Course Code: CE 455
Course Title: Traffic Engineering and Management

Lecture 11: City road and street networks

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Outline

- Aspects of street network, Link to different attributes,
- Essential principles of sustainable street networks, approach,
- connectivity index, Transect zones, design standards
- FHWA road classification
- Road classification according to RHD geometric design and some RHD geometric design standards
- Traffic calming through towns and village
- RHD road designations
- Types of roads and Agencies responsible for various roads in the country
- Road network patterns, nodal points, links, routes
- Conceptualization, Vision 2040, road network design problem, road network pattern assessment analysis
- Traffic service levels and design parameters, hierarchy of road network, network control, operation and monitoring

The street network configuration affects three fundamental aspects of urban transportation.

- Safety
- Transportation mode choice
- Emergency response

THE LINK TO SAFETY

- **Sustainable street networks improve traffic safety**.
  Over 30,000 Americans perish each year in traffic crashes (National Highway Traffic Safety Administration, Fatality Analysis Reporting System [FARS], 2009 data). Pedestrians account for a significantly higher percentage of fatalities than their typical mode share would indicate (4,092 pedestrians died in traffic crashes in 2009, which represented 12.1 percent of all traffic fatalities). Bicyclists (termed pedalcyclists in the FARS database) are also overrepresented (630 bicyclists died in traffic crashes in 2009, which represented 1.9 percent of all traffic fatalities). A good street network is a powerful tool for reducing traffic crashes and fatalities while creating beautiful places.

  Hierarchical street patterns (arterial-collector-local) with cul-de-sac subdivisions depending on arterials do not perform as well as sustainable street networks and cause more traffic crashes. Hierarchical street networks divert traffic to high-speed arterials that have large intersections. Most motor vehicle crashes occur at intersections. Even short, local trips must use arterials because there is not a supporting network of connected collectors and local streets. The speed at which motor vehicles move on these arterial streets increases the likelihood and severity of crashes.

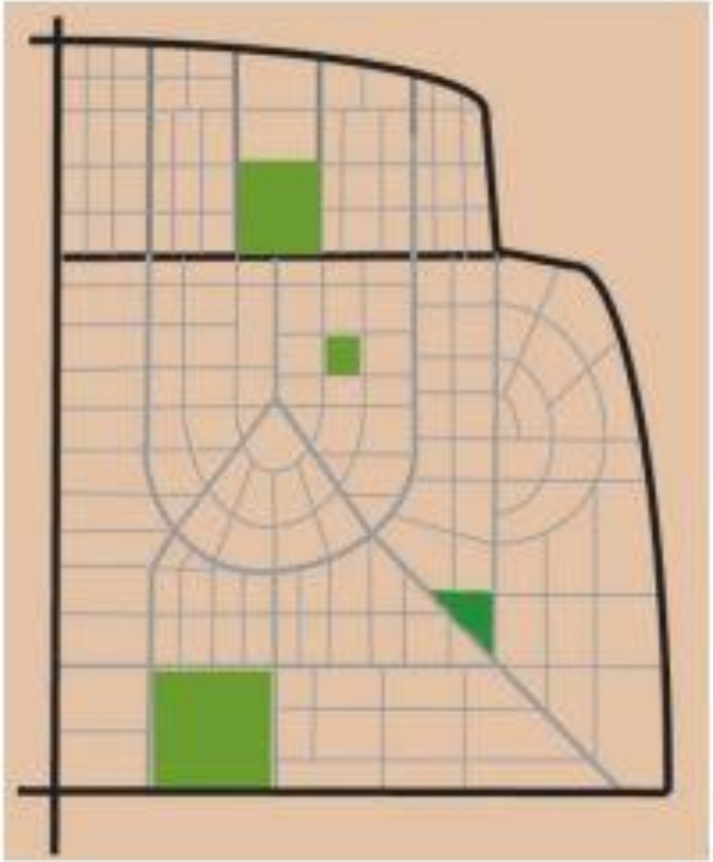
A 2011 study of 24 California cities found a 30 percent higher rate of severe injury and a 50 percent higher chance of dying in cities dominated by sparsely connected cul-de-sacs compared with cities with dense, connected street networks (Marshall, W. and Garrick, N., "Does the Street Network Design Affect Traffic Safety?" ***Accident Analysis and Prevention*** 43[3]: 769-781). A 2009 study from Texas found that each mile of arterial is associated with a 10 percent increase in multiple-vehicle crashes, a 9.2 percent increase in pedestrian crashes, and a 6.6 percent increase in bicyclist crashes (Dumbaugh, E. and Rae, R., "Safe Urban Form: Revisiting the Relationship between Community Design and Traffic Safety," ***Journal of the American Planning Association*** 75[3]:309-329).

Cul-de-sac developments break up connectivity and create longer trips (Credit: Michele Weisbart)

The Link To Transportation Mode Choice

- **Sustainable street networks increase the number of people walking, bicycling, and taking transit, which help reduce vehicle miles traveled.**

  Connectivity enables people to take shorter routes. It also enables them to travel on quieter streets. These shorter routes on quiet streets are more conducive to bicycling and walking. The California study cited above found that places with a dense, connected street network had three to four times more people walking, bicycling, or using transit to get to work. This in turn led to a 50 percent reduction in vehicle miles traveled per capita in these cities (Marshall, W. and Garrick, N., "***The Spatial Distribution of VMT Based upon Street Network Characteristics***," 90th Meeting of the Transportation Research Board, Washington, D.C., January 2011).



Interconnected street network with small blocks

The Link To Emergency Response

with small blocks
(Credit: Marty Bruinsma)

- **Sustainable street networks allow more effective emergency response.**
  Two primary reasons why sustainable grid street networks work better for emergency response are (1) maximizing the number of addresses served from each station and (2) providing a redundancy of routes. Studies in Charlotte, North Carolina, found that when one connection was added between cul-de-sac subdivisions, the local fire station increased the number of addresses served by 17 percent and increased the number of

households served by 12 percent. Moreover, the connection helped avoid future costs by slowing the growth of operating and capital costs; most of the cost to run a fire station is in salaries. Furthermore, the Congress for the New Urbanism's (CNU) report on emergency response and street design found that emergency responders favor well-connected networks with a redundancy of routes to maximize access to emergencies. Emergency responders can get stuck in culs-de-sac and need options when streets back up ("***Effect on Connectivity on Fire Station Service Area and Capital Facilities***," 2009 presentation by the Charlotte, North Carolina Department of Transportation, http://charmeck.org/city/charlotte/citymanager/CommunicationstoCouncil/2009Communications/Documents/CNUPresentationcolor.pdf).

THE LINK TO ECONOMIC ACTIVITY

- **A sustainable and resilient street network fosters economic and social activity.** While the number of lanes on each street are limited, maximum travel options (routes) are enhanced by sustainable street networks because collectively, more lanes are provided on more streets with better connectivity. By providing opportunities for all modes of travel, an ideal street network enhances social equity and provides an ideal setting for high quality design at all scales: building, neighborhood, and region. The resulting communities can be some of the most beautiful places with the highest values in the world.

  An excellent local example of this principle is the Las Olas area of Fort Lauderdale. Las Olas was developed in the 1920s when communities were still developed around a grid street network. Local real estate studies consistently find that the Las Olas area enjoys the most resilient and sustainable values in Broward County. Commercial lease rates in Las Olas remain at a premium and Las Olas has surpassed Broward Boulevard as the premier address for office users ("***Year End 2011 Broward Office Report***," Commercial Florida Realty Services, LLC). According to this report, new office space is not likely to be developed in the central business district for the forseeable future; however, planned development of multi-family residential could actually spur more activity resulting in even higher demand for office space. This demonstrates the positive impact of mixed-use areas.

Affordable housing also benefits from a sustainable grid street network. Affordable housing developments are often located in older neighborhoods with at least a partial grid street network in place. This allows residents to take advantage of the transportation benefits offered by shorter walks to work or public transportation, and being able to bicycle on connected local streets and collectors, rather than arterial boulevards. In addition, a recent report from the Center for Real Estate at the Massachusetts Institute of Technology (MIT) debunks the notion that affordable housing

developments depress the values of nearby single-family dwellings. Using data from 36,000 property sales between 1982 and 2003, the researchers found that home value changes over time in the areas near affordable housing developments simply "tracked" those in nearby market areas with no affordable housing options (Pollakowski, H., Ritchay, D., and Weinrobe, Z., "***Effects of Mixed-Income, Multi-Family Housing Developments on Single-Family Housing Values,***" April 2005).

- **A sustainable and resilient street network enhances active transportation and community vitality.**
  The health benefits of a traditional grid street network, which enhances connectivity and active transportation options, are numerous. Street network designs impact the likelihood residents will engage in walking, bicycling, or wheeling (physical activity) as a mode of active transportation. Active transportation can reduce the risk of diseases impacted by sedentary lifestyles, including Type 2 Diabetes, heart disease, high blood pressure, stroke, dementia, breast and colon cancer, as well as those related to poor air quality such as impaired lung development, lung cancer, and asthma, among others (Buchman, A. S., et al., "Total Daily Physical Activity and the Risk of AD and Cognitive Decline in Older Adults," ***Neurology***, 2012, 78: 1323-1329; Lee, C. D., Folsom, A. R., and Blair, S. N., "Physical Activity and Stroke Risk: A Meta-Analysis," ***Stroke: Journal of the American Heart Association***, September 18, 2003, 34: 2475-2482, available at http://stroke.ahajournals.org/content/34/10/2475.full.pdf; Bell, J. and Cohen, L., ***The Transportation Prescription: How Transportation Policies and Plans Influence Health***, PolicyLink and Prevention Institute, 2009, available at http://www.policylink.org; Frank, L. D., Andresen, M. A., and Schmid, T. L., "Obesity Relationships with Community Design, Physical Activity, and Time Spent in Cars," ***American Journal of Preventive Medicine***, 2004, 27[2]: 87-96; Slattery, M. L., et al., "Energy Balance and Colon Cancer — Beyond Physical Activity," ***Cancer Research***, January 1, 1997, 57[1]: 75-80; and U.S. Department of Health and Human Services, ***Physical Activity and Health: A Report of the Surgeon General,*** 1999, available at http://www.cdc.gov/nccdphp/sgr/index.htm).

Residents living along a sustainable street network are more likely to have higher levels of social capital (know their neighbors, participate politically, trust others, and be socially engaged) than those residing along car-oriented suburbs (Leyden, K. M., "Social Capital and the Built Environment: The Importance of Walkable Neighborhoods," ***American Journal of Public Health***, September 2003, 93[9]: 1546-1551). These are vital components contributing to mental health and well-being of the community, as well as the opportunity for residents to age in place (Cagney, K. and Wen, M., ***Social Capital and Health: Part II Chapter 11. Social Capital and Aging-Related Outcomes,*** 2008, 239-258). Additional benefits of such cohesion produced by gridded street networks include more eyes on the street, which provides support, safety, and reduction in violence (Cohen, L. et al., ***Addressing the Intersection: Preventing Violence and Promoting Healthy Eating and Active Living***, Prevention Institute, 2010, available at www.preventioninstitute.org).

Disparities in affordable transportation access can also be addressed by a sustainable street network (TransForm in collaboration with the California Department of Public Health, ***Creating Healthy Regional Transportation Plans: A Primer for California's Public Health Community on Regional Transportation Plans and Sustainable Communities Strategies,*** 2012, available at www.transformca.org). Broward County residents expressed they would actively commute rather than use a car if they had better connectivity and felt safe walking, bicycling, or wheeling throughout their community (Urban Health Partnerships, Inc., ***Broward Complete Streets Initiative Community Engagement Report***, 2012).

ESSENTIAL PRINCIPLES OF SUSTAINABLE STREET NETWORKS

Sustainable street networks come in many shapes and forms, but have the following overarching principles in common.

- The sustainable street network both shapes and responds to the natural and built environment.
- The sustainable street network privileges trips by foot, bike, and public transit because these are the most sustainable types of trips.
- The sustainable street network is built to walking dimensions.
- The sustainable street network works in harmony with various transportation systems, such as pedestrian, bicycle, transit, and private vehicle. Large parts of all of these networks are coincidental with the street network, but if any parts are separate from the street network, they must connect and interact with the network.
- The sustainable street network protects, respects, and enhances a city's natural features and ecological systems.
- The sustainable street network maximizes social and economic activity.
- The sustainable street network provides the option to age in place and affordably access daily activities and goods.

APPROACH

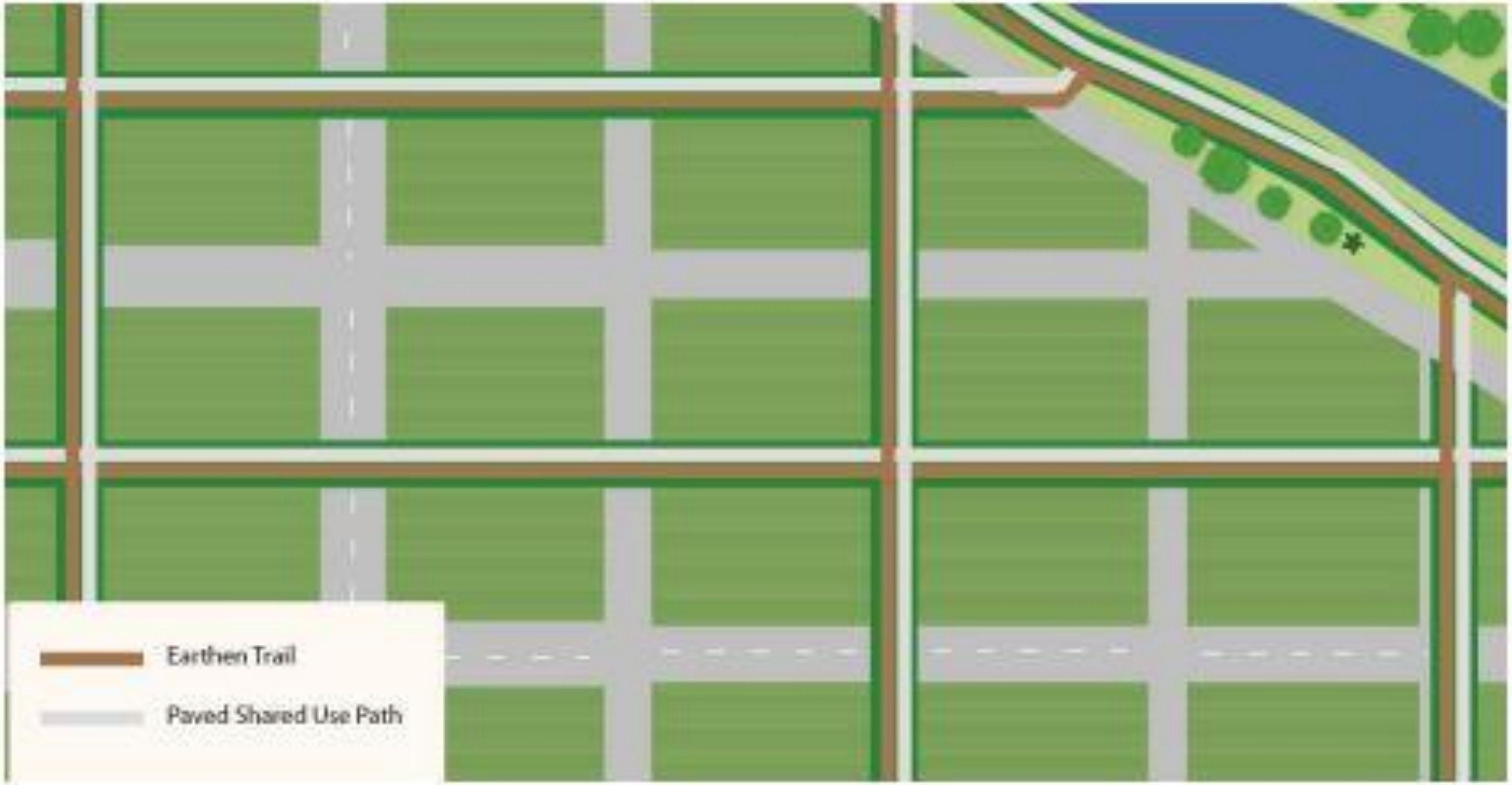
Sustainable street networks should provide for the following outcomes.

- Sustainable street networks should provide a high level of connectivity so that motorists, pedestrians, bicyclists, and transit riders can choose the most direct routes and access urban destinations.
- Intersperse arterial thoroughfares with a system of intermediate collector thoroughfares serving local trips connecting neighborhood destinations.
- Build network capacity and redundancy through a dense, connected network of small streets rather than through an emphasis on super-wide arterial facilities with high capacity.
- Expand the typical definition of collectors to recognize their role in connecting local origins and destinations rather than just connecting local streets to arterial boulevards.
- Multimodal street network planning should be integrated into long-range transportation plans, comprehensive plans, and land use plans.

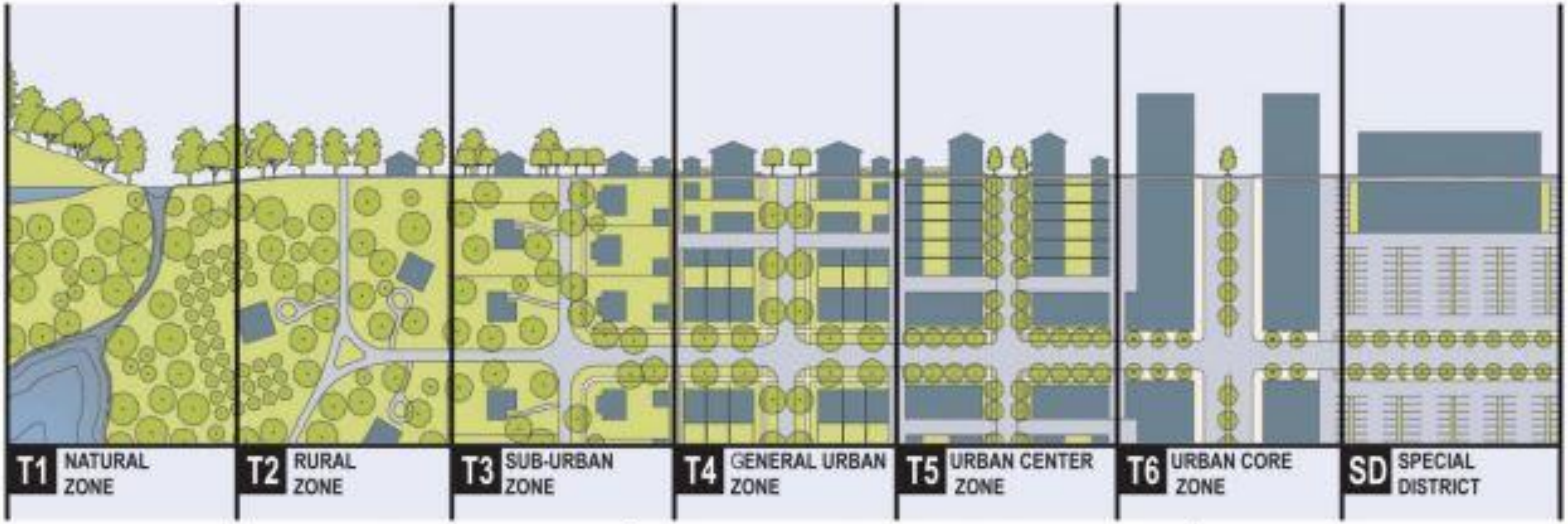
CONNECTIVITY INDEX

A Connectivity Index can be used to quantify how well a street network connects destinations. Indices can be measured separately for motorized and non-motorized travel. Several methods can be used according to the Victoria Transport Policy Institute (VTPI) at www.vtpi.org.

- The number of roadway links divided by the number of roadway nodes or intersections (Ewing, 1996). A higher index means that travelers have increased route choice, allowing more direct connections for access between two locations.
- The ratio of intersections divided by the sum of intersections and deadends, expressed on a scale from zero to one (U.S. Environmental Protection Agency, 2002). The closer the index is to 1.0, the more connected the street network.
- The number of surface street intersections within a given geographic area, such as a square mile (intersection density). The more intersections, the greater the degree of connectivity.
- An Accessibility Index as the ratio of direct travel distances to actual travel distances. Well-connected streets result in a high index. Less connected streets with large blocks result in a lower index.
- The Walking Permeability Distance Index (WPDI) deals specifically with an accessibility index for walking trips. (Allan 2001; Soltani and Allan 2005). It aggregates walkability factors such as street connectivity, street width, and sidewalk quality.



Integrating bicycle and pedestrian paths into new development
(Credit: Michele Weisbart)



The transect zones (Credit: Duany, Plater, Zyberk & Company)

DESIGN STANDARDS

1. Establish a block size maximum of 1,320 linear feet (perimeter).
   - Ensure greater accessibility within the block through alleys, service courts, and other access ways.
   - Where block size is exceeded, retrofit large blocks with new street, alleys, pedestrian and/or bicycle connections.
   - For existing street networks, do not allow street closures that would result in larger blocks.

2. The basic form of the street network system is shaped by the spacing and alignment of the major thoroughfares (continuous boulevards and avenues). Major continuous thoroughfares should be spaced as follows based on context zone.
   - Dense urban centers (T5 and T6)
     - Thoroughfares @ 1,320 feet
   - General urban centers (T4)
     - Thoroughfares @ 2,640 feet
   - Conventional suburban areas
     - Thoroughfares @ 5,280 feet

3. Require multiple street connections between neighborhoods and districts across the whole region. This is achieved by having boulevards and avenues that extend beyond the local area. Adjacent neighborhoods must also be connected by multiple local streets.

4. Connect streets across urban freeways so that pedestrians and bicyclists have links to neighborhoods without having to use streets with freeway on and off ramps.

5. Maintain network quality by accepting growth and the concomitant expansion of the street network (including development, revitalization, intensification, or redevelopment) while avoiding increases in street width or in number of lanes

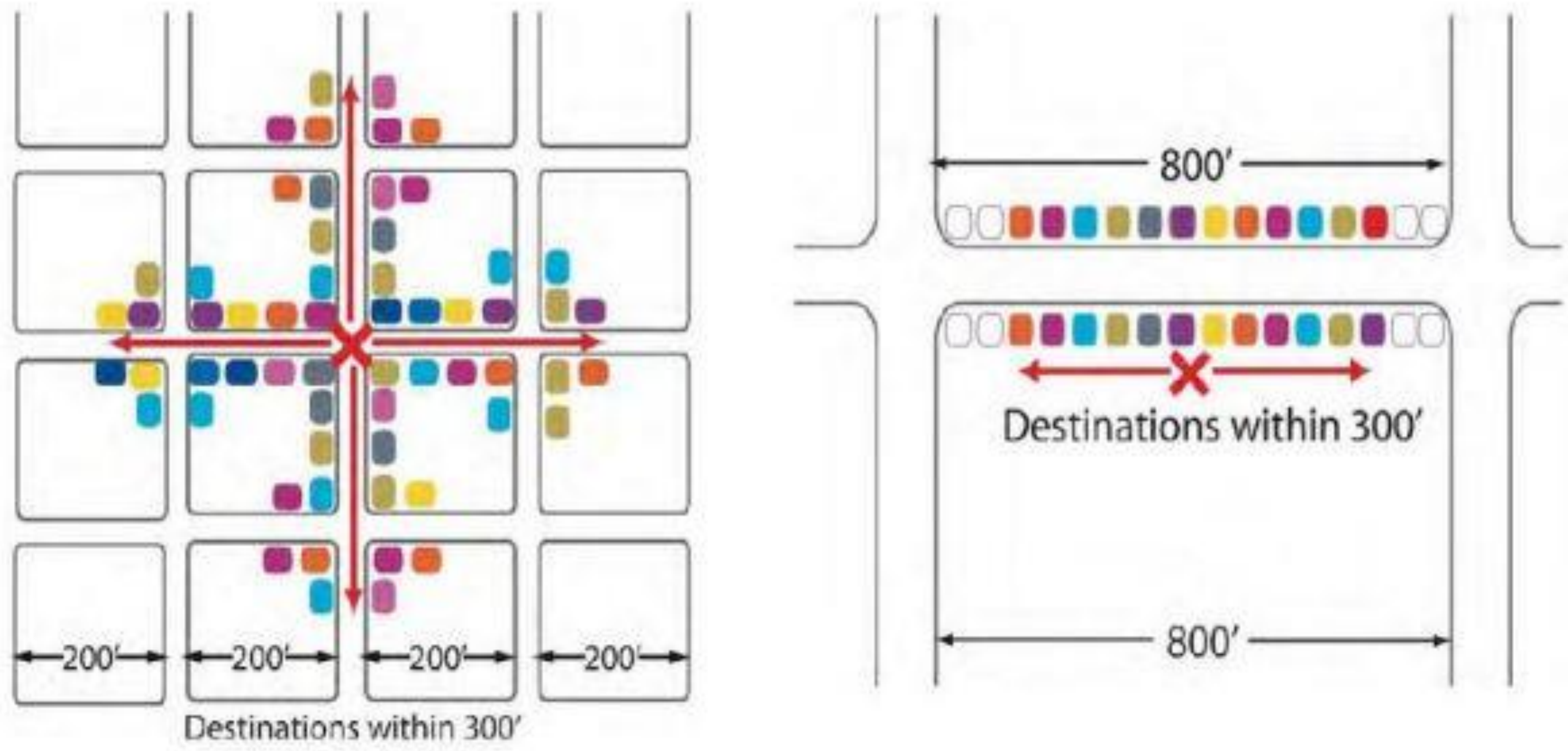
6. Provide on-street curbside parking on most streets. Exceptions can be made for very narrow streets, streets with bus lanes, or where there is a better use of the space.

7. Establish maximum speeds of 20 to 35 mph.
    - Use design features that support lower-speed environments including tight corner radii, travel lanes of 10 to 11 feet in width, robust landscaping, roundabouts, and frequent marked pedestrian crosswalks.
    - On local streets, the speed should be 20 to 25 mph or less.

8. Maintain network function by discouraging the following poor connectivity features.
    - One-way streets
    - Turn prohibitions
    - Full or partial closures (except on bike boulevards, or areas taken over for other uses of public space)
    - Removal of on-street parking (except when replaced by wider sidewalks, an enhanced streetscape, bus lanes, bike lanes, etc. rather than additional vehicle lanes)
    - Gated streets
    - Widening of individual streets
    - Conversion of city streets to limited access facilities

9. Include a system of bicycle facilities with parallel routes no more than one-half mile apart.

10. Pedestrian facilities should be defined by block lengths and should be located on both sides of streets.



Many more destinations can be reached walking 300' within a network of short blocks than in one with long blocks (Credit: Marty Bruinsma)

11. Local streets should be configured in a fine-grained multimodal network internal to neighborhoods.

12. Pedestrian shortcuts should be provided in locations where the network is broken.

13. Classify major streets using the common street and context types presented in Table 4.1. However, some streets are unique and deserve a special category that lies outside the common street network types. Table 4.2 describes these special streets. Chapter 5, "Traveled Way Design," contains guidance related to cross sections of these street typologies. New street types should be welcomed as well.

Boulevard example: Hillsboro Boulevard
(Credit: City of Deerfield Beach)

Boulevard example: Las Olas Boulevard
(Credit: Luisa Fernanda Arbeláez)

FHWA road classification

Avenue example (Credit: City of Charlotte, NC)

Avenue example (Credit: Kimley-Horn and Associates, Inc.)

Table 4.1 Common Street Types

Street Type	Description	Comment
Boulevard* (conventionally called arterials)	Walkable, moderate speed divided arterial in urban environments that traverses and connects districts and cities. Primarily a longer distance route for all vehicles including transit, goods movement, and emergency response. Design speeds should be 35 mph or less.	Serves as primary transit routes. Should have bike lanes and sidewalks standard. May have shared-use paths. Often has a planted median. May have on-street parking when passing through urban centers and urban cores.
Avenue* (conventionally called collectors or urban minor arterials)	Walkable, low speed collector or minor arterial that serves as a short-distance connector between districts or urban centers and provides access to abutting land. Links streets with boulevards. For all vehicles including transit. Design speeds should be 30 mph or less; strong consideration should be given for 25 mph or less when on-street parking is provided.	Serves as primary pedestrian and bicycle routes. Should have local transit routes. May or may not have a median. May or may not have on-street parking depending on context.

Street* (conventionally called local streets)	Walkable, low speed facility that primarily serves as access to abutting properties and local traffic in neighborhoods. Connects to adjoining neighborhoods. Serves local function for vehicles and transit. Design speeds should not exceed 25 mph.	Can be commercial or residential. Bicycles are served by shared space. Commercial streets should always have sidewalks. Residential streets should have sidewalks unless traffic volumes are less than 1,200 per day and speeds are 25 MPH or less.
Alley/Lane	Walkable link between streets; allows access to garages.	Narrow space characterized by walking speeds.
*May have segments with specialized functions and features such as a Main Street segment.		

Table 4.2 Special Street Types

Special Street Type	Description	Comment
Main Street	Slower vehicle speeds, favors pedestrians most, contains the highest level of streetscape features, typically dominated by retail and other commercial uses	Functions differently than other streets in that it is a destination
Drive	Located between an urbanized neighborhood and park or waterway	Can be a local street or an alley
Transit Mall	The traveled way is for exclusive use by buses or trains, typically dominated by retail and other commercial uses	Excellent pedestrian access to and along the transit mall is critical. Bicycle access may be supported.
Bike Boulevard	A continuous through street for bicycles, but short distance travel (local access) for motor vehicles	Usually a local street with low traffic volumes and low speeds
Festival Street	Contains traffic calming, flush curbs, sidewalks separated by bollards, and streetscape features that allow for easy conversion to public uses such as farmers' markets and music events	Often a commercial street in a downtown context that has the special design features listed to the left
Shared Space	Slow, curbless street where pedestrians, motor vehicles, and bicyclists share space	May support café seating, play areas, and other uses

Street example (commercial): Sanford, FL (Credit: Billy Hattaway)

Street example (residential) (Credit: Kimley-Horn and Associates, Inc.)

Alley example (residential): Chapel Hill, NC (Credit: Ryan Snyder)

Alley example (commercial): Boca Raton, FL (Credit: Kimley-Horn and Associates, Inc.)

Main Street example with street café
(Credit: Kimley-Horn and Associates, Inc.)

Drive example near Victoria Park
(Credit: Kimley-Horn and Associates, Inc.)

16th Street Transit Mall: Denver, CO
(Credit: Ryan Snyder)

Bicycle boulevard with bike box intersection
(Credit: Toole Design Group)

Festival street with flush sidewalks separated by bollards (Credit: Kimley-Horn and Associates, Inc.)

Shared space: Copenhagen, Denmark (Credit: Ryan Snyder)

Table 2.1 Road Cross-Section Standards

Design Type	Design year traffic volume PCU / peak hour (typical MV AADT)	Cross-section widths in metres			Indicative Road Classification
		Crest width	Carriageway (no. of lanes)	Paved shoulders	
1	4500 – 8500 (19,000–36,000)	36.2	2 x 11 (6)	1.8	
2	2100 - 4500 (7,000 – 19,000)	21.6	2 x 7.3 (4)	1.8	National
3	1600 – 2100 (5,000 – 7,000)	16.3	7.3 (2)	1.5	Regional
4	800 – 1600 (1,000 – 5,000)	12.1	6.2 (2)	1.5	
5	400 – 800 (500 – 1,000)	9.8	5.5 (2)	1.2	Feeder
6	<400 (<500)	9.8	3.7 (1)	1.2	

Notes
This is a summary table – refer to Section 4 before using these standards

Table 2.2 Typical Design Speeds

Design Type	Design Speed (km/h)		
	Plain	Rolling	Hilly
1 - 2	80 –100	80	-
3	80	65	50
4	65	50	40
5 - 6	50	40	30

Notes
Terrain: typical cross-slopes
Plain: 0 – 10%
Rolling: 11 – 25%
Hilly: >25%

Table 2.3 Speed Related Design Parameters

Design Speed (km/h)	Sight Distance (m)			Minimum Curvature Values	
	SSD	ISD	OSD	Horizontal curve (radius (m))	Vertical curve (K value)
Two lane roads					
30	30	60	120	35	2
40	45	90	180	65	4
50	60	120	250	120	9
65	90	180	360	250	18
80	120	250	500	500	35
100	180	360	720	1000	70
Single lane roads					
30		60		120	4
40		90		250	9
50		120		500	18
65		180		1000	35

Notes:

1. This is a summary table – refer to the appropriate sections of the manual before using these parameters
2. Sight distances (see Section 2.6) SSD – Stopping Sight Distance; ISD - Intermediate Sight Distance; OSD – Overtaking Sight Distance
3. Horizontal curves (see Section 5) The radii are those needed to achieve SSD with 5% superelevation (3% for the 1000m radius curve)
4. Vertical curves (see Section 6) Two lane roads: K values are those needed to achieve SSD; Single lane roads: K values are those needed to achieve ISD
5. For parameters relating to dual carriageway roads refer to the appropriate sections of the manual

Table 2.4
Passenger Car Unit (PCU) Values

Vehicle Type	PCU Value
Truck	3.0
Bus	3.0
Minibus	3.0
Utility	1.0
Car	1.0
Baby taxi	0.75
Motorcycle	0.75
Bicycle	0.5
Cycle Rickshaw	2.0
Bullock Cart	4.0

Source: p72, RMSS, Vol. V11A

Table 2.5 Generalised Traffic Flow Characteristics

Road Classification	Peak hour flow as % of daily flow	No. of MVs as % of total PCU flow	NMV / MV ratio (PCU)
National	8	34	0.15
Regional	10	33	0.3
Feeder	10	13	2.5

Source: Tables 3.13 , 3.20, 3.22, derived from RMSS, Vol. V11A

There are five basic carriageway widths within the six Design Type configurations:

3.7m wide - This is the standard single lane carriageway width, and is suitable for the more lightly-trafficked Feeder Roads. Vehicles travelling in opposing directions can pass each other by putting their outer wheels on the shoulder.

5.5m wide - This is a minimum width two-lane carriageway. Large vehicles can pass each other at slow speed.

6.2m wide - This is the lowest economic cost option for a very wide range of traffic volumes. It allows most vehicles to pass with sufficient clearance to avoid the need to slow down or move aside.

7.3m wide single - This is a high standard two-lane single carriageway.

7.3m wide dual - This is a high standard carriageway as one half of a dual 2-lane road.

11m wide dual - This is a three-lane carriageway as one half of a dual 3-lane road.

4.5 Traffic Calming Through Towns and Villages

Most accidents on rural roads in Bangladesh happen in towns and villages, and the accidents almost always involve a vehicle which is speeding through the centre. Projects which improve roads through towns and villages may make the accident situation worse because speeds will increase. In order to prevent this it is essential that traffic calming be applied. Traffic calming is the term used to describe self-enforcing engineering measures that reduce the speed of motor vehicles. Lower speeds reduce both the likelihood of an accident happening and the severity of injuries if it does occur. Effective traffic calming results in a better environment for all and improved safety for vulnerable road users (pedestrians, cyclists, rickshaw users). The engineering measures that can be used to calm traffic include:

- false roundabouts (a roundabout where there is no junction)
- speed humps
- road narrowings and deflections
- footway widening
- using upright signs / kerbs / planting / carriageway markings to form “gates” at the entrance to the town or village
- rumble strips that make a noise and give a slight jolt when vehicles go over them.

To have any chance of being effective the individual measures must be implemented as part of an overall traffic calming plan for each town and village. Preparing these plans requires specialist experience, and assistance should be sought from RHD’s Road Safety Division.

1.3 ROAD CLASSIFICATION

The Roads and Highways Department (RHD) within the Ministry of Communications, is responsible for the management of approximately 20,850 km comprising three categories of road classes; National, Regional and Feeder type 'A' roads.

1.3.1 National Highways

National Highways are defined as Highways connecting national capital with different divisional and old district headquarters port cities and international highways.

These roads have been categorised as National Highways considering the national importance and geographical positions. Each National Highway has been provided with a name and a number, such as Dhaka-Chittagong Highway has been numbered **N-1** whereas N stands for National. This number can only be changed by RHD head quarter.

1.3.2 Regional Highways

Regional Highways are defined as Highways connecting different regions and new district headquarters not connected by National Highways Feeder Road.

Regional Highways are named after National Highways of national importance. Names and numbers of these highways are decided such as Comilla-Lalmai, **R-140**, whereas R stands for Regional meaning the Region. This number can only be changed by RHD head quarter.

1.3.3 Feeder Road

Feeder Roads are defined as Roads connecting Upazila head quarters and other important rural centres (growth centres) with the existing Road network.

These connecting roads are defined as Feeder Roads. There are two types of Feeder roads. Feeder road - Type A and Feeder road - Type B. Name and numbers of these roads are decided such as Akhaura-Agartala, **F-1203** whereas F stands for feeder.

1.4 ROAD LINK

1.4.1 Definition

Every road has been divided into one or more links. Every link has got a link name and a number, such as Moulavibazar-Fenchuganj-Sylhet road, **N-28** , which has got three links; (1) Moulavibazar-Rajnagar **link no. 322**, (2) Rajnagar- **Fenchuganj link no. 323**, (3) Fenchuganj-Sylhet **link no. 324**.

1.4.2 Same Road and Link number

Some roads have not been divided in to more than one link. Road number and link number is same, such as Brahmanbaria-Lalpur, which has got road number **F- 1210** and also link number **1210**.

1.4.3 Link conditions

Links are not dependent on distance. Links depend on important places, traffic volume, road intersections and other factors. A link will be named and start with 0 kilometres where it begins and proceed towards the next link and measure its length in kilometres. Thereafter the next link will also start with 0 kilometres and measure the link length as previously described. The RHD head quarter has prepared these links and provided them with a number. Therefore only the RHD head quarter is allowed to change these.

Table 1: Description of the Types*, Definitions and Agencies Responsible for various Roads of the Country (2003)

Sl. No.	Type	Definition	Ownership and Responsibility
01.	National Highways	Highways connecting National Capital with Divisional HQ/s or seaports or land ports or Asian Highways.	RHD*
02.	Regional Highways	Highways connecting District HQ/s or main river or land ports or with each other not connected by National Highways.	RHD
03.	Zila Road	Roads connecting District HQ/s with Upazila HQ/s or connecting one Upazila HQ to another Upazila HQ by a single main connection with National/Regional Highway, through shortest distance/route.	RHD
04.	Upazila Road	Roads connecting Upazila HQ/s with Growth Center/s with another Growth Center by a single main connection or connecting Growth Center to Higher Road System**, through shortest distance / route.	LGED*/LGI*

Source: LGED geometric design manual

05.	Union Road	Roads connecting Union HQ/s with Upazila HQ/s, Growth Centers or Local Markets or with each other.	LGED*/LGI*
06.	Village Road	a) Roads connecting Villages with Union HQ/s, local markets, farms and ghats or with each other. b) Roads within a Village.	LGED*/LGI*
τ	The above road types do not include the roads belonging to the Pourashavas and the City Corporations. The responsibility for development and maintenance of such roads will lie with the respective Pourashavas and the City Corporations.		
*	RHD-Roads and Highways Department, LGED - Local Government Engineering Department, LGI - Local Government Institutions.		
**	Higher Road System - National Highway, Regional Highway and Zila Road.		

Rural Road

Rural road comprises of Upazila roads, Union roads and Village roads in the rural areas of Bangladesh.

Road network consists of large number of interwoven roads exhibiting many patterns ranging from star-like to grid-like with irregular patterns becoming recognized.

(Zang and Lund University, 2004).

ROAD NETWORK PATTERNS

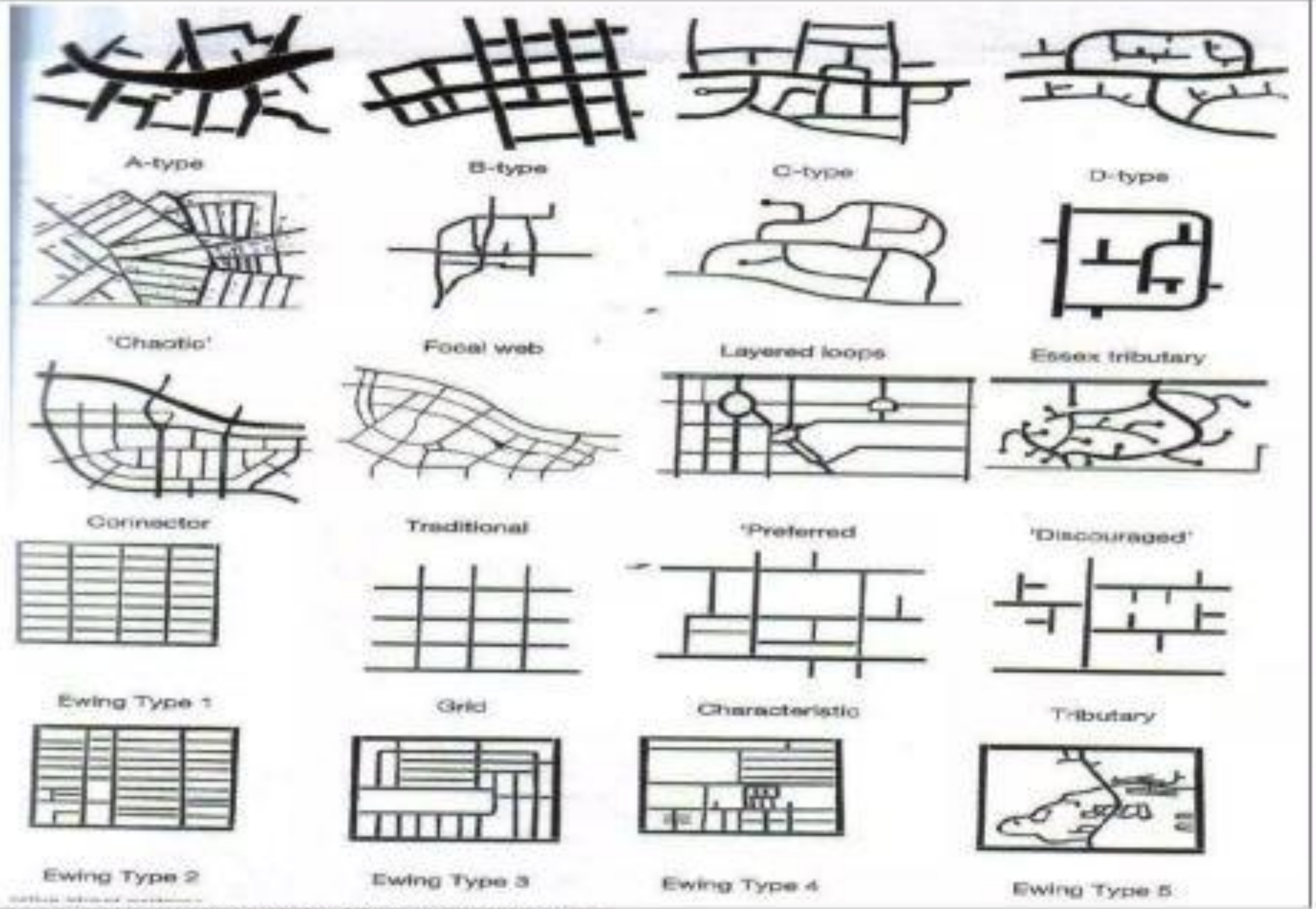


Fig. 3.1a: Sampled Road Network Patterns
Source: Marshall (2005)

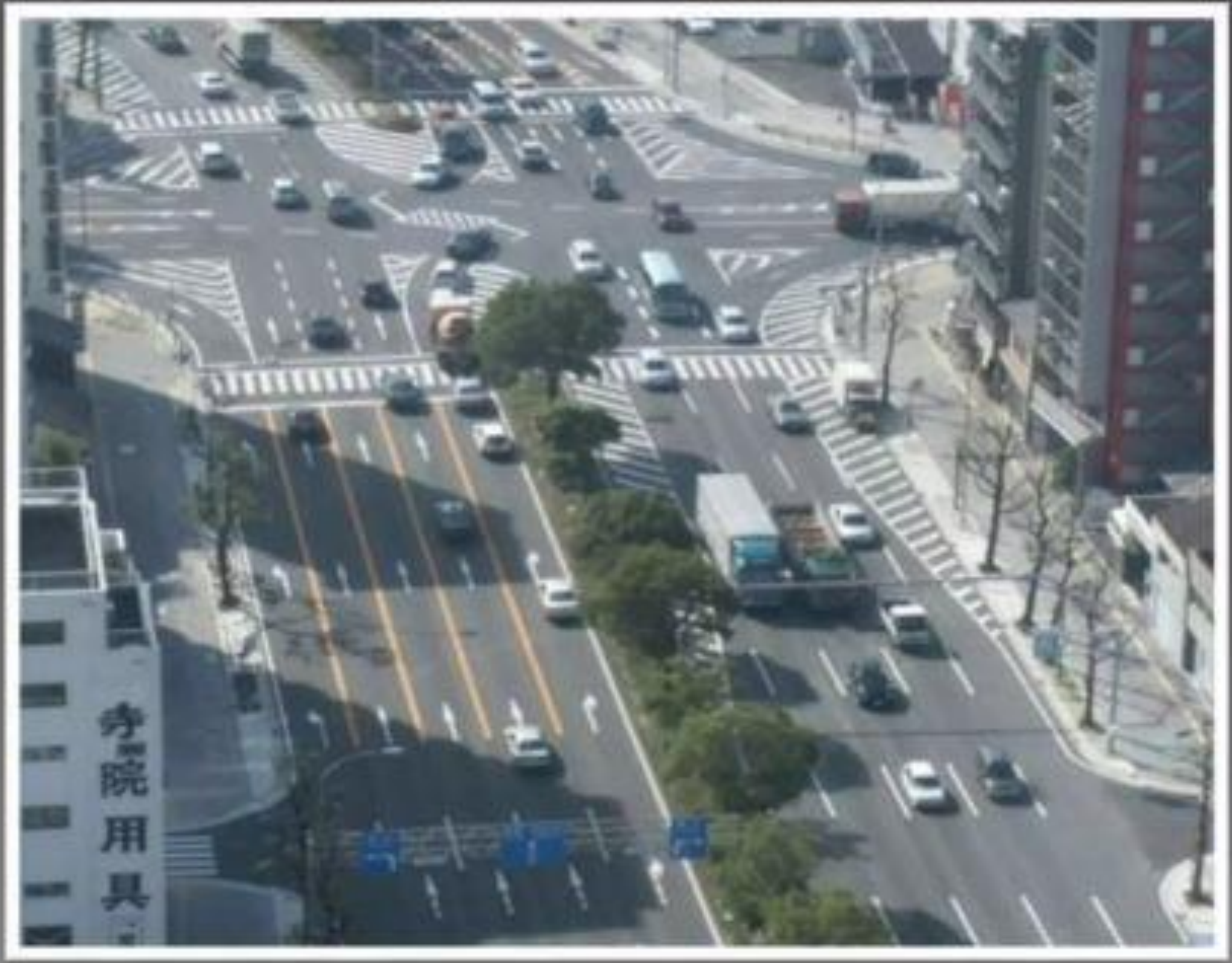
The road network is made up of **Nodal Points**, **Links** (spatial separation) and **Control Facilities** that determine the degree of connectivity and accessibility in the network.

THE ROUTE

- The route in the network consists of primary and secondary roads known as arterial and minor roads respectively.

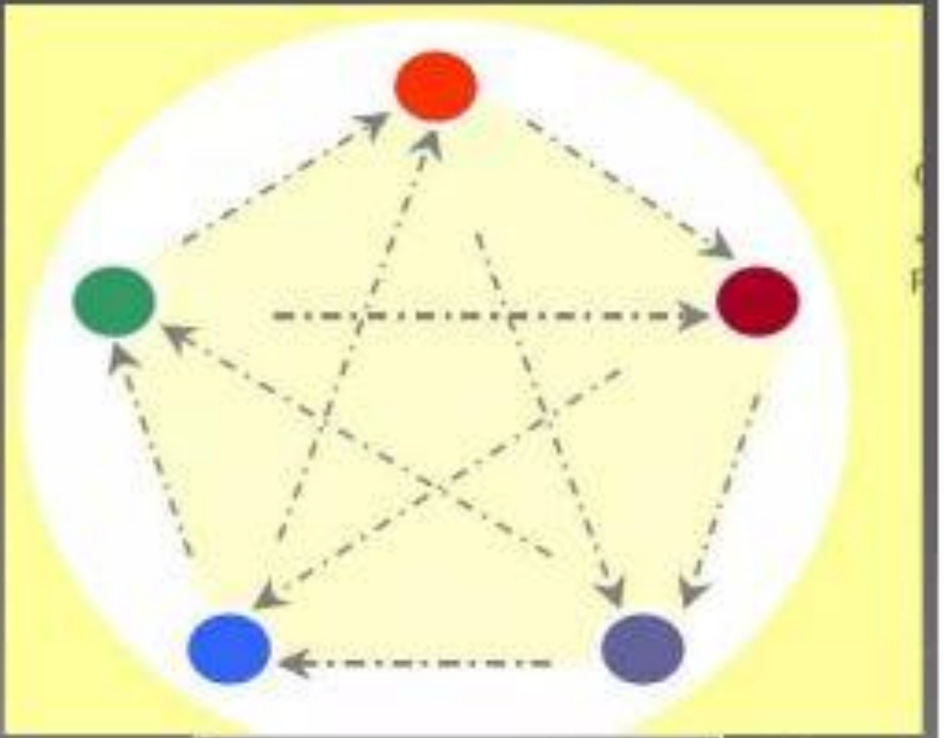
- They have intersections with collector and local streets. In addition, arterial roads link up to expressways and freeways with inter-changes (Wikipedia contributors, 2008).

THE URBAN SETTING



CONCEPTUALIZATION

The urban areas all over the world (countries such as China, France, USA, UK, Nigeria etc) with high population density and loads of human activities tend to increase the construction of roads. This led to high concentration of vehicular & pedestrian movements especially along the access roads.



Nodes and Links

Vision 2040	Characteristics	Construction Concepts	Directions for solutions
	Available Durable Reliable	**Reliable Infrastructure**	• Lifetime engineering • Fast, hindrance-free maintenance • Balancing demand and capacity • Asset management tools
	Energy efficient Sustainable Environment	**Green Infrastructure**	• Saving natural resources • Emission Control
	Accessible Smart Safe	**Safe & Smart Infrastructure**	• Safe design • Smart design • Smart communication • Smart monitoring
	Multi-functional Multi usable Public security	**Human Infrastructure**	• Public security • Multi-functional use • Human design

DESIGN

- Road Network Design Problem (RNDP) has long been recognized to be one of the most difficult and challenging problems in transportation.

- In the past two decades, we have witnessed the development of a vast, growing body of research focused on formulations and solution procedures for the RNDPs, which deal with the selection of either link improvements or link additions to an existing road network, with given demand from each origin to each destination.

Design criteria consist of a detailed list of considerations to be used in negotiating a set of road standards. These include:

- Resource management objectives
- Environmental constraints
- Safety, physical environmental factors (such as topography, climate, and soils)
- Traffic requirements
- Traffic service levels. (i.e Level Of Service)
- Vehicle characteristics

TRAFFIC SERVICE LEVELS DEFINITIONS USED TO IDENTIFY DESIGN PARAMETERS

	A	B	C	D
FLOW	Free flowing with adequate passing facilities.	Congested during heavy traffic such as during peak logging or recreation activities.	Interrupted by limited passing facilities, or slowed by the road condition.	Flow is slow or may be blocked by an activity. Two way traffic is difficult and may require backing to pass.
VOLUMES	Uncontrolled; will accommodate the expected traffic volumes.	Occasionally controlled during heavy use periods.	Erratic; frequently controlled as the capacity is reached.	Intermittent and usually controlled. Volume is limited to that associated with the single purpose.
VEHICLE TYPES	Mixed; includes the critical vehicle and all vehicles normally found on public roads.	Mixed; includes the critical vehicle and all vehicles normally found on public roads.	Controlled mix; accommodates all vehicle types including the critical vehicle. Some use may be controlled to minimize conflicts between vehicle types.	Single use; not designed for mixed traffic. Some vehicles may not be able to negotiate. Concurrent use between commercial and other traffic is restricted.

CRITICAL VEHICLE	Clearances are adequate to allow free travel. Overload permits are required.	Traffic controls needed where clearances are marginal. Overload permits are required.	Special provisions may be needed. Some vehicles will have difficulty negotiating some segments.	Some vehicles may not be able to negotiate. Loads may have to be offloaded and walked in.
SAFETY	Safety features are a part of the design.	High priority in design. Some protection is accomplished by traffic management.	Most protection is provided by traffic management	The need for protection is minimized in by low speeds and strict traffic controls.
TRAFFIC MANAGEMENT	Normally limited to regulatory, warning, and guide signs and permits.	Employed to reduce traffic volume and conflicts.	Traffic controls are frequently needed during periods of high use by the dominant resource activity.	Used to discourage or prohibit traffic other than that associated with the single purpose.
USER COSTS	Minimize; transportation efficiency is important.	Generally higher than "A" because of slower speeds and increased delays.	Not important; efficiency of travel may be traded for lower construction costs.	Not considered.

ALIGNMENT	Design speeds is the predominant factor within feasible topographic limitations.	Influenced more strongly by topography than by speed and efficiency.	Generally dictated by topographic features and environmental factors. Design speeds are generally low.	Dictated by topography, environmental factors, and the design and critical vehicle limitations. Speed is not important.
ROAD SURFACE	Stable and smooth with little or no dust, considering the normal season of use.	Stable for the predominant traffic for the normal use season. Periodic dust control for heavy use or environmental reasons. Smoothness is commensurate with the design speed.	May not be stable under all traffic or weather conditions during the normal use season.. Surface rutting, roughness, and dust may be present, but controlled for environmental or investment protection.	Rough and irregular. Travel with low clearance vehicles is difficult. Stable during dry conditions. Rutting and dusting controlled only for soil and water protection.

Source: *(Transportation Engineering Handbook, USA).*

CHARACTERISTICS

Road network patterns can affect traffic performance, travel behavior, and traffic safety. Thus, a deep understanding of the properties of different network patterns can provide useful guidance for design and improvement of road systems.

HIERARCHY OF ROAD NETWROKS

The hierarchy of roads categorizes roads according to their functions and capacities.

While sources differ on the exact nomenclature, the following slide gives the basic nomenclature.

The basic hierarchy comprises:

1. Arterials Roads
2. Collectors Roads
3. Local roads.

HIERARCHY IN SOME COUNTRIES

UNITED KINGDOM

All UK roads (excluding motorways) fall into the following four categories:

A - roads – major roads intended to provide large-scale transport links within or between areas.

B - roads – roads intended to connect different areas, and to feed traffic between A - roads and smaller roads on the network.

Classified unnumbered – Smaller roads intended to connect together unclassified roads with A and B roads, and often linking a housing estate or a village to the rest of the network. Similar to 'minor roads' on an Ordnance Survey map and sometimes known unofficially as C - roads.

Unclassified – Local roads intended for local traffic. The vast majority (60%) of roads in the UK fall within this category.

FRANCE

Autoroutes

Along with the rest of Europe, France has Motorways or *Autoroutes* similar to the British network. Unlike in the UK, the network is mostly accessible on payment of a toll, which is usually distance-dependent.

Route Nationale

Before the construction of Autoroutes, the *Routes Nationales* were the highest classification of road in France.

Routes Départementales

France (including overseas territory) is split into 100 departments, the second-highest tier of local government, similar to a UK county or US state. These roads vary in quality, from newly built local dual carriageways and downgraded *Routes Nationales*. Generally, they are quieter than the Routes Nationales, and of a reasonable standard.

Routes Communales

In general, each settlement in France is a Commune - akin to a British Civil Parish. They are numbered with a letter C prefix.

ROAD NETWORK PATTERN, ASSESSMENT AND ANALYSIS

The analysis of the road network involves the recognition of the patterns and qualities of the roads.

Many techniques had earlier been used in analyzing road network patterns (Mackaness and Beard, 1993; Thomson and Richardson, 1995; and, Jiang and Harrie, 2004) namely,

- **Connectivity**
- **Shortest path spanning tree, and**
- **Minimum cost spanning tree from graph theory to facilitate structural analysis and road selection in the road networks.**

Modern techniques introduced for the explanation of the effects of accessibility on Urban values range from geographically weighted regression technique, multinomial logit models, to geo-spatial analysis adopting the Geographical Information Systems (GIS).

NETWORK CONTROL, OPERATION AND MONITORING

Monitoring the status of the road network and prevailing traffic conditions is fundamental to road network operations.

Network controllers and operators must have continual access to quantitative and qualitative information to manage and maintain the road network as effectively as possible.

CONTROL CENTRE

CONCLUSION

This review borrows techniques found useful in other fields like operational research, transportation and urban planning to explain and analyze road networks across the world, for the purpose of determining the concept, design approach, characteristics, hierarchy, scope, accessibility and analysis and then control and operation. These have underscored the importance of this review.