CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

Do the population density and coverage rate of transit affect the public transport contribution?

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Abstract: The article tried to study the public transport role as one of the means that contribute to sustainable urban development by investigating the effect of the coverage rate for public transport on the number of those who use public transport in the neighbourhoods of Kut city. This article investigates the link between public transportation and supportive urban design trends. The research spatial and temporal limits are represented by the municipal boundaries Al-Kut city, which are shown in the master plan of the city for the period 2008–2012. The results showed a positive but weak relationship between public transport (variable factor) and the proportion of public transport coverage and population density (independent factors). These factors do not explain the apparent, which is confirmed by the high B₀ value and its great reliability, and this result is inconsistent with the hypothesis that states a positive effect between public transport and the coverage rate. However, this relationship is abnormal and indicates an imbalance in the distribution of land uses and the provision of services in the structure of Kut city. Furthermore, it is a negative indicator of the city’s structure, where a good and efficient structure requires a strong relationship. As for public transport passengers, they seem to be restricted by this for poor services.

Subjects: Transport & Vehicle Engineering; Transportation Engineering; Planning; Transport Planning

Keywords: public transport; coverage rate; population density; public transport; weighted regression model; GIS

1. Introduction

To plan an efficient and attractive public transportation system, it is necessary to know the determinants affecting it (Wei Et Al., 2021). An equitable transit system can cater to the needs of captive riders and maximize transit service coverage (Welch & Mishra, 2013). Access coverage is essential in public transit planning, as this is how service is provided to riders (Edrisi Et Al., 2021; Wang & Yan, 2017). The proximity of demand (population and employment) to stops or stations on the network significantly explains its greater or lesser usage by potential users (Gutierrez & Garcia-Palomares, 2008; Nie, 2021). Public transit accounts for 1 % of passenger miles travelled but attracted strong public support (Aguero-Valverde & Quiros-Calderon, 2021; Anderson, 2014; Hawkins & Nurul, 2021).

The issues Kut city is experiencing for several reasons, including traffic congestion, accidents on the road, longer commute times, and environmental problems, along with numerous other issues, are what motivated this study.
On the other hand, many city areas are not well covered by public transport. The article is trying to investigate the relationship of public transport with the coverage rate in the neighborhoods of Kut city. The importance of the article comes by highlighting the importance of public transport, as it can solve a large part of this problem by reducing the number of trips as it is an effective alternative to the private car while preserving growth and economy, and at the same time by reducing traffic (Pulugurtha Et Al., 2019), which is perhaps the most significant source pollution within the city. Therefore, this article aims to create a sustainable urban environment by adopting public transportation and analyzing the relationship between public transportation and urban form patterns that support public transportation. The research hypothesis is that increasing the coverage rate and the intensity of development increases the use of public transport. The spatial and temporal limits of research are the municipal boundaries of Kut city, which are shown in the map of the city master plan for the period of 2008–2012. The quantitative analysis has been linked to descriptive analysis and uses SPSS and GIS to analyze spatial relationships and to explain the relationship between public transportation and the coverage rate.

In their comparative study AlQuhtani and Anjomani, they dealt with the variables in population density around the transit-oriented development nodes for the capital of Dallas-Fort Worth, where a model was used that measures the relationship between population density and independent variables. Developed according to a transit-oriented development approach, it is denser than others (Alquhtani & Anjomani, 2021).

Hernández D. discussed the issue of the coverage ratio for transit and its relationship to the costs of public transportation services, as well as the social and economic level of people and its relationship to accessibility with its all dimensions (cost, effort, time), as it appears through the study that the higher income of households has the ability of higher rate of the accessibility. As it appears that the transit network takes a dense central form in the centres of High-density urban areas and extends radially as we move away from the centre and may leave in its extension distances unserved by the transit network as we move towards the suburbs, and it is possible to compensate for this deficiency by providing the necessary services for daily and even weekly needs in the unserved suburbs. It bears high transportation costs in terms of cost, time, and effort, thus reducing the accessibility, which in turn affects low-income families, unlike families with high incomes, who have less influence on this factor. (Hernández, 2017)

Shiravi et al. suggested an accurate methodology based on the technology of the LiDER (Light Detection and Ranging), which is used first in flood risk studies, as it was adopted in building a virtual 3D model for the city, which basically shows the number of floors in all its areas, which plays a major role in determining the population density of users or beneficiaries of Public transport, as the previous methods in determining the coverage density for transit depend mainly on the surface area of the transit stations, which cannot reflect the true density of the population for transit traffic, and which does not give a true perception of the coverage rate of transit traffic because it assumes that the distribution in all transit stations is homogeneous and this not real on the real. (Shiravi Et Al., 2014). Foda and Osman pointed to the importance of the stations’ locations for the efficiency of public transport, as the spatial characteristics of these locations and the distance travelled by the user, which in turn affect the efficiency of the service and the extent of users’ satisfaction with the quality and quality of the public transport service, plays the pedestrian transport network intended by the user before reaching the transport station. (Origin) Moreover, after arrival (Destination) is of great importance in the efficiency of the site, and the GIS environment can help the decision maker in developing spatial indicators for the locations of these stations through the efficiency of the station site and its connection with the pedestrian network through the development of several unique indexes to measure the efficiency of transit stations such as (Ideal Stop-Accessibility, Actual Stop-Accessibility, and Stop Coverage Ratio). (Foda & Osman, 2010)

Previous works of literature dealt with the percentage of public transportation’s contribution from many aspects, some of which are based on service frequency, safety in public transportation,
the convenience of transportation, and the socio-economic level of the population. The research dealt with the city entirely and not parts of it, so that the spatial comparison and calculating the coverage percentage are more accurate for each locality to know their impact on the percentage of public transport users.

2. Theoretical background

Land use planning and transportation are intertwined in many ways. It is impossible to separate these two parts because they are very intertwined. There are also various options for encouraging public transit, limiting private car trips, and limiting urban sprawl using land-use planning. The most important of these solutions are increasing the density and mix of land uses to increase access to public transportation, combining land use with the efficiency of public transportation networks to facilitate access and activate public transportation, and improving urban design quality to encourage pedestrian movement. A private car’s efficiency for the number of people is poor, but it is quick and adaptable. When compared to foot traffic, public transit has a lot of capacity and speed, but it has very little flexibility. The ties between walking and public transportation should be linked and strengthened to make the private car a competitive mode of transportation. The essence of public transportation as a directive for urban development is to increase the density surrounding public transportation routes to lower the walking distance to this service (raising the coverage rate) to the distance that a person can walk without exerting effort, Figure 1.

As a result, there are more destinations near these routes and more flexibility, lowering public transportation costs (Wang & Yan, 2017).

The objectives of transportation planning are continually changing in response to city conditions. The current transportation goals are to prioritize public transportation, hence boosting accessibility, backing up and encouraging land use clustering, and calming traffic (Brinklow, 2010, p. 6). Public transportation helps to reach sustainability goals by being friendly to urban design, encouraging people to walk, making them safer, and improving the environment.

Public transportation has a favourable impact on raising the urban development intensity and mixed-use land, establishing a suitable threshold for public transportation services introduction (Bento Et Al., 2005, p. 5). The number of prospective passengers on the public transportation route grows as growth intensifies. It aids in providing more passengers, and the public transportation service gets more hesitant as revenues rise. The frequency with which public transportation is provided directly impacts the quality of that service. As a result, high densities should be focused

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**Figure 1. Correlation of public transport and the land use form (Jasim Et Al., 2021).**
along public transportation's main lanes to enhance the number of potential consumers within walking distance of public transportation services (Sinha Et Al., 2021).

Spatial spread impedes interaction, so there is a general preference for short-distance traffic over long-distance traffic. The traffic volume between two areas depends on the intensity of land use and the distance between them (obstruction), so Figure 1 shows that the traffic interaction has a positive relationship with the density of land uses. Furthermore, negative with increasing the distance between the two regions. The interaction is high when the two regions are of high density and when the distance between them is close. While the interaction is small when the intensity of land use in the two regions is low, and the distance between them is far (Black, 2018, p. 25). As public transport needs a high demand for movement, the dense and infrequent centres provide a suitable environment for public transportation activity. Naturally, the more people living within the service area, the more sustainable the public transport service is. Research has shown that proximity to a public transport station is linked to the extensive use of public transport and fewer trips by car and that the distance from home to the nearest public transport stop directly affects the share of public transport from trips or the percentage of car trips increase and the percentage of non-motorized trips. Cervero showed how the proportion of rail journeys decreases with increasing distance from the railway station. Residents who live within an estimated range (150–500 feet) of a California railway station are the most frequent public transportation users (Cervero & Duncan, 2008, p. 2). Increased development along public transit corridors can improve urban environments by putting residential, commercial, and industrial uses closer together, encouraging people to walk more frequently, and minimizing vacant areas. Walking about will grow safer, especially in large urban areas, as pedestrian traffic along with significant streets increases. The likelihood of using public transportation will improve if there is a greater mix and balance between housing and work in metropolitan regions.

3. Methodology and materials
The research methodology was built by linking quantitative analysis to descriptive analysis and using the analysis environment of SPSS and GIS to build spatial relationships and build appropriate models for the city of Kut to reach the interpretation of the phenomenon, which is the relationship between the contribution of public transport and the coverage rate. This methodology has been applied in the geographical scope represented by the municipal boundaries and the master plan of the city of Kut, which determines the distribution of the city's neighbourhoods. As for the transportation system, it currently relies on public transport paths within the road network. Data were obtained from the Directorate of Urban Planning in Kut City and field surveys.

4. The case study

4.1. Kut city description
The built-up area of Kut city covers about 44 square kilometres and is located on an important site on the rivers of Gharraf and Dujaili, a branch off of the Tigris River (Jasim et Al., 2022; Mohammad & Jassim, 2014). The Kut is linked to Baghdad, located about 180 km from the capital. The city centre coordinates are 32.508651°N 45.790801°E and are shown in Figure 2.

5. Analysis of the current situation for public transport in the city of Kut
Public transport is one of the most critical transportation components in Iraqi cities. It is a significant infrastructure component as it provides movement for individuals. The public transport infrastructure differs from one place to another according to the transport infrastructure and the means of transportation that residents can travel.

In Kut, public transportation is provided by minibuses with capacities ranging from 11 to 24 passengers. These buses do not have designated bus stops; instead, they stop where the passengers want them to. Besides, the pauses lack, the lack of movement speed and flexibility in traffic jams, and exceeding the time taken to complete the passengers have contributed to the popularity
of minibuses with a capacity of 11 to 14 passengers. For many reasons, these vehicles give flexibility to public transportation operations (Simpson, 2003, pg.145; Senecal & Leach, 2019). It is considered a fast method because the passenger's number is less than the large buses, and because it operates between two stops, the number of stops depends on the number of passengers who board and disembark on the road, and then it does not operate as many regular stops as buses. Its movement does not hinder the flow of traffic, such as large buses and cargo cars, and because it has a small capacity, it does not need a long time to be filled with the specified number of passengers. However, minibuses have certain drawbacks, the most notable of which are the lack of space in the vehicle and the difficulty of getting on and off. The large buses are more economical when calculating the total economic costs per passenger (Simpson, 2003, p. 149).

5.1. Analysis of the coverage rate of transit for Kut city
The BUFFER ZONE analysis was used to determine the coverage rate of transit in Kut city. The buffer zone was made around public transport routes with a distance of 350 meters, which is the distance resulting from the average distance travelled to the public transport service in Kut city, which amounted to 356 meters, according to the questionnaire. The result is the numbered Figure 3a). By comparing the area covered with the neighbourhoods in Figure 3b and Table 1, we can identify the unserved areas in the city.

To find the percentage of serviced area for each neighbourhood in the city, we use one of the (Overlay) analyses in (GIS), which is (Intersect). An intersection between the two layers of neighbourhoods is made, and the lanes buffers layer for established public transport routes. After calculating the percentage of the serviced area for each neighbourhood, it is compared with the original area of the neighbourhood, so we get the coverage percentage, and as shown in Table 1, we notice that the coverage rate for public transport is good, especially for fully developed areas. The good coverage rate results from the flexibility of the public transport system if public transport lines are accessible to any area where the minimum number of passengers is available in coordination with the private transport agencies.

(A) Analysis of the number of public transport passengers for neighbourhoods:

The data of the Urban Planning Directorate in Wasit Governorate were relied upon as part of their surveys that took samples from the neighbourhoods of Kut city. The number of public
Figure 3. A- Buffer of 350 m distance, B- The intersection of public transport with the city’s Neighbourhoods.

Table 1. Coverage rate for public transport in Al-Kut neighbourhoods

| No. | No. of Neighborhoods | Neighbourhood area (m²) | The served area (m²) | Coverage rate |
|-----|----------------------|-------------------------|---------------------|---------------|
| 2   | 101                  | 228,139.93              | 228,139.93          | 1             |
| 3   | 102 + 104            | 173,563.44              | 173,563.44          | 1             |
| 4   | 103                  | 219,224.905             | 219,224.905         | 1             |
| 5   | 105                  | 326,561.12              | 326,561.12          | 1             |
| 6   | 106 + 104 + 102      | 263,629.48              | 224,527.56          | 0.85          |
| 7   | 107                  | 631,793.34              | 631,793.34          | 1             |
| 8   | 108                  | 459,965.475             | 281,700.235         | 0.61          |
| 9   | 109                  | 367,408.585             | 367,408.585         | 1             |
| 10  | 110                  | 96,953.96               | 96,953.96           | 1             |
| 11  | 110                  | 213,182.035             | 211,482.6           | 0.99          |
| 25  | 206                  | 1,247,080.71            | 413,042.135         | 0.33          |
| 26  | 207 + 209            | 1,657,457.335           | 589,631.59          | 0.36          |
| 27  | 210                  | 857,403.67              | 281,681.6           | 0.33          |
| 28  | 212                  | 581,063.925             | 507,286.29          | 0.87          |
| 29  | 213                  | 1,143,254.96            | 714,801.27          | 0.63          |

transport passengers was spatially represented for each neighbourhood as in Figure 4a) (and it is noticed that any specific spatial pattern does not characterize the distribution. Instead, the number of passengers varies from one place to another and is not linked to a specific place within the city’s structure

6. Results

6.1. Analysis using linear regression

For comparing the results between global and local regression, linear regression was applied first, and the extracted variables shown in (Figures 3 and 4) were used to build the model depending on the formula shown, obtaining the results shown in Table 2, which show a positive relationship
between the number of public transport passengers and each of the intensity and coverage rate reaches 0.162, and the modified $R^2$ is 0.129.

6.2. Analysis using weighted geographical regression
The same variables were adopted in the previous analysis, and the maps have also been produced to clarify their spatial distribution. The weighted geographical regression depends on the spatial distribution of the phenomena for the analysis, as shown in Figure 5.

Table 2. Relationship between the number of public transport passengers and each intensity and coverage

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|---|----------|-------------------|---------------------------|
| 1     | .403  | .162     | .129              | 22.61121091               |

ANOVA

| Model | Sum of Squares | df | Mean Square | F     | Sig.  |
|-------|----------------|----|-------------|-------|-------|
| 1 Regression | 4958.846 | 2  | 2479.423 | 4.850 | .012  |
| Residual | 25,563.343 | 50  | 511.267 |       |       |
| Total | 30,522.189 | 52  |           |       |       |

Coefficients

| Model | Unstandardized Coefficient | Standardized Coefficient | t    | Sig |
|-------|---------------------------|--------------------------|------|-----|
| 1 (Constant) | 21.213 | .8752 | .388 | .2424 | .012 |
| Density | 0.99 | .036 | .034 | 2.715 | .009 |
| Cover | 0.27 | .115 | .235 | .815 |
And after executing the program with the same variables applied in multiple linear regression. The results are shown in Table 3. As we note that the correlation coefficient $R^2$ is 0.17, and the adjusted $R^2$ is 0.14. In other words, the urban form factors that affect the number of public transport passengers explain less than a quarter of this phenomenon.

However, the important feature in this analysis is to give different values for each factor (neighbourhoods); as shown in Figure 6a, the correlation values are variable across the place, and their values are greater in the south of the city, where the poor marginal areas, whose income level is low. That is, public transport passengers are linked more than others to the percentage of coverage. In Figure 6b, the model residuals are shown, and we note that the values also vary across places and range between negative and positive.

Figure 6 shows the model parameters, whose values are also variable according to the location. From Figure 7a it is clear that the density parameters are greater in the north of the city and gradually decrease to reach the lowest values in the south, which means that this variable is more effective in the north. At the same time, Figure 7b shows the coefficient $B_9$ whose values are significant in the southern and eastern parts of the city and values that have nothing to do with the studied phenomena (density and coverage). The coverage parameters are comparable to $B_0$ in terms of the values distributed, with the largest values found in the south and east of the city, as shown in Figure 7c.

7. Discussion
A weak correlation was observed between the weighted linear and global regression variables when comparing the results of the two analyses. The most important factor remains to give multiple indicators, especially for each neighbourhood, through which it is possible to find a more accurate classification of the studied phenomenon. The results of the two analyses

| Table 3. Weighted geographical regression results |
|----------------|----------------|----------------|
| OID | VARNAME | VARIABLE | DEFINITION |
| 0 | Bandwidth | 87,075.607821 | Public |
| 1 | ResidualSquare | 25,424.219948 | Density |
| 2 | Effective Number | 3.009753 | |
| 3 | Sigma | 22.551798 | |
| 4 | AICc | 486.430274 | |
| 5 | $R^2$ | 0.173818 | |
| 6 | $R^2$ Adjusted | 0.140603 | |
| 7 | Dependent Field | 0 | |
| 8 | Explanatory Field | 1 | |
| 9 | Explanatory Field | 2 | |
confirmed the research hypothesis, as a positive but weak relationship appeared between public transport and the variables of development intensity and coverage rate. These factors do not explain the apparent, which is confirmed by the high Bo value and its great reliability, and this result is inconsistent with the hypothesis that states a positive effect between public transport and the coverage rate. This relationship is abnormal and indicates an imbalance in the distribution of land uses and the provision of services in the structure of Kut city. It also appears that the urban environment does not encourage public transportation. Many obstacles cause danger or discomfort, lack of comfort, and others, meaning that there is a poor service, whether the public transport administration, the quality of vehicles, or the public transport network. As for public transport passengers, they seem to be restricted by this for economic reasons.

8. Conclusion
The analysis results found that the relationship between public transport as a variable factor and the proportion of public transport coverage and population density as independent factors is
a non-strong relation, which is a negative indicator of the city’s structure. The good and efficient structure of the city requires a strong relationship, and the results showed that the percentage of public transport users is good despite the poor services, whether the public transport administration, the quality of vehicles, or the public transport network. This indicates that a large proportion of the population of the neighbourhoods of Kut city are passengers restricted by transportation, as a large number of users is considered a great motivator to improve public transport, and that the conditions are ready to increase the contribution of public transport when improvements are made to it. Not only for economic considerations but for social considerations related to social justice.

In the next decade, the cities of Iraq, including Al-Kut city, will witness a major challenge to the transportation system and its implications for sustainable urban development as a result of the increase in population and the rise in the level of income, which will lead to an increase in movement in general. An increase in the ownership of a private car. Public transportation can be the appropriate means to improve living conditions and enhance the conditions of the built environment in general.

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