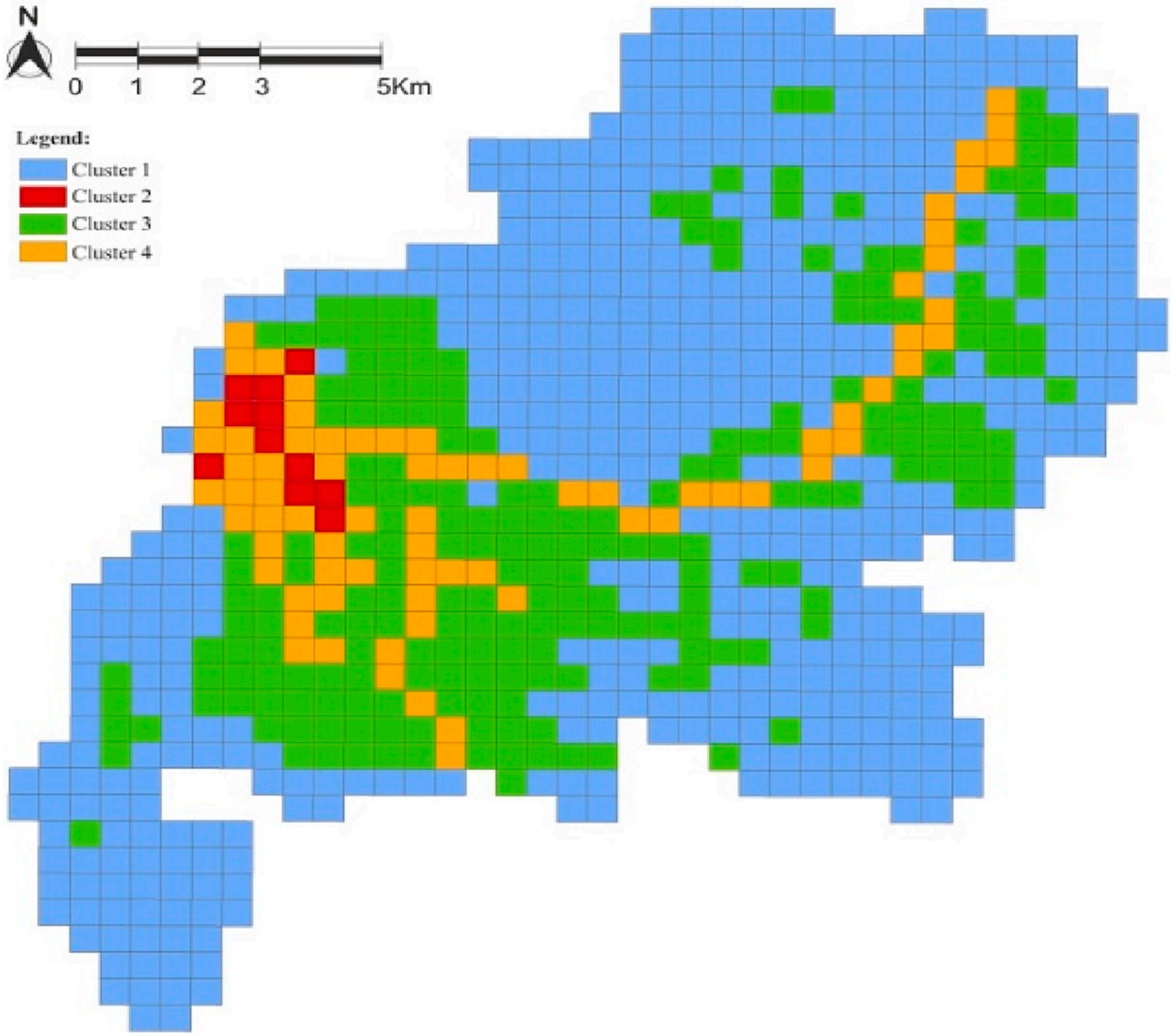



**Fig. 6.** Map of computation result.

various activities, such as commercial and non-commercial services, and education. Therefore, most experts define shopping malls as a feature of urban centers with diverse activities. Moreover, the urban anchors were mainly located in proximity to the main road or to the local public transportation route. One urban planner expert described that "The location of shopping malls is the location of urban centers… shopping malls represent the diversity of functions. Various functions can be found in this place, i.e., retail/shops, offices, education facilities, beauty shops, cafés, restaurants, and so on."

Experts that represent local authorities defined urban center (s) based on their knowledge of Makassar's spatial planning policy. For example, one of the experts pointed out, "The industrial area in the eastern part of the city, which is designated as an industrial zone, can be called Makassar's urban center." In addition, another expert from government representatives described that "[An] Urban center is a place with one dominant function, such as commercial center, office center, industrial center, education center, et cetera. This statement contradicts statements from other experts that describe an urban center as a place with various activities. Indeed, Makassar's spatial planning policy used the terms "integrated commercial center," "integrated offices center," "integrated education center," and "integrated housing and settlement center." These terms were perceived by some of the experts from the local authorities as a dominant feature. In fact, the designated center has other functions.

In the interviews, experts pointed out the locations of the urban centers in the Makassar urban area. All of the experts agreed that Makassar has several urban centers, i.e., in the downtown central business district (CBD) and outer CBD. One of them is the suburban center that forms a linear pattern along main road from the western to the eastern part of the city. This information also highlights the belief that urban centers are mainly developed along a primary road and, at the same time, highlights the perception that one of the indicators that influence recognition of urban centers is their relationship with transport infrastructure. The experts pointed out most locations based on the district names or specific landmarks. The locations of the centers transformed into the unit of analysis (grid form) can be seen in Fig. 8.

## 5. Discussion

The maps developed from computation and expert interview results show three categories of urban centers, i.e., primary, secondary, and tertiary centers (Fig. 9). The classification of Makassar's urban center into three categories is based on the values of the analyzed indicators. Meanwhile, the categorization of Makassar's urban center based on the expert interviews' is based on the land use function and locations that are frequently mentioned by the expert.

The primary center (red cluster) in the computation results is in the western part of the city. The red cluster is the area with the highest

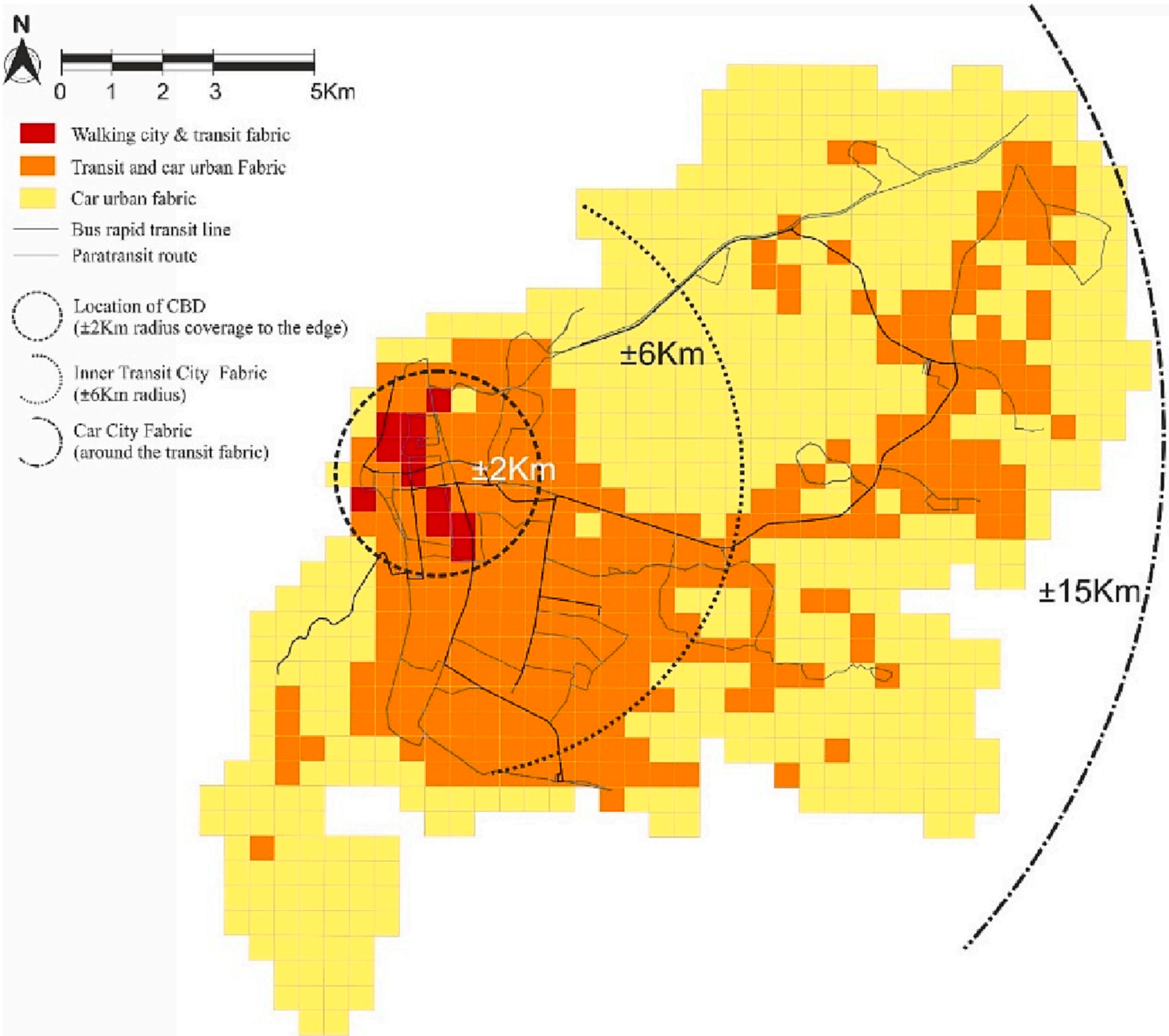



**Fig. 7.** Classification of Makassar's urban fabrics based on Transport-related urban fabric typology (Newman et al., 2016).

values in terms of density and diversity, as well as the one in closest proximity to the primary street. The red cluster is also the location of Makassar's CBD. A high number of intersections in this area represent the narrow street and smaller building blocks which is a sign of a walkable neighborhood. The main function of this center is commercials and offices. Similar functions are also mentioned in other primary centers outside the CBD in the southern part of the city, as seen from the availability of shopping malls.

The secondary center (orange cluster) from the computation results also lies in the CBD area and continues to the outskirt area in the linear form. The map shows the trend of Makassar urban centers' establishment in the expanded area. The urban centers developed outside the CBD tend to concentrate along the primary street. The centers outside the CBD provide facilities for the surrounding mass housing neighborhoods in the green cluster. A high density of intersections in the green cluster represents the small parcels of mass housing in the suburban area—the main function of the orange and green clusters that represent commercial services and residential areas, respectively. The result of the expert interview also points out the location of the secondary center in the eastern part of the city along the primary road (Jl. Perintis Kemerdekaan). Another secondary center, according to the experts, is in the western part of the city near the CBD. This area also serves as the location for commercial activities and offices. Tertiary centers based on computation and expert interview results overlap, especially in the inner-city part, serving the main purpose of residential area. Low-density residential areas and undeveloped land mainly occupy the blue cluster. The expert interview results show the blue cluster to be mainly beyond the center coverage.

Based on computation results, the more indicators are included in the computation, the more detailed the results of the cluster division and the wider the pattern coverage in the mapping results. Once the design indicator is included in the computation, the trend of centers developing in linear pattern in the eastern part of the city is vividly mapped in computations with two and four clusters division. The design indicators that represent proximity to the primary street also share similarities with the results of the expert interviews. The results of computations with two clusters division are similar to the findings of McMillen and McDonald (1998). Both results assert that urban center facilities tend to develop along transport facilities to gain the cost advantage of physical proximity and to reduce consumer shopping cost. In addition, experts state that location of urban centers around the primary road provides easy access for the customers.

Compared to other computations, computation 8 exhibits more detailed results in identifying Makassar urban centers (Fig. 7). Comparing the result with expert interviews, computation 8 results are similar to those from expert interviews since most of the centers that

**Table 3**
Results from the expert interviews (categorized, un-weighted): urban center definitions and indicators to define an urban center.

| **Mobility Attractor** |
|---|
| A center has many visitors demonstrated by traffic congestion and on-street parking in the surrounding area |
| Always attracts vehicle users |
| A center has a high traffic attraction |
| |
| **Activities/Function** |
| Many social and economic activities concentrate in one point |
| Various activities and functions that concentrate in one point |
| Various functions concentrate in one point |
| Various functions in one point |
| Various functions |
| Center is a node of various activities |
| Center has a variety of activities or an agglomeration of activities |
| High commercial activities & high trade activities |
| Has similar characteristics, for example a trading area or economic activities (business, trade) |
| A center usually has similar functions |
| There are economic, social and government activities |
| Accommodates economic activities |
| There are industrial and government activities surrounded by large scale residential areas |
| Urban center is the hub of activities. It can be the hub of settlement, the economic hub, the sports hub, or the hub of government, etc. |
| Accommodates commercial activities and entertainment |
| A center accommodates commercial and recreational functions |
| A center establishment is influenced by one dominant function such as education or offices which are followed by other function |
| Commercial function and open space |
| Accommodates business, industrial, service, and education activities |
| A center is established due to the availability of trading and service activities |
| |
| **Facilities** |
| In the surrounding area there are facilities for changing between different modes of transportation |
| Various facilities in one point |
| |
| **Density and Intensity** |
| High intensity |
| High land use intensity |
| High building density |
| High intensity of activity |
| A center has high building density compared to other areas |
| |
| **Shopping Mall** |
| The location of the shopping mall |
| There is a shopping center |
| An urban center is marked by the availability of shopping mall/department store |
| |
| **Transportation** |
| Center is mostly placed in the location that is served by the primary street |
| In the surroundings there are transportation mode interchange facilities |
| The area is served by public transportation routes |
| Ease of good accessibility |
| Complete transportation infrastructure |
| Served by the main road |
| Easy to access |
| Served by public transport and has a complete transportation infrastructure |
| High accessibility |

were mentioned by the experts are captured in this computation. This includes the area of an urban anchor (shopping malls), which is well captured in the orange cluster in computation 8. The major difference is illustrated in the location of the Makassar Industrial area in the eastern part of the city. The experts mentioned this area as an urban center, while the computation only captured the narrower area since, currently, the area serves for warehousing with a low density. The continuous linear pattern in computation 8 is also different from the results of the expert interviews, where a discontinued linear pattern is depicted in the inner-city part (Fig. 7) due to differences in center boundaries mentioned by the experts.

The linear pattern in computation 8 is firmly shaped. In this case, experts implicitly reported that most of Makassar's urban centers were well served by the local public transport service since most of the local public transit routes run along the primary streets. This statement is also similar to the formation of the orange cluster in computation 8 whereby the "distance to the primary street" is the most influential indicator. Both quantitative and qualitative approaches demonstrated that Makassar's urban centers outside the CBD are formed along the primary street and create a linear pattern. The pattern is successfully demonstrated in computation 8 represented by the orange cluster.

It can be argued that the expert interviews method is only able to depict the distribution of Makassar's urban centers but cannot provide detailed information about the values of the different dimensions of the built environment. Contrastingly, spatial cluster analysis is able to provide both urban center distribution and information regarding the 3D characteristics of the centers. Despite the differences in center categorization, the results of both methods share major similarities in the location of Makassar's urban centers. Spatial cluster analysis is however more reliable in recognizing Makassar's urban centers and provide more objective results.

Based on the most detailed computation result, additional findings about Makassar urban fabrics are shown in the map (See Table 4). The 3D evidence is the main indicator to assign the transport-related urban fabrics according to scholars' descriptions on the following Table 3. The identification of urban fabrics can describe the dynamic process of urban areas and address the issue of a fundamental mismatch between land use (demand location) and transport infrastructure supply, as mentioned by Dimitriou (2013), to provide a better public transit system.

According to Table 4, three types of urban fabrics are formed based on the value of the 3D as the main indicator in urban fabric categorization. As mentioned by scholars, the fabrics can be present and can overlap within the urban area. Newman and Kenworthy (1996) characterized the three urban fabrics based on physical features. The red cluster represents the highest density area as walking and transit fabric; the result of cluster analysis described the red cluster as the section with the highest density and diversity, and the highest number of intersections represented in the grid form. The highest-density area with narrow streets, short blocks, and zero setbacks, Makassar CBD, can be classified as a walking urban fabric. The area of a walking urban fabric in a radius of 0–2 km maximum is also similar to the Newman and Kenworthy (2015) classification.

The orange cluster is a joint result of secondary and tertiary centers. The orange cluster represents medium-density areas as transit and urban car fabric. This study adopts this typology and manages to quantify the physical features (read: built environment dimensions) with the approach of spatial cluster analysis. The coverage areas for transit and car city fabrics are 2–8 km and 8–20 km, respectively. Most of the transit city fabric areas have a grid structure around the CBD area and the eastern part of the city (suburban area). The grid structure represents the high value of the "proportion of streets with intersections" in the tertiary center. The linear form of the urban center along the primary streets is also found in this orange cluster.

Compared to the other fabrics, the yellow cells have the lowest density thresholds, with separated uses, surrounded by the arterial road. The yellow cluster represents the area as car urban fabric—the cul de sac type of the street and decentralized form found within the yellow cluster. In suburban areas, the grid form represents the enclaves of residential areas or mass housing that develop along the primary road. According to the extensive coverage of low-density areas representing car urban fabric, Makassar remains a car-dependent city. Certainly, the categorization of Makassar urban fabrics requires further investigation, especially on socio-demographic perspectives, which are not provided in this study. The identified walking, transit, and car urban fabrics provide dedicated zoning for each type of urban transport system. These maps can now be utilized to support local planning and policies, especially to

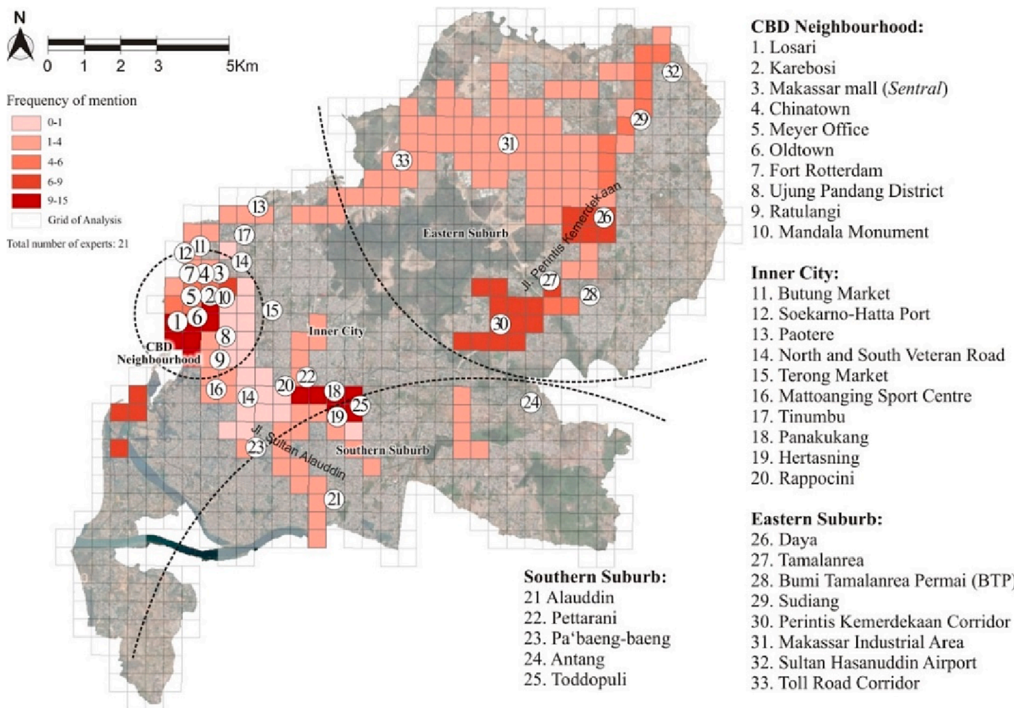



**Fig. 8.** The result of the expert interviews.

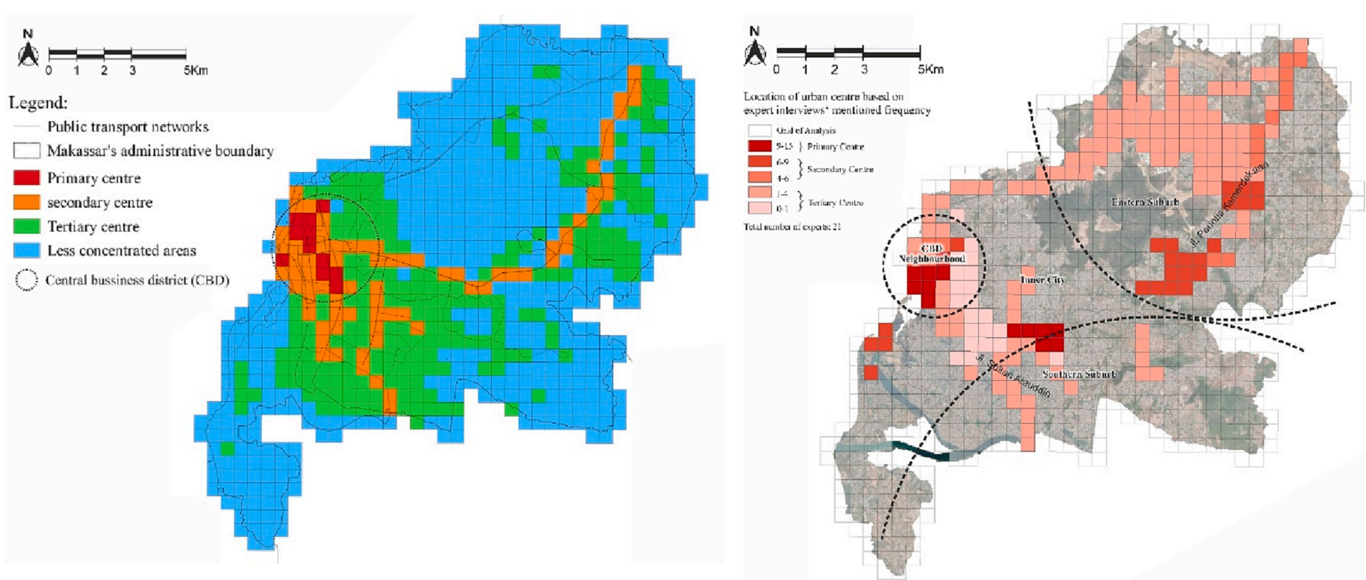


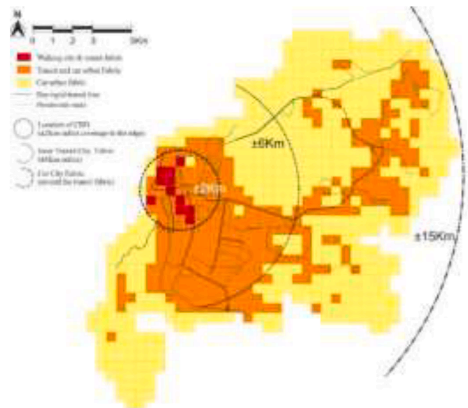
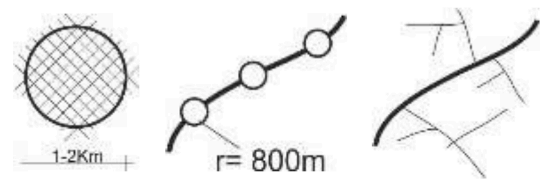

**Fig. 9.** Makassar urban center distribution based on the computation and expert interview results.

address development priorities for each zone.

Transit systems have become a common solution to overcome urban traffic congestion problems and have been seen as a sustainable transport concept (Calthorpe, 1993; Cervero, 1998; Ewing, 1997; Woo, 2021). The map of Makassar urban fabrics provides information of zones that can be developed further if the city wants to support its transit system. The main transit-based public transportation system should be planned based on the distribution of the urban center and urban fabric typology. Bertaud et al. (2011) described that the transit system would be more effective with radial movement, i.e., many origins with a single destination (CBD). The CBD has to be the primary destination for the transit system. Therefore, the primary center in the walking city fabric has to maintain its role as the primary destination by continuing to increase density. Urban planners and decision-makers should guide vertical development in the primary center to achieve the demanded density. In addition, urban centers outside the CBD should be developed in bead-on-a-string form (Hall, 2015) or in the linear polycentric form to maintain a linkage between public transport networks and urban centers.

On the other hand, the yellow cluster, which was categorized as car city fabric, can be altered and dedicated as potentially suitable zones for last-mile feeder services such as (shared) bicycles and micro-mobility services (Milakis et al., 2020) or car-sharing. These types of modes are still mostly found in developed countries. In the developing countries last-mile services, which also play a role as transit feeders, are frequently known as paratransit (mini- and midi-busses; Cervero, 2000) and two

**Table 4**
Urban fabric and its land use characteristics.

| | Walking city fabric | Transit city Fabric | Car City fabric |
|---|---|---|---|
|  | High density<br>Mixed use<br>Organic structure | Medium density<br>Mixed use<br>Grid base<br>Centralized | Low density<br>Separated uses<br>Arterial grid and cul de sac based<br>Decentralized |
| | Pattern illustration: | | |
| |  | | |
| Quantitative result | Source: Hall, 2015; Kosonen, 2013; Newman & Kenworthy, 1996; Newman & Kenworthy, 2015; Newman et al., (2016) | | |

and three wheelers (Ehebrecht et al., 2018; Goletz and Ehebrecht, 2020). Conflicts and competition among public transportation service providers have occurred in many cities in developing countries (Nguyen and Pojani, 2018). For the case of Makassar, categorization into types of urban fabrics and zoning can help to reduce the conflicts since all the public transport providers would have their own service zones. Accordingly, informal transport should be incorporated into the mix of legitimate transport offerings so that it continues to provide a complementary service (Cervero, 2000). The results make it possible to determine the dedicated zones and provide the possibility of incorporating informal transport into well-planned strategies. In the end, an integrated transportation system can be achieved.

As many scholars have mentioned (McMillen, 2001; Newman et al., 2009; Hall, 2015), a concentrated transport demand in a viable center enables the transit system to operate continuously in the most effective and efficient way. Looking at the Makassar context that currently operates a bus-based public transport system, this study provides tools and measures to support local authorities in developing public transport nodes and concentrating the transport demand into a viable center. The recognition of urban centers can help planners to determine the public transport networks to be linked to the identified centers, especially in an established city like Makassar. The values of indicators to recognize the viable center for transit can be a measure to be used in transport policy for determining a viable center that can support the transit system within the city. Having these quantitative values enables policies to be implemented with precision and to be measured quantitatively. The transport planning policy becomes a guideline for transit planning within the center neighborhood. Investment priorities can be addressed to centers with the aim of attaining 3D improvement around the stations and creating more compact neighborhoods as well as containing urban sprawl.

## 6. Conclusion and future research

The novelty of this study is introducing the quantitative and qualitative analysis in defining urban centers. Quantitative analysis entailed using spatial cluster analysis with indicators that represent 3D to support transit system implementation within cities in developing countries. On the other hand, qualitative analysis with expert interviews also shows various indicators that define an urban center. Both methods complement each other. The results of the quantitative analysis make it possible to determine the level of each center based on its indicators, which cannot be achieved through qualitative analysis. However, the results of the qualitative analysis can be used to validate the results of the quantitative analysis. This study can help the established cities in developing countries to recognize viable centers for the transit system implementation and address their development priorities. The limitation of the expert interview in this study is laid on the subjective point of view and the center boundaries that might differ among experts. On the other hand, the quantitative approach provides more objective and reliable results.

Besides the distribution of urban centers, this study has categorized the Makassar area based on urban fabric typology based on the morphological pattern. However, this categorization requires further investigation, especially from the socio-demographic perspective to have complete information on Makassar's transport-related urban fabric. The typology of urban fabrics is applicable to planning an integrated transportation system. Many cities experience various challenges such as institutional cooperation and coordination, integrated planning, funding, etc. in implementing the transit system. One of the challenges related to recognizing viable transit centers without census-based data.

Planners in developing countries face a challenge in practice since their background education is based on the theories/concepts that originated from developed countries. Urban planning practice in developing countries requires addressing local characteristics to bridge the gap between theory and practice (Denoon-Stevens et al., 2020). A widely known transit system is a concept that developed based developed country cases. This research provides an approach to implementing the transit system concept in areas showing local urban characteristics in developing countries. This study proposes an alternative approach to overcoming the planning challenges and providing knowledge of the urban areas based on their original and local characteristics. Since the proposed method provides insight from the planning perspective, planners and decision-makers should consider this approach as an initial assessment before planning a transit system. Planners and decision-makers can benefit from this research to guide the development of priorities and policies. Examples include the priority to increase the 3D by addressing investment in specific viable centers; or assigning public transport networks to serve the identified center. The result can help Makassar authority to achieve a sustainable solution in the development of urban and transport systems.

Eventually, the proposed method fills the gap of lacking methods in urban center identification without census-based data, especially in the cases of cities in developing countries. Furthermore, the study also identified the typology of urban fabrics that should be considered in transport planning. As shown, such a method can deliver valuable insights for transportation planning and decision-making for adjusting the transport system in established urban areas. The method generates results based on the local urban characteristics and can possibly be adapted to other cases.

## Author contributions

**Venny Veronica Natalia** contributes to conceptualization, Methodology, formal analysis using ArcGIS, statistics software, qualitative software (Atlas.ti), investigation, validation, resources, writing (Original draft) and writing (Review and Editing), visualization.

**Simon Nieland** contributes to conceptualization, methodology, formal analysis using SQL query, statistics software, validation, writing (Review and Editing).

**Mirko Goletz** contributes to conceptualization, methodology, formal qualitative analysis, validation, writing (Review and Editing).

## Declaration of Competing Interest

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