The Impact of Transit-Oriented Shopping Mall Developments (TOSMDs) on Metro Station Ridership: Dubai Metro Redline

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Abstract Transit-oriented shopping mall development (TOSMD) is a novel concept in urban planning practice. The array of TOSMD attractiveness factors is not currently included in the forecasting models for station ridership. As a result, a station near a TOSMD can reach its capacity because its design and development didn’t take into account TOSMD, while TOSMD contributes passenger flow to the station. Depending on the setting, the number of visiting tourists could exacerbate this problem. Therefore, this study aims to empirically identify the critical TOSMD attractiveness factors and clarify their impact in terms of shopper passengers contributing to the ridership at stations near TOSMDs in the case of the Dubai Metro Redline. A sample of 700 shopper passengers were surveyed at seven stations near TOSMDs. We used principal component analysis with confirmatory factor analysis, and structural equation modelling to explain the impact of TOSMD attractiveness on shopper passenger ridership at stations near TOSMDs. Eleven independent TOSMD attractiveness factors were found to be associated with the extent of shopper passengers’ intention to use a station near a TOSMD. Resident and tourist shopper passengers showed variability in the factors impacting their use of stations near TOSMDs. The study assists in empirically validating the impact of TOSMD attractiveness on ridership at stations near TOSMDs, as a means of increasing the economic sustainability of transit networks. It provides statistically fit models for clarifying the generated resident and tourist shopper passenger ridership contributing to a station ridership as a result of its nearby TOSMDs. For a more comprehensive analysis, future studies could be repeated for transit networks in other cities.

Keywords Transit-oriented shopping mall development • TOSMD • Attractiveness factors • Station use • Passenger forecasting models

1 Introduction

The growth rates of gross leasable area (GLA) of shopping malls in countries such as the USA, Russia, France, and Turkey have been continuously increasing [1]. However, a US report released by Cushman & Wakefield [2] showed that in the USA, while there were more than 4000 major...
chain closures during 2016 however, consumers were still attracted to grocery stores, dollar stores, and dining experiences. Changes in shopping mall attractiveness factors can contribute to fluctuating patterns of growth in different areas of shopping mall development, and have increased the focus on mixed-use models in future and redeveloped malls. A mixed-use transit-oriented shopping mall development (TOSMD) refers to a shopping mall (SM) near a rail transit station in a transit-orientated development (TOD) context, where shoppers drive their cars less and instead ride nearby mass transit [3]. Major components of a shopping mall can include stores, food courts, restaurants, cinemas, children’s play areas, interactive entertainment, social use areas, relaxation spaces, and promotional areas [4]. Therefore, the development of TOSMDs can contribute to making areas surrounding a rail station more attractive, and could potentially increase the ridership of shopper passengers using the transit station near a TOSMD.

A transit station near a TOSMD can reach capacity in a short time as a result of congestion in a nearby shopping mall [5], resulting in costly upgrades and disruption to the rail service and travellers. In addition, population growth in cities, as well as visiting tourists, can exacerbate this problem. Hence, there is a need to understand the impact of TOSMD attractiveness on the ridership of passengers using a nearby transit station and its capacity to serve boarding shopper passengers.

Our understanding of transit station use as a result of TOSMD attractiveness is limited. Furthermore, the potential benefits of coordinated transportation and land-use planning through TOD are sometimes not adequately considered [6], particularly in the case of TOSMDs. Our previous study proposed a framework for TOSMD attractiveness factors [3]. It used the seven elements of the extended service marketing mix (product, price, place, promotion, people, physical evidence, and process) and the five factors related to TODs (density, diversity, urban design, destination accessibility, and distance) to understand transit station use by shoppers passengers as a result of TOSMD attractiveness. However, this framework has not been empirically examined. Therefore, this paper empirically examines the impact of TOSMD attractiveness factors.

The study attempts to link and predict the contribution of those attractiveness factors, in the form of the shopper passenger ridership, to the ridership of a nearby transit station in the case of Dubai Metro Red Line stations. Other level-of-service factors (such as punctuality, availability, public transport policies, and fare level) are neutralised by selecting the same geographical context, namely Dubai Metro Red Line in the United Arab Emirates (UAE). To achieve this goal, the study investigates the research question: “How do TOSMD attractiveness factors impact the ridership in a nearby transit station?” To understand this relationship, the study has the following three objectives:

- To review transit passenger forecasting models (PFMs) and station boarding factors (SBF)
- To review the capture of TOSMD attractiveness factors and the ridership of tourist shopper passengers (TSPs) in PFMs
- To compare and determine how the ridership of shopper passengers (both tourists and residents) boarding at a station near a TOSMD changes with TOSMD attractiveness factors, using seven Dubai Metro Red Line metro stations near TOSMDs.

The study is organised as follows: Sect. 2 presents a review of the existing literature relevant to transit passenger forecasting models (PFMs), station boarding factors (SBF), TOSMD attractiveness factors, and tourist shopper passenger (TSP) ridership for transit stations. Section 3 presents the methodology and data analysis techniques. Section 4 presents and discusses the results of the study, and finally, the last section concludes with the implications of the findings, limitations, and proposed further research.

2 Literature Review

2.1 Introduction

Several studies have been conducted to evaluate and clarify the driving factors behind metro station ridership and station boarding [8–10]. Statistical models have been used to develop passenger forecasting models (PFMs) relating transit stations as a function of the station’s environment and the transit features [12–13]. These models have applications such as forecasting the potential station ridership along transit corridors, identifying the factors contributing to station boarding, optimising transit station design, and planning future expansions and design modifications. Therefore, to achieve the study objectives, this section reviews the current literature relating to PFMs, station boarding factors (SBFs), TOSMDs captured in PFMs, and tourist shopping passengers (TSPs) captured in PFMs.

2.2 Transit Passenger Forecasting Models (PFMs)

Traditionally, urban planners have used McNally’s [14] regional four-step travel forecasting models, which consider trip generation, distribution, mode choice, and route assignment. This method is used despite complexity and accuracy issues, incomplete travel input data (estimation is typically based on relatively old household surveys, which
may include a small number of transit trips in the area of interest), insensitivity to land use, and institutional barriers to consultation and collaboration (transit providers are often not part of the modelling process), in addition to being cumbersome and expensive [15].

Direct models have therefore been developed based on multiple regression analysis as a complementary approach for estimating ridership [12–13, 15]. Such models are a less complicated and less expensive alternative to the four-step models. They are also directly responsive to land-use characteristics within the station catchment areas. However, direct models lack the regional perspective of the four-step models. In determining the variables impacting station ridership, researchers such as Choi et al. [16] have investigated metro ridership at the station level and the station-to-station level and concluded that ridership factors could be the same. Drawing circular catchments showing prospective passenger areas and GIS mapping approaches [17] have been used in determining the space located near railway stations with a view towards increasing their density so as to increase the number of potential train users. Chakour and Eluru [18] recently added that time to travel to a station is a significant factor negatively impacting the choice of a station and ridership, respectively. Policies can also influence users of public transport. Handy [19] and Vessali [20] indicated that factors such as zoning and restrictions on parking could play a significant role in the success of the TOD urban planning concept, and hence could also play a significant role in a TOSMD.

The following two approaches were identified to summarise the recent approaches to station ridership forecasting. The first approach examines a station-to-station (origin–destination matrix) ridership as the basis for the station ridership forecast, whilst the second explores station-level ridership-weighted variables (distance–decay-weighted regression). The origin–destination (O–D) matrix [21] utilises an automatic fare collection (AFC) system data to infer rail passenger trip O–D matrices from an origin to replace expensive passenger O–D surveys. The distance–decay-weighted regression approach [15] applies weights to a range of variables affecting the station ridership; including characteristics of the stations (type, number of lines, accessibility within the network), and the areas it serves (population and employment characteristics, land-use mix, street density, presence of feeder modes) according to the distance–decay functions. Prior direct ridership models at the station level used fixed distance thresholds. They did not reflect the impact on travel of concentrated housing and employment at a longer/shorter distance from the station in cases where these developments were located within the station catchment area.

In conclusion, while many other factors influence transit ridership, population density, employment density, land-use mix, walking accessibility, transit accessibility, automobile accessibility, and central business district (CBD) characteristics are among the most consistently studied factors by forecasters [22]. Furthermore, including these variables in PFM addresses the shortcomings of the four-step model. Additionally, these factors deal with the built urban environment, transportation policy, and alternatives to the automobile and social factors influencing transit ridership.

2.3 Station Boarding Factors (SBFs)

Sohn and Shim [10] referred to three categories of station boarding factors (SBFs), including (1) built environment, (2) external connectivity, and (3) intermodal connection. These three categories contained 24 metro boarding independent variables identified from previous studies [12–13, 24–29]. Among those identified, seven variables were significantly associated with station boarding, namely employment, commercial floor area, office floor area, net population density, the number of transfers, the number of feeder bus lines, and a dummy variable indicating transfer stations.

However, Sohn and Shim [10] and several other researchers [11, 15, 23, 31–34] did not drill down into the sub-variables of the “commercial floor area”. Therefore, there is a need to investigate these sub-variables, specifically in the case of TOSMDs, to improve the accuracy of PFM at transit stations near TOSMDs for optimal TOD and to increase the economic benefits for transit networks.

2.4 TOSMD Attractiveness Factors

Shopping malls have become a significant element in the urban landscape, as better mobility can improve cities’ economies, tourism intensity [35], and place marketing. Place marketing means designing a place to satisfy the needs of its target markets [36]. It implies creating competitive market offerings that can better satisfy the city’s target market needs [38–42]. Historically, Huff [43] assumed that the centripetal power exercised by a shopping mall was directly proportional to the size of the retail centre and inversely proportional to the consumer’s distance or travel time to the shopping mall. A large shopping mall tends to provide a wider product assortment. Distance, however, represents a cost or disutility to the consumer [44]. Nevin and Houston [44] categorised shopping area attributes into three dimensions, namely assortment, facilities, and market posture. Wong et al. [45] increased the number of shopping mall attributes from the 16 originally identified by Nevin and Houston [44] to 21 factors. These 21 attributes fall under five dimensions, namely (1) location, including convenient location, located at retail belt;
(2) quality and variety, including owner’s reputation, merchandise quality, service quality, merchandise variety, service variety, general price level; (3) popularity, including uniqueness, fashion; (4) facilities, including parking facilities, adequate and well-designed vertical transport, store atmosphere, layout, resting seats; and (5) sales incentives, including availability of supermarket, sales promotion, food court, special events/exhibit, and late closing hours.

The majority of shopping mall attractiveness studies have focused on attributes of shopping malls within the shopping mall context, to predict and optimise mall patronage [46, 47], identifying the optimal mix of activities in shopping malls, developing retailing strategies [49–51], understanding socio-spatial dynamics [52], and determining mall rent [53].

However, in order to optimise the potential benefits of coordinated transportation and land-use planning particularly in the case of TOSMDs, there is a need to analyse the impact of the internal and external attractiveness factors of TOSMDs [3, 6, 54]. Therefore, the TOSMD’s internal attractiveness factors of product, price, place, promotion, people, physical evidence, and process, and the external attractiveness factors of density, diversity, urban design, destination accessibility, and distance need to be empirically examined [3], to identify which attractiveness factors contribute to ridership in the form of shopper passengers boarding at metro stations near TOSMDs.

2.5 Tourist Shopper Passengers (TSPs) Captured in PFMs

Passenger forecasting models (PFMs) tend to pay less attention to tourist passengers. Therefore, city planners sometimes do not consider the number of tourist arrivals in their studies as a factor in the design of transit supply. They tend to extend the benefit of visiting tourists by keeping the supply of public transport at the same level and tolerating a certain degree of congestion during tourist seasons [35]. Hall [55] indicated four roles of transport for tourists: first, linking the market of origin with the tourist destination; second, providing access and mobility within a wide destination area (region or country); third, offering access and mobility within a tourist attraction or destination; and fourth, providing travel along a recreational route.

Albalate and Bel [35] noted that studies had given less attention to the factors impacting the third role identified by Hall [55]. They provided guidance for factors impacting tourist transit passengers (TTP), as illustrated in Fig. 1.

Therefore, tourist shopper passengers (TSPs), as part of TTPs, are captured to a lesser extent in PFMs.

In conclusion, transit PFMs tend to ignore transit shopper passengers (residents or tourists) in their models. Hence, this study addresses the identified gap for TOSMDs and empirically examines to what extent attractiveness factors of TOSMDs impact ridership in the form of resident and tourist shopper passengers boarding at transit stations near TOSMDs.

3 Methods

This research was designed to identify and clarify the salient TOSMD-related attractiveness factors that affect the ridership caused by shopper passengers (unit of analysis) on the Dubai Metro Red Line stations where a TOSMD exists nearby. A survey was undertaken to gather data on shopper passengers at these stations. This method was selected as it was relatively easy for passengers to understand and complete, and was capable of producing a large volume of data in a limited period, and its results could be used for statistical analyses [56, 57]. Shopper passengers (individuals) boarding at seven metro stations near TOSMDs were surveyed to understand their perspectives on shopping mall attractiveness and ridership preferences. Structural equation modelling (SEM) was used to clarify the impact of the identified TOSMD attractiveness factors on the ridership of shopper passengers. Figure 2 provides an overview of the steps taken in this study.

3.1 Case Study Area

Dubai is an example of a city which has sought to differentiate itself as a shopping hub, and has more than 65 shopping malls [58]. The city has an area of only 4114 km² [59] and a population of 3.3 million [60]; however, it was visited by 15.92 million visitors in 2018 [61]. The large number of visitors to Dubai shopping malls are located near the city’s domestic Metro Red Line.

The Dubai Metro Red Line, also called Phase (1), is 52.1 kilometres long and was opened in 2009. It has two stations connected to Dubai airport (T1, T3) and a number of stations connected or adjacent to (within around 0.8 km radius) large shopping malls. These stations are circled in Fig. 3 and include (from left to right) Ibn Battuta Mall, Dubai Marina Mall, Mall of Emirates, Dubai Mall, BurJuman Shopping Centre, Al Ghurair Centre, and Deira City Centre. These malls are typically in high-density, mixed communities along Sheikh Zaid Road and the old Deira area. The Dubai Metro Red Line stations include urban-designed walkways which connect the mall and a nearby metro station.

The number of passengers checking in at Dubai Metro Red Line stations during the period from 2013 to 2018 (the period when there were no major changes in the line services) is depicted in Fig. 4.
As can be seen in Fig. 4, Dubai Metro Red Line stations near the TOSMDs generally have higher numbers of passengers checking in. This study uses the Dubai Metro Red Line as a single case rather than a comparison of different sub-cases, as there are few studies directly addressing the study problem within a homogeneous, one-study context capturing the relationship between metro station use and the attractiveness of TOSMDs. Although the case study methodology, particularly the single case, is inconsistent with the requirements of generalisation [62, 63], Yin [64] and Flyvbjerg [65] identify the value of using typical cases in analytical generalisation and the ability of a theory to be tested in a similar theoretical setting to further define its explanatory power [66]. Hence, this study provides a practical opportunity to identify and clarify the impact of TOSMD attractiveness factors on ridership at transit stations near TOSMDs along the Dubai Redline, and could be repeated for transit networks in other cities.

3.2 Data Collection

The data used to examine the station use by shopper passengers and the attractiveness factors of TOSMDs and the variables in the modelling were collected from various sources. The number of passengers checking in at each station of the Dubai Metro Red Line were obtained from the Rail Operations Department, Road and Transport Authority (RTA), which is responsible for the operation of Dubai Metro. The seven TOSMDs were identified using GIS and Google Maps based on a walkable distance around 0.8 km [11, 15, 67, 68]. The initial list of independent TOSMD attractiveness factors was synthesised from the literature review (refer to Sect. 2.4). The study used data
collected from a 72-question survey (refer to the Online Appendix). The survey was divided into six sections addressing demographic and behavioural characteristics of the respondent shopper passengers. It measured the importance of a shopping mall and its neighbourhood characteristics impacting passengers’ decisions to visit the mall near a metro station, using a five-point Likert scale [49, 69]. The survey questionnaire was pre-tested using a collaborative participant pre-testing method [70] with a sample of 10 shopper passengers.

Data for the main study was collected daily during the period from April 2019 to October 2019. The survey was mainly distributed during the afternoon daily peak time between 4:00 pm and 8:00 pm by sampling conducted at the seven metro stations near shopping malls, as shown in Fig. 3. It was determined that the survey period and the afternoon data collection time provided the greatest diversity of participants, including workers and their families. Participants were purposively selected based on first asking the shopper passengers if they had come from the shopping mall to board the metro at the nearby station [71]. If the answer was “yes”, these shopper passengers were asked to participate in the survey. The daily morning peak time between 6:00 am and 9:00 am was avoided since shopping mall shops commonly open after 9:00 am. Therefore, target shopper passenger prospective

Fig. 3 Dubai Metro Red Line route map and stations within 0.8 km (circled) of the shopping malls

Fig. 4 Number of passengers checking in at stations of the Dubai Metro Redline during the period from 2013 to 2018 Source: Rail Operations Department (RTA) Database for Dubai Metro operations from 2013 to 2018
respondents were not available during this time. Shopper passengers were given the option to complete the survey on a paper based form or using a given web link to the study survey. Out of 1200 surveys distributed, 700 survey responses were received (response rate = 58%), including 366 online completed survey responses (52%) and 334 completed forms of survey responses (48%).

The data obtained from the 700 surveyed shopper passengers was used to explore the principal list of attractiveness factors of TOSMDs, which was used to construct the SEM model explaining the impact of TOSMD attractiveness factors on the shopper passenger ridership using Dubai Metro Red Line stations near TOSMDs.

3.3 Descriptive Statistics

Of the 700 surveyed shopper passengers boarding at the seven metro stations near TOSMDs (see Fig. 3), 69% were identified as residents and 31% tourists of Dubai, 47% were men and 53% women, and 54% were aged 18–34 and 46% older than 34. Twelve independent variables were identified and analysed based on TOSMD attractiveness factors (refer to Sect. 2).

Table 1 presents a profile of the 700 respondent shopper passengers (including residents, tourists, and both) in terms of the level of importance of factors of TOSMD attractiveness and the level of agreement to potentially use a metro station near a shopping mall. The table shows the comparative mean (M) and standard deviation (SD) scores of resident and tourist shopper passengers. As can be seen in Table 1, more than half the respondent shopper passengers ranked a TOSMD’s internal attractiveness factors as important or very important, including: product (M = 4.229; SD = 0.602), price (M = 4.115; SD = 0.549), place (M = 3.928; SD = 0.576), promotion (M = 3.96; SD = 0.562), people (M = 4.294; SD = 0.517), physical evidence (M = 4.226; SD = 0.544), and process (M = 3.872; SD = 0.616). Resident shopper passengers (RSPs) mean score (3.97) for the promotion factor was slightly higher than its equivalent for tourist shopper passengers (TSPs) (3.939). However, TSP mean scores for product (4.268), price (4.116), place (4.002), people (4.312), and physical evidence (4.277) were generally higher than their TSP equivalents for product (4.211), price (4.114), place (3.895), people (4.285), and physical evidence (4.203).

Similarily, a high percentage of respondents ranked TOSMD external attractiveness factors as important or very important, including density (M = 3.554; SD = 0.988), diversity (M = 3.531; SD = 0.767), urban design (M = 3.987; SD = 0.634), destination accessibility (M = 4.091; SD = 0.582), and distance (M = 3.822; SD = 0.75). RSP mean scores for urban design (3.988) and destination accessibility (4.103) were higher than the equivalents for TSPs (3.983 and 4.067, respectively). However, TSP mean scores for density (3.653), diversity (3.565), and distance (3.825) were higher than their RSP equivalents for density (3.509), diversity (3.515), and distance (3.821).

Nonetheless, a high percentage of respondents agreed with the intention to use the metro station close to a mall (M = 3.462; SD = 0.864) including RSPs (M = 3.553; SD = 0.863) and TSPs (M = 3.263; SD = 0.833). This high percentage was explained in particular by the availability of walking access from the station to the mall (M = 4.09; SD = 0.997), with RSP mean scoring of 4.141, higher than TSPs (3.977).

3.4 Analytical Approach

This study mainly explores the impact of TOSMD attractiveness factors on ridership among shopper passengers boarding at transit stations near TOSMDs. We used a principal component analysis (PCA) approach in measuring the impact of these factors and assessing measurement validity, similar to other studies such as El-Adly [49]. The TOSMD attractiveness factors were the independent constructs, and ridership of shopper passenger boarding at a nearby transit station was the dependent construct.

The statistical data for the Dubai Metro Red Line indicated that stations next to shopping mall developments generally have higher ridership than many other stations. The data provided by the shopper passengers was analysed according to the level of importance they attributed to the identified TOSMD attractiveness factors, and their ridership preference for using a metro station near a shopping mall. Confirmatory factor analysis (CFA) was then used to validate the outcome of the PCA analysis, following the empirical model presented by Sohn and Shim [10], which examined on-boarding factors affecting demand at a station level. Similar to Sohn and Shim [10], structural equation modelling (SEM) was conducted to ultimately identify and clarify the impact of TOSMD attractiveness factors on shopper passenger ridership using stations near TOSMDs.

4 Analysis and Results

4.1 Attractiveness Factors of TOSMDs

Principal component analysis (PCA) showing the salient TOSMD attractiveness factors is displayed in Table 2. It shows that 39 items explain 75.07% of data variability, with reliability of Cronbach α = 0.821 and > 0.7 for each factor. Furthermore, 13 items (i.e. q0019: grocery store presence, q0024: prices offer value for money, q0030:...
Table 1: Internal and external attractiveness factors of TOSMDs ($n = 700$)

| Item | Residents | Tourists | Total |
|------|-----------|----------|-------|
| **Internal factors** | | | |
| Scale Shopper passengers | | | |
| *Product* | | | |
| Cinematic present | 4.211 0.607 | 4.268 0.588 | 4.229 0.602 |
| A variety in product quality | 4.2 | 0.729 | 4.201 0.739 | 4.209 0.731 |
| Presence of fun and entertainment | 4.289 0.66 | 4.329 0.637 | 4.301 0.652 |
| **Price** | | | |
| Prices are appropriate to my income | 4.114 0.543 | 4.116 0.563 | 4.115 0.549 |
| Overall price level in the mall | 4.235 0.599 | 4.196 0.577 | 4.223 0.592 |
| Comparatively low prices | 4.042 0.666 | 4.023 0.694 | 4.036 0.675 |
| **Space** | | | |
| Size of the mall | 3.979 0.569 | 3.939 0.545 | 3.96 0.562 |
| Average size of shops | 3.895 0.554 | 4.002 0.617 | 3.928 0.576 |
| Number of shops | 3.895 0.554 | 4.002 0.617 | 3.928 0.576 |
| **Promotion** | | | |
| Promotional campaigns in the mall | 3.979 0.661 | 3.954 0.619 | 3.971 0.648 |
| Organising events in the mall (e.g. shows) | 3.982 0.678 | 3.936 0.617 | 3.906 0.659 |
| Loyalty programs | 4.037 0.746 | 3.927 0.732 | 4.003 0.741 |
| **People** | | | |
| Staff friendliness and helpfulness | 4.156 0.58 | 4.223 0.595 | 4.180 0.585 |
| Staff knowledge and training | 4.243 0.617 | 4.205 0.642 | 4.231 0.624 |
| Availability of customer service | 4.455 0.567 | 4.507 0.578 | 4.471 0.572 |
| **Physical evidence** | | | |
| Lack of crowdedness in the mall | 4.42 0.729 | 4.201 0.739 | 4.209 0.731 |
| Comfortable controlled temperature | 3.979 0.569 | 3.939 0.545 | 3.96 0.562 |
| Atmosphere in the mall (e.g. music and lighting) | 4.264 0.632 | 4.256 0.54 | 4.261 0.604 |
| **Process** | | | |
| Ease of reaching the mall (e.g. directions) | 4.225 0.491 | 4.215 0.464 | 4.221 0.482 |
| Ease of finding a desired store inside the mall (e.g. Virgin store) | 3.919 0.664 | 3.995 0.632 | 3.943 0.635 |
| Ease of finding a desired product inside the mall (e.g. iPhone mobiles) | 3.484 0.979 | 3.384 1.066 | 3.453 1.007 |
| **Density** (agglomeration and the number of business establishment in a mall area) | 3.509 0.598 | 3.653 0.982 | 3.554 0.988 |
| Crowdedness and compactness of buildings around the mall | 3.41 1.107 | 3.575 1.104 | 3.461 1.108 |
| Total population in the neighborhood around the shopping mall | 3.607 1.059 | 3.817 1.006 | 3.673 1.047 |
| High number of shops surrounding the shopping mall | 3.531 1.148 | 3.566 1.153 | 3.529 1.149 |
| **Diversity** (mixed-use developments’ attributes) | | | |
| The need for mixed residential and commercial buildings around the shopping mall | 3.525 0.954 | 3.279 0.857 | 3.260 0.924 |
| Availability of scenic and recreational areas around the mall (e.g. water fountain) | 3.503 0.938 | 3.562 0.862 | 3.549 0.907 |
| Availability of community services area around the shopping mall (e.g. government services) | 3.751 0.935 | 3.854 0.956 | 3.783 0.941 |
| **Urban design** | | | |
| Availability of safe and air-conditioned walkways around the mall | 3.988 0.662 | 3.938 0.57 | 3.987 0.634 |
| Availability of parking facilities | 3.996 0.764 | 3.945 0.734 | 3.980 0.754 |
| Availability of clear signage around the mall | 3.473 0.975 | 3.675 0.975 | 3.576 0.975 |
| **Destination accessibility** | | | |
| Availability of walking access around the mall (e.g. pedestrian crossings, bridges and tunnels) | 4.103 0.575 | 4.067 0.598 | 4.091 0.582 |
| Accessibility to facilities and amenities around the shopping mall (e.g. hospitals) | 4.119 0.767 | 4.064 0.781 | 4.101 0.771 |
| Accessibility to downtown or city center | 4.148 0.717 | 4.196 0.672 | 4.163 0.703 |
| **Proximity of shops in the area around the mall** | | | |
| Proximity of shops in the area around the mall | 3.767 0.96 | 3.767 1.012 | 3.767 0.975 |
| Proximity of a metro station | 3.555 1.077 | 3.557 1.173 | 3.556 1.107 |
| Proximity of intercity public transport | 4.141 0.585 | 4.151 0.606 | 4.144 0.591 |
| **Shopper passengers ridership construct** | | | |
| I intend to use the metro station close to the mall because; there is car traffic congestion in the area of the mall | 3.553 0.863 | 3.263 0.833 | 3.462 0.864 |
| I intend to use the metro station close to the mall because; there is lack of enough car parking spaces in the area of the mall | 3.531 1.19 | 2.95 1.024 | 3.226 1.155 |
| I intend to use the metro station close to the mall because; there is walking access from the station to the mall | 3.166 1.128 | 2.863 0.991 | 3.071 1.095 |

*Scale values range from 1 ("not important") to 5 ("very important")

**Scale values range from 1 ("strongly disagree") to 5 ("strongly agree")" above: the higher the mean, the higher the attractiveness of that particular aspect

$M$ mean, SD standard deviation, Freq frequency
convenient facilities and amenities, q0034: mall image and publicity, q0038: staff extended working hours, q0040: modern mall internal decoration, q0046: freedom in the mall, q0049: car traffic congestion around the shopping mall, q0054: economic diversity in the neighbourhood around the shopping mall, q0056: availability of cycling lanes around the mall, q0062: access to different transport mode options, q0066: proximity of other modes of transport, q0067: I intend to use the metro station close to the mall because the station is at a walkable distance from the mall) were excluded from the analysis, as they were not significantly loaded (less than 0.5) to any of the 13 revealed constructs [3]. These 13 constructs were product, price, place, promotion, people, physical evidence, process, density, diversity, urban design, destination accessibility, distance, and shopper passenger ridership at the station.

4.2 Confirmatory Factor Analysis (CFA) and Structural Equation Model (SEM)

Confirmatory factor analysis was conducted to validate the identified attractiveness factors of TOSMDs impacting the ridership of shopper passengers using stations near a TOSMD [72]. According to Lei and Wu [73], a model is well specified and valid if the sample is large enough, and the normed fit index (NFI), comparative fit index (CFI), and goodness-of-fit index (GFI) are over 0.9 [74, 75]. The study’s model showed a reasonable fit [76]: $\chi^2 = 2950$ ($P = 0.00$), degrees of freedom (DOF) = 1005, goodness-of-fit index (GFI) = 0.9, the adjusted goodness-of-fit index (AGFI) = 0.83, the comparative fit index (CFI) = 0.9, the normed fit index (NFI) = 0.9, and the root mean square residual (RMR) = 0.054.

However, attractiveness factors of TOSMDs vary from one context to another (refer to Sect. 2.4). Therefore, in line with Sohn and Shim [10], SEM was then used to examine the causal impact of the attractiveness factors of TOSMDs on the shopper passenger ridership (including RSPs and TSPs). Table 3 shows the regression weights of TOSMD attractiveness factors impacting all shopper passenger ridership (including residents and tourists) boarding-in at Dubai Metro Red Line stations near TOSMDs. The $r^2$ is 0.31 for the ridership of all shopper passengers using Dubai Metro Red Line stations near TOSMDs ($r^2 = 0.39$ for RSPs, and 0.35 for TSPs). Price (0.20), place (0.14), people (0.016), and density (0.35) factors positively impact the ridership of all shopper passengers. However, the promotion factor shows a negative impact (−0.35) on the ridership of all shopper passengers. Furthermore, product, physical evidence, diversity, urban design, and destination accessibility factors are not significantly associated with the ridership of all shopper passengers. Table 3 also shows variability in the TOSMD attractiveness factors impacting the ridership of RSPs and TSPs. While place (0.14), people (0.18), and distance (0.17) factors are associated with the ridership of RSPs, they are not associated with the ridership of TSPs. However, the product (−0.19) factor is negatively associated with only the ridership of TSPs.

5 Discussion and Conclusion

This study investigated the impact of TOSMD attractiveness factors (the independent constructs) on the ridership of shopper passengers using transit stations near TOSMDs (the dependent constructs), to inform and potentially enhance the existing forecasting models of station ridership and increase the economic sustainability of transit networks of the Dubai Metro Red Line. The study initially showed high volumes of ridership at stations near TOSMDs (refer to Fig. 4).

The independent constructs were categorised into (1) internal factors (product, price, place, promotion, people, physical evidence, and process), and (2) external factors (density, diversity, urban design, design accessibility, and distance). The 700 shopper passengers representing the dependent construct were categorised into resident shopper passengers (RSPs), and tourist shopper passengers (TSPs), refer to Table 1.

The study’s PCA identified 12 independent constructs of TOSMD attractiveness factors that contributed to the dependent construct of ridership at transit stations near TOSMDs in the form of shopper passenger ridership using those transit stations. The cumulative percentage of variance explained in this relationship was 75.07%, with reliability of 0.821, and attractiveness factors with reliability above 0.7 for each construct shown in Table 2. The table showed all shopper passengers’ scoring of a TOSMD’s internal attractiveness factors of product, price, place, promotion, people, physical evidence, and process. Also, it showed all shopper passengers’ scoring of a TOSMD’s external attractiveness factors of density, diversity, urban design, destination accessibility, and distance, where a score of four identified an important factor. Additionally, the results in Table 1 showed differences in scoring of TOSMD attractiveness factors between RSPs and TSPs. All shopper passengers showed an agreement to use a metro station close to a mall mainly because there is walking access from the station to the mall ($M = 4.090$, SD = 0.997).

The study also presented a SEM model that explained the relationship between the identified independent constructs of TOSMD attractiveness factors and the dependent variable of shopper passenger ridership using metro stations near TOSMDs. The model was initially validated and
Table 2  TOSMD factors impacting shopper passenger ridership

| Item                                      | Code | Factor  |
|-------------------------------------------|------|---------|
| Cinema present                            | q0020X | 0.825   |
| A variety in product quality present      | q0021X | 0.858   |
| Presence of fun and entertainment activities in the mall (e.g. gaming arcade) | q0022X | 0.814   |
| Prices are appropriate to my income       | q0023X | 0.756   |
| Overall price level in the mall           | q0025X | 0.801   |
| Comparatively low prices                  | q0026X | 0.775   |
| Size of the mall                          | q0027X | 0.714   |
| Average size of shops                     | q0028X | 0.860   |
| Number of shops                           | q0029X | 0.774   |
| Promotional campaigns in the mall         | q0031X | 0.829   |
| Organising events in the mall (e.g. shows) | q0032X | 0.718   |
| Loyalty programs                          | q0033X | 0.794   |
| Staff friendliness and helpfulness        | q0035X | 0.799   |
| Staff knowledge and training              | q0036X | 0.788   |
| Availability of customer service          | q0037X | 0.854   |
| Lack of crowedness in the mall            | q0039X | 0.792   |
| Comfortable controlled temperature        | q0041X | 0.841   |
| Atmosphere in the mall (e.g. music and lighting) | q0042X | 0.785   |
| Ease of reaching the mall (e.g. directions) | q0043X | 0.657   |
| Ease of finding a desired store inside the mall (e.g. Virgin store) | q0044X | 0.799   |
| Ease of finding a desired product inside the mall (e.g. iPhone mobiles) | q0045X | 0.794   |
| Crowdedness and compactness of buildings around the mall | q0047X | 0.872   |
| Total population in the neighbourhood around the shopping mall | q0048X | 0.794   |
| High number of shops surrounding the shopping mall | q0050X | 0.821   |
| The need for mixed residential and commercial buildings around the shopping mall | q0051X | 0.772   |
| Availability of scenic and recreational areas around the mall (e.g. water fountain) | q0052X | 0.852   |
| Availability of community services area around the shopping mall (e.g. government services) | q0053X | 0.684   |
| Availability of safe and air-conditioned walkways around the mall | q0055X | 0.826   |
| Availability of parking facilities        | q0057X | 0.813   |
| Availability of clear signage around the mall | q0058X | 0.850   |
| Availability of walking access around the mall (e.g. pedestrian crossings, bridges and tunnels) | q0059X | 0.751   |
| Access to facilities and amenities around the shopping mall (e.g. hospitals) | q0060X | 0.831   |
| Access to downtown or city centre         | q0061X | 0.707   |
| Proximity of shops in the area around the mall | q0063X | 0.766   |
| Proximity of a metro station              | q0064X | 0.701   |
| Proximity of intercity public transport   | q0065X | 0.754   |
| I intend to use the metro station close to the mall because there is car traffic congestion in the area of the mall | q0068X | 0.752   |
| I intend to use the metro station close to the mall because there is lack of enough car parking spaces in the area of the mall | q0069X | 0.739   |
| I intend to use the metro station close to the mall because there is walking access from the station to the mall | q0070X | 0.727   |

Extraction method: principal component analysis
Rotation method: varimax with Kaiser normalisation
*Rotation converged in 7 iterations

n = 700, Cumulative % of variance explained = 75.074, Cronbach’s alpha = 0.821
Table 3 Regression weights of TOSMD attractiveness factors impacting shopper passenger ridership using Dubai Metro Redline stations near TOSMDs

| Shopper passengers no. | Product        | Price          | Place          | Promotion    | People        | Physical evidence | Density       | Diversity      | Destination accessibility | Distance      | All shopper passengers | Estimate | SE  | CR  | P    | Resident shopper passengers | Estimate | SE  | CR  | P    | Tourist shopper passengers | Estimate | SE  | CR  | P    |
|------------------------|----------------|----------------|----------------|--------------|---------------|------------------|---------------|---------------|--------------------------|---------------|-------------------------|----------|----|----|-----|--------------------------|----------|----|----|-----|--------------------------|----------|----|----|-----|
| Shopper passengers no. | < Product      | 0.20           | 0.14           | -0.35        | 0.16          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Price        | 0.14           | 0.10           | -0.35        | 0.16          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Place        | 0.14           | 0.10           | -0.35        | 0.16          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Promotion    | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < People       | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Physical evidence | 0.16         | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Density      | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Diversity    | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Urban design | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Destination accessibility | 0.16       | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|
| Shopper passengers no. | < Distance     | 0.16           | 0.08           | 0.00         | 0.19          | 0.02             | 0.35          | -0.08         | -0.01                    | 0.07          | -0.01                   | 0.81     | 0.08| -0.24| 0.81| 0.09                    | 0.08     | 1.58| 0.11| 0.11| -0.19                   | 0.17     | -2.07| 0.04| 0.04|

R² = 0.39

** footnote: 
*Significant (P < 0.05); **Highly significant (P < 0.001); 
Not significant (P > 0.05).
significance of the five constructs, which could be explained by the expectation of shoppers that shopping malls would cover large areas, and indicates that the respondents were comfortable with the experience of shopping in larger spaces where there is less shopper congestion. Within the people construct which was rated very high \((M = 4.294)\), customer service was very highly considered \((M = 4.471)\), followed by staff knowledge and training \((M = 4.231)\) and then staff friendliness and helpfulness. The respondents did not rate the issue of the density of shops and population in the area surrounding the mall importantly in the descriptive data, but this may be explained by greater shopper focus on the shopping mall than the surrounding area.

The promotion construct was the only construct shown to be negatively correlated with shopper passenger ridership. This outcome can be accepted, as some shoppers may prefer to avoid Dubai mall crowding, e.g. on New Year’s Eve when there is a fireworks event.

Additionally, the product construct (explained by the presence of a cinema, and the fun and entertainment activities, e.g. gaming arcade in the mall) was found to be negatively associated with the ridership of tourists and positively correlated for residents. This result can be explained by the fact that tourists are less motivated to attend cinemas and activities, as this was not their primary reason for travel to Dubai. Similarly, the distance construct (explained by the proximity of a metro station and proximity to intercity public transport) was found to positively impact only the ridership of residents but negatively impact ridership for tourists. This result can be explained by the fact that since residents live in Dubai, they rate the issues of proximity highly.

The five identified TOSMD attractiveness factors can be accepted, as Dubai uniquely has more than 65 malls, while its area is only 4000 km\(^2\). As a result, shopping mall competition is expected to be high. Therefore, the five identified TOSMD attractiveness factors and their explanatory items reflect attributes that allow a shopping mall to outperform its competitors, i.e. in the form of comparatively low prices, staff friendliness, customer service, etc.

As identified in the literature, the impact of TOSMD attractiveness factors has not been adequately considered in passenger forecasting models (PFMs), which have focused on factors such as the association between commercial floor area and station boarding. Hence, there was a need to examine to what extent TOSMD attractiveness factors impact ridership in the form of resident and tourist shopper passengers boarding at transit stations near TOSMDs, in order to better optimise TOD and to increase the economic benefits of transit networks. The study identified critical TOSMD attractiveness factors and clarified their impact in the form of shopper passenger ridership contributing to the ridership at stations near TOSMDs for the Dubai Metro Red Line.

The study was limited in that the causal relationships were tested with a single case study using the seven Dubai Metro Red Line stations near TOSMDs. It did not investigate the reverse causal effect, which might have influenced the latent constructs identified in the study. Furthermore, personality traits, and date and time of the survey may have affected shopper passengers’ perceptions of TOSMD attractiveness factors; however, the consistency in descriptive survey data between stations and residents and tourists provides some confidence in the trends. These limitations warrant further investigation and could be incorporated into the design of future studies and be repeated in other cities’ transit networks.

Despite its limitations, the study provides urban policymakers and rail transit urban planners with a practical basis from which to clarify shopper passenger ridership (including residents and tourists) using a transit rail station near a TOSMD. Furthermore, it provides a potential means of enhancing the accuracy and comprehensiveness of existing forecasting models (used to forecast transit station ridership) by identifying and clarifying the impact of TOSMD attractiveness factors on ridership at transit stations near TOSMDs. In particular, the approach may provide an understanding of shopper passengers contributing to the ridership at those stations in isolation from other transit stations not near TOSMDs in the same line and service context. Therefore, it is considered useful for cities with existing or growing rail network stations seeking to understand the expected ridership impact of TOSMDs on nearby transit network stations in the form of added shopper passenger ridership flowing into stations near TOSMDs. This understanding is considered useful for effective TOD approaches to rail network and shopping mall patterns of development, and economic sustainability in the form of guiding private or government investment as to where the best results will be achieved when developing metro stations.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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