Multiscale Transit Oriented Development (TOD) for sustainable communities

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Abstract. Transit Oriented Development in districts and cities planning is dependent on multiple factors including: location, context, population density and redevelopment strategy. Transit Oriented Development Institute (US national planning organization to promote sustainable communities around rail stations) identifies ten principles which characterize the TOD communities and among them: stations and communications hubs located in sites with highest ridership potential, higher density mixed-used, walkable development in ½ mile radius from station, pedestrian oriented communication with retain and café streets, public squares in proximity of stations, reduce of parking space, multi-modal connections and stations which act as generators of communities redevelopment. The research examines the concept of TOD on chosen case studies, describes the pattern of urban form which best suites TOD districts and cities and evaluate current practices. The research examines the concept of TOD on chosen case studies, describes the pattern of urban form which best suites TOD districts and cities and evaluates current practices. The paper is based on analysis of TOD projects on different scales: from TOD introduced at international scale (e.g. the Bus Rapid Transit (BRT) system in the selected Latin America large cities), at national scale in large metropolitan cities (e.g. in high density Central Business Districts of Dalian city in China) and at urban, urban fringe and neighborhood scale of Edmonton in Canada. The literature review study examines the patterns of transit-oriented development and highlights current planning practices. The research was based on identifying contemporary case studies, through the analysis of literature, reports, government and policy documents, conference proceedings and websites of international networks relevant to transit-oriented development.

1. Introduction
Transit-oriented development influences on urban form and changes character of contemporary cities directed to accessibility and mobility. It integrates traffic with urban land use to create transit-oriented cities and metropolis which use their public transport and organize life around centrally located rail or bus stations acting as community hubs [1]. Transit Oriented Development (TOD) have a strong effect on vitality of urban ecosystems, delivers multiple environmental benefits and wider recreation areas accessibility. In urban, highly transformed landscape, TOD is a bonding element which delivers to city environment biodiversity and help to reduce energy demands. Mixed-used areas planned around
transit-oriented hubs with easy access to public green areas deliver a wide range of benefits to local communities. Moreover, the interrelated system of greenery and transport can be supplemented with eco-solutions such as rainwater harvesting and efficient waste management. This paper focuses primarily on the place which connectivity takes in transit-oriented development systems on different scales. The research examines TOD projects in various scales: from TOD introduced in suburban areas, urban fringes to TOD in large metropolitan cities (e.g., in high density Central Business Districts—CBDs).

2. Methods and materials

Transit-oriented development (TOD) has been classified as one of the forms of sustainable urban transport, which generates a higher degree of human interaction [2]. Bernick and Cervero [3, p. 5] define TOD as “a compact, mixed-use community, centered around a transit station that, by design, invites residents, workers, and shoppers to drive their cars less and ride mass transit more.” Pedestrian-friendly, mix-used (integrated housing, employment, retail, commercial uses) high or medium density TOD communities are located usually within a radius of about 600-800 meters from a transit stop. Bernick and Cervero [3] emphasize the role of the “three Ds” (density, diversity, and design) in the transit-oriented development. TOD communities can create belts of activity located along transit lines [4]. This form of sustainable urban transport is seen as an antidote to both traffic congestion and environmental problems caused by transport. A new term of transit joint development (TJD) was added to the urban planning language to describe the role of public and private partnership in transit-oriented development and separate TOD, managed by public agencies [5]. While TOD is focused on neighborhood in scale, TJD joins city blocks with real estate development scales (one of the largest TJDs in the United States of America - the Metro Center in Bethesda, Maryland – a combination of an office space, hotel, retail space and residential development, all within walkable distance) [6].

Community life centered on transit stations, was introduced in the concept of transit village in where the sense of community is supported by physical features (for example indoor and outdoor public spaces), open spaces, as well as green areas and community services [7].

This paper focuses primarily on the place which connectivity takes in transit-oriented development systems on different scales. The research examines the concept of TOD on chosen case studies, describes the pattern of urban form which best suites TOD districts and cities, and evaluates current practices. The paper is based on analysis of TOD projects on different scales: from TOD introduced at international scale (e.g., the Bus Rapid Transit (BRT) system in the selected Latin America large cities), at national scale in large metropolitan cities (e.g., in high density Central Business Districts of Dalian city in China) and at urban, urban fringe and neighborhood scale of Edmonton in Canada. The literature review study examines the patterns of transit-oriented development and highlights current planning practices. The research was based on identifying contemporary case studies, through the analysis of literature, reports, government and policy documents, conference proceedings and websites of international networks relevant to transit-oriented development.

3. TOD typology

Since transit-oriented development was incorporated into urban planning, diverse TOD typologies have been introduced. Dittmar and Ohland [8] used geographical configuration, to divide TOD communities into: urban downtown, urban neighborhood, suburban town center, suburban neighborhood, neighborhood transit zone, and commuter town. Metropolitan Planning Commission analyzing the case study of TOD in San Francisco Bay Area [9] put attention to much broader range of TOD system, with an emphasize on TOD regional center. White and McDaniel basing also on geographical configuration distinguished six forms of TODs, such as: Single-Use Corridors (in a sense of transit corridors), Mixed-Use Corridors, Neo-Traditional Development (similar in development to new urbanism movement principles, such as, among many others items: traditional urban layout, narrow streets), Transit-Oriented Development: compact, mixed-used development around transit stops, Hamlet or Village Concept: concentrated around a central green area and
Purlieu: measuring approximately 150 acres and inhabited by 7,000 residents, with comprehensive and detailed design regulations [10]. TOD investments can be grouped around light rail stations, trolley stations, metro centres, busway stations (e.g. BRT Curitiba, Brasil) and park-and-ride lots.

D. Belzer and G. Autler [11] analyzing the case studies of transit-oriented development in America highlighted diversity of TOD in different periods of history, and introduced the following classification: The Early 20th Century Development-Oriented Transit, when streets and their residential communities located in proximity, providing a link between urban and suburban zones, were developed by a single owner, The Post-War Years Auto-Oriented Transit (with examples of San Francisco Bay Area Rapid Transit (BART) system, MARTA in Atlanta, and Metro in the Washington, D.C), with TOD as a part of a larger, regional system – combination of private cars and public transport, with little regard for local facilities, Today Transit-Related Development (with examples of Portland, Oregon San Diego Mission Valley Trolley Corridor), when transit agencies and federal government cooperate to add value to local transport investments around transit stations using smart growth and new urbanism movement principles and Tomorrow Transit-Oriented Development when growing interest in transit ridership and urban living is observed.

4. TOD benefits
Among the multiple benefits of TOD, the following can be listed: transit ridership increase, contribution to wellbeing of local communities and to the economic development, air pollution and energy consumption rates reduction, decrease of local infrastructure costs, public safety increase. Belzer and Autler [11] identified six principles of successful TOD, which also could be included in the list of TOD’s benefits: location efficiency (in the sense of providing of high-quality transit, a mix of uses and pedestrian-friendly design with access to community amenities, value recapture (in the sense of reduced spending on transportation though introduce of financial instruments, such as a location efficient mortgage - LEM and creation of housing units with lower-than-average parking), livability, contributing to wellbeing of local communities (increase of income, employment, public transport, improved access to open spaces and recreation and service facilities, financial return of investments costs and efficient regional land-use pattern resulted in lesser fragmentation of green areas, more concentrated development around transit centres and reduction of urban sprawl phenomenon. The City and County of Denver, among goals mentioned above identified also the benefits of: choices (housing, transportation and shopping) and mix-used transit stations “composed of employment, residential, cultural, recreational and shopping amenities” [12 p. 32]. California Department of Transportation in the research paper: Factors for Success in California’s Transit-Oriented Development, identified 10 benefits of TOD: provide mobility choices, Increase public safety, increase transit ridership, reduce rates of vehicle miles traveled (VMT), increase households’ disposable income, reduce air pollution and energy consumption rates, conserve resource lands and open space, play a role in economic development, contribute to more affordable housing, decrease local infrastructure costs [6,13].

TOD practices in Colombia (e.g.: TOD NAMA) embraces public and private investments along the transit corridors and stations such as: mixed land use, proper human design within walking distance to the stations, different types of housing, fast and comfortable transport, pointed into decrease of private cars use (e.g.: TOD NAMA). TOD NAMA aims to encourage the projects for development of low-income housing with commercial areas to create a friendly neighborhood [14].

5. TOD – Environment and Energy
Transit-Oriented Development connects transport centres distributed at a distance of 500 m from each other, which allows to keep a city at a human scale, and which constitutes the link between transport and land use. TOD in BRT (Bus Rapid Transport) system in Curitiba combines mix-use development (residential, commercial, cultural, institutional and industrial uses), and bus-based services. It has an influence on preservation of land resources, delivers better accessibility to public green areas and
helps to lower energy and infrastructure costs, through reducing distances between housing, workplaces, retail businesses, and other amenities and destinations.

Mixed-used areas, planned around transit-oriented hubs, with easy access to public greenery, deliver a wide range of benefits to local communities. Transit Oriented Development (TOD) has a strong effect on vitality of urban ecosystems, delivers multiple environmental benefits and wider recreation areas accessibility. In urban, highly transformed landscape, TOD is a bonding element, which brings to the city environment biodiversity and helps to reduce energy demand. Moreover, the interrelated system of greenery and transport can be supplemented with eco-solutions, such as rainwater harvesting and efficient waste management system.

6. Multiscale TOD from regional to neighborhoods scale

Transit stations of mix-uses (employment, residential, cultural, recreational and shopping amenities) act as entry points to the regional transit network, and contributes to the metropolitan region’s economies. The greatest potential for transit-oriented development exist in the highly-congested urban centers and transit corridors which provide a competitive advantage to transit, walking, and biking [12]. TOD contributes to regional land-use pattern and balance between jobs and housing, at regional, subregional and local scales [11]. Calthrope in his book: The Next American Metropolis [15] differentiates between urban and neighborhood TODs. According to his research urban TODs, located on rail transit lines are focused on providing employment while neighborhood TODs, located along local bus lines, create first of all, housing development opportunities. At the neighborhood scale, access to services depends on bicycle and pedestrian paths quality and density, while at urban scale on transport connections between neighborhoods. To create pedestrian and bicycle friendly environment several features should be taken into account such as: gridline street pattern, greening streets and squares, increase safety on streets, buildings located closer to a street within walking distance between, visual enclosure, minimal amount of parking lots [16]. Lynch [17] listed five basic components: paths, edges, district, nodes and landmarks, which build urban form and can be attributed to TOD in neighborhood area. Paths are identified together with minor roads: sidewalk, trails, edges act as barriers, with freeways, byways, arterials, districts with transit station’s catchment area, nodes with street intersections and landmarks with transit stops. According to Calthrope [15] public spaces should occupy 10% of total area, while core and employment 10-40% and housing 50-80% in TODs neighborhood. Differently, in urban TODs the ratio of public spaces to the total area is 5-15%, core and employment 30-70% and housing 20-60%. The presence of a retail centers, workplaces, offices, restaurants in proximity of transit station are superior features of most TOD projects. Calthrope [15] divided the retail space adjacent to the transit stop into: convenience shopping and services, neighborhood centers with a supermarket, specialty retail centers and community centers with convenience shopping and department stores (p. 77).

6.1. TOD at international scale – the case study of BRT in Latin America

6.1.1. Problem overview

Mejía-Dugand et. al [18] analyzing Bus Rapid System in Latin America described evolution and spread of new solutions using the system’s path and development behavior in similar contexts, sectors and technologies. In the research of the environment around Bus Rapid Transit (BRT) stops Rodriguez, Tovar [19] examined selected large cities of Latin America. Two main types of such stops were recognized: regular ones and terminals – the stops at the end of the line, or the ones with an important transfer flow from different BRT lines occurs.

6.1.2. Planning solutions

Rodriguez, Tovar [2013] introduced a typology of the BRT bus stops in Latin America. Ten main types were distinguished: Mixed-use corridor, Downtown city center, Urban center, Institutional use corridor, BRT-oriented satellite center, Nexus, Guatemala city corridor, Community center,
Neighborhood center and Green area [19]. Each has its own unique characteristic. Mixed-use corridor group embraces the stops, which present a high mixture of land uses, including institutional ones. Downtown city center met only in Quito embraces its old town district, with a high concentration of public entities, pedestrian pathways and public and private infrastructure such as hotels and restaurants. Urban center is described by high-density multifamily structures and public spaces with pedestrian amenities and rather weak BRT orientation. Institutional use corridor joins stops for institutional use i.e. hospitals or schools. BRT-oriented satellite center reflects high density of the population, pedestrian pathways, green areas, public spaces and other BRT-oriented facilities. Nexus is characterized by connections between BRT lines and other transportation services, while Guatemala city corridor shows a low degree of consolidation. Community center reflects single-family attached uses and institutional land uses oriented towards the BRT. According to planning principles, Neighborhood center can be established in the zone of high density of population in rather low-quality residential areas, with considerable commercial development well BRT-oriented. Finally the Green area stops are characterized by undeveloped land, and high-quality green spaces with some institutional land uses located far from activity centers [19].

6.2. TOD at metropolitan scale the case study of MRTP Dalian, China

6.2.1. Problem overview. Mobility depending on the private cars in Chinese cities is around 60%. Such level of motorization is a real threat for the sustainable development of the urban areas. Dalian, as many Asian cities, is much more densely populated than European or American cities and conditions for TOD implementation are less favorable. After the reforms from the 90’s of the 20th century the historical center of the city was dedicated to financial and service industry, while the inhabitants moved outskirts staying far from the facilities and amenities concentrated in the urban center [1]. The effort for the change from single-centered to multi-centered city has to be done. This way the transport would be dispersed to other urban centers in which the different functions would be distributed.

6.2.2. Planning solutions. Most of the legal acts used now by TOD in Dalian come from last decade of the 20th century. Regulations on Urban Green from 1991 can serve as an example where the proportion of green area relative to the urban is stipulated. In 2011, the Dalian Bureau of Urban Construction was established for monitoring the conditions of urban development within the legal conditions. The autonomy of the city administration led to establish the principle of the development for this coastal city – “growth-first” [1]. The need of coordination between both land-use and transport planning was stressed. According to TOD concept municipal government created a new city-transport development plan – Urban Master Plan (UMP) and Plan for Mass Rapid Transit System (MRTP). According to UMP Dalian should remain a multi-center structure: urban center would be dominant, surrounded by secondary urban centers. The next 11 satellite communities are under construction. MRTP plans to create 191 rail-based transit lines through the center and the satellites. First line runs from the west to the east and the second is circular and connects the commercial and residential areas. The coordination of the two modes: metro and bus was introduced. Some bus lines whose route was parallel to the metro were cancelled along with the number of the buses in order to reduce the air pollution. At the same time new bus lines connecting nearby important transport terminals were added [1].

6.3. TOD in urban/neighborhood scale – the case study of Edmonton, Canada

6.3.1. Problem overview. Edmonton needs some changes in order to adjust the different types of stations to fulfilled the TOD’s requirements. Mainly higher residential density, create a safe, accessible circulation system for different modes of transport stressing the importance of pedestrian and cycle pathways. In the Edmonton TOD is defined as planned urban development integrated with
transit station and at its core. There are 15 LRT stations divided into 6 categories: centre station, employment station, neighborhood station, downtown station, institution/recreation station and enhanced neighborhood station [20].

6.3.2. Planning solutions. Centre stations (i.e. Clareview, Southgate) are situated close to large shopping centers. They offer: good car access, parking places. However, there is very limited pedestrian and bike access. To adjust to the TOD system principles the residential area should be established accompanied by employment. Walking and cycling access has to be implemented together with quality of green areas. Employment station (i.e. Belvedere) currently with poor bike and pedestrian access is relatively undeveloped. To come up with the standards of TOD station job opportunities e.g.: professional offices, services as well as new high quality residential areas should be added to the existing facilities. Enhanced neighborhood station (i.e. Coliseum, Stadium) is a typical residential area with relatively poor pedestrian and cyclists access to the services. In order to be turned into a TOD station more density of the apartments and no-motor accessibility improvement is needed, along with service areas equipped with shops, restaurants, offices close to the station. In the Neighborhood station area (e.g.: Mckernan-Belgravia) most of the buildings are apartment houses, in proximity there is a lack of services and commercial business. Some areas have pedestrian and cyclists access toward station. In order to be changed into TOD hub apartments or townhomes along the mayor streets should be added to the city structure, as well as different services close to the station. Institution/recreation station (i.e. University) is accompanied by institutional or residential buildings. There are well prepared pedestrian and cycling pathways within university campuses, however the quality of those paths in residential area should be improved. To adjust to the TOD system the service area should be established together with offices to create employment. Downtown station (i.e. Central) is the area with high density of housing, as well as educational and recreation facilities with easy access to cyclists and pedestrians transport [20]

7. Conclusion
The TOD analysis of BRT system in Latin America major cities refer to the nine main factors crucial for sustainable development, such as: pedestrian-friendly connected with green or public spaces, single-family attached residential uses not centrally located, high-density residential multifamily, undeveloped land, well-maintained mixed-use areas, well-maintained green spaces, BRT-oriented public facilities for institutional use, large-scale commercial development and consolidated nonindustrial urban fabric. Ten main types of multiscale solutions were distinguished: Mixed-use corridor, Downtown city center, Urban center, Institutional use corridor, BRT-oriented satellite center, Nexus, Guatemala city corridor, Community center, Neighborhood center and Green area. For metropolitan area of Dalian the polarized system based on one major city – Dalian and 11 satellite interconnected communities was introduced. According to the Urban Master Plan Dalian should remain a multi-center structure. In Edmonton the LRT stations were divided into 6 categories: centre station, employment station, neighborhood station, downtown station, institution/recreation station and enhanced neighborhood station.

Households in the proximity of TOD system and living within 1 km distance from the station have higher accessibility to their jobs and services. Living in such zone causes more likely a change of transport form and results in reduction of time spent for getting to the workplace. Rapidly growing cities and the investments in the TOD system could lead to the development on more sustainable pathways. The proximity of transport hubs should be accompanied by the proper urban design such as: e.g. walking and cycling pathways, creation of café streets and public squares. The research shows that the integrated urban design in multiscale: from TOD introduced in suburban areas, urban fringes to TOD in large metropolitan cities (e.g. in high density Central Business Districts – CBDs) delivers multiple benefits to the society. Moreover, the urban development connected with the transport expansion, if properly conducted may generate an increase of the number of users, but poor integration
of station designs with the neighbourhood may cause the chaotic spatial organization and urbanized landscape degradation

References:

[1]  Mu R, De Jong M 2012 Establishing the conditions for effective transit-oriented development in China: the case of Dalian, *Transport Geo.* 24 pp. 234–49
[2]  ACurtis C, Renne J L, Batoli L 2009 *Transit-oriented development: Making it Happen*, Ashgate, Burlington,
[3]  Bernick M, Cervero R 1997 *Transit Villages for the 21st Century*. New York: McGraw-Hill,
[4]  Cervero R, Day J 2008 Suburbanization and transit-oriented development in China, *Transport Policy* 15 pp. 315–23, UC Berkeley Center for Future Urban Transport, University of California, Berkeley, USA
[5]  Cervero R, Hall P, Landis J 1992 *Transit Joint Development in the United States*. Monograph 42. Institute of Urban and Regional Development, University of California, Berkeley
[6]  Cervero R, Ferrel C H, Murphy S, 2002 *Transit-Oriented Development and Joint Development in the United States: A Literature Review*, Research Results Digest, Transit Cooperative Research Program, Federal Transit Administration, Number 52
[7]  Cervero R 1998 *The Transit Metropolis: A Global Inquiry*. Island Press, Washington, D.C.
[8]  Dittmar H, Ohland G 2004 *The New Transit Town: Best Practices in transit oriented development*. Island Press, Washington D.C.
[9]  Metropolitan Planning Commission. 2007. Station area planning manual. Oakland, CA. [http://ctod.org/pdfs/2007MTCStationAreaPlanningManual.pdf](http://ctod.org/pdfs/2007MTCStationAreaPlanningManual.pdf)
[10]  White S M and Mc Daniel J B 1999 TCRP Legal Research Digest 12: The Zoning and Real Estate Implications of Transit-Oriented Development. Transportation Research Board of the National Academies, pp. 1-50.
[11]  Belzer D, Autler G 2002 *Transit Oriented Development: Moving From Rhetoric To Reality*, A Discussion Paper Prepared for The Brookings Institution Center on Urban and Metropolitan Policy and The Great American Station Foundation
[12]  Ratner K A, Goetz A R 2013 The reshaping of land use and urban form in Denver through transit-oriented development, *Cities* 30 pp. 31–46
[13]  Arington G B, Parker T 2002 *Statewide Transit-Oriented Development Study- Factors for Success in California’s Transit-Oriented Development*. Sacramento: California Department of Transportation
[14]  [http://transport-namas.org/wp-content/uploads/2014/04/GIZ-EMBARQ_Transport-NAMA-Overview_Final_14_01_2014_SR.pdf](http://transport-namas.org/wp-content/uploads/2014/04/GIZ-EMBARQ_Transport-NAMA-Overview_Final_14_01_2014_SR.pdf)
[15]  Calthorpe P 1993 *The Next American Metropolis: Ecology, Community, and the American Dream*. Princeton Architectural Press, Princeton, N.J.
[16]  Ewing R 1999 *Pedestrian and Transit- Friendly Design: A Primer for Smart Growth Network*, American Planning Association
[17]  Lynch K 1960 *The Image of the City*. The Technology Press & Harvard University Press, Cambridge
[18]  Mejia-Dugand S, Hjelm O, Baas L, Rios R A 2012 Lessons from the spread of Bus Rapid Transit in Latin America, *J Cleaner Product* 50 pp 82-90
[19]  Rodriguez D, A, Tovar E V 2013 Bus Rapid Transit and Urban Development in Latin America, *Land Lines* ed. Ann LeRoyer, Lincoln Institute of Land Policy pp 14-20
[20]  Barua S, Alam D 2008 Transit Oriented Development (TOD) in Edmonton, Canada, *Urb. Public Transport. Syst.* pp 42-52