

## Modularity Transportation by TOD Model in City of Ramadi in Iraq

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**Citation:** Al-Saadi, M. A., & Saeed, A. A. (2025). Modularity Transportation by TOD Model in City of Ramadi in Iraq, *Journal of Cultural Analysis and Social Change*, 10(4), 536-547. <https://doi.org/10.64753/jcasc.v10i4.2893>

**Published:** December 05, 2025

### ABSTRACT

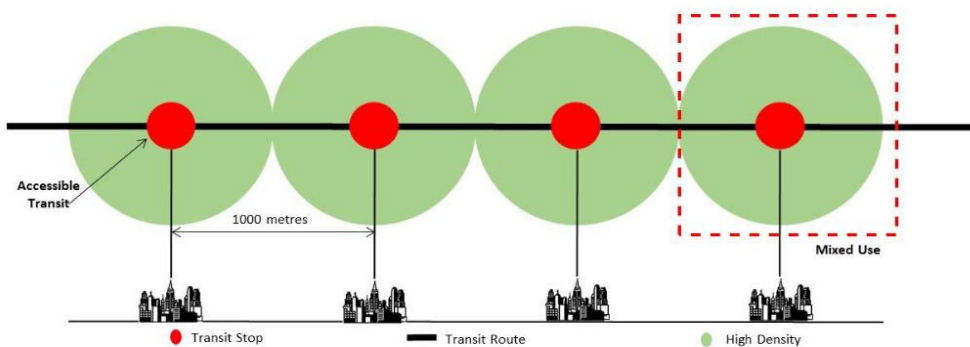
Striving to provide a sustainable transportation environment and developing urban city centers has become a basic requirement for current and future societies, especially with accelerating pace of urbanization. Therefore, an integrated transportation system with land uses within TOD system provides environmental treatments through developing traffic movement, encouraging walking and cycling, and introducing public transportation, which area lacks. The study, as well as diversity of mixed land use with high density, would achieve gains on economic and social dimensions and preserve land's "compact city" image. Research presents a model for developing and analyzing possibilities of establishing a TOD center for Iraqi city of Ramadi according to independent indicators selected from experiences and based on TOD planning principles through an analytical approach to inputs in SPSS program, adopting a multiple linear regression model, which includes modeling relationship between land use and transportation. And reaching conclusions about intervention values for all variables with a positive and negative impact, in order to evaluate realistic performance of variable adopted for study area, from possibility of creating TOD in proposed location and possibility of replicating it in other squares in city of Ramadi to achieve integration at city level.

**Keywords:** TOD, Integration, Ramadi, Mixed Use, Density.

### INTRODUCTION

The integration between land use and urban transportation aims to develop centers of sustainable urban growth, and this goal is best achieved by creating a TOD that has a landscape of walkable and livable communities within high-density mixed land uses. Users have easy access to open spaces while at same time having efficient transportation facilities. TOD focuses on creating development within area of influence of transport stations, a distance (500-800 m) from center of the station, or in form of a corridor in case of stations spaced no more than 1 km apart as shown in Figure (1).

TOD will stimulate pedestrian trips to reach various facilities such as work, shopping and entertainment, by creating an environmentally and community-friendly infrastructure with an economic feasibility of project that benefits a larger number of people, thus increasing the number of users in transportation facilities that will improve use of friendly transportation system. environment over time[25]



**Figure 1.** TOD along Transit station

**Research problem:** City of Ramadi lacks a main station that provides capabilities of establishing transportation systems such as tram, metrobus, and subway. Which makes it necessary to formulate research hypothesis in following way: Establishing a TOD station in main squares or nodes achieves integration between transportation and land uses within a pure environment, and strengthens economic and social exchanges therein.

### Research Aims

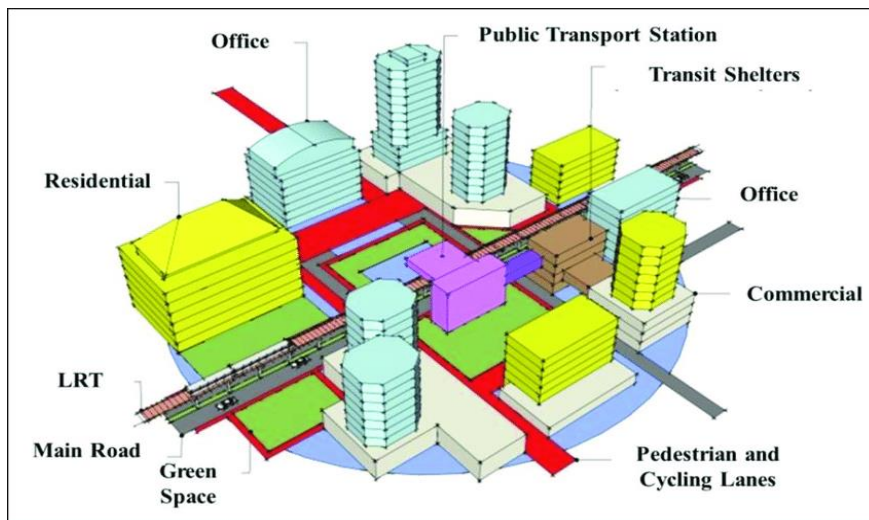
- 1- Introducing the public transportation system in city of Ramadi by developing high-density areas, would increase walking trips and sustainable transportation and also lead to reducing transportation problems in city.
- 2- Providing job opportunities, shopping centers, as well as public facilities in zone of influence, while developing mixed land uses, which reduces daily trips.
- 3- Reducing use of private vehicles, reducing traffic in city of Ramadi, and reducing demand for associated parking lots.
- 4- Ensuring the development of a safe community, special attention to safety of children, elderly, women and people with different abilities through modifications to city's structure.
- 5- Reducing city's carbon footprint by shifting towards environmentally friendly transportation options.

### RESEARCH METHODOLOGY

Research was conducted by defining criteria and indicators to analyze potential location of TOD in city of Ramadi, and using criteria and indicators to analyze potential for its establishment. The research method is based on survey and analytical method. Research was based on data and its use to evaluate feasibility of study area in establishing project. Data sources are from field surveys and literature, as well as government documents.

### Definition of TOD

It is a form of mixed-use development integrated horizontally and vertically. It is walkable and usually concentrated within an average radius of 600 meters from center of transit station. Development of High-density is concentrated around station to facilitate transportation for a greater number of people and encourage use of multi-modal transportation. This type of development uses existing infrastructure, improves transportation network and creates transportation options (fig 2).



**Figure 2.**Standard of TOD (Sub-center) [H. S. Hasibuan et al., 2014]

From the concept of TOD, there is a more sustainable approach at the urban level, and increasing density (while reducing its impacts) supports high transportation frequencies and public transportation and provides diverse activities and uses of housing, commerce, government facilities, and local services that support community. The vibrant community of the station area, thereby improving use of surrounding land. Intervention, including principles of smart growth. It can help achieve city's environmental, economic and social goals. It may include pedestrian bridges for access to reduce interference of traffic volumes.

**Influence Area**

This area includes areas directly adjacent to transit station, i.e. within walking distance within 10-12 minutes (fig3), in which development of high-density, mixed-use and compact system, is being developed to support all basic needs of residents.



**Figure 3.** Zone of influence of TOD . Researcher

**Compact And High-Density**

TOD enhances densification in by providing a higher FAR, (FSI) and higher employment and population density compared to area surrounding and outside influence zones (fig 4). For sustainable development, minimum percentage compared to outside station must be 300-500%, i.e. three to five times, and it increases with increase in size of city.

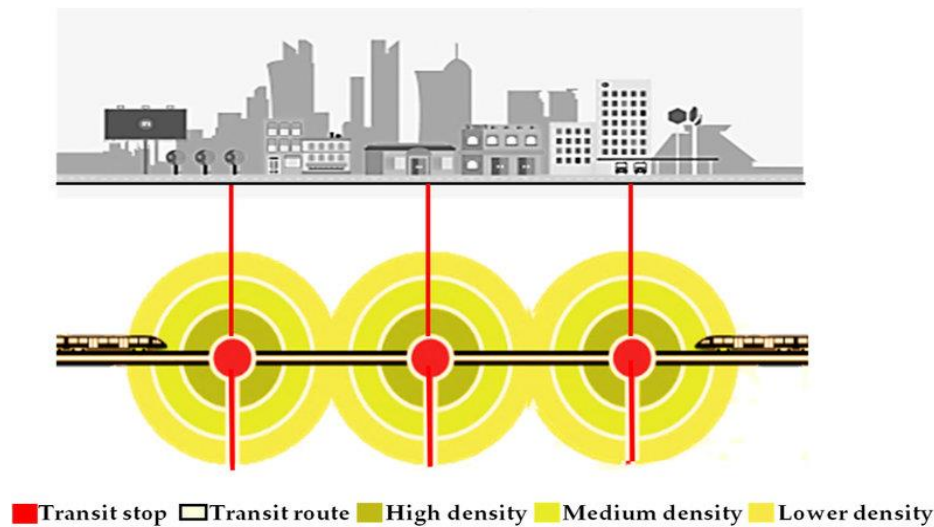


Figure 4. TOD compact nodes [Sara Nafi et al , 2021]

### Mixed Use

Mixed uses in the TOD area would reduce trip times by providing most activities such as entertainment , shopping and public amenities such as parks, schools , etc. within walking distance. It would also improve ease of access, i.e. ensure that traffic volumes are distributed in two directions , especially during peak hours. A combination of land uses helps optimize infrastructure and physical resources, as all components such as routes , parking, infrastructure, etc., it remains active at all times of day.

### Multi-Model Transportation

TOD impact zone has an integrated, multi-modal, high-quality transportation system to achieve optimal use of facilities by users alike. With system enjoying seamless physical connectivity and integration of information for public transportation systems that provide quality services that ensure user satisfaction in terms of safety and comfort. Hierarchy of facilities in a transportation system gives priority to pedestrians followed by bicycles, buses, and parking. With designated parking spaces for bicycles and possibility of expansion in future.

### Previous studies

In order to improve intensive relationships between land use and transportation demand, TOD types were developed, and Table (1) shows some global experiments and their details, along with most important indicators adopted in each experiment.

Table 1. International Experiences With Most Important Indicators That Were Adopted

The cases	Indicators
OTHELLO STATION, SEATTLE (USA) (ATELIER ZUIDVLEUGEL ,2007)	- Linking urban development to transportation -Mixed-use (housing, recreational and facilities) - High quality of space
OHLONE- CHYNOWETH COMMONS, SAN JOSE (USA) (BREZNAU. S, 2004)	- Replacement of parking lots with TOD option -Mixed-use benefiting from the tram station -Project consists of residential units below market price, retail stores, and a children's nursery
PORTLAND (USA) (GIBSON, K. & ABBOTT, C. , 2002)	- Containing increasing urban sprawl and preserving natural environment -Construction of housing, offices and retail stores - 50% of trips correspond to public transportation
ZUID-HOLLAND (Zuid Province,2007)	Building housing units and 12,000 square meters of offices around the transportation stations - Alternatives to transportation models - Impacts on real estate prices

KARLSRUHE (GERMANY) (ENGEHAUSEN, V.F. & BRÄUNCHE, E.O. 2008)	- Train-tram system - Dual function along its route: local at a speed of 30 km/h and regional up to 100 km/h. - Different housing styles -Mixed Land use
Source : researchers depended on Armando Ortuño Padilla,2017.	

**Case Study: Baghdad Square at Eastern Entrance to Ramadi City Center**

**General Description**

City of Ramadi, center of Anbar Governorate, is located in eastern part of governorate, about (110) kilometers west of capital, Baghdad. It has an area of (15,007.64) hectares and a circumference of (54,575) km, map (1). Its population is 368,876 people, while the number of families is (73,785), according to data (Anbar Supply Branch - data for first quarter - 2024).

The study area is “Baghdad Square” in city of Ramadi, oval in shape and represented by coordinates of its center (E: 343095, N: 3699858) (fig.5) It is a yard that was built in 2022 for an urgent need at a major intersection based on original plan. It consisted of a yard for a large water tank, which was removed from service and remained there for more than 30 years (fig.6).

As for criteria and basic indicator of proposed location of TOD, which requires basic transportation to reach city center and has comprehensive roads to reach the square. The main access to it is via main road. In first stage of planning, a suitable location is basic requirement because it connects two important commercial centers, which are central business district on one hand and industrial district on other. This axis is a congestion point in eastern Ramadi area.



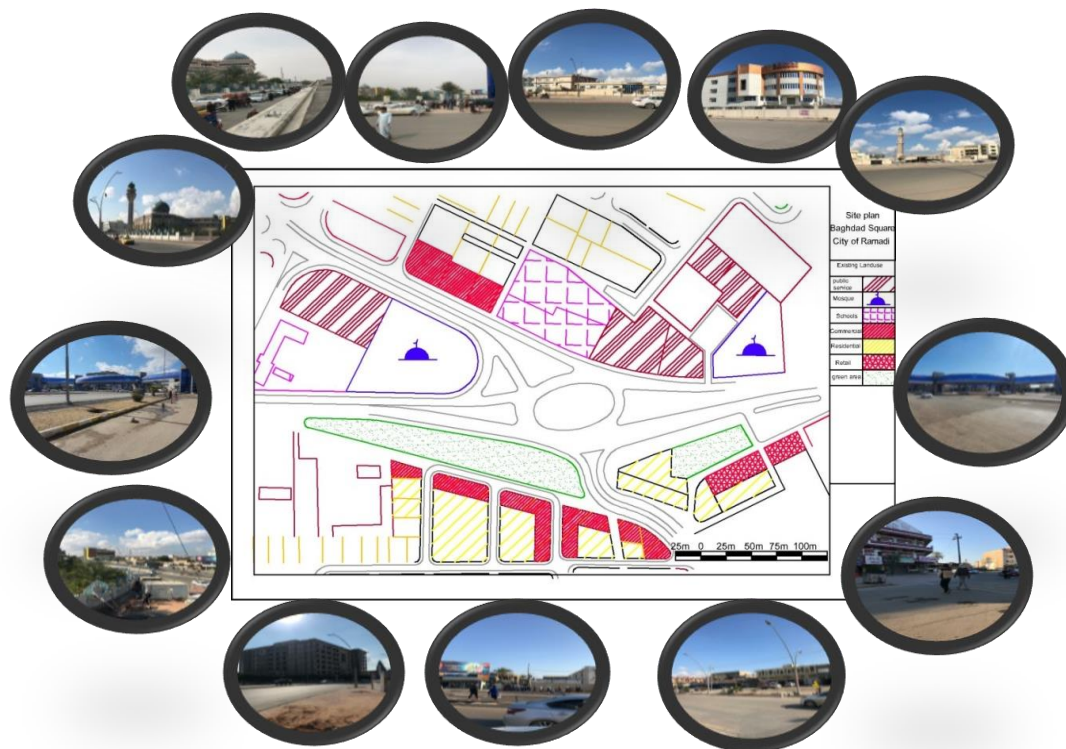
**Figure5.** Model Of Baghdad Public Square ,Ramadi City,Iraq.Ramadi Municipality Directorate/ 2021



**Figure 6.** Baghdad Public squares: a ) Before design 2020 . b ) After 2021.Researchers

## Reasons For Choosing Study Area

Urban transportation is one of most fundamental issues in urban planning (V. A. Perk, M. Catala, 2009). The introduction of a transportation system (tram or metrobus) in city of Ramadi may lead to multiple transportation models that lead to significant changes in traffic flow and thus affect population attraction and development of areas surrounding each proposed station (E. Boucq, P. Francis, (2008)). [And then activities are generated. This is one of most important reasons for choosing study area. As in Figure (7). The result of this makes square a desirable “place” to live and work (H. Dittmar, and G. Ohland,2000). The proposed TOD in city of Ramadi covers an oval area with a minimum radius of 350 meters from public transportation station. It complies with standards for occupying a jobs variety, whether recreational, retail, or high-density residential, with presence of open and public spaces (P. Calthorpe, 1993). Transportation network that stimulates development of surrounding area will not be achieved until after completion of development of transportation system in city of Ramadi, and most important incentive is construction of tram or metrobus network. The square has a specific character that requires studying the appropriate TOD classification for its development. Taking into account generation of problems related to the basic requirements of the region, that is, there must be integration in spatial planning between transportation and land uses.



**Figure 7.** Square of Baghdad-City of Ramadi. Researchers Depended on Ramadi Municipality

### Traffic Flow

Main entrance is from eastern side of capital, Baghdad, and was reason for naming it after capital. It leads to central business district to west. It is also a main road with a width of 40 meters with multiple uses, especially service and administrative. It is a main road for exiting center towards east, as for north. There are two entrances to square, first via a bridge from July 17 Street, which is primarily for industrial use, with recreational use represented by main amusement park in city of Ramadi. The second, from north side, is an entrance coming from Grand Mosque. From north side, there are two entrances: first is from Street (20), which is primarily a commercial street and has a very large traffic density. The second is Al-Malaab Street, with a width of (30) metres, which has a lower traffic density due to lack of commercial and service uses (Map 1).

During peak hours, traffic volume reaches 1,060 units/hour, as a site that suffers from road congestion or traffic congestion during peak hours is one of main criteria in proposed sites for establishing (TOD). Decreased in quality of life of citizens due to their dependence on private cars and lack of parking is main reason for birth of (TOD) in city of Ramadi.

### Transit Frequency

It is proposed to establish a TOD in city of Ramadi to operate 6 sets of metrobuses (or trams) to improve quality, comfort and adherence to public transportation schedule. It confirms operational evaluation of train

schedule and travel duration. It is proposed to operate for 15 hours, from 06.00 to 21.00 and advance every 5 minutes, during peak hours, which is from 7 to 9 am and 5 to 7 pm. These data reveal that Baghdad Square meets standards and indicators for a maximum of 15 minutes for transmission frequency. It also meets TOD site's basic requirement of minimum service time of 13 hours for zone transportation mode (05.00-18.00). There are other means of transportation available, such as private taxis. Based on field surveys and simulations, transit times required to move from transit to other modes of transportation (including walking and bicycle) is approximately 3-5 minutes. Urban TOD classification is appropriate for study area (Table 3).

### Mixed Use

Based on basic design map of current city of Ramadi, there are seven uses within radius of the square, including the green zone (Map 1). It includes government area (infrastructure and civil defense departments, schools, and Grand Anbar Mosque), residential area, and commercial area (for offices, trade, and services) (figure7). This means that development meets basic requirements of urban and semi-urban TOD types. Current situation, according to land uses, has already met criteria for minimum types of land uses, but pattern of use division needs to be rearranged. Land use areas are currently considered a linear strip (Map 1) and have not currently formed a unified composition of land uses.

### Building Density

Building heights reach +50 m, or equivalent of 3-12 floors (Figure 7). This means that location of square is suitable for developing high-rise buildings. The area is suitable for developing urban TOD classification. Regulation of building density can be obtained from local government in spatial plan (Directorate of Urban Planning) in (Figure 7) The FAR ranges from 1.2 to 2.4 (urban classification), and number of floors allowed ranges 2 - 4 floors (urban and peri-urban classification). The current building coverage ratio (BCR) for area is between 60-75% (urban and peri-urban TOD classification) based on spatial planning data, and in terms of current building density, plaza development results in an urban TOD classification only.

### Retail Properties

Commercial and service areas along streets, especially on Main Street and Twenty Street, cover regional and local services. This wide-ranging service can be seen through a variety of commercial and service activities in vicinity of square, as it is famous as a commercial area for automobile spare materials (due to relocation of industrial district), building materials, interior decoration, and sanitary ware. Based on this service scope, Bagdad Square is suitable for urban TOD classification.

### Data Preparation

Data derived from this study include information about the square, its coordinates, and site boundaries. Data were collected from the municipality of Ramadi and the Directorate of Urban Planning in Anbar, in addition to data acquisition (GPS) and on-site survey (Figures 5, 6). Then import data from map of Ramadi city in AutoCAD into ArcMap (Map 1) to integrate geospatial information and its characteristics as the basic data for the next step in spatial analysis.



**Map (1).** Master plan of city of Ramadi with study area. Directorate of Urban Planning in Anbar

## Classification and Standards

There are many studies related to TOD classification, and Table (2) shows most important classifications with their sources.

**Table 2.** Urban TOD Classification and Their Literary Sources

No.	Details	Resource
1	Introduced TOD typology	(H. Sung, J. T. Oh, 2011)
2	The typology was developed	(D. S. Vale, 2015) & T. Mafame, 2017)
3	Proposed TOD classifications : Regional Center, Urban Center, Sub-Urban Center and Transit-town Center	(N. L. A. Widyahari, P. N. Indradjati, 2015)
4	Found Regional, Urban, and Suburban TOD suitable for city	(H. M. Taki, M. M. H. Maatouk, 2018)
5	Identified TOD Regional with presence of thematic mixed land-use , served by various modes of transportation systems.	(T. Jaiswal, 2008)

City's service scale here works as a secondary economic center located in main traffic of city, such as intercity bus stations, tram stations, or metrobus stations, for its role in direct access to crossing points without changing other means of transportation. It is considered a sub-center, serving local housing and helping to develop housing for low class. And medium, and equipped with public facilities and open spaces to provide easy access via various means of urban transportation. Table (3) shows Criteria and indicators.

**Table 3.** Criteria & Indicators Of TOD In Urban Center

Criteria & Indicators	Transit mode Short distance commuter :	Transit frequency	Mixed landuse	Building intensity	Building coverage ratio	Retail characteristics
Details	Metrobus APB BRT MRT/LRT Inter region bus	5-15 minutes	Min. 4 types of land use (office , residential , retail , and entertainment)	Density (high-medium) Existing FAR 1.2-3 Intervention –max. FAR 5 Number of floor Existing :5 Intervention :15	Existing :50% Intervention:60%	Regional , local and community scale

Source : (H. Dittmar, and G. Ohland,2000) & (P. Calthorpe, 1993 )

## Indicators

TOD planning principles support “physicality-based TOD view,” especially walkable environment (Calthorpe, P. ,1993). Likewise, emphasis was placed on principles of built environment and highlighting “three dimensions” (density, diversity and design), as fundamental pillars in TOD planning (Cervero, R. & Kockelman, K. 1997), while two performance indicators were added: accessibility and distance (Ewing, R., et el, R., 2010) added two more regarding demand management (including cost and parking), and demographics. More comprehensive indicators were added, namely infrastructure indicators (i.e. road performance and service performance), and economic indicators such as land price, which were evaluated at neighborhood level (Motieyan, H. & Mesgari, 2018). Hence, the TOD Suitability Index has been proposed as a dependent variable, referred to as the “Actual TOD Index” which measures efficiency and suitability of proposed site. The “potential TOD index” should be able to measure characteristics of urban development in all regions.

**Application of TOD Concept**

Baghdad Square has reached basic criteria for location of TOD, which is proposed to have a basic transportation facility (MRT, BRT, Bus station) connecting city center with its eastern sectors, and also to have a collector road to reach square requiring a maximum radius of 700 meters ( 10 minutes walk) to main station. This means developing square to be a transportation hub in city of Ramadi, facilitating direct access for users of proposed public transportation with multiple transportation options (walking and bicycle). The arena is an oval area with a radius of 195-345 metres.

**Modeling and Statistics**

It includes modeling relationship between land use and transportation using “three-dimensional” indicators. This relationship is explained, but it may not be comprehensive and effective enough to measure TOD for an area, which necessitates introduction of additional variables, such as accessibility and movement model, because these services vary throughout day. Spatial saliency analysis techniques are most reliable methods. The degree of influence of each TOD indicator was used to measure spatial suitability for establishing project. To calculate TOD index, it was found that multiple linear regression analysis method, in general, is an effective way to collect effect of multiple indicators and evaluate project establishment.

Achieving efficiency requires collaboration between planners, policy makers, investors and stakeholders and a bottom-up approach to planning process. Data is also obtained from interviews and questionnaires with experts in various scientific fields to obtain weight value for each indicator.

**Statistical Model Inputs**

Inputs represent independent variables and dependent variable in (multiple linear regression) model to determine impact of each indicator, whether negatively or positively, on program’s outputs, as follows:

Indicators	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>10*</sub>	X <sub>11</sub>	Y
Definition	Land use	FAR	Floors	Social satisfaction	Transportation Frequency	Pedestrian	Cycling	Station	Estate price	Time if accessible	Spatial suitability
Unit	No.	No.	No.	%	Vehicle/h	Person/h	Bicycle/h	No.	\$/	Minutes	%

\*Saeed, Ahmed Adnan, and Luay Taha Mullahwaish, 2020

**Model Outputs**

Model Summary <sup>b</sup>							
Model	Mod R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics		
					R Square Change	F Change	
1	.946 <sup>a</sup>	.894	.743	.65003	.894	5.927	

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	17.847	3.406		5.240	.001
	Land use	.151	.134	.176	1.121	.299
	FAR	-.033-	.029	-.188-	-1.128-	.296
	Floors	.480	.113	.670	4.249	.004
	social satisfaction%	-.038-	.016	-.448-	-2.339-	.052
	vehicle /h	.003	.001	.608	4.410	.003
	Pedestrian /h	-.001-	.001	-.089-	-.563-	.591
	bicycle /h	.010	.004	.356	2.438	.045
	station R	-.044-	.011	-.555-	-4.030-	.005
	Estate price / \$	-.002-	.001	-.418-	-3.094-	.017
arriving time/min	.145	.072	.315	2.021	.083	

## RESULTS and DISCUSSION

The discussion is based on the program outcomes, as the results are summarized as follows:

**Table 4.** Descending Order of Independent Variables Over Dependent Variable

Indicators	+ impact	- impact	Factors	Existing/mean	Intervention
Floors	+		0.480	3	10
Land use	+		.151	6	7
arriving time	+		0.145	6.4 min.	11
bicycle /h	+		.010	132 /h	201
vehicle /h	+		.003	1077	2002
station R		-	0.044	293m	316
social satisfaction%		-	0.038	66.66	85
FAR		-	0.033	4.1	8
Estate price / \$		-	0.002	999	800
Pedestrian /h		-	0.001	838 / h	1098

Note: Intervention values were based on maximum limit within the inputs for each variable (+) and minimum value for each variable (-).

The results from table (4) show following:

1- Highest positive impact on construction of TOD project in city of Ramadi is number of floors index, and this explains importance of index in accommodating largest number of uses, especially in scarcity of land, as well as construction of mixed-use buildings, which explains impact of land use variable, which comes in second place. That is, achieving highest density suitable for study area.

2- Ease of access to station center (for pedestrians, bicycles, and bicycles), with a positive effect represented by a relatively short arrival time compared to standard (15 minutes), which helped to propose establishment of a TOD in Baghdad Square, which encourages walkable paths.

3- Traffic volume of private cars entering study area has a negative impact on traffic congestion and environmental pollution and conflicts with two movement models (pedestrians and bicycles) in Paragraph (2), which requires finding sustainable alternatives that support idea of project.

4- The radius of site is small to fully accommodate idea in some parts, which may include surrounding real estate within development area, especially since the social satisfaction effect is currently acceptable.

5- The variation in real estate prices is variable according to market mechanisms (supply and demand), as rate of increase ranges to (19%) according to field survey over a maximum period of one year, which confirms its negative impact on development of site as a center for sustainable urban growth (TOD).

## CONCLUSIONS

1- The success of establishing the TOD project in city of Ramadi is linked to construction of mixed-use, high-density, walkable buildings around the station that generate more vibrant communities with economic development by integrating high-density land uses with (non-motorized) modes of transportation, which increases public safety. It guarantees support for transportation uses in city.

2- TOD provides a base for a variety of housing, employment, local services, property development that support vibrant station community. It contributes to creating multi-modal transportation options, including walking, cycling, and public transportation.

3- TOD directs high-density development around transit stations, providing a balanced approach to accommodating growth. However, in return, it increases the value of the land for sites that have access to transportation to enjoy increases in land value compared to sites far from station while reducing infrastructure costs by incorporating "green" infrastructure strategies.

4- Reducing traffic pressure on main city center by creating a new secondary city center that includes a new transportation station, an education center, high-urban density and parking.

## Recommendations

1- Using results of research on basis of which policies for improvements can be developed or a detailed decision regarding location of TOD can be made in order to help planning decision makers determine priorities. Focus on methods and models that measure actual or proposed implementation of TOD concept. With need for more models based on other characteristics of region.

2- Determining built environment indicators for appropriate walking distance, as well as evaluating performance through participation of stakeholders and relevant government departments and their significant influence on weighting of variables that affect value of indicators. Therefore, engaging communities, private sector and public sector, with additional interviews to give a vision of what citizen wants. This is an essential element that maintains success of project.

3- Expanding TOD measurement. For example, people living near transportation stations are affected by policies and demographics in area. Hence, there is a need for more models based on other characteristics.

## Acknowledgement

Special thanks to Director of Ramadi Municipality, Director of Urban Planning, and Director of Ration card manager in Anbar Governorate, for accurate statistics they provided for data required in research.

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