An Expanded Functional Classification System for Highways and Streets

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP RESEARCH REPORT 855

An Expanded Functional Classification System for Highways and Streets

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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The needs for highway research are many, and NCHRP can make significant contributions to solving highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement, rather than to substitute for or duplicate, other highway research programs.

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Finally, the contribution and guidance of the NCHRP Project 15-52 panel should be mentioned. Without their hard work and diligence in providing comments, this work would not have been successfully completed.

FOREWORD

By B. Ray Derr
Staff Officer
Transportation Research Board

This report presents an expanded functional classification system for highways and streets that builds upon the current system to provide a better basis for the preliminary engineering of a design project, including developing the purpose and need. In particular, it provides additional contexts beyond urban and rural, facilitates accommodation of modes other than personal vehicles, and adds overlays for transit and freight. Two case studies illustrating application of the expanded system to actual projects are included. The report will be useful to planners and designers and could be useful when developing preliminary designs. A careful agency review is recommended to ensure that the system is well suited to the agency's particular circumstances.

Since 1984, the AASHTO "Green Book" (*A Policy on the Geometric Design of Highways and Streets*) and other roadway design criteria have been based on a functional classification system of a hierarchical network composed of arterials, collector roads, and local roads. This classification is further broken out by an urban or rural designation. This system is described in *Highway Functional Classification Concepts, Criteria and Procedures* (FHWA-PL-13-026). This system of highway classification has been under increasing scrutiny and discussion because of some incompatibilities with context-sensitive design, practical design, and other innovative approaches. The following are some concerns:

- Designation as urban or rural is insufficient to adequately account for the range of contexts for a highway or street.
- The current system is focused on the needs of vehicle drivers and does not help in serving the needs of other types of users (e.g., transit riders, pedestrians, bicyclists). In particular, it does not help with design decisions that must balance benefits for one mode against disbenefits for another (e.g., narrower lanes that benefit pedestrians but make it harder for trucks to use the road).
- Classification leads to recommended or limited design choices that may not be optimal for the particular facility. These restrictions promote "designing to standards" rather than a careful consideration of the safety, operational, and other impacts of design decisions.
- The public often questions the use of these classifications as the basis for design decisions.

In NCHRP Project 15-52, the University of Kentucky and Nelson\Nygaard reviewed the current functional classification system as well as alternative systems that have been used by transportation agencies internationally. Strengths and weaknesses were assessed to inform the development of a composite system that better meets the needs of planners and designers. Lastly, possible impacts on other uses of the current functional classification system were assessed (e.g., project funding, federal reporting) to prevent unintended consequences.

For more information on the research performed, please see *NCHRP Web-Only Document 230: Developing an Expanded Functional Classification System for More Flexibility in Geometric Design*.

Readers of this report will also be interested in the results of the following NCHRP projects that complement this report:

- NCHRP 15-47, available as *NCHRP Research Report 839: A Performance-Based Highway Geometric Design Process* (http://www.trb.org/main/blurbs/175375.aspx)
- NCHRP 15-50, to be published as *NCHRP Research Report 876: Guidelines for Integrating Safety and Cost-Effectiveness into Resurfacing, Restoration, and Rehabilitation (3R) Projects*

CONTENTS

Introduction

This guidance has been developed to demonstrate the application of the Expanded Functional Classification System (Expanded FCS) for highways and streets. The Expanded FCS provides a flexible framework, which can replace the existing functional classification scheme, in order to facilitate optimal geometric design solutions that take into account environmental context, road functions, and user needs. This system builds upon existing efforts of state departments of transportation (DOTs) that have initiated and implemented a new classification system to address contextual multimodal deficiencies of the existing classification system.

The major objective of the Expanded FCS is to provide enhanced information to designers to better inform the design decision process through the process shown in Figure 1. This enhanced information is provided by increasing the resolution of a roadway's design context to enable understanding of the role the roadway plays within the community; identifying the role of the roadway within the local, city, and regional transportation network; and identifying the multiple roadway user groups and their priority within the design corridor. [In this document, the term "roadway" is considered to include all facilities intended for travel in the right-of-way (e.g., travel lanes, shoulders, bicycle lanes, sidewalks).]

Having this information within the expanded framework of the functional classification system gives practitioners a practical tool for determining appropriate design criteria and elements by helping them better understand the impacts of the tradeoffs necessary to balance user needs and safety, and address other community issues.

Proper contextual roadway designs require an understanding of the function of the roadway within its current and expected future context and the needs of the potential roadway users. The Expanded FCS and associated design matrix can assist in identifying the preliminary requirements for proper consideration of roadway context and user needs. This approach provides the framework for determining user needs and ordering

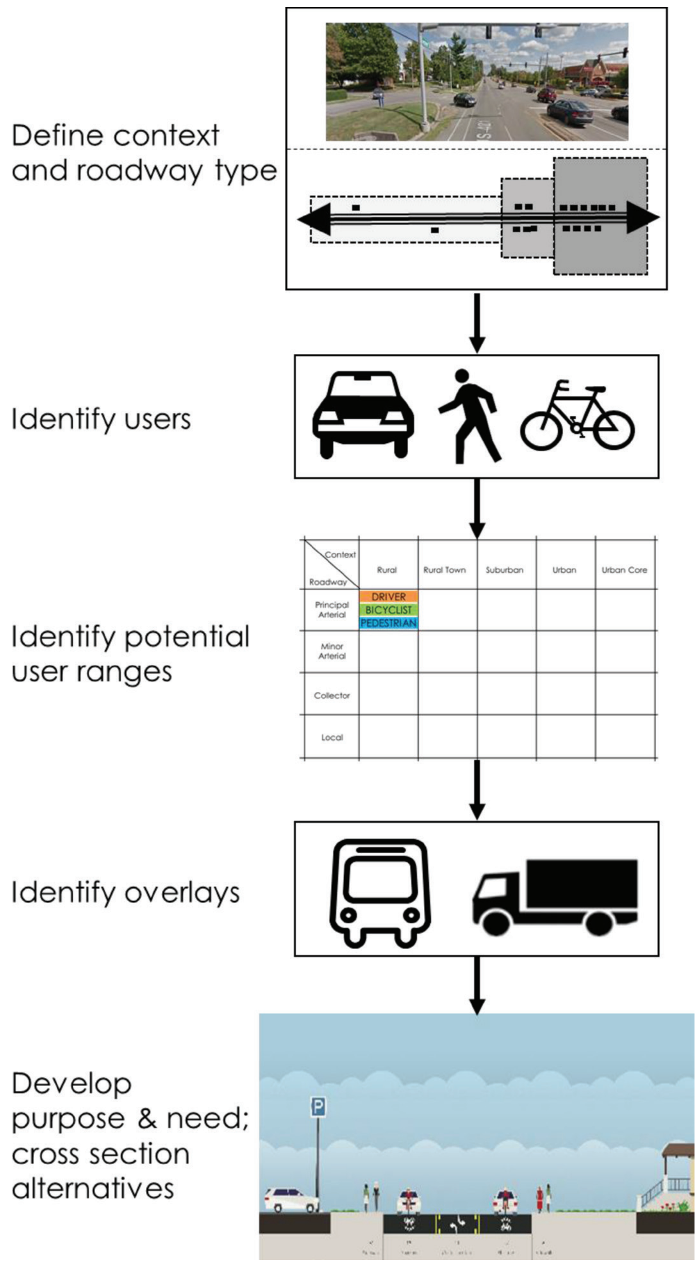


Figure 1. Implementation steps for Expanded FCS.

Proper contextual roadway designs require an understanding of the function of the roadway within its current and expected future context and the needs of the potential roadway users.

user levels on a given roadway. It assumes the planner/designer can develop alternative system/network strategies for meeting all user needs. This process can assist in providing input and refinement to the purpose and need document, which establishes the framework for the design to be developed. In the end, the final balancing of facilities to accommodate user needs becomes part of the process of following project development principles for achieving context sensitive solutions.

Relationship to Other Guides

This guidance supplements and expands on policies, guides, and standards commonly used by designers and planners of state and local transportation agencies and engineering and public works divisions. It provides a simple yet dynamic approach that integrates several processes and tools into a comprehensive planning and design framework. The Expanded FCS reflects current design thinking and can be used in conjunction with other important publications including *A Policy on Geometric Design of Highways and Streets* (AASHTO 2011); *Guide for the Planning, Design and Operation of Pedestrian Facilities* (AASHTO 2004b); *Guide for the Development of Bicycle Facilities* (AASHTO 2012); *A Guide for Achieving Flexibility in Highway Design* (AASHTO 2004a); *Guide for Geometric Design of Transit Facilities on Highways and Streets* (AASHTO 2014); *Urban Street Design Guide* (NACTO 2013); *Urban Bikeway Design Guide* (NACTO 2011); and *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach* (ITE and Congress for the New Urbanism 2010), as well as complementary state department of transportation design policies and manuals, local municipal street design standards, urban design guides, and guidance published by other standard-setting organizations.

This guidance adds to information found in the previously mentioned publications by providing comprehensive guidance on the following:

1. Expanding the context definitions beyond the binary urban/rural distinction and recognizing the network importance of roadway types.
2. Identifying the multiple roadway user groups and their priority.
3. Defining a balanced approach for potential design ranges by considering a broader set of factors for planning and designing roadways.
4. Considering other modal (transit and freight) overlays and their implications for roadway design.
5. Understanding the purpose and need for a project in order to develop design alternatives to accommodate drivers, bicyclists, pedestrians, and transit/freight users in an efficient and contextually appropriate design.

Expanded FCS Overview

Context

The five distinct contexts identified in the Expanded FCS have been determined to not only represent unique land use environments, but also identify distinctions that require wholly different geometric design practices in terms of desired operating speeds, mobility/access demands, and user groups. The context categories (illustrated in Figure 2) are as follows:

1. **Rural**: Areas with lowest density, few houses or structures (widely dispersed or no residential, commercial, and industrial uses), and usually large setbacks.
2. **Rural Town**: Areas with low density but diverse land uses with commercial main street character, potential for on-street parking and sidewalks, and small setbacks.
3. **Suburban**: Areas with medium density, mixed land uses within and among structures (including mixed-use town centers, commercial corridors, and residential areas), and varied setbacks.

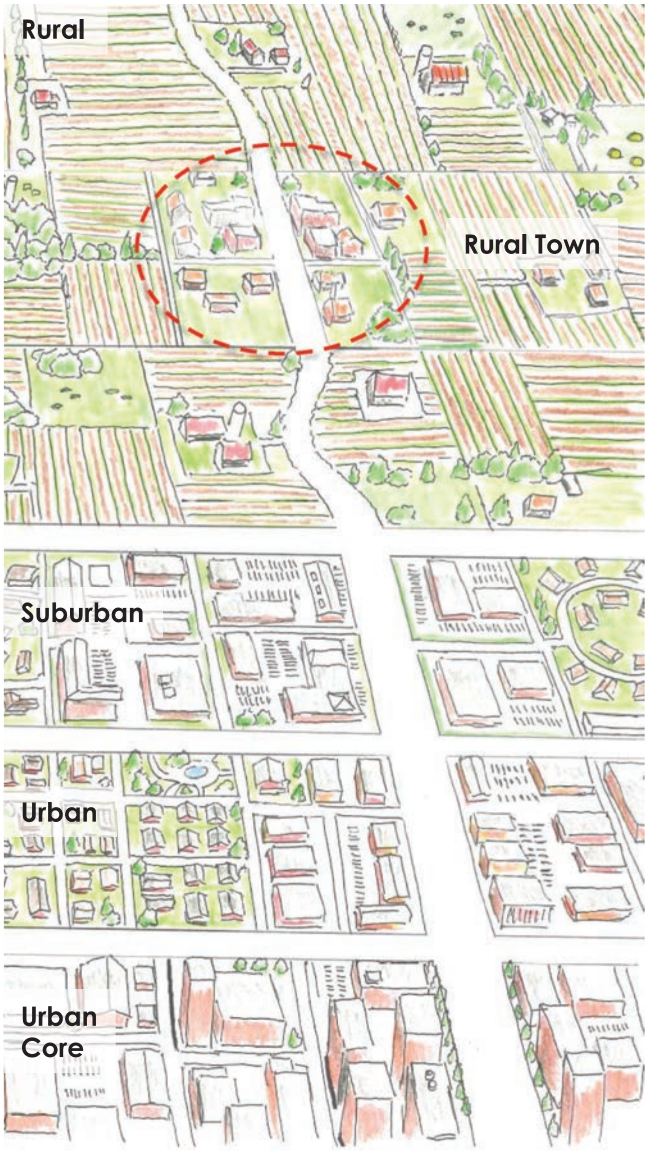


Figure 2. Five context categories.

4. **Urban**: Areas with high density, mixed land uses and prominent destinations, potential for some on-street parking and sidewalks, and mixed setbacks.
5. **Urban Core**: Areas with highest density, mixed land uses within and among predominately high-rise structures, and small setbacks.

Roadway Types

Functional classification has, for decades, relied on three general thoroughfare types for classification: arterials, collectors, and locals (more recently, arterials have been further subdivided into *principal* and *minor*, resulting in four classification types currently being used). Decades of familiarity with these terms, and many federal funding mechanisms being based in whole or in part on these four classifications, have resulted in continued use of the same labels.

The roadway types used in the Expanded FCS are based on the function of the roadway within its network and the connectivity the roadway provides among various centers of activity. Network function is defined based on the regional and local importance of the roadway to vehicle

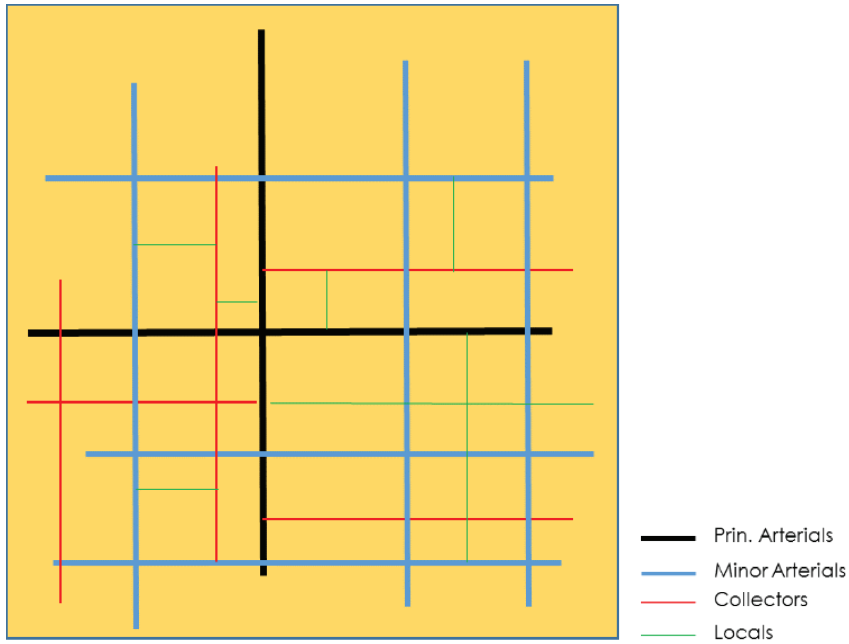


Figure 3. Four of the five Expanded FCS roadway types.

movement. Connectivity identifies the types of activity centers and locales that are connected with the particular roadway. The Expanded FCS roadway types (illustrated in Figure 3) are as follows:

1. **Interstates/Freeways/Expressways**: Corridors of national importance connecting large centers of activity over long distances.
2. **Principal Arterials**: Corridors of regional importance connecting large centers of activity.
3. **Minor Arterials**: Corridors of regional or local importance connecting centers of activity.
4. **Collectors**: Roadways of lower local importance providing connections between arterials and local roads.
5. **Locals**: Roads with no regional or local importance for local circulation and access only.

The Expanded FCS will not address context types for Interstates, Freeways, and Expressways because designs for these facilities are based on federally developed standards with little flexibility.

The primary difference between the Expanded FCS and existing functional classification system is the absence of differentiation between minor and major collectors. These roadway types were combined because of the inability to sufficiently distinguish design, operating, and modal characteristics of the two types. Therefore, existing classifications of roadways may be readily transferred from one system to the other; however, special attention may be needed in addressing minor collectors, as in some cases these roadways may be better classified as local roads. Note that the major/minor collector distinction currently serves as the dividing line between eligible-for-federal-aid and ineligible-for-federal-aid roadways within rural areas. Adoption of the Expanded FCS would require a new definition for eligible/ineligible-for-federal-aid roadways.

Roadway Users

The Expanded FCS identifies three user groups: drivers, bicyclists, and pedestrians. The term "drivers" refers to automobile drivers; drivers for transit and freight are handled as an overlay

(discussed in the next section). Fundamental design accommodation elements for each mode are also identified, and design ranges for each are provided based on the overall roadway network type. Various user needs should be identified from the outset and considered when balancing and making the necessary tradeoffs among design elements in order to develop contextually appropriate multimodal solutions.

Driver accommodations are identified as follows:

- Operating speed.
- Mobility (freedom of movement and delay within the traffic stream).
- Access to adjacent properties/roadways.

Similar to automobile roadway types, bicycle facility classes, where established, identify priority and network importance of bicycle facilities. The primary difference in automobile and bicycle networks is the scale of the bicycle network is smaller, consistent with the overall range of bicyclists. Three standard bicycle facility classes have been established:

- **Citywide connector** connects the city or major activity centers and stretches over several miles.
- **Neighborhood connector** connects neighborhoods or sub-areas, which establishes connections to higher-order facilities or local activity centers.
- **Local connector** provides internal connections of short lengths within neighborhoods.

Bicycle facility designs are generally categorized based on the amount of separation between the facility and motorized traffic, which varies according to the bicycle route's classification and the roadway type it is on. Bicycle facility designs are categorized as follows:

- High separation: Facility is physically separated from traffic by a physical barrier or lateral buffer.
- Medium separation: Facility is a dedicated space adjacent to motorized traffic.
- Low/No separation: Facility is joint use for motorized and non-motorized traffic.

Pedestrian facilities are generally categorized according to their width. This document uses the following categories:

- Site-specific facilities for pedestrians, due to absence or rare occurrence of pedestrians.
- Minimum width—the minimum required width based on local ADA requirements.
- Wide width—wider than the minimum required width for a pedestrian facility.
- Enhanced width—wider than the wide width to accommodate congregating groups of pedestrians, street furniture, and pedestrian activities.

In addition to the facility width, separation of the pedestrian facility from the travel way is an important consideration. However, this design element is primarily dependent on the design speed of the automobile facility rather than on the level of activity on the roadway. Typically, medium- and high-speed automobile facilities will require pedestrian facilities to be separated from the travel way by a tree lawn, landscaped buffer, bicycle lanes, or parking areas. For low-speed automobile facilities, the sidewalk may be attached to the curb, directly adjacent to the travel way without a need for a buffer area.

The correlation of context, roadway types, and users results in the Expanded FCS matrix (Figure 4). This allows for the development of a multimodal, context-based design with some degree of flexibility. Each matrix cell defines the various users (drivers, bicyclists, and pedestrians) and identifies which characteristics are to be balanced.

The accommodation of drivers and bicyclists is considered across the entire network and reflected in the roadway-type classification of each facility. The combination of facilities will provide the required coverage to address and balance the needs of both user groups based on the

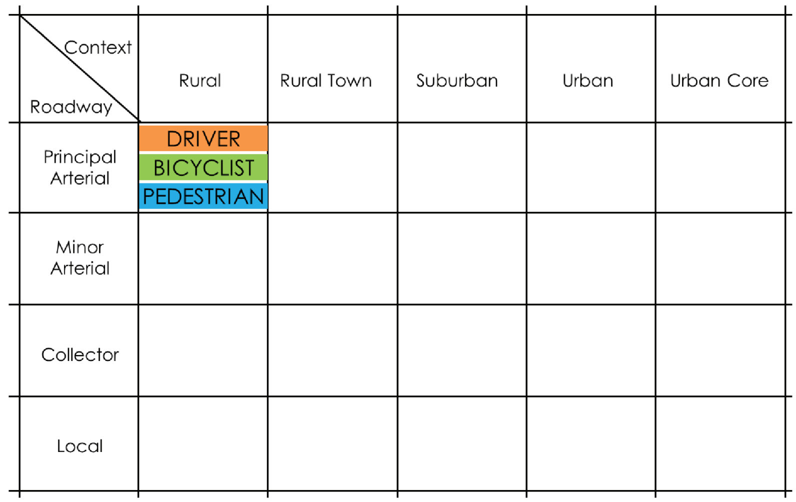


Figure 4. Expanded FCS framework user matrix.

roadway context. Pedestrian needs are also defined based on the roadway context, but there is no specific network classification for facilities to accommodate their needs. It should be also noted that a corridor may transition into different contexts over its length and this will be reflected in the design considerations and cross sections.

Overlays

In addition to the context, roadway type, and user groups presented in the matrix, other design needs may be addressed through the application of overlays to handle special users, such as transit and freight, or other demands. Overlays add further complexities and require their design demands to be accounted for in the solutions developed. Users of the Expanded FCS could also develop additional overlays as appropriate to address specific area needs.

Application

When approaching a corridor design, the design team can utilize the Expanded FCS to understand the role the roadway will play both in the environment in which it will be constructed and within the network. Various user groups that must be accommodated within the roadway are also identified, so that their competing needs and spatial demands may be considered. To assist in balancing and prioritizing these needs, the importance of the roadway within the individual network of each road user is also identified.

This approach assumes that the Expanded FCS will be initially applied to all state-maintained roadways and replace the existing functional classification system. It is anticipated that the context and roadway types for each roadway will be periodically reviewed and revised (consistent with current practices) as needed to accommodate change.

It is also possible that a transportation agency may elect to implement Expanded FCS in a staged approach where the changes are considered at a project level. Once a project is started, the project team will have to review the context and roadway-type designations and determine whether these are applicable or require any adjustments. Once this determination is made, the project team can proceed with validating each component of the classification process, including context, roadway type, and users, and proceed in developing a contextual design utilizing context sensitive solutions (CSS) to balance project needs and community values. This process assumes that the project team will be diligent in determining the complexities of the context,

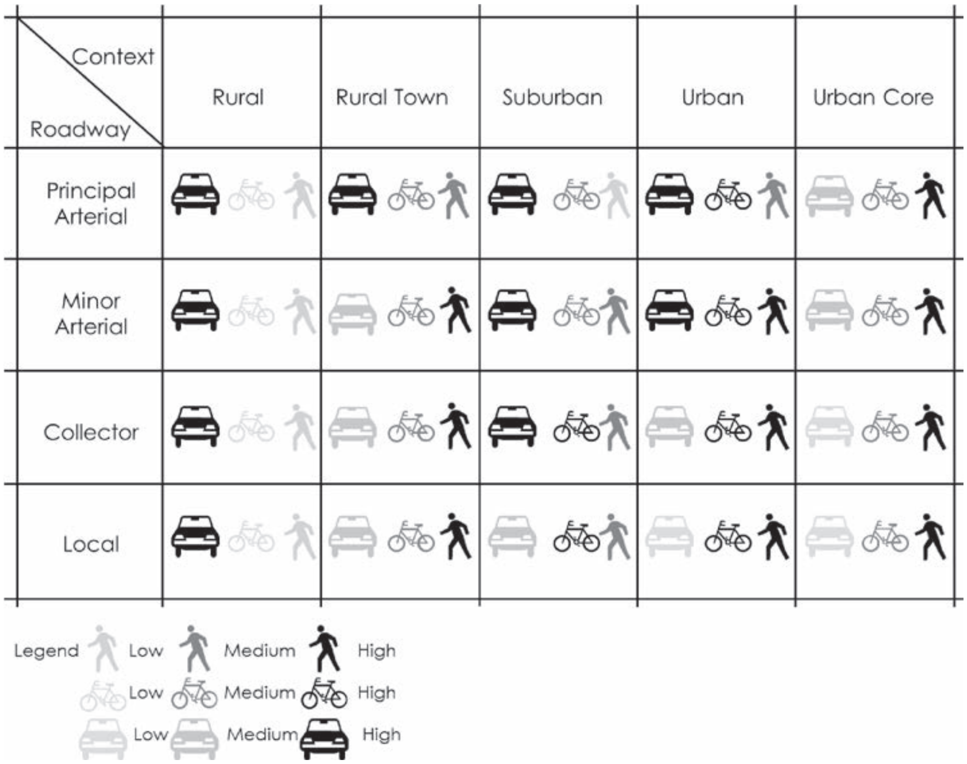


Figure 5. Typical user priorities in the Expanded FCS.

both current and future, as well as all other subtleties associated with the social and natural environment surrounding the project. Once the appropriate matrix cell that addresses the context–roadway environment is defined, the project team could start developing the preliminary designs considering community comprehensive plans including the future land use plan, and any other pertinent information (including zoning ordinances) in order to develop an evolving design that could address potential changes in the roadway context. The need for a robust CSS process (involving all stakeholders) is integral to the successful implementation of the Expanded FCS and development of contextually appropriate designs.

Balancing modal needs is central to Expanded FCS. It is understood that there is the possibility that the designer will not be able to provide the best facilities for all the users at all times and at the same location in all roadways. There will be instances where the mobility needs for some groups require adjustments and/or consideration of alternative routes as well as the use of revised system overlays. On high-speed arterials, for example, bicycles and pedestrians may need to be accommodated on a parallel roadway with lower speeds where the proper designs could be attained to accommodate their mobility needs. Likewise, a corridor with high bicycle demand and mobility needs may require the presence of bicycle facilities that would lower speeds and possibly reduce the number of available vehicle lanes if there is limited right-of-way. Design considerations for how to achieve this are presented in the Modal Considerations and Accommodations chapter.

Figure 5 shows the overall matrix concept identifying potential levels of use, i.e., typical user priorities, for each possible mode. Typical uses are based on current traffic trends and existing networks, and they should not be viewed as modal accommodation for each context and roadway-type combination.

Context Settings

Overview

The Expanded FCS provides five context categories to move beyond the traditional urban–rural dichotomy. Five categories allow for a more distinct or specific position along the contextual continuum, which ranges from very little development to very highly developed. The context of a project situation can be compared to the five Expanded FCS categories in order to determine the best fit. The primary factors considered within each category are as follows:

- Density (existence of structures and structure types).
- Land uses (primarily residential, commercial, industrial, and/or agricultural).
- Building setbacks (distance of structures to adjacent roadways).

The continuum is not perfectly gradual for the determining factors among the five categories, and therefore some degree of situational analysis, experience, and professional judgment is required. Furthermore, in real-world situations, discontinuities will exist even when the overall assessment is clear. The Expanded FCS context assessment does not rely on a quantitative analysis (neither persons per square mile nor building square footage) and can be used in states with broad comparative development differences between urban cores or rural areas. These differences are largely a matter of scale and intensity (additionally, the activity patterns vary significantly). The Expanded FCS does not provide quantitative guidance for transitional areas between categories. However, transitional areas remain an important design consideration, affecting safety, function, and design detail. This issue needs to be addressed at the project level and associated treatments need to be considered at that level. The context category and roadway-type decisions become the starting point that leads to geometric design choices, because these choices address the modes to be accommodated and their interactions. A robust CSS process (involving all stakeholders) can assist the project team in understanding the various project issues and modal needs in order to develop a contextually appropriate design.

Population growth and migration, along with economic expansion and geographic features, become major influences on development, which greatly influences settlement patterns. Land areas adjacent to expanding urban development are subject to significant discontinuities along the development continuum. Sporadic development of residential and/or commercial type may occur on the margin of all categories. Industry may be spotted throughout the landscape but is highly tied to available transportation facilities and skilled population. Even under the mostly static development pressure, incongruences will occur among the major factors in any road segment under consideration. Transportation professionals must assign the context category based upon generally observed homogeneity within and among the determining factors as well as consideration of expected future changes in land use patterns.

The rural-to-urban-core continuum in a predominately rural state may differ significantly from the rural-to-urban-core continuum in a predominately urban state or in states that have extremely large-scale urban areas with intensive development. For example, New York City, Chicago, Miami, Atlanta, and Los Angeles clearly have unique urban development patterns and intensities. Additionally, differences occur regionally in structural types for some uses such as housing. As an example, housing structure type can vary from the single detached structure to duplex structures to row houses to condominium multistructure complexes to medium-density low-rise apartment structures to high-density high-rise apartment structures. Some areas may not have such a variety of types or a majority of one type dependent upon the time period of development or other development factors. Agencies may need to supplement the photographs/graphic examples of the Expanded FCS to better reflect the actual nature of the five categories in their jurisdictions. Some cases may warrant additional context categories or subcategories.

Rural areas across the United States also have extreme geological differences that include mountains, swamps, plains, and desert, which hinder or significantly impede even sparse development. Poor soil conditions will also affect the potential for agricultural production in the rural area. However, even these areas may require roadways for regional or national system network connectivity. At the other end of the continuum lies the urban core, which may be largely devoid of regular traffic except at the fringes. Most urban cores encourage and facilitate pedestrian traffic with sidewalks, plazas, and pedestrian bridges. Typically, urban areas accommodate and encourage bicycle use. Urban and urban core areas have the highest volume of activity and the patterns of activity are usually complex.

The roadway planning and design process should take into account anticipated future context conditions that are often defined through state, regional, and local planning documents. At the state level, there are usually statewide long-range transportation plans that not only include vehicle transportation but also have modules or separate plans that address the future needs of the other users. These plans are more likely to exist in high-growth states with larger populations and larger metropolitan areas. At the regional and city/county level, there are usually finer-grained transportation plans with more specificity of corridor needs and desires for all modes. Local jurisdictions have comprehensive plans, zoning ordinances, subdivision regulations, and possibly special overlay districts that guide future context development. Some districts may have transportation/land use studies that address future corridors, and urban areas may have street design guidelines; all of which may influence future roadway context. Even for some rural roads and rural towns/villages, there are planning studies that may address a desired future roadway context. The caution here is that some plans with their varying horizons have more validity than others. Some areas grow faster than projected/planned, while others decline faster than expected/planned. The assessment of future changes will take some reality testing with stakeholders/officials/designers/planners to determine the likelihood of future context change.

Determining Context: Factors and Process

Three primary factors are used to determine context for the Expanded FCS:

- Density
- Land uses
- Building setbacks

These factors are easy to identify by observing the landscape adjacent to an existing or planned roadway. Some other features such as topography and soil type, land value, population density, and building square footage can generally suggest points on the development continuum. All of these are relative to context, but the Expanded FCS does not rely on these features.

The key questions to determine a roadway segment's context category are: (1) Does it for the most part meet the category's primary factors?, and (2) Does the landscape adjacent to the roadway look similar to the photographs/graphic examples? The Expanded FCS provides assessment

Table 1. Expanded FCS context categories and primary factors.

Category	Density	Land Use	Setback
Rural	Lowest (few houses or other structures)	Agricultural, natural resource preservation, and outdoor recreation uses with some isolated residential and commercial	Usually large setbacks
Rural Town	Low to medium (single-family houses and other single-purpose structures)	Primarily commercial uses along a main street (some adjacent single-family residential)	On-street parking and sidewalks with predominately small setbacks
Suburban	Low to medium (single- and multifamily structures and multistory commercial)	Mixed residential neighborhood and commercial clusters (includes town centers, commercial corridors, big box commercial and light industrial)	Varied setbacks with some sidewalks and mostly off-street parking
Urban	High (multistory, low-rise structures with designated off-street parking)	Mixed residential and commercial uses, with some institutional and industrial and prominent destinations	On-street parking and sidewalks with mixed setbacks
Urban Core	Highest (multistory and high-rise structures)	Mixed commercial, residential and institutional uses within and among predominately high-rise structures	Small setbacks with sidewalks and pedestrian plazas

terminology and selected photographs/graphic views to assist in determining the most appropriate current and future context category of a roadway segment. The user must recall that there will be exceptions along any roadway, and these occur more often in the vicinity of urban areas.

The following sections include a description and photographs/graphic examples of each category based on the primary factors outlined in Table 1.

Rural

The rural context category ranges from no development (natural environment) to some light development (structures), with sparse residential and other structures mostly associated with farms. The land is primarily used for outdoor recreation, agriculture, farms, and/or resource extraction. Occasionally a non-incorporated hamlet or village will include a few residential and commercial structures. In a rural setting, there are no or very few pedestrians, bicyclists are most likely of recreational nature, and transit is limited or non-existent. However, some of these may be present in the vicinity of a hamlet or village. Examples of commercial uses include a general store, restaurant, and filling station—these are usually located at crossroads. Setbacks for structures in rural areas are usually large but can certainly shrink in the immediate vicinity of a hamlet or village. Transit service availability is often absent but does vary widely depending on the jurisdiction. On-demand service is typically found to provide special service.

Key Rural Characteristics

- Lowest density (few houses or other structures).
- Agricultural, natural resource preservation, and outdoor recreation uses predominate, with isolated residential and commercial structures.
- Usually large setbacks or constrained setbacks due to topography.

Figures 6 through 8 show photographs that exemplify the types of views seen from roads in rural areas.

Photograph to the left shows a rural agricultural area under farm use. A residence and farm buildings are setback from the roadway. Farm equipment used for irrigation and fences are in the foreground.

Figure 6. Rural farm use.

Photograph to the left shows natural forested area. This rural area is not built upon and is not being used for agricultural purposes.

Figure 7. Rural natural environment.

(a) (b) (c)

(a) Only one residential structure is seen in the top right. (b) Small-scale resource extraction with agricultural use. (c) Cattle ranch.

Figure 8. Variety of rural context settings.

Rural Town

The rural town category is characterized by low density (low-rise—one or two story—structures) but a concentrated development of diverse uses—residential and commercial. Rural towns are generally incorporated but have limited government services. Some exceptionally larger rural towns may also serve as county/parish/borough seats with court houses and other government services. Rural towns usually have a roadway section that has a main street character (or even a town square) with on-street parking and sidewalks and in some cases bicycle lanes. Transit is uncommon in these areas. The diversity of use can include a variety of commercial establishments to serve the surrounding rural area. Some relatively compact residential uses can be expected and possibly schools. The setbacks for structures are relatively small.

Key Rural Town Characteristics:

- Low- to medium-density residential (single-family houses and other single-purpose structures).
- Commercial uses predominate along main streets (ranging from lower to higher densities).
- On-street parking and sidewalks with predominately small setbacks.

Photographs in Figure 9 capture scenes that are typical of rural towns.

(a) (b)

(a) Variety of commercial establishments along a rural town's main street having sidewalks and on-street parking. (b) Single-family residential use on adjacent street.

Figure 9. Rural town with main street.

Suburban

Locations classified as suburban include a diverse range of commercial and residential uses that have a medium density. The buildings tend to be multistory with off-street parking. Sidewalks are usually present, and bicycle lanes may exist. Sometimes the development includes suburban town centers or commercial corridors. The range of uses encompasses health services, light industrial (and sometimes heavy industrial) uses, quick-stop shops, gas stations, restaurants, and schools and libraries. Typically, suburban areas rely heavily on passenger vehicles, but some transit may be present. Residential areas may consist of single and/or multifamily structures. Setbacks are varied. Suburban areas are usually connected and closely integrated with an urban area. In addition, suburban areas may have well-planned and well-arranged multi-uses that encourage walking and biking. Planned multi-use clusters may integrate residential and commercial areas along with schools and parks. It is important for project teams to understand the activity patterns these areas support and future development intentions.

Key Suburban Characteristics

- Low to medium density (single-family structures predominate with some multifamily structures and multistory commercial).

(a) (b)

Both (a) residential and (b) commercial areas accommodate off-street parking and have perimeter sidewalks.

Figure 10. Residential and commercial medium-density structures in a suburban area.

- Mixed residential neighborhood and commercial clusters (includes town centers, commercial corridors, big box commercial and light industrial use).
- Varied setbacks with some sidewalks and mostly off-street parking.

The photographs in Figure 10 capture typical suburban landscapes.

Urban

Urban locations are high density, consisting principally of multistory and low- to medium-rise structures for residential and commercial use. Areas usually exist for light and sometimes heavy industrial use. Many structures accommodate mixed uses: commercial, residential, and parking. Urban areas usually include prominent destinations with specialized structures for entertainment, athletic, and social events as well as conference centers and sometimes could be considered the main street of the town. Various government and public use structures exist that are accessed regularly. Streets have minimal on-street parking. Wide sidewalks and plazas accommodate more intense pedestrian traffic, while bicycle lanes and transit corridors are frequently present. Off-street parking includes multilevel structures that may be integrated with commercial or residential uses. Due to the differences in developmental scale among urban areas as well as growth demand,

(a) (b)

(a) Low-rise commercial structures with minimum-width sidewalks. (b) Low-rise residential and mixed commercial structures.

Figure 11. Urban mixed use.

urban–urban core context boundaries change over time with the urban core area expanding in high-growth situations and possibly contracting in low- or no-growth situations.

Key Urban Characteristics:

- High density (multistory low-rise structures with designated off-street parking).
- Mixed residential and commercial uses, with some institutional industrial uses and prominent destinations.
- Minimal on-street parking and sidewalks with closely mixed setbacks.

The photographs in Figure 11 capture views of the urban landscape from roadways.

Urban Core

Urban cores house the highest level of density with its mixed residential and commercial uses accommodated in high-rise structures. While there may be some on-street parking, it is usually very limited and time restricted. Most parking is in multilevel structures attached or integrated with other structures. The area is accessible to automobiles, commercial delivery vehicles, and public transit. Sidewalks and pedestrian plazas are present along with multilevel pedestrian bridges connecting commercial and parking structures. Bicycle facilities and transit corridors are typically common. Some government services are available, while other commercial uses predominate, including financial and legal services. Structures may have multiple uses, and setbacks are not as generous as in the surrounding urban area.

Figure 12. Pedestrian plaza (foreground) and hotel convention center.

(a)

(b)

(a) Highest density urban core with high-rise structures and surface transit (underground transit may also exist). Sidewalks are present with minimum setbacks and little or no on-street parking. (b) Mixed uses with a pedestrian plaza.

Figure 13. Urban core.

Urban Core

- Highest density (multistory and high-rise structures).
- Mixed commercial, residential, and institutional uses within and among predominately high-rise structures.
- Small setbacks with sidewalks and pedestrian plazas.

The photographs in Figures 12 and 13 depict street views of an urban core.

Note: See Case Study 1 for a demonstration of the full range of context settings along an arterial.

Transportation Networks

Automobile, Bicycle, and Pedestrian Networks

Automobile Network

For decades, functional classification has relied upon three general thoroughfare types: arterials, collectors, and locals. More recently, arterials have been further subdivided into *principal* and *minor*, resulting in four classification types that are now in common use. Because of decades of industry familiarity with these terms and because many federal funding mechanisms are based, in whole or in part, on these four classifications, the Expanded FCS retains the same labels.

The simplicity of the current functional classification is both its strength and weakness (Aubrach 2009). This simplicity has facilitated effective communication among policymakers, planners, designers, and citizens. However, this simplistic approach does not recognize all other layers, users, and functions a roadway is often called upon to fulfill. As such, it does not allow for a more complete approach in designing streets and other thoroughfares.

The Expanded FCS roadway types follow basic transportation system functions and are defined based on their network function and connectivity (Figure 14). Key characteristics of each roadway type are as follows:

1. **Interstates/Freeways/Expressways**—Corridors of national importance providing long-distance travel
   - Limited access.
   - Through traffic movements.
   - Primary freight routes.
   - Possible transit network support.
   - No pedestrian or bicycle traffic.
   - Guided by FHWA design standards.
2. **Principal Arterial**—Corridors of regional importance connecting large centers of activity
   - Through traffic movements.
   - Long-distance traffic movements.
   - Long-haul public transit buses.
   - Primary freight routes.
3. **Minor Arterial**—Corridors of local importance connecting centers of activity
   - Connections between local areas and network principal arterials.
   - Connections for through traffic between arterial roads.
   - Access to public transit and through movements.
   - Pedestrian and bicycle movements.
4. **Collector**—Roadways providing connections between arterials and local roads
   - Traffic with trips ending in a specific area.
   - Access to commercial and residential centers.

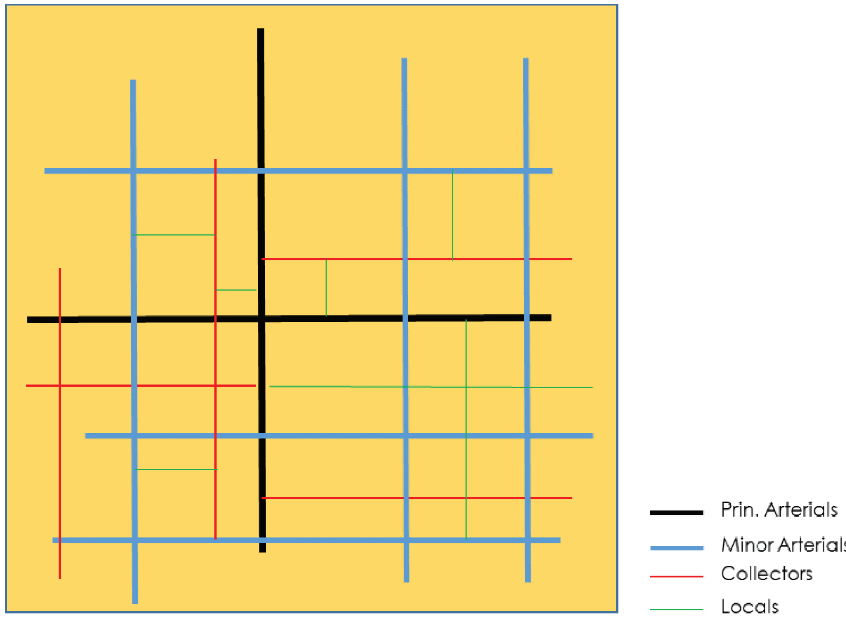


Figure 14. Example of four-category network.

- Access to public transportation.
- Pedestrian and bicycle movements.

5. **Local**—All other roads
   - Direct property access—residential and commercial.
   - Pedestrian and bicycle movements.

Interstates/Freeways/Expressways are not addressed in the Expanded FCS, and they are not included in the Expanded FCS matrix because FHWA design standards govern their design.

The route's physical connectivity does not indicate the desired speed range. Rather the context itself has a greater influence on the facility speed and the associated cross section of the roadway used to guide the drivers' speed. As an example, even though a principal arterial may connect multiple cities in a region, if it traverses an urban core area, it should be designed as a low-speed urban roadway capable of accommodating all users, not a high-speed facility focused only on automobile traffic.

In addition to connectivity, other factors may be used to determine the roadway type. Each of these factors is identified and discussed in the following subsections.

Efficiency of Travel

Trip makers traveling in a private vehicle will typically seek out roadways that allow them to travel to their destinations with as little delay as possible in the shortest amount of time. Therefore, higher-order driver facilities accommodating such travel should be planned within a network to connect major centers of activity.

Route Spacing

Directly related to network definition is the concept of distance (or spacing) between routes. For a variety of reasons, it is not feasible to provide high-speed facilities to accommodate every possible trip in the most direct manner possible or in the shortest amount of time. Ideally, regular and logical spacing between routes of different classifications exists. High-separation-level routes should be spaced at greater intervals than medium-separation-level routes, which are spaced at much greater intervals than low/no-separation routes. Spacing varies considerably for different areas. In densely populated urban areas, spacing of all route types is smaller and more consistent than spacing in sparsely developed rural areas. Geographic barriers greatly influence the layout and spacing of routes.

Vehicle Volumes

The amount of vehicle traffic, current and design year volumes, to be accommodated is another indicator of the type of facility and its functional classification (the project may either reduce or increase vehicle traffic depending on community needs and roadway system considerations). The amount of vehicle traffic affects several factors, including roadway vehicular capacity, vehicular delays, and most important, the number of lanes required to accommodate the traffic. Although the roadway project will be required to accommodate users throughout its entire design life (and, likely, beyond), many of the design choices required to accommodate traffic under a future scenario (e.g., more lanes) may be detrimental to year-of-opening conditions (for example, by encouraging higher speeds and longer pedestrian-crossing distances). Therefore, design recommendations should be developed with not only opening year, future year, and intermediate operations in mind, but also an understanding of the impacts on peak and off-peak operating conditions in order to develop the “best” or phased-approach scenario for all users throughout the entire design life and not just the peak hour.

Bicycle Network

In addition to the automobile-oriented definitions of roadway type, classes for bicycles are also proposed to confer structure and priority for bicycle networks. Similar to automobile roadway-type classifications, these facilities are classified based on the network connectivity a facility provides. However, the network scale is modified to reflect shorter travel ranges. Cities have existing bicycle networks that could be incorporated into the classification system.

Three classes of bicycle facilities are proposed:

- **Citywide connector** (CC)—providing citywide connections, connections to major activity centers, or regional bicycle routes stretching over several miles that attract a high volume of use as they serve a primary commute or recreational purpose.
- **Neighborhood connector** (NC)—providing neighborhood or sub-area connection, which establishes connections to higher-order facilities or local activity centers such as neighborhood commercial centers.
- **Local connector** (LC)—providing local connections of short lengths, which provide internal connections to neighborhoods or connect to higher-order facilities.

In addition to connectivity, other factors may be used in planning a bicycle network. Each of these factors is identified and discussed in the following subsections.

Efficiency of Travel

Trip makers will typically seek out roadways that allow them to travel to their destinations with as little delay as possible and in the shortest amount of time. Therefore, higher-order bicycle facilities should be planned within a network to connect major centers of activity by considering recreational, work/commuting, and other trip types.

Mode Range

Range should also be considered. The National Survey of Pedestrian and Bicyclist Attitudes and Behaviors Report identified an average trip length of 65 minutes, which translates to 15–20 miles (NHTSA 2002). Therefore, in establishing a bicycle network, trip lengths longer than this range should factor in integration with transit facilities.

Bicyclist Safety

Another issue is the vulnerability of bicyclists, and facilities and options to address safe bicycling should be considered. This may often require greater separation between bicyclists and traffic, especially in facilities with high speeds.

Route Spacing

Directly related to network definition is the concept of distance (or spacing) between routes. For a variety of reasons, it is not feasible to provide high-order facilities to accommodate every possible trip in the most direct manner possible or in the shortest amount of time. Ideally, regular and logical spacing between routes of different classifications exists. High-separation-level routes should be spaced at greater intervals than medium-separation-level routes, which are spaced at much greater intervals than low/no-separation routes. This spacing varies considerably for different areas. In densely populated urban areas, spacing of all route types is smaller and generally more consistent than the spacing in sparsely developed rural areas. Geographic barriers greatly influence the layout and spacing of routes.

Bicycle Volumes

The amount of bicycle traffic anticipated to use the facility is another indicator of the type of facility and its functional classification. Future community plans to address bicycle mobility issues and options should be considered in determining the type of facility and its functional classification. The amount of bicycle traffic affects several factors, including bicycle capacity, vehicular delays, and most important, the level of risk associated within the bicycle and auto traffic mix. Three basic categories of bicycle volume are considered for categorization purposes: (1) low volume, which consists of rare or occasional bicycle traffic; (2) medium volume, which has some bicycle trips (measured in bicycles per day); and (3) high volume (measured in bicycles per hour). Each of these volumes will require a different treatment based on the context–roadway interaction.

Higher-order bicycle facilities with higher volumes are considered primarily for relatively dense areas for the purposes of intermodal connection and reasonably short trips to work or shop in or between urban core, urban, and suburban areas, although rural towns may also have such networks within a smaller concentration. While rural areas do not exhibit the density typically associated with successful bicycle networks, these may occur in certain circumstances. In addition, recreational users may favor longer trips and lower interruptions provided by rural roadways, and higher volumes of recreational cyclists may be found in rural areas along popular routes or near other recreational areas such as rural parks that attract cyclists.

While it is desirable to develop an area-wide bicycle network plan, it is possible for bicycle facilities to be planned on a corridor-by-corridor or project-by-project basis. In pursuing this approach, it is imperative that an aerial perspective be maintained to understand how the ultimate network would work together to deliver a holistic solution.

Pedestrian Networks

While other modes readily lend themselves to a network planning strategy for incorporated areas, pedestrian activity and accommodation may be defined by the individual context of the area. This is in part because of the relatively short range of typical pedestrian activity. Moreover, pedestrian facilities may be even more localized, such as at a storefront or surrounding a bus stop, and not extend throughout the entire context area.

However, in denser urban areas, pedestrian activity may also cross contexts or land use boundaries, necessitating the accommodation of pedestrian traffic through a context area to another major area of activity. For example, a corridor connecting a university campus with a downtown area may require enhanced sidewalks even if the context may not demand such treatment. In addition, for larger context zones, such as suburban areas, pedestrian facilities may be focused on connecting areas of potential or anticipated pedestrian activity, such as connecting a residential subdivision to another subdivision or a nearby shopping center or transit stop (Figure 15). As such the sidewalk or path treatment may not need to continue the entire longitudinal length of the roadway but may need to have the potential to make more meaningful connections. For example, a corridor with a suburban context may not require continuous pedestrian facilities if the centers of activity with potential pedestrian traffic are discontinuous. However, where evidence of pedestrians exists or where pedestrian travel is likely expected, a minimum sidewalk width should be a priority to provide improved safety for pedestrian movements outside of the high-speed traffic area.

In addition to connectivity, other factors may be used to plan a pedestrian network. Each factor is identified and discussed in the following subsections.

Figure 15. Suburban area showing potential pedestrian connections between residential uses and commercial center without defined facilities along the arterial roadway.

Efficiency of Travel

Pedestrians typically seek out roadways (paths) that let them travel to their destinations along routes they perceive as safe and interesting. Distinct from other modes, pedestrians also consider, but are less directed by, the route with the shortest travel time. Therefore, higher-order pedestrian facilities should be planned within a network to connect major centers of activity, considering recreational, work/commuting, and other trip types.

Mode Range

Range should also be taken into account. A typical pedestrian range of 0.25–0.50 mile is often used as an acceptable walking distance in the United States; however, this length may increase in urban areas where walking is the preferred method of transport (NHTSA 2002). In establishing a pedestrian network, trip lengths longer than this should factor in integration with transit and enhanced pedestrian facilities. Due to the relatively short range of pedestrian travel, the level of pedestrian activity can often be directly associated with the area's context and land use.

Pedestrian Safety

Another issue is the vulnerability of pedestrians, and facilities and options to address pedestrian safety should be considered. Providing a separation between the pedestrian facility and the traffic, and widening the available sidewalk are methods to improve safety and pedestrian comfort by reducing potential conflicts and exposure for pedestrians. This may be especially important for roadways with medium or high speeds.

Block Length

The length of blocks affects pedestrian travel demand. In general, desirable block lengths range from 200–400 feet and should not exceed 600 feet (ITE and Congress for the New Urbanism 2010). Long blocks tend to discourage pedestrians.

Pedestrian Volumes

The amount of pedestrian traffic anticipated to use the facility will assist in determining the type of facility and its functional classification. The amount of pedestrian traffic affects several factors, including pedestrian facility capacity, vehicular delays at signalized intersections, and most important, the level of risk associated with jaywalking pedestrians. Four basic categories of pedestrian volume are used for classification purposes: (1) rare or occasional volume; (2) low volume, which has a few pedestrians (measured in pedestrians per day); (3) medium volume, which has several pedestrians (measured in pedestrians per hour); and (4) high volumes (measured in pedestrians per hour and over a short time period). Each of these volumes will require a different facility based on the context–roadway interaction.

Overlays

While the corridor planning/design team often directly addresses the inclusion of auto, bicycle, and pedestrian users, they may establish other user groups, such as transit and freight, to meet the unique needs of the system and the network they operate in. These user groups may then be applied to the corridor as overlays that add to the understanding of the total users for the roadway. To balance the needs of overlays, information regarding the frequency, use, and importance of the individual routes within the overlay network is essential, as discussed in the following sections.

Transit Networks

Transit routes are typically fixed and well-defined by the local transit agency to meet the demands of transit ridership. Additional resources are available to determine the best network and routing plans for transit facilities as well as guides to aid in the design of transit facilities (AASHTO 2014). Providing additional guidance for these is beyond the scope of this report. However, it is imperative to incorporate transit facilities into the overall transportation network so that they can be considered in the context of the overall transportation network and not viewed separately.

Recent trends of increased ridership may require a closer examination of such transit overlays and their potential impacts on design. A close coordination with transit agencies, which typically are independent from DOTs, is essential to properly define transit overlays for roadways where transit either exists or is anticipated to be located.

Freight Networks

Freight networks typically describe where large trucks needing special accommodation may be concentrated on the roadway network. Studying land use to identify industrial centers and/or multimodal ports and manufacturing and commercial areas may determine the location of freight networks. Once freight-generating land uses are identified, preferred supply and delivery routes can be identified that connect the centers where activity originates with expected destinations. Heavy freight (i.e., large trucks) is typically routed to larger, higher classification roadways, such as major and minor arterials, where increased mobility is preferred. However, in addition to evaluating the roadway types to serve freight corridors, planners/designers should avoid sensitive context zones, such as urban and urban core areas, to minimize interactions between freight and vulnerable road users.

Freight networks should be characterized based upon the frequency and size of expected freight traffic. Lower classification roadways may accommodate occasional through freight vehicles, while certain roadway and land use contexts may preclude large freight traffic. On heavy freight routes, the roadway, adjacent facilities, and intersections should be designed to accommodate freight traffic and movements safely and efficiently. Moderate- or occasional-use freight facilities may marginally accommodate larger freight vehicles while being designed to provide lower speeds and shorter crossing distances for other users. Within these roadway–context combinations, operational efficiencies may be affected as freight traffic traverses the corridor.

Network Overlay Application

As described previously, good modal network layouts can be assembled for each user group and, once complete, may be overlaid on top of one another to develop a representation of the entire transportation network and its users (Figure 16). This is critical for identifying conflicts between user groups so that revisions may be made to best accommodate all users—not necessarily on all roadways but within the entire transportation network.

Incompatibilities between the needs of user groups will likely arise throughout the network planning and project development process. When these conflicts occur, an alternative network strategy can be applied to identify parallel routes with accommodations more compatible to the transportation needs of one or more of the user groups. For example, while it may be desirable to accommodate bicyclists on an arterial, heavy vehicle volumes may present a challenging tradeoff decision when considering how to accommodate significant bicycle demand. In this case, parallel roads can be used to divert the bicycle traffic and establish the required separation to accommodate them. While it is easily understood that all users must be accommodated within the transportation system, all roads cannot be all things to all people. However, all users can be fully supported by the total network. It is therefore imperative that a designer evaluates the needs of all users, as well as understands the priority of users within the route and each of their nodal networks. In establishing modal networks, the primary consideration will be identifying the generators for each mode and then providing a connection between major points of trip attraction

While it is easily understood that all users must be accommodated within the transportation system, all roads cannot be all things to all people.

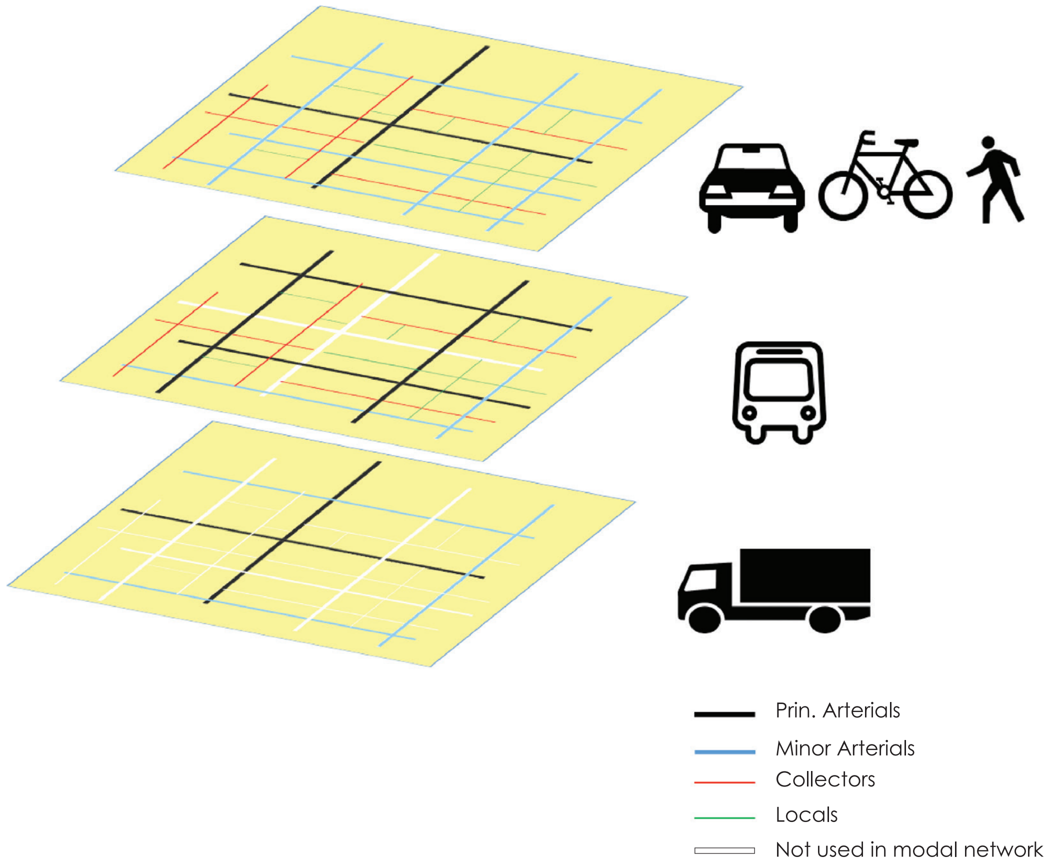


Figure 16. Overlay of transit and freight modal networks.

or generation. For instance, a roadway in the urban core with heavy pedestrian-focused retail should place a high priority on pedestrian movement as it serves as the point of attraction. Roadways connecting the activity center with either residential or transit centers may also need to prioritize pedestrian movements but may also lower priority if an alternative is identified that better accommodates the mix of users, such as establishing a pedestrian-only corridor closed to automobile traffic. At a minimum, the design should accommodate intended users on the road of concern or be moved to a parallel route. Where possible, enhancements should be made beginning with the highest priority user first.

As is evident from the foregoing discussion, this application of the Expanded FCS requires expansion of the documented public transportation system to include pedestrian and bicycle networks as well as to identify future connections within these networks. Transportation agencies routinely establish roadway networks and clearly understand the role of these networks. On the other hand, bicyclist and pedestrian networks are not used widely and this may pose an initial issue for the Expanded FCS implementation. Due to the relatively limited range of pedestrian activity, it may not be necessary to identify a comprehensive pedestrian network, but rather the individual context of the area may be used to determine the level of pedestrian activity, with individual projects identifying special connections to transit and adjacent contexts. The longer range of bicycle travel however has the tendency to routinely pass through several context zones, increasing the need for a global network determination of bicycle facilities. This process can begin with a consultation of the appropriate stakeholders to identify existing facilities. For example, cities typically have an inventory of sidewalks, and bicycle groups often have bicycling maps developed for their members. Such resources can provide the basis for additional discussions with these stakeholders, aiming to identify the relative need for each facility within the respective network. This process can rely on CSS principles to define modal priorities and hence establish the network classifications for bicyclist and pedestrian facilities.

An agency can follow a CSS-based approach to establish these networks:

- Identify appropriate stakeholders.
- Identify centers of activity that could attract and/or generate pedestrian and bicyclist activity.
- Solicit stakeholder input on route choices and priorities and collect existing maps and other data.
- Develop preliminary network classifications and solicit stakeholder input.
- Finalize and publish pedestrian and bicyclist networks.

Note that the absence of a comprehensive bicycle network does not render the application of the Expanded FCS useless. As opposed to utilizing a preexisting network, a project team in conjunction with project stakeholders and public input may identify the priority of bicycle facilities for a roadway dependent upon the existing and anticipated bicycle volumes, adjacent facilities, traffic generators and attractions both within and outside the project area or along the route in question. Addressing bicycle routes in this manner will allow for advancement of modal equality; however, full network planning will be required to provide a truly cohesive system.

Modal Considerations and Accommodation

The following sections discuss issues associated with users and present design considerations for each mode in order to achieve a contextual design solution. The Expanded FCS matrix is also presented along with considerations for transit and freight overlays.

Driver Accommodation

The metrics used to define the context–roadway interaction for drivers are the target operating speed and the balance between mobility and access.

Target Operating Speed

Target operating speed is grouped into three categories: low (<30 mph), medium (30–45 mph), and high (>45 mph). These definitions coincide, in general, with the existing high and low design speed concepts in *A Policy on Geometric Design of Highways and Streets* (AASHTO 2011), or Green Book, and can form the basis for initial designs. Speed, in general, decreases along the context continuum (from rural to urban core) as well as along the roadway type (from principal arterials to locals).

The speed used in the Expanded FCS is the target operating speed of the roadway. The rationale for selecting operating speed in the Expanded FCS is the need to recognize the influence of driver desire and expectations. Moreover, the goal is to develop a facility where the operating speed is close to the design speed, resulting in an environment with smaller speed differences among drivers. Smaller speed differences could improve safety, because they will eliminate discrepancies between design speed and operating speeds, creating a more uniform speed profile among drivers. These speeds need to be considered with both existing and future volumes and contexts.

The limits for each category are based on established practices and extensive research. The speed of 25 mph is considered the upper limit for the low-speed environments based on current trends of several urban areas to facilitate a speed limit of 25 mph. Note that 20 mph is considered the survivability speed for pedestrians and bicyclists in the event of a collision with a vehicle. Such collisions typically result in injuries, but non-drivers have a high chance of surviving when speeds remain at or below 20 mph. As such, speeds of 20 mph or less should be considered in areas of higher pedestrian activity in the urban and urban core environments. Target speeds for urban and rural towns have been designated as low/medium because of the competing issues within these contexts and the varied pedestrian and roadside environment. The designer should examine the available speed range to select the operating speed most appropriate for all users given the facilities and context. The lower limit for high speeds is based on the Green Book definition of high-speed roads, which are those with speeds of 50 mph and above.

Access and Mobility

The typical tradeoff between access and mobility presented in the existing classification system is enhanced in the Expanded FCS to reflect the influence of roadway and context as they change across the various matrix categories. Access is defined as the frequency of driveways or intersections and is grouped in three categories based on distance between access points: low (>0.75 mile), medium (0.75–0.25 mile); and high (<0.25 mile). Mobility is defined—qualitatively—as a function congestion level: low (congested conditions), medium (some congestion), and high (no congestion; free flow). Volumes referred to here are during the peak period.

The values for the access are based on current understanding of access management concepts and principles. While it is desirable for access density to decrease on higher mobility roadways, within certain contexts, this rule does not hold true, as when the roadway serves as the primary means of access. Mobility levels are based on generalized concepts of the level of service (LOS) for a facility and correspond to broad values of all roadways.

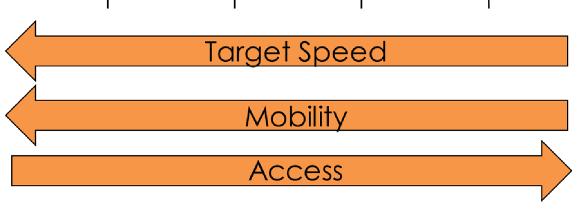
Expanded FCS Matrix Approach

For the driver, the interaction of access and mobility varies along the context continuum: mobility decreases from rural to urban core and access increases from rural to urban core.

Figure 17 shows an example for principal arterials. In a rural setting, the mobility is expected to be high with low congestion levels, while access may be low with few driveways or intersections along the corridor. As the context settings change with increased density and smaller building setbacks as well as pedestrian volumes, mobility declines (i.e., more congestion is anticipated) and access increases, which provides more opportunities to access land uses (which also change from rural character to a more developed environment). The target operating speed also changes along the context continuum, with higher speeds anticipated in rural settings. This reflects the higher mobility in these locations. Reductions in operating speed are anticipated as the context transitions to developed and urban settings.

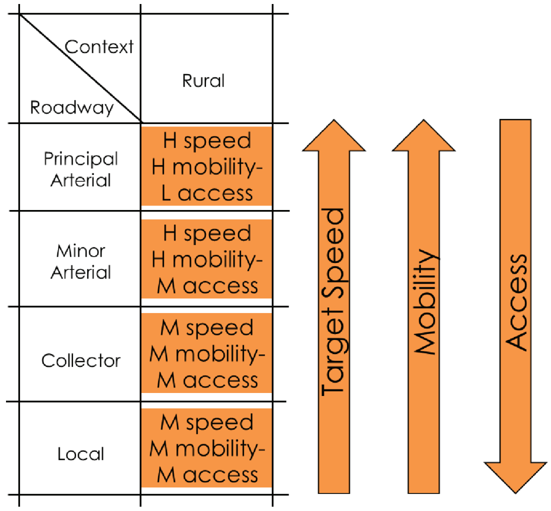
Similar changes are also noted along the roadway-type continuum. Mobility decreases (from principal arterial to local roads), while access increases along the same direction. Figure 18 illustrates this concept for rural settings. Mobility increases as the roadway type rises in category, reflecting the anticipated higher mobility levels of arterials compared to local roads. In a reverse manner, access levels increase as the roadway type decreases in category, reflecting

Context / Roadway	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	H speed H mobility- L access	L/M speed M mobility- H access	M/H speed M mobility- M access	L/M speed M mobility- M access	L speed M mobility- M access



H = high, M = medium, L = low

Figure 17. Interaction of metrics for Expanded FCS matrix along context continuum.



H = high, M = medium, L = low

Figure 18. Interaction of metrics for Expanded FCS matrix along roadway continuum.

the greater need for access for local roads. The target speed also changes among the categories, with an increasing trend from local to arterial roads. This reflects the mobility trends previously noted. The changes along both axes of the matrix enable a three-dimensional interpretation of the typical access–mobility graph used in the existing functional classification system. Note that speed is less of a factor in mobility for urban areas than for rural areas. Satisfactory mobility/capacity may be maintained in urban areas even at low speeds. This has the additional benefit of decreasing injuries for vulnerable users.

A summary of the complete interactions and relationships for drivers is shown in Figure 19. The matrix indicates how driver metrics change based on the interactions of different combinations of context and roadway. The product is a three-dimensional representation of the effects of access, mobility, and speed.

Roadway \ Context	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	H speed H mobility- L access	L/M speed M mobility- H access	M/H speed M mobility- M access	L/M speed M mobility- M access	L speed M mobility- M access
Minor Arterial	H speed H mobility- M access	L/M speed M mobility- H access	M speed M mobility- M access	L/M speed M mobility- M/H access	L speed M mobility- M/H access
Collector	M speed M mobility- M access	L speed M mobility- H access	M speed M mobility- H access	L speed M mobility- H access	L speed M mobility- H access
Local	M speed M mobility- M access	L speed M mobility- H access	L speed L mobility- H access	L speed L mobility- H access	L speed L mobility- H access

H = high, M = medium, L = low

Figure 19. Expanded FCS driver interaction matrix.

Design Considerations

The primary design characteristic for drivers is mobility. However, because roadways may have other modal traffic, the level and type of separation from vehicles provided for the other users may also need to be considered. These considerations should be based on the volumes of motorized, pedestrian, and bicycle traffic. Increased separation may be needed between high volumes of other users and motorized traffic. This can be achieved using either barriers or with separate facilities. Additional discussion on separation is provided with the discussions of other modes.

Another issue to consider is that not all routes are conducive to bicyclists and pedestrians (i.e., high-speed principal arterials). In such cases, alternative routes should be identified that could satisfy the mobility needs of these users and accommodate them as needed. However, in some restricted cases, speeds must be reduced or varied to accommodate specific users more safely.

For principal and minor arterials in rural town and urban contexts, designers can select from a wider range of speed choices (low though medium) to accommodate pedestrian and bicyclist demands and provide for a safe design for all users.

Bicyclist Accommodation

This section of the guidance presents the concepts underlying the treatment of bicyclists in the bicycle facilities classifications in the Expanded FCS. The primary consideration for a bicycle facility is the level of separation between motorized and bicycle traffic. Other factors that can help determine the proper treatment of bicyclists are discussed as well.

Separation

Bicycle facilities can be generally categorized based on the amount of separation they provide from motorized traffic. For the purposes of the Expanded FCS, bicycle facilities are categorized as follows:

- High separation—provides physical separation from traffic in the form of physical barrier or lateral buffer.
- Medium separation—provides a dedicated space adjacent to motorized traffic.
- Low/No separation—provides joint-use facilities for motorized and non-motorized traffic.

The amount of separation necessary for a facility is dependent mostly on the following:

- The amount of bicycle traffic on the facility.
- The speed of motorized traffic on the adjacent roadway.
- The amount of motorized traffic on the adjacent roadway.

The need for variances in separation may be demonstrated by examining two extreme examples. First, consider a high-speed urban arterial that also serves as a regional bicycle connection; it has a heavy volume of bicycle traffic. In this instance, a cycle track or even independent multi-use path may be appropriate to serve the bicycle traffic. Providing a separate facility reduces the number of conflicts between the two modes of traffic, which may be frequent considering the high traffic volumes of both modes as well as the potential severity of conflicts due to high speeds of the motorized facility. Conversely, at a low-speed neighborhood street serving only local riders, bicycles and vehicles may share the same space because of the low probability of conflict and low speed differences between the two modes.

The Expanded FCS matrix identifies a proposed level of separation that may be considered for each bicycle facility category according to roadway type and context. Potential treatments that may be included within each of these separation levels are as follows:

- Low/No-separation treatments
  - No specific treatment, for cases with rare or occasional bicycle traffic.
  - Sharrows—for cases when a bicycle lane is not feasible and they can be used with narrow lanes, ensuring that a driver cannot pass a cyclist except very slowly.
- Medium-separation treatments
  - Bike lanes—for separating bicycles from vehicular traffic.
- High-separation treatments
  - Buffered bike lane/cycle track—for cases with high bicycle volume.
  - Multi-use path—for cases with high bicycle and pedestrian traffic.

Expanded FCS Matrix Approach

The level of separation provided should be based on speed of traffic, context, and roadway type, and is defined for all three levels of bicycle traffic. The separation changes along the context continuum to reflect the effects of target operating speed. For example, higher speeds on principal arterials require some balancing of the separation to be provided based on the amount of anticipated bicycle traffic and context. For rural and suburban contexts, high bicycle volumes require high separation and the designer should determine the type to be used based on the discussion provided in the next Design Considerations section. In all other contexts with lower speeds, a medium separation is recommended for high-volume traffic (Figure 20).

Similarly, there are interactions between bicycle separation and roadway type. For example, on local roads, the slow-moving traffic does not require any special separation for bicyclists; therefore, for all bicycle facility classes, low separation is recommended (Figure 21).

The complete interaction of the roadway type, context, and bicycle separation is shown in Figure 22. All options are provided to allow for the designer to determine the appropriate facility required to accommodate bicycle traffic based on the bicycle facility classifications that may exist. The matrix presents the minimum accommodation that should be expected for travelers of all modes. However, these levels of accommodation may be increased to address local priorities and where sufficient space exists to provide enhancements.

Context / Roadway	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M/H separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation

Bicycle facility class: CC = citywide connector, NC = neighborhood connector, LC = local connector
Separation level: H = high, M = medium, L = low

Figure 20. Interaction of bicycle separation levels by context in Expanded FCS matrix.

Roadway \ Context	Rural
Principal Arterial	LC: L separation; NC: M separation; CC: H separation
Minor Arterial	LC: L separation; NC: M separation; CC: H separation
Collector	LC: L separation; NC: M separation; CC: M separation
Local	LC: L separation; NC: L separation; CC: L separation

Bicycles

Bicycle facility class: CC = citywide connector,
NC = neighborhood connector,
LC = local connector
Separation level: H = high, M = medium, L = low

Figure 21. Interaction of bicycle separation levels by roadway type in the Expanded FCS matrix.

Roadway \ Context	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M/H separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation
Minor Arterial	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: M separation; CC: M separation
Collector	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: L separation; CC: M separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: M separation; CC: M separation	LC: L separation; NC: L separation; CC: M separation
Local	LC: L separation; NC: L separation; CC: L separation	LC: L separation; NC: L separation; CC: L separation	LC: L separation; NC: L separation; CC: L separation	LC: L separation; NC: L separation; CC: L separation	LC: L separation; NC: L separation; CC: L separation

Bicycle facility class: CC = citywide connector, NC = neighborhood connector, LC = local connector
Separation level: H = high, M = medium, L = low

Figure 22. Expanded FCS bicyclist interaction matrix.

Design Considerations

Sharrows with *narrow* lanes may be used when the narrow lane would not cause safety concerns or exceptionally delay traffic flow, including in the following cases:

- Small speed differences between bicycles and vehicles.
- Low volume of vehicular or bicycle traffic.
- Short-length bicycle facilities (<0.25 miles).

Sharrows with narrow lanes are no more than 10 feet wide and traffic speeds are low (less than 20 mph). Conversely, sharrows with wider lanes typically provide a wide travel lane of 13–14 feet with supplemental striping and/or signing. The wider lane allows for vehicular traffic to cautiously pass slower bicycle traffic. It may be a solution for constrained roadways with minimal speed differences between bicycle and vehicular traffic (<30 mph).

Bike lanes, while providing space exclusive from motorized vehicle travel lanes, do not provide physical separation. Bicycle–vehicular conflicts at intersections with turning traffic and from opening-door incidents with parked vehicles are not eliminated. Narrower bike lanes (~4 feet) should be used only when right-of-way is constrained and not in the presence of on-street parking, unless an additional buffer is provided. Additionally, narrower bike lanes should not be used for high-speed facilities and/or facilities with a combination of high volumes of vehicular and bicycle traffic. In the presence of higher-speed traffic or high traffic volumes, wider bike lanes are warranted to create additional separation between facilities.

Off-street paths (and trails) are cycle routes that are not part of the regular street network.

An ancillary consideration is the separation of bicyclists from pedestrian activities. Separation of bicyclists from both motorized vehicles and pedestrians should be based on the volume of autos/pedestrian traffic and bicycle traffic as well as the anticipated speed of bicyclists and autos. Vehicular speed should be targeted based on the functional classification and context of the roadway. In addition, bicycle speed may fluctuate based on whether the roadway has been designated for FHWA "Design Bicyclist" Group A, B, or C (advanced, basic, or children bicyclists, respectively; FHWA 1992).

Bicycle separation is highly contingent on the difference between bicycle speed and motorized traffic speed. As speeds go up, as indicated in the matrix (Figure 22), separation should also increase. However, if lower volumes of bicycle traffic are anticipated and more bicycle commuting traffic is anticipated, higher bicycle speeds (and possibly increased comfort riding in traffic) may be assumed, allowing reduced separation. If conflicts arise and vehicular or bicycle traffic cannot be accommodated on parallel routes, lower target speeds and roadway design (e.g., narrower lanes, lowered mobility) to achieve them should be considered, in lieu of increased separation.

While bicycle facilities are aligned to fit well with the overall vehicular functional classification, bicycle facilities should be considered in terms of the overall bicycle network. The overall bicycle network should be planned to allow connections to recreational cycling areas for casual users (Group B or C) and provide commuting and general transportation opportunities for Group A users. While it would be beneficial to develop a formal area-wide bicycle network that can be overlaid with vehicular, pedestrian, and transit uses, it is not necessary as long as network connectivity is considered on a project-by-project basis.

Bicycle facilities can be considered longitudinal treatments along the length of the roadway, and limited intersection elements may be required. However, considerations for turns for primary junctions within the bicycle network should be incorporated into the plan such as the use of bike boxes. The AASHTO *Guide for the Development of Bicycle Facilities* (AASHTO 2012) and the National Association of City Transportation Officials (NACTO) *Urban Bikeway Design Guide* (NACTO 2011) address bicycle design for specific intersection issues.

Access density is also a consideration with bicycles, especially with cycle tracks and buffered bike lanes. In areas of high access density, the separation of bicycle traffic should be avoided because it increases the number of crossing conflicts for ingress and egress traffic.

Rural bicycle facilities also necessitate additional consideration in the design process. As noted previously, bicycle networks are more prevalent within urbanized areas because of the increased density, allowing the shorter range of cycling to be a more effective transportation solution. However, rural areas may experience high volumes in special circumstances, often arising from high demands from recreational riders. Understanding the unique and varying needs of recreational bicyclists is important in understanding the final design of the facility. For instance, routes that have a high level of use by bicycle club riders may be used by experienced riders comfortable riding next to or sharing lanes with higher-speed traffic, while recreational facilities surrounding parks or other attractions may be used by riders of all abilities and necessitate higher-separation facilities due to high vehicular speeds.

Pedestrian Accommodation

This section of the guidance presents the concepts underlying the treatment of pedestrians in the Expanded FCS. The primary consideration of a pedestrian facility is its width. Other factors that can help determine the proper treatment of pedestrians are also discussed.

Facility Width

Pedestrian facilities can be generally categorized by their width. For the purposes of this document, they are categorized as follows:

- *—no facilities for pedestrians, except for occasional site-specific facilities.
- Minimum width—the minimum required width based on ADA requirements.
- Wide width—wider than minimum required width for a pedestrian facility.
- Enhanced width—more space than the wide width in order to accommodate congregating groups of pedestrians and street furniture.

The first category [noted with an asterisk (*)] indicates that, for occasional pedestrians to be accommodated, the site-specific conditions and future plans for the area must be examined to determine whether facilities may be placed or alternative accommodations such as shoulders for pedestrian/bicycle use should be considered.

In addition to the facility width, separation of the pedestrian facility from the travel way is also an important consideration. However, this design element is primarily dependent on the target operating speed of the automobile facility rather than on the level of activity on the facility. Typically, medium- and high-speed facilities will require separation from the travel way whether in the form of a landscaped buffer, bicycle lanes, or parking areas. For low-speed facilities, the sidewalk may be attached to the curb, directly adjacent to the travel way without a need for a buffer area.

The width necessary for a pedestrian facility depends on many factors, but most notably on the following:

- The amount of pedestrian traffic adjacent to the roadway.
- The speed of motorized traffic on the adjacent roadway and required separation.
- The amount of motorized traffic on the adjacent roadway.

The absence of physical separation between a sidewalk and the travel way may reduce the available functional width of the sidewalk in areas of high-speed and high-volume traffic because pedestrians shy away from the edge of the roadway. Therefore, the final design of the facility should ensure both proper width and separation to meet the anticipated needs of pedestrians within a corridor.

The need for variations in width may be demonstrated by examining two extreme examples. First, consider a high-speed urban arterial that also serves as a connector between large centers of activity (e.g., a university campus and the downtown area) that have heavy volumes of pedestrian traffic. In this instance, a wide- or enhanced-width detached facility may be appropriate to serve the pedestrian traffic. Providing a separation improves pedestrians' comfort levels and could reduce the number of conflicts between the two modes, which may be frequent given the high traffic volumes of both facilities, and the potential severity of conflicts due to the high speeds of the motorized facility. Conversely, on a low-speed local street serving only local pedestrians, a minimum- or wide-width attached facility may be appropriate, depending on the pedestrian volumes, in order to decrease the probability of conflicts.

The proposed functional classification matrix identifies a proposed level of facility width that may be considered for each pedestrian facility category according to roadway type and context. The following section identifies potential treatments that may be included within each of these width ranges.

Expanded FCS Matrix Approach

The width of the pedestrian facility is defined for the anticipated or potential levels of pedestrian traffic for each context and roadway type; the separation of the pedestrian facility from the travel way is based on the speed of the motorized traffic. The width changes along the context continuum to reflect the traffic volumes anticipated for the facility. For example, design of principal arterials in high-speed environments needs to consider the pedestrian traffic volumes in order to determine the appropriate width. In this case, for rural and suburban contexts, high pedestrian volumes require wide width (which here can be viewed as a separate facility) to establish a safe pedestrian environment, while in cases where pedestrians are present rarely or occasionally, whether to add pedestrian facilities requires additional consideration and appropriate facilities need to be included commensurate with pedestrian volumes. Similar considerations are developed for the other contexts with lower speeds where the anticipated pedestrian volumes would indicate the width to be provided (Figure 23).

There is no interaction between pedestrian facilities and roadway, because the designed facility width will depend on the level of pedestrian traffic. However, as previously noted, medium- and

Context / Roadway	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced

Pedestrian traffic levels: P1 = rare/occasional, P2 = low, P3 = medium, P4 = high

Pedestrian facility width: * = site specific, Min = minimum, Wide = greater than minimum, Enhanced = wide for large congregating pedestrian groups

Pedestrian facility separation should be considered in conjunction with driver target speeds.

Figure 23. Interaction of pedestrian separation levels by context in Expanded FCS matrix.

Context / Roadway	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Minor Arterial	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Collector	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Local	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced

Pedestrian traffic levels: P1 = rare/occasional, P2 = low, P3 = medium, P4 = high

Pedestrian facility width: * = site specific, Min = minimum, Wide = greater than minimum, Enhanced = wide for large congregating pedestrian groups

Pedestrian facility separation should be considered in conjunction with driver target speeds.

Figure 24. Expanded FCS pedestrian interaction matrix.

high-speed roadways do require increased separation of pedestrian facilities and the travel way of the road. The complete interaction of the Expanded FCS matrix and pedestrian facility width is shown in Figure 24. The matrix presents the minimum accommodation that should be expected for travelers of all modes. However, these levels of accommodation may be increased to address local priorities and where sufficient space exists to provide enhancements.

Design Considerations

The primary design characteristic of pedestrian facilities is the width of the sidewalk or path that can comfortably accommodate the demand in a given context. Pedestrian facility widths are defined as minimum per ADA requirements. This width has the ability to accommodate a high demand of pedestrians allowing for walking single file in each direction. In higher-density areas, pedestrians may walk several across or in larger queues, which requires wider sidewalks to accommodate the higher volumes of pedestrian traffic. In the most active pedestrian centers, sidewalks can serve as not only walking routes, but also places where people congregate. In these contexts, enhanced and wider sidewalks are necessary to not only accommodate pedestrian groups, but also provide for activity areas and street furniture, such as waiting areas, benches, or even outdoor seating, depending upon the adjacent land use.

An ancillary design consideration for pedestrian facilities is whether to increase separation from motorized (and bike) traffic when medium or high speeds or volumes could expose pedestrians to risk or deter them from walking because they may feel uncomfortable or unsafe. In these instances, a buffer between the traffic and the pedestrians is desirable. Buffer widths vary depending on land uses, and different types of buffers can be used to create an inviting pedestrian environment. On-street parking or bicycle lanes can also act as buffer. Desirable widths vary from 2–4 feet for local and collector roadways to 5–6 feet for arterials (AASHTO 2004b).

Increased tree lawns, shielding, or physical separations could be used as buffers, and, in extreme cases, off-roadway paths may provide the best pedestrian experience. To determine the pedestrian LOS when buffers are used, the designer needs to take into account the reduction to the effective facility width due to the presence of the separation (e.g., trees, shrubs, or grass) based on the approach and values outlined in the *Highway Capacity Manual* (TRB 2016).

Intersections are of particular concern to pedestrians. As such, nodal treatments and provision of appropriate pedestrian-crossing treatments are critical. Where possible, for high pedestrian movement, narrow crossing widths should be used. Crossing widths can be minimized through tighter intersection curb radii and minimizing the number of lanes to be crossed. These treatments may conflict with vehicular demands, which prioritize mobility (which requires more lanes) or transit and freight routes (which may require wider turning radii). Consideration may be given to alternative guidance for auxiliary turn lanes that coexist with bicycle and pedestrian traffic. Design should take into account the increased exposure and risk to other modes in the presence of auxiliary turn lanes (which increase crossing distance and encourage bicycle conflicts) in light of any decrease in safety caused by their exclusion. It is imperative that the designer evaluate the needs of all users, as well as understand the priority of users within the route and each of their modal networks.

Expanded FCS Matrix

The preceding sections identified the specific issues related to each user group and the design considerations that need to be addressed when balancing each group's needs to deliver a contextually appropriate multimodal design. Figure 25 shows the complete Expanded FCS matrix, which presents the treatment options for each user group (drivers, bicyclists, and pedestrians) and identifies the interactions along the context and roadway-type continuums.

Proper contextual roadway designs require an understanding of how the roadway functions in its context and the needs of the potential roadway users. The Expanded FCS matrix can be used to identify preliminary requirements that should be given due consideration when assessing current and future roadway context and user needs. In a general project development approach, this process can assist with providing input and refining the purpose and need document, which establishes the framework for the design to be developed.

Transit Rider Accommodation as an Overlay

This section of the guidance presents the design considerations for accommodating transit within the Expanded FCS. Transit routes are typically fixed and well-defined by the local transit agency to meet the demands of the transit ridership. As such, there are no specific considerations to be provided as in the other modes. Close coordination and cooperation with local agencies is imperative in establishing the transit overlays in order to ensure proper accommodation of transit needs. The *Guide for Geometric Design of Transit Facilities on Highways and Streets* (AASHTO 2014) provides additional considerations for design elements of the transit overlays.

Design Accommodations

Transit routes may not require significant additional facilities beyond those provided for vehicular traffic, if mobility and speeds of the vehicular routes align with transit goals. However, curbside lanes should be designed to accommodate the width of the design transit vehicle—typically resulting in lane widths of 11–12 feet. Additional width may be necessary if bicycles share the curb lane with on-street low-separation facilities. Nodal treatment considerations should ensure wide

Context / Roadway	Rural	Rural Town	Suburban	Urban	Urban Core
Principal Arterial	H speed H mobility-L access	L/M speed M mobility-H access	M/H speed M mobility-M access	L/M speed M mobility-M access	L speed M mobility-M access
	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC, CC: M separation	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC: M/H separation; CC: H separation	LC: L separation; NC, CC: M separation
	P1: *; P2: Min; P3, P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Minor Arterial	H speed H mobility-M access	L/M speed M mobility-H access	M speed M mobility-M access	L/M speed M mobility-M/H access	L speed M mobility-M/H access
	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC, CC: M separation	LC: L separation; NC: M separation; CC: H separation	LC: L separation; NC, CC: M separation	LC: L separation; NC, CC: M separation
	P1: *; P2: Min; P3, P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Collector	M speed M mobility-M access	L speed M mobility-H access	M speed M mobility-H access	L speed M mobility-H access	L speed M mobility-H access
	LC: L separation; NC, CC: M separation	LC, NC: L separation; CC: M separation	LC: L separation; NC, CC: M separation	LC: L separation; NC, CC: M separation	LC, NC: L separation; CC: M separation
	P1: *; P2: Min; P3, P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced
Local	M speed M mobility-M access	L speed M mobility-H access	L speed L mobility-H access	L speed L mobility-H access	L speed L mobility-H access
	LC, NC, CC: L separation	LC, NC, CC: L separation	LC, NC, CC: L separation	LC, NC, CC: L separation	LC, NC, CC: L separation
	P1: *; P2: Min; P3, P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P1: *; P2: Min; P3: Wide; P4: Wide	P2: Min; P3: Wide; P4: Enhanced	P3: Wide; P4: Enhanced

Speed, mobility, accessibility, and separation level: H = high, M = medium, L = low
Bicycle facility class: CC = citywide connector, NC = neighborhood connector, LC = local connector
Pedestrian traffic levels: P1 = rare/occasional, P2 = low, P3 = medium, P4 = high
Pedestrian facility width: * = site specific, Min = minimum, Wide = greater than minimum, Enhanced = wide for large congregating pedestrian groups
Pedestrian facility separation should be considered in conjunction with driver target speeds.

Figure 25. Expanded FCS multimodal matrix by context and roadway type.

turning radii to accommodate transit vehicles. While low-order transit routes and infrequent turns may not require special accommodation, higher-priority routes for transit should have smooth turning radii to minimize unnecessary delays at turns. In addition, for high-priority or express routes, special controlled lanes should be considered for either bus rapid transit or light rail to designate lanes and/or areas for transit service within the right-of-way. Moreover, special operational parameters such as bus transit priority at signals may be contemplated, even though they may affect the travel time of other modes. Cooperation with local transit agencies will allow future transit facilities and routes to be identified in order to define future needs and land uses.

On bicycle priority routes, which call for lower vehicle speeds, the wider lanes used to accommodate transit may encourage higher speeds. When this occurs, increased separation of bicycle facilities may be an option to mitigate this increase in speed as well as to improve bicyclist safety.

Nodal considerations include bus stop locations and potential bus pullouts. Pullout locations should be placed and designed based on an examination of the safe operation and specific needs of the transit provider and its users. As previously noted with respect to pedestrian treatments, enhanced-width pedestrian facilities and connections to adjacent activity centers (such as shopping/business, transit stops, or even parking in park-and-ride areas) should be provided. In addition, some separation of the pedestrian facilities from the roadway may be considered in order to address possible safety concerns.

Freight Accommodation as an Overlay

Freight routes may not require significant additional facilities beyond those provided for vehicular traffic, if mobility and speeds of vehicular routes are consistent with freight movement. However, curbside lanes should be designed to accommodate the width of the design freight vehicle—typically resulting in lane widths of 11–12 feet. Additional width may be necessary if bicycles share the curb lane with on-street low-separation facilities. Nodal treatments should ensure wide turning radii to accommodate trucks. While low-order freight routes and infrequent turns may not require special accommodation, higher-priority routes for freight should have smooth turning radii to minimize unnecessary delays and possibility of crashes at turns.

On bicycle priority routes, which call for lower speeds of vehicular traffic, the wider lanes used to accommodate freight may encourage higher speeds. When this occurs, increased separation of bicycle facilities may be imperative to avoid conflict and improve bicyclist safety.

Note: See Case Study 2 for a demonstration of multimodal accommodation on an arterial.

Application of the Expanded Functional Classification System

This section provides practitioners with an overview of the design concepts associated with the Expanded FCS. It describes the concepts for identifying design element considerations and tradeoffs for balancing modal needs in order to deliver a contextually appropriate multimodal design for the context and roadway-type combinations in each Expanded FCS matrix cell. The reader may also refer to the two case studies that utilize the Expanded FCS framework.

Application Overview

When approaching a corridor design, the design team can utilize the Expanded FCS to analyze the environment the roadway will be constructed in and the roadway network. Various user groups that must be accommodated within the roadway, often with competing needs or spatial demands, are identified also. To assist in prioritizing and balancing these needs, the importance of the project within the individual network of each road user is also highlighted. A concept that needs to be clarified from the outset is that accommodating all the users at all the times on all roadways is impossible. The following sections provide detail on how to determine:

- Appropriate context category.
- Appropriate roadway type.
- Levels of accommodation needed for different modal users (priority and balance).
- Use of network overlays such as transit and freight.
- Design considerations that may assist in balancing design needs and accommodating competing needs on a corridor.

Each matrix cell provides a range of design options based on the defined context zone and roadway type (Figure 25). Once the context–roadway cell is identified, the modal needs and volumes must be considered to further narrow the range of design options. During this step, the needs of the driver, bicyclist, and pedestrian should be determined and examined. Lists of potential accommodations, based on the concepts defined for each user group in the previous section, should be developed. Any special overlays, such as transit or freight routes, that need to be considered should be identified next. Once individual user group needs are defined, they should be synthesized to identify what design tradeoffs will be necessary to best accommodate all users. Alternative designs should be developed and evaluated in order to deliver context-appropriate design. However, the project may extend beyond a single context, which should be addressed through the use of transition zones. *NCHRP Report 737: Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways* (Torbic et al. 2012) provides additional guidance on proper transition considerations and design. Special attention needs to be paid when speed transitions from high to low and when connecting contexts with changes in modal accommodations. The project team needs to also consider potential future changes in the context, for example, how community needs and goals, land use plans, and other items could have an impact on the design.

Once all these individual components are selected, the cross section may be assembled and how each component can best fit within the available right-of-way needs to be determined. Available tools for evaluating different options can be used to determine the advantages and disadvantages of each alternative. For example, *Highway Capacity Manual* (TRB 2016) and *Highway Safety Manual* (AASHTO 2010) procedures can be employed to determine the operation and safety effects of each choice; simulation can be used to determine the impacts of integrating vehicle and bicycle facilities; and *Highway Capacity Manual* procedures can be used to determine the operational efficiency of pedestrian and bicycle facilities. Performance-based design concepts and principles can be implemented to evaluate safety and operational performance of alternatives. The designer needs to establish the metrics to use for these comparisons and develop a systematic process to evaluate each alternative and compare their impacts as they relate to the purpose and need goals and specific objectives.

Single-Context Application

This section describes the process for defining design choices and criteria for consideration for a few Expanded FCS matrix cells.

Rural Principal Arterial

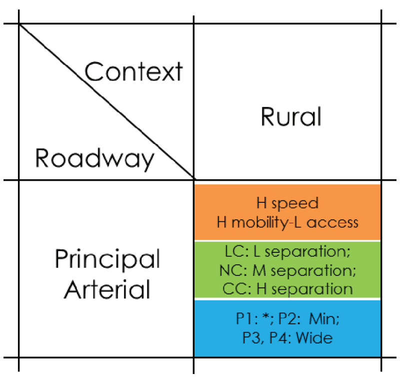


Figure 26. Cell for a rural principal arterial from the Expanded FCS matrix.

Figure 26 shows an Expanded FCS matrix cell that defines the rural context for a principal arterial. In this case, a roadway provides for high-speed driving, translating into high mobility and low levels of access. The appropriate facility for bicyclists is based on the class of the bicycle facility and its use. The facility for pedestrians is based on the amount of traffic anticipated, and it could be for targeted sections of the project. Finally, considerations for transit and freight will be based on the existing overlays, and their presence will have an impact on the selection of design element values.

In a typical rural principal arterial, there may be rare or occasional pedestrians (Figure 27), which requires no additional design considerations. In the event that there are pedestrians, then an enhanced-width sidewalk in the form of a separate pedestrian path may be needed. The presence and volume of bicyclist traffic will dictate the separation of the bicyclist from the traffic and thus the facility to be used. Bicycle volumes are expected to increase as the bicycle network category increases from a local to a citywide connector requiring greater separation. For local connectors, wide outer lanes with sharrows or SHARE THE ROAD signs may be appropriate due to the low bicycle volume. Similarly, for a neighborhood connector, a bike lane may be appropriate, and for citywide connectors, a separate facility is preferred. In the event there is not adequate space to accommodate the high separation required for a citywide connector, the target operating speed for drivers may be revisited and adjusted (e.g., 5 mph lower) to provide a safer facility for the bicycle traffic.

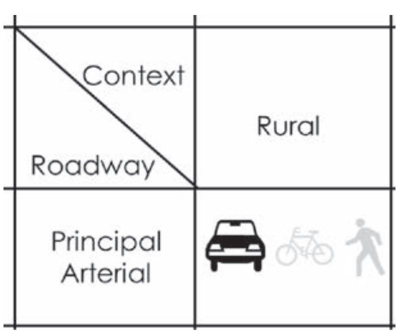


Figure 27. Relative importance of modal networks in a typical rural principal arterial.

The presence of any transit may require minimal adjustments to the lane widths to accommodate buses if they are larger than the design vehicle selected for the facility. The same is needed if there is a freight overlay, requiring the design consideration of the typical truck that uses the facility. The presence of trucks may also have implications for shoulder widths and grades.

Suburban Minor Arterial

Figure 28 shows an Expanded FCS matrix cell that defines the suburban context for a minor arterial. In this case, a roadway provides for medium speed driving, translating into medium mobility and medium levels of access. The appropriate facility to be provided for the bicyclists is based on the class of the bicycle facility and its use. The facility for pedestrians is based on the amount of anticipated traffic. Finally, design considerations for transit and freight will be based on the existing overlays, and their presence will have an impact on the selection of design element values.

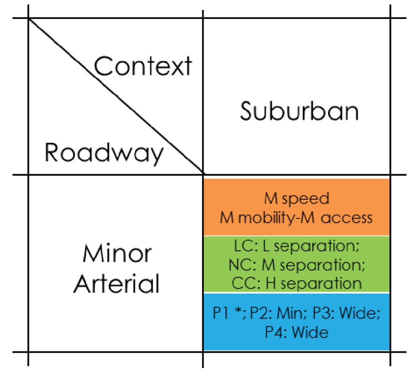


Figure 28. Cell for a suburban minor arterial from the Expanded FCS matrix.

In a typical suburban minor arterial (Figure 29), pedestrian activity may be concentrated around specific locations, and there may be a need for targeted accommodation at these locations. Possibly areas with high pedestrian traffic will exist in the vicinity of certain land uses (e.g., commercial, educational, office) that may require appropriate facility width commensurate with the level of pedestrian traffic. High traffic will require wide sidewalks and possibly street furniture to accommodate higher volumes. The pedestrian facility should be detached, and an appropriate buffer between the traffic and the pedestrians should be provided. If on-street parking is allowed or a bicycle lane is included, then the buffer could be eliminated. The bicycle network classification will also dictate the separation of the bicyclist from the traffic. As the network changes from local to citywide connector, bicycle volumes are expected to increase, establishing a need for greater separation. For local connectors, sharrows may be appropriate because of the medium vehicular speeds. Similarly, for a neighborhood connector, a bike lane may be appropriate, and for citywide connectors, a buffered lane may be considered. In the event that there is not adequate space to accommodate a buffered lane for a citywide connector, a wide bike lane may be considered as an alternative or the target operating speed for drivers may be revisited and adjusted (e.g., 5 mph lower) to provide a safer facility for the bicycle traffic. In this case, accommodating bicyclists on parallel routes could be evaluated to determine its feasibility.

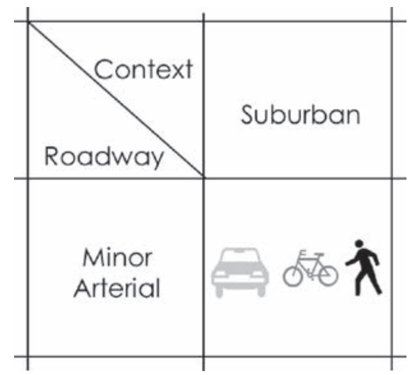


Figure 29. Relative importance of modal networks for a typical suburban minor arterial.

The presence of any transit may require adjustments to lane widths to accommodate buses if they are larger than the design vehicle selected for the facility. The same is needed if there is a freight overlay, requiring design consideration of the typical truck that uses the facility. The presence of trucks may also have implications for shoulder width and grades.

Corridor Concepts

The preceding discussion addressed how the Expanded FCS is equipped to handle roadway corridors that are bound within a single context. However, frequently, this is not the situation. When roadways traverse a variety of contexts, additional consideration should be given to the context transitions and the various design features to be used. Two examples are provided here to identify the issues and areas of attention.

An issue that also merits attention is balancing modal needs and priorities along a corridor, because they may vary. These issues are also presented here, and they form the basis for tradeoffs among the often-competing needs of each user group in order to develop and deliver a sound, contextually appropriate multimodal solution.

Example 1

The first corridor is a principal arterial transitioning contexts from rural to rural town to rural (Figure 30). The issues of concern extend beyond the accommodation of the users within each

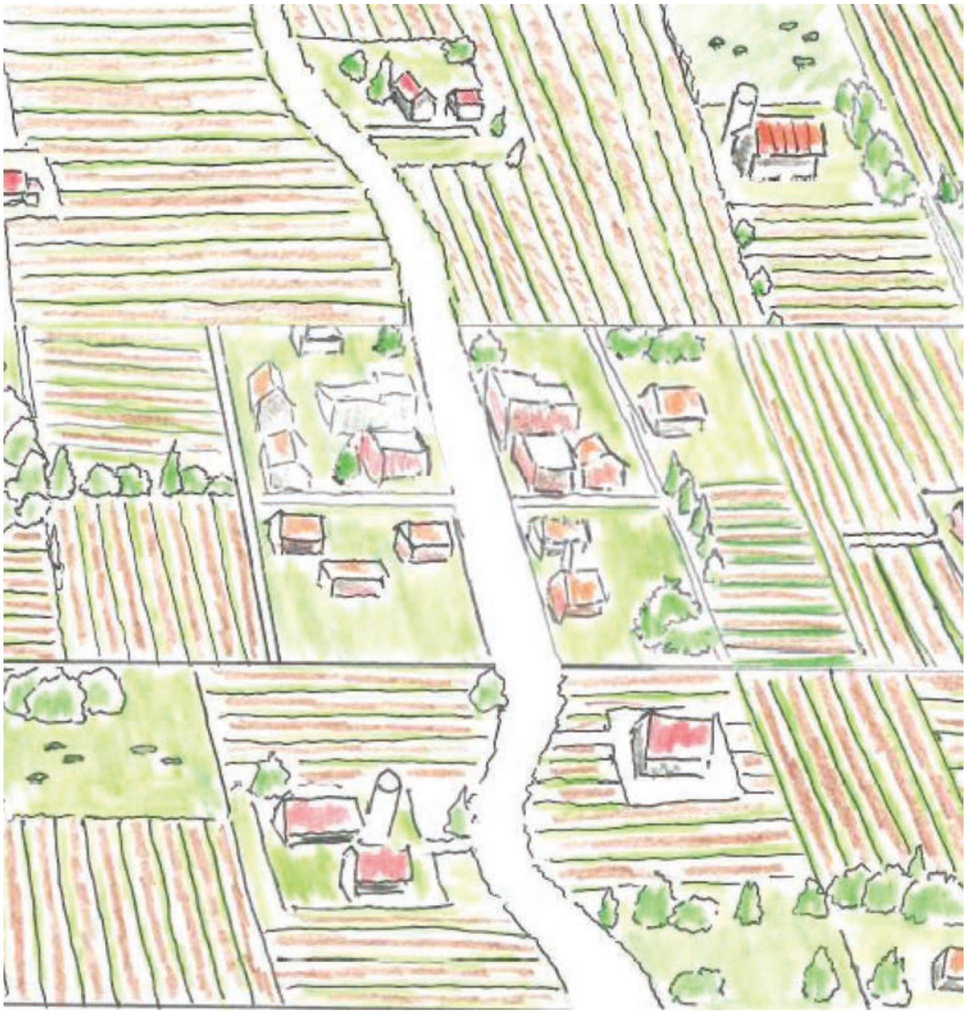


Figure 30. Principal arterial transitioning from rural to rural town to rural context.

segment, as discussed previously, to providing users with the appropriate clues about changes in the roadway context and accommodating the users while they move through one context to the next.

The operating target speed change from high to low for the rural to rural town transition should be communicated to drivers by more than just speed limit changes. Design features that gradually change from the rural cross section to the rural town cross section should be used to provide visual clues and positive guidance. This may involve gradual elimination or narrowing of the shoulder, narrowing of the travel lanes, use of pavement markings, and addition of gateways or roundabouts, or central island medians (Torbic et al. 2012).

Accommodating users in the transition zone is critical. For drivers, visual clues and positive guidance for the required speed reduction need to be placed over a transition zone. For bicyclists, the first step is determining whether different bicycle facilities are in place in each zone, requiring a different level of separation. In the event that there is agreement, then the separation type could be carried forward into the transition zone and rural town context. In this case, local connectors requiring low separation could be addressed through the use of sharrows. For neighborhood and citywide connectors, a review of the separation level in the rural and rural town contexts should be undertaken to identify whether there are any differences. For example, if sharrows are used in the rural setting and bike lanes are used in the rural town context, transitioning to a bike lane in the transition zone is appropriate. Obviously, similar facilities in the context areas will not require additional special consideration, but they should ensure continuity in the separation level. For arterials, there is also a change in the separation level from high in the rural to medium in the rural town context. This transition requires additional considerations especially when changing from a separate multi-use path to an on-street facility.

Accommodating pedestrians also follows the same considerations in the rural to rural town transition. Pedestrian facilities present in the rural town may need to be extended through the transition zone and connect with the rural context facilities. This is more significant when the enhanced-width facility in the rural context is an off-road facility, because a transition to a sidewalk would need to be provided.

Transitioning from the rural town to rural context could follow a reverse order and complement the rural to rural town transition.

Example 2

The second example examines a minor arterial that transitions from a rural to urban context while passing through a suburban area (Figure 31). The same concerns and issues that were discussed in the previous example are applicable here as well. In this case, proper attention should be placed on how the roadway will transition from the rural to the suburban setting. Appropriate treatments could be identified to allow for the transition from high to medium operating speeds.

Accommodating users in the transition area between rural to suburban contexts is critical. For drivers, visual clues and positive guidance for the required speed reduction need to be placed over a transition zone, because a large speed reduction is anticipated. For bicyclists, the first step is determining if different bicycle facilities are in place, thus requiring a different level of separation. In the event that there is agreement, the separation type could be carried forward into the transition zone. In this case, local connectors requiring low separation could be addressed with the use of sharrows. For neighborhood and citywide connectors, a review of the separation level in the rural and suburban contexts should be undertaken to determine whether there are any differences. For example, if sharrows with wide lanes are used in the rural settings and bike lanes in the suburban context, then transitioning to a bike lane within the transition zone is appropriate. Obviously, similar facilities in the two context areas will not require additional special consideration, but they should ensure continuity of the separation level.

Accommodating pedestrians also follows the same considerations in the rural to suburban context transition. Pedestrian facilities present in the suburban context need to be extended, if required, through the transition zone and connect to any rural context facilities. This is again more critical when the enhanced facility in the rural context is an off-road facility, because it will need to transition to a sidewalk (minimum or wide width).

Within the suburban context, pedestrian accommodation needs should be examined to determine whether pedestrian accommodation will be the same throughout the corridor, or only necessary for targeted lengths of the corridor. The sidewalk width may be changed to accommodate specific needs as the pedestrians move though the corridor. For example, initially a minimum-width sidewalk could be provided, but it could be wider approaching areas with higher activity and building density. In addition, the vehicle speed will also dictate whether the facility is adjacent or separated from the roadway. For speeds 45 mph or greater, some buffer should be provided between the pedestrian facility and the roadway.

Figure 31. Minor arterial transitioning from rural to suburban to urban context.

For the suburban to urban transition, a set of similar considerations should be examined. Although the speed remains the same—medium for both contexts—there may be lower values used in the design element and speed limits due to higher building density and reduced setbacks. Greater reliance on positive guidance, such as use of optical narrower lanes or other treatments, is required to ensure drivers properly understand the context transitions.

Bicyclist accommodation must be addressed in the transition zone, since there is the potential for a different treatment within each context. This is more important for arterials, where the separation changes from high to medium and thus may require a transition from one type of facility to another.

Pedestrian facilities also need to be addressed in the transition zone, because sidewalks may need to be different widths in each context. In the urban context, high numbers of pedestrians require enhanced sidewalk treatment to account for potentially greater numbers of aggregating pedestrians. Enhanced facilities may be also needed in the vicinity of bus stops or other major points where pedestrians may congregate. In the event that speeds in the urban area are lower than 45 mph or on-street parking is allowed, then the pedestrian facilities can be adjacent to the roadway and they would not require any additional separation.

Conclusion

The goal of the Expanded FCS is to achieve appropriate contextual multimodal roadway designs. This goal is achieved with:

- Expanded context categories
- Recognition of network importance in roadway types
- Consideration of all roadway user groups

The Expanded FCS provides a flexible framework for professionals to conceptualize projects based on their current/future context and create a modal balance to achieve successful outcomes. The output of the Expanded FCS process aids in the development of the purpose and need statement and helps professionals define the required design elements and their potential tradeoffs.

The Expanded FCS matrix provides professionals with a range of design options based on the context and roadway type. Modal needs and volumes must be accounted for to determine each mode's requirements and any special overlays that may be necessary. These considerations will allow the planner/designer to identify potential areas of concern and determine the tradeoffs required to best accommodate all users. Alternative designs should be developed and evaluated in order to deliver a design that is contextually appropriate. The planner/designer is advised to follow the principles and process of CSS for further project development and delivery.

The reader may refer to the following two case studies for demonstrations of how the Expanded FCS can be applied to various contexts (Case Study 1) and how the framework can be used to achieve multimodal accommodation (Case Study 2).

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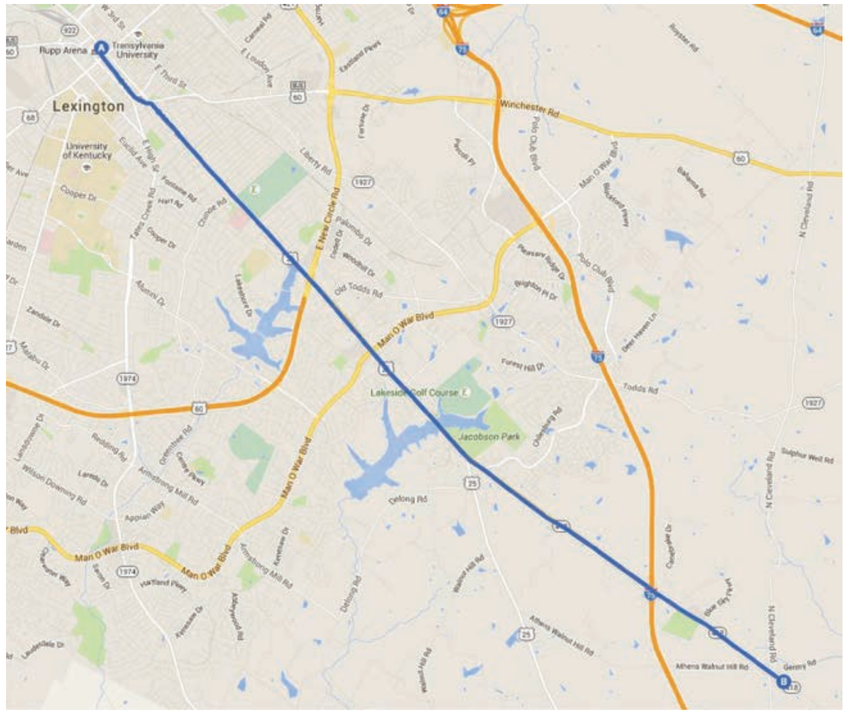
CASE STUDY 1

US 25/US 421/KY 418; Richmond Road (10.5 miles), Lexington, Fayette County, Kentucky

OVERVIEW

The roadway in this case study is a principal arterial (urban-rural) that extends 10.5 miles. It traverses the five context categories of the Expanded FCS. The analysis included aerial photography, visual survey, review of the state's functional classification, review of city transit information, and review of city/county bicycle information. The state highway department designates the roadway functional type as principal arterial (urban/rural). The study provides an analysis of context using the Expanded FCS methodology. Design considerations are established using the appropriate cell of the Expanded FCS matrix, which designates ranges to accommodate drivers, bicyclists, and pedestrians. Additionally, consideration is given to any transit or freight route information as an overlay. These matrix cell ranges for each context are then translated into a cross section alternative.



Case Study Corridor

A

B

Roadway Context

The following table displays milepoint segments and their context descriptions: density, land use, and setbacks. A significant spot development anomaly occurs at two places along the corridor—where it intersects an Interstate (traveler-associated commercial services) and where an adjacent small commercial area exists (regional commercial activity) in the rural segment. This spot development extends for nearly 1 mile [milepoint (MP) 8.2–9.1].

These context segments were determined without depending upon census data or governmental boundaries for service areas, using Expanded FCS context descriptions from Table 1.

Roadway context overview

Milepoint	Density	Land Use	Setbacks	Expanded FCS
0.0–0.7	High density, multistory and high-rise buildings; highest density within the corridor	Commercial, institutional (court houses and government offices) and residential uses; on-street parking and parking structures	Small setbacks with wide sidewalks and enhanced pedestrian facilities (benches, street furniture and pedestrian plazas)	Urban Core
0.7–2.5	High density, some multistory buildings	Mainly residential with some commercial uses; educational use; off-street parking	Medium (old established neighborhoods) and small setbacks with narrow sidewalks	Urban
2.5–4.4	Medium density with primarily single-story buildings	Primarily strip and big-box commercial uses; some multifamily and single-family residential (accessed by collectors)	Commercial properties have larger setbacks with significant parking areas between street and buildings	Suburban (1)
4.4–6.4	Medium density with single and some multistory buildings	Primarily single-family residential clusters with some commercial and institutional uses	Residential areas are buffered and are accessed by intersecting collectors. Commercial/institutional properties have larger setbacks with significant off-street parking areas	Suburban (2)
6.1–8.2	Low density, sparse residential with occasional agriculture-related structures	Agricultural uses with fenced areas	Large setbacks	Rural
8.2–9.1	Medium density	Commercial	Large setbacks	Spot Development
9.1–10.0	Low density, sparse residential with occasional agriculture-related structures	Agricultural uses with fenced areas	Large setbacks	Rural
10.0–10.5	Single- and two-story buildings in a several-block area of low to medium density	Single-family residential and commercial with on-street parking	Small setbacks and narrow sidewalks	Rural Town

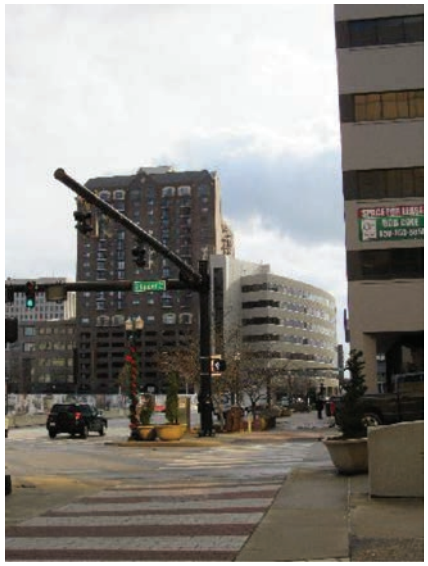
The area of development covered by this case study follows a traditional wheel-and-spoke roadway network. This partially accounts for the rather clean segment boundaries of context. In addition, the area is currently subject to urban services growth which limits development into rural parts of the county, concentrates development patterns (and context boundaries), as well as limits options for future growth and expansion. One area of note is the section from MP 8.2 to 9.1, an area of spot development/non-conforming use associated with the arterial's intersection with the Interstate highway in the otherwise predominately rural segment. With the area being less than one mile of arterial and the commercial services being primarily for the Interstate traveler and some regional commercial uses, it was decided not to assign the short segment as suburban context as discussed in the latter section of this report.

Based on a review of the 2013 Comprehensive Plan Update, no significant land use change is planned that would impact the context for this principal arterial. Some additional residential development is projected adjacent to the arterial in the Suburban (2) segment in keeping with the existing context.

Roadway Type

Richmond Road is signed as US 25 and US 421 and is currently classified as a principal arterial in Kentucky. US 25 and US 421 provide direct access to the cities of Richmond, Frankfort and Georgetown and beyond—including Covington/Cincinnati and Louisville. This section of roadway also serves as the primary route to access Interstate 75/71 from the City of Lexington. Average daily traffic volume on US 25/421 ranges from 24,000 vehicles per day (vpd) west of I-75 to 44,000 vpd within the urban core. East of I-75, traffic drops significantly to 3,000 vpd. Travel speeds range from 55 mph in the rural areas to 25 mph within the urban core. While serving a significant volume of through traffic accessing the urban core and within the urbanized areas, the arterial also serves high volumes of local traffic accessing the commercial, residential, and institutional areas near the corridor. This use best fits the proposed principal arterial roadway type which includes "corridors of regional importance connecting large centers of activity."

Urban Core (MP 0.0 to 0.7)



Urban Core Context

- Highest density (multi-story and high-rise structures with integrated parking)
- Mixed commercial, residential and institutional uses
- Small setbacks with sidewalks and pedestrian plazas

This is the urban core of the second-largest city in Kentucky that is consolidated with Fayette County; the city's 2014 population was 310,797, anchoring a metropolitan city–county area of 489,435 people and a combined two-county statistical area of 708,677 people.

Context / Roadway	Urban Core
Principal Arterial	L speed M mobility-M access LC: L separation; NC, CC: M separation P3: Wide; P4: Enhanced

The Expanded FCS matrix cell to the left defines the design considerations for the urban core–principal arterial section of the corridor. The roadway context is urban core due to the small setbacks, the mixed land use (residential, commercial and institutional), and high density of buildings. Most of the buildings are high-rise, multistory.There are enhanced-width sidewalks with street furniture and pedestrian facilities (benches) and plazas, and there is on-street parking along most of the section. The roadway type is a principal arterial, because it supplies regional network connectivity to traffic through the town and gives access to the area centers of activity. The roadway operates as a one-way pair.

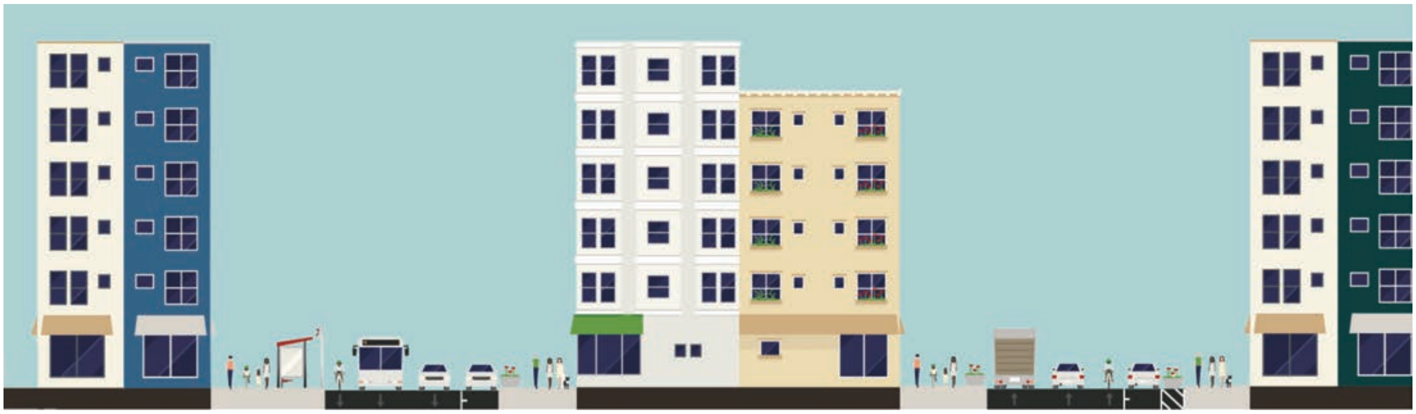
Driver Accommodation: According to the definitions for an urban core principal arterial, the roadway should provide low operating target speeds (<25 mph). Due to the principal arterial designation, the upper range of speeds is considered appropriate at 25 mph. This translates into medium mobility and medium levels of access.

Bicyclist Accommodation: The roadway is considered a citywide connector as it draws ridership from all areas within the city and accesses downtown Lexington. This designation requires a medium separation treatment; a 6.5-foot bike lane is considered appropriate in this section of the corridor due to the lower speeds, but includes additional width for interactions with transit vehicles and parking.

Pedestrian Accommodation: The land use indicates high pedestrian activity with several destinations in the area and therefore an enhanced-width sidewalk is recommended. Street furniture and pedestrian plazas may be considered due to aggregating pedestrians in this section.

Overlays: There is heavy transit demand along the corridor and the lanes must be designed to accommodate transit buses. There is also some freight demand—mainly small delivery trucks, which should be considered during the final cross section design.

Cross Section Alternative



The cross section above was developed using the matrix cell guidance provided by Expanded FCS. Other cross section alternatives may be reasonable and warranted. This one features a 25 mph speed limit with a reduced number of narrow 10-foot lanes (an outside 11-foot lane to accommodate transit vehicles). Left and right turn lanes are eliminated within the urban core to calm travel speeds, minimize pedestrian crossing distances and minimize conflicts with bicycles. A wider 6.5-foot bike lane is used to increase separation from parking and transit. The cross section shows little to no building setback of an urban core. Enhanced sidewalks with occasional "parklets" that benefit pedestrian are in use. On-street parking is provided as well as transit stops. The one-way pairs culminating on the right are clearly visible in the aerial photograph below. The shadows are indicative of the high-rise and multistory structures of the urban core.

Urban (MP 0.7 to 2.5)

Urban Context

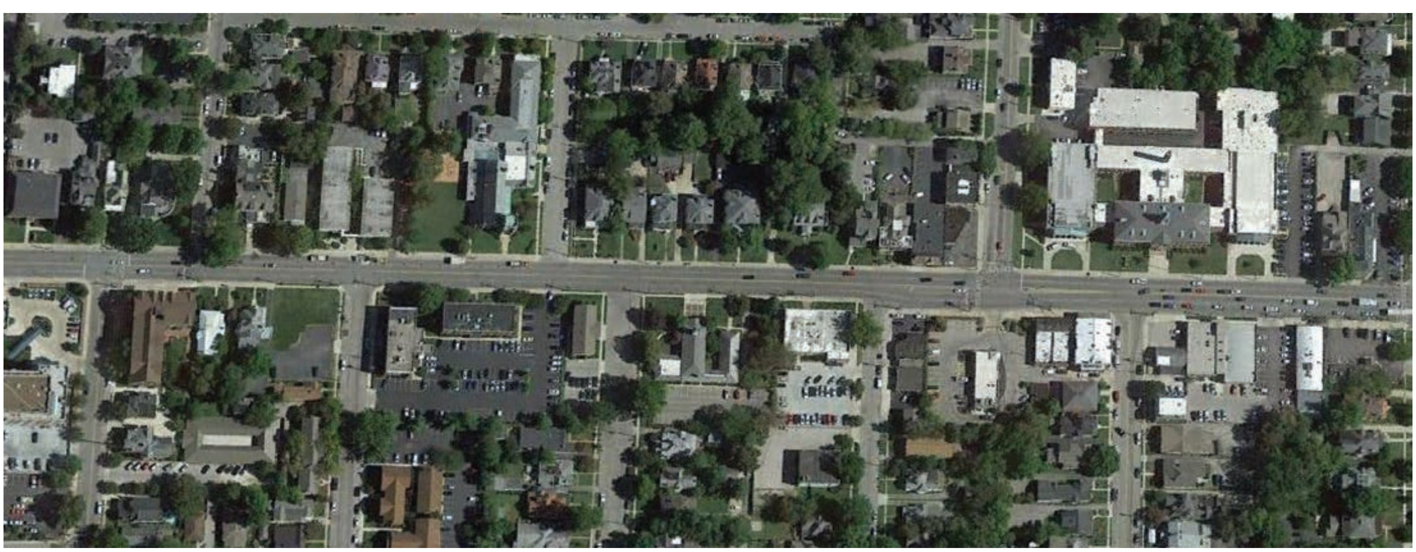
- High density (multistory structures with designated off-street parking)
- Mixed residential and commercial uses with some institutional and other special uses
- Minimum on-street parking and sidewalks with mixed setbacks

This urban segment has multistory structures of residential and commercial use. There is no on-street parking. Sidewalks are provided and the setbacks are mixed.

Context / Roadway	Urban
Principal Arterial	L/M speed M mobility-M access LC: L separation; NC: M/H separation; CC: H separation P2: Min; P3: Wide P4: Enhanced

The Expanded FCS matrix cell to the left defines the design considerations for the urban–principal arterial section of the corridor. The roadway context is urban due to the small setbacks, the mostly residential land use (with some commercial and educational uses), and single-family homes with some low-rise buildings. There is some off-street parking to accommodate the commercial land uses. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the town and facilitates access to the downtown centers of activity.

Driver Accommodation: According to the definitions for an urban principal arterial, the roadway should provide medium speed (30–40 mph) and, given the context, a target speed on the lower end of the spectrum of 30 mph is considered appropriate. This translates into medium mobility and medium levels of access.



Bicyclist Accommodation: The roadway is considered a citywide connector and, in this case, requires a high separation. A 6-foot bike lane is appropriate due to the limited bicycle demand in this section of the corridor.

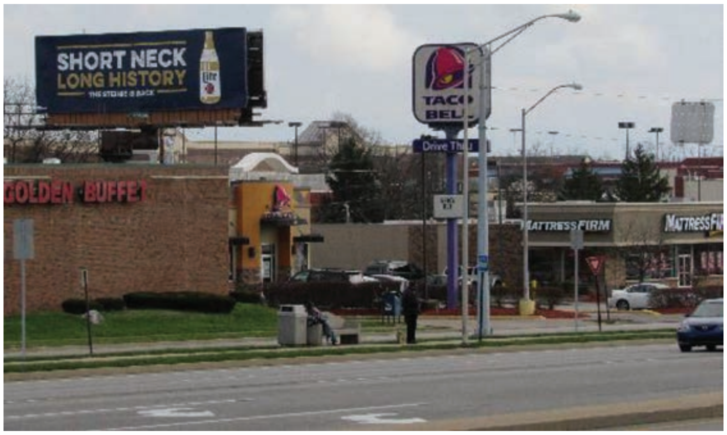
Pedestrian Accommodation: Generally, the land use indicates moderate levels of pedestrian traffic; however, volumes are not anticipated that would crowd a typical sidewalk or have areas with congregating pedestrians. Therefore, a minimum-width sidewalk is recommended. There are limited areas (commercial and educational land uses) that require a wide or enhanced sidewalk to accommodate aggregating pedestrians in the vicinity of these land uses.

Overlays: There is transit demand along the corridor and the lanes should be designed to accommodate transit buses. There is also some freight demand, mainly small delivery trucks, and this needs to be considered during the final cross section design.

Cross Section Alternative

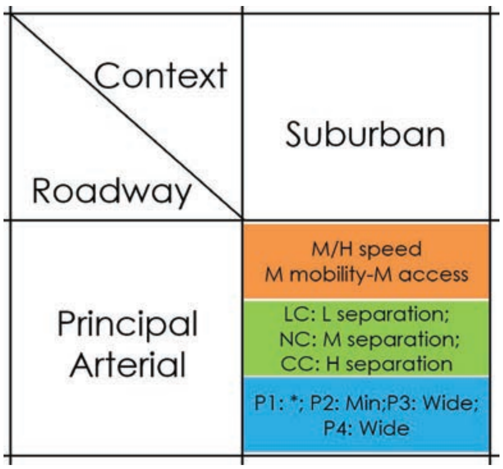
The cross section above was developed using the matrix cell guidance provided by the Expanded FCS. It features narrow lanes (11 feet) with turn lanes to accommodate higher auto-focused travel with a speed limit of 25 mph due to the presence of on-street bicycle facilities. Bike lanes and wide sidewalks are provided with intermittent enhancements. There are little to no building setbacks in commercial areas and, in these commercial areas, on-street parking is provided. In residential areas, where off-street parking is present, no parking is shown. Other cross section alternatives may be reasonable and warranted. The aerial photograph below clearly shows the commercial/institutional development toward the left, and the single-family residential development to the right. Structures are typically multistory.

Suburban Section 1 (MP 2.5 to 4.4)



Suburban Context

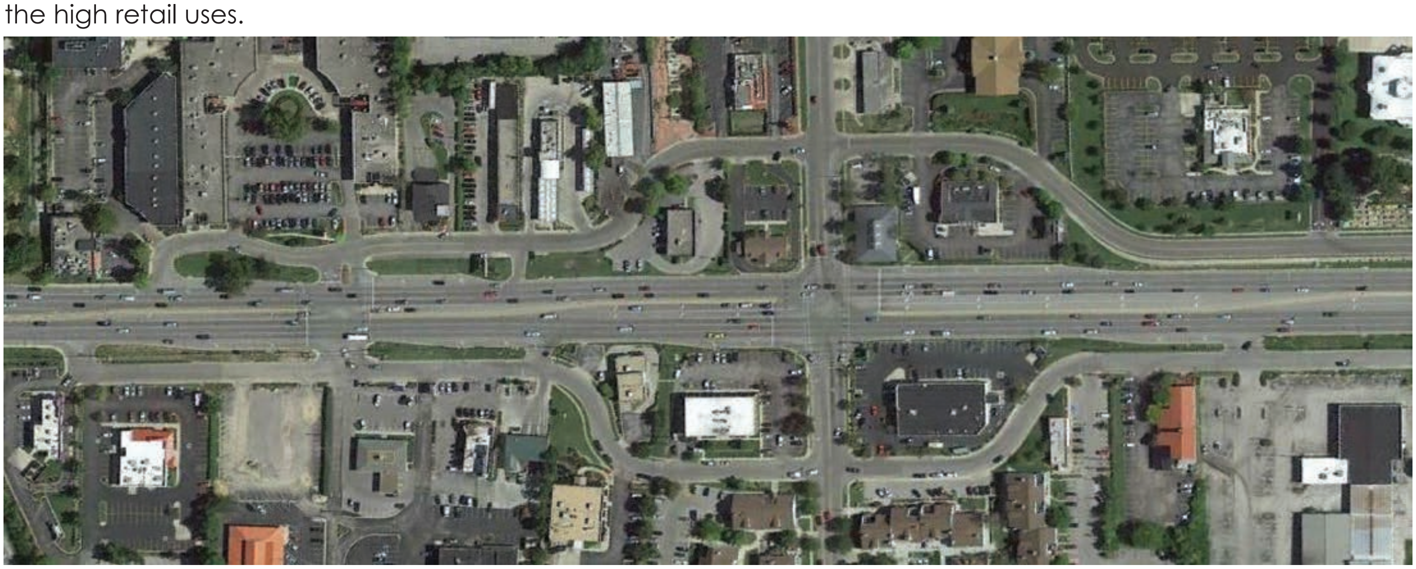
- Medium to low density
- Mixed residential and commercial clusters
- Varied setbacks with some sidewalks and mostly off-street parking



This segment meets the density, land use and setback criteria for a suburban context as defined by the Expanded FCS. The land use consists of primarily commercial strip and cluster development with some multifamily and single-family residential.

The Expanded FCS matrix cell on the left defines the design considerations for the suburban–principal arterial section of the corridor. The roadway context is suburban due to the increased setbacks and lower development density. The primary land use is big-box commercial retail and low-rise buildings on out lots. All parking is off-street with parking facing the primary corridor. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the town and facilitates access to the downtown centers of activity, I-75 and the primary commercial activity centers on the corridor.

Driver Accommodation: According to the definitions for a suburban principal arterial, the roadway should be designated at medium speed. Due to the increased density of development over the previous section and increased access points, the lower end of the "high" speed category (≥45 mph) is recommended. This section is signed with a speed of 45 mph. While the principal arterial provides for medium access, access management principles should be applied to supply consolidated access points and improved internal circulation to benefit the high retail uses.



Bicyclist Accommodation: The roadway is considered a citywide connector and, in this case, requires high separation due to the higher speeds on the corridor. A buffered bike lane is recommended to separate bicycle traffic from the high volume vehicular traffic. An alternate may allow for bicycle usage on frontage roads, but the high number of access points and indirect routing of these roads make this option undesirable.

Pedestrian Accommodation: The land use indicates low pedestrian traffic with mainly local destinations to/from the retail areas or transit stops. However, minimal pedestrian traffic is anticipated and the development and land use favors automobile-centric use. Therefore, sidewalks are necessary; however, wide or enhanced treatments are not required to accommodate large groups of pedestrians. ADA-compliant minimum sidewalk widths are recommended.

Overlays: Transit is present on the corridor with multiple stops on both sides of the roadway. Consideration may be given to providing bus pull-outs or enhanced bus stops to accommodate transit/pedestrians accessing the suburban retail area. Some heavy freight traffic does use the corridor to access the outlying urban areas and connect to I-75 on the east end of the corridor.

Cross Section Alternative

The above 45 mph cross section alternative for this suburban arterial was developed using the matrix cell guidance provided by the Expanded FCS. Other cross section alternatives may be reasonable and warranted. The cross section design specifies four 11-foot travel lanes with turn lanes and buffered bike lanes as well as minimum sidewalks. Access management is necessary, and no on-street parking is provided. Transit service is available and bus stops are planned in accordance with the city's transit route overlay. The aerial photograph below clearly shows the commercial development of this suburban section with controlled access. Each establishment has dedicated off-street parking, and a network of service roads is apparent.

Suburban Section 2 (MP 4.4 to 6.4)

Suburban Context

- Medium to low density
- Mixed residential and commercial clusters
- Varied setbacks with some sidewalks and mostly off-street parking

This suburban area contains some commercial/institutional areas that include health services but is predominately single-family residential in clusters with intersecting collector access.

Context / Roadway	Suburban
Principal Arterial	M/H speed M mobility-M access LC: L separation; NC: M separation; CC: H separation P1: *; P2: Min;P3: Wide; P4: Wide

The Expanded FCS matrix cell to the left defines the design considerations for the suburban–principal arterial section of the corridor. The roadway context is suburban due to the increased setbacks, which are primarily residential in this section of the corridor. Development faces away from the primary street and has direct access off of the secondary street network. Additional residential development adjacent to the arterial is indicated in the 2013 Comprehensive Plan Update for the area but would not change the future context. Some low-rise commercial retail centers and office use surround the primary intersection at Man O' War Boulevard. All parking is off-street. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the town and facilitates access to the downtown centers of activity, I-75, and the primary commercial activity centers on the corridor.

Driver Accommodation: According to the definitions for a suburban principal arterial, the roadway should be signed at medium speed and, given the context, a target speed of 45 mph is considered appropriate, due to the lower access spacing and increased setbacks off residential properties on this section. This translates into medium mobility and medium levels of access.

Bicyclist Accommodation: The roadway is considered a citywide connector and, in this case, requires a high separation. A primary attraction in the area is Jacobson Park, which can serve many of the residential areas on the corridor and in the vicinity. A multi-use bicycle/pedestrian path is proposed on the north side of the corridor. Cross-street bicycle/pedestrian access should be accommodated at all signals through the section.

Pedestrian Accommodation: The land use indicates low pedestrian traffic with mainly local destinations and potentially some recreation traffic to/from the residential areas to Jacobson Park which would require a minimum width. However, pedestrians may also share use of the multi-use path described above if connection to major crossing points at intersections are provided on the south side of the roadway.

Overlays: There is no transit on this section of the corridor. Some heavy freight traffic does use the corridor to access the outlying urban areas and connect to I-75 on the east end of the corridor.

Cross Section Alternative

Other cross section alternatives may be reasonable and warranted. The above 55 mph cross section alternative for this suburban arterial was developed using the matrix cell guidance provided by the Expanded FCS. The cross section design accommodates four wider travel lanes (11 feet) with median and turn lanes. A multi-use path connects to park and residential areas. Access management is necessary, and no on-street parking is provided. Transit service is available and bus stops are planned in accordance with the city's transit route overlay. The aerial photograph on the facing page shows some commercial/institutional land use while the photograph below shows the transition to park and single-family residential accessed from intersecting collectors.

Rural (MP 6.1 to 8.2, 9.1 to 10.0)

Rural Context

- Lowest density (few houses or other structures)
- Agricultural uses predominate with isolated residential and commercial
- Usually large setbacks

This rural segment has the lowest density with a few isolated houses and occasional farm structures with large setbacks. Agricultural uses dominate the area but are interrupted by spot development (non-conforming use of less than one mile, accommodating Interstate traveler and regional commercial services).

Context / Roadway	Rural
Principal Arterial	H speed H mobility-L access LC: L separation; NC: M separation; CC: H separation P1: *; P2: Min; P3, P4: Wide

The Expanded FCS matrix cell on the left defines the design considerations for the rural–principal arterial section of the corridor. The roadway context is rural due to the large setbacks, the mostly agricultural land use, and sparse single-family homes with some low-rise agricultural buildings. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the county to rural towns and access to suburban/urban centers of activity.

Driver Accommodation: According to the definitions for a rural principal arterial, the roadway should be signed as high speed and, given the context, a target speed of 55 mph is considered appropriate. This translates into high mobility and low levels of access. Access is at medium level given the varied agricultural land uses and need for land access.

Bicyclist Accommodation: There is no demand for bicycles and therefore no dedicated bicycle facilities are provided, though riders may make use of the wide shoulders or the travel way itself.

Pedestrian Accommodation: There is no demand for pedestrians in this area beyond rare or occasional foot traffic and therefore there is no need for any dedicated pedestrian facilities within the rural area.

Overlays: There is no freight or transit demand in the area and thus no additional considerations are needed for specific overlays.

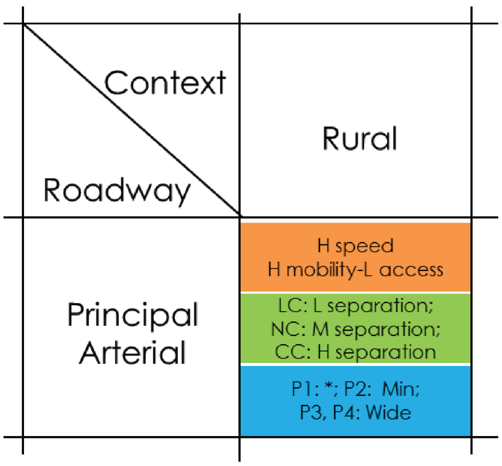
Cross Section Alternative

Other cross section alternatives may be reasonable and warranted. The cross section above was developed using the rural arterial matrix cell guidance provided by the Expanded FCS. This option features a wide four-lane roadway with wide shoulders and a higher speed limit of 55 mph. A median is provided for safety. The aerial photographs on the facing page and below clearly show agricultural use and the large setbacks of most structures (residential and farm). The non-conforming commercial use at the Interstate intersection is not shown below but is shown on the following pages.

Rural – Spot Development (MP 8.2 to 9.1)

Rural Context
- Low density, with spot suburban development
- Small commercial development surrounded by agricultural uses
- Medium suburban-type setbacks

This short sub-segment (less than 1 mile) within the overall rural segment has a somewhat suburban commercial context that centers on the interchange of the rural arterial with I-75. The uses are commercial services related to travelers. In addition, there is a small adjacent commercial/industrial complex.



The Expanded FCS matrix cell on the left defines the design considerations for the rural–principal arterial section of the corridor. The rural roadway context is interrupted by this compact commercial use area. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the county to rural towns and access to suburban/urban centers of activity and I-75. While this sub-segment offers a substantially different context and land use than the surrounding agricultural uses, its short length as well as the relative compatibility of its context with the surrounding rural context in terms of speed and mobility means it can fit the spot development designation. Therefore, it is proposed that the roadway cross section need not differ substantially from adjacent sections, and the context need not change. Operational improvements may be warranted such as “Congested Area” warning signs or advisory speed plaques.

Driver Accommodation: According to the definitions for a rural–principal arterial, the roadway should provide high speed but, given the congestion and commercial context, a target speed of 45 mph is considered appropriate. This translates into medium mobility and medium levels of controlled access. This spot development is clearly automobile centric.

Bicyclist Accommodation: There is no demand for bicycles and therefore no dedicated bicycle facilities are provided though riders may make use of the wide shoulders or the travel way itself.

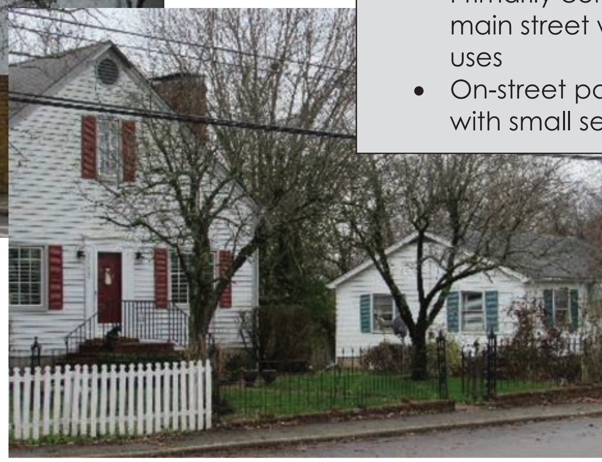
Pedestrian Accommodation: The automobile-oriented nature of the businesses and isolated location eliminates pedestrian demand along the roadway itself, though pedestrians should be considered within and between adjacent businesses.

Overlays: There is some freight that requires wider lanes and turning lanes as well as special consideration at the commercial access points, but there is no transit demand in the area and thus no additional considerations are needed for specific overlays.

Cross Section Alternative

The cross section above was developed using the rural arterial matrix cell guidance provided by the Expanded FCS. Due to the short length of this development cluster, the basic cross section of the roadway is maintained, though this design is augmented with turn lanes within the center median as necessary to serve the development. The aerial photograph below shows the clustered commercial development along this otherwise rural arterial with its agricultural uses.

Rural Town (MP 10.0 to 10.5)



Rural Town Context

- Low to medium density (single-family and other single-purpose structures)
- Primarily commercial uses along a main street with adjacent residential uses
- On-street parking and sidewalks with small setbacks

Context / Roadway	Rural Town
Principal Arterial	L/M speed M mobility-H access LC: L separation; NC, CC: M separation P2: Min; P3: Wide; P4: Enhanced

This rural town (a small unincorporated village) in the rural services area of Lexington–Fayette Urban County to the east of I-75 is located at the junction of KY 418 and KY 1973.

The Expanded FCS matrix cell on the left defines the design considerations for the rural town–principal arterial section of the corridor. The roadway context is rural town due to the small setbacks, the mostly residential land use (with some commercial and educational uses), and single-family homes with some two-story buildings. There is limited off-street parking to accommodate the commercial land uses. The roadway type is a principal arterial, since it supplies regional network connectivity to traffic through the rural town and facilitates access to residential and limited commercial uses.

Driver Accommodation: According to the definitions for a rural town principal arterial, the roadway is signed at low speed and, given the roadway context, a target speed of 25 mph is considered appropriate. This offers medium mobility and high levels of access. Turn lanes are not provided in order to minimize crossing distances and calm traffic speeds through the town.

Bicyclist Accommodation: The road could be considered a local connector for bicyclists and would require a low separation. In this case, sharrows can be used to indicate the presence of low-volume bicycle traffic mixed with low-speed vehicular traffic.

Pedestrian Accommodation: The land use indicates low pedestrian activity, requiring a minimum-width sidewalk.

Overlays: There is no freight or transit demand in the area and therefore no additional considerations are needed for specific overlays.

Cross Section Alternative

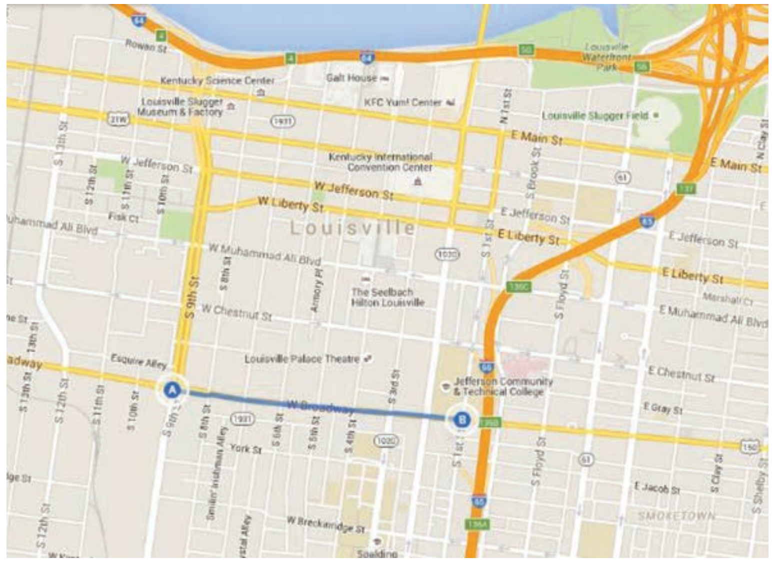
The cross section above was developed using the rural town arterial matrix cell provided by the Expanded FCS. Other cross section alternatives may be reasonable and warranted. This option features narrow lanes with on-street parking available. Setbacks are varied. The aerial photograph on the facing page shows the relatively compact mixed residential and commercial uses of this rural town that is centered on the intersection of two state numbered highways. The intersection at the town center is four-way stop controlled.

CASE STUDY 2

US 150; W. Broadway Avenue (0.73 mile), Louisville, Jefferson County, Kentucky

OVERVIEW

The roadway in this case study is a principal arterial (urban) that extends 0.73 mile. It traverses a single context category of the Expanded FCS. The analysis included aerial photography, visual survey, review of the state's functional classification, review of city transit information, and review of city/county bicycle information. The state highway department designates the roadway functional type as principal arterial (urban). The study provides an analysis of context using the Expanded FCS methodology. Design considerations are established using the appropriate cell of the Expanded FCS matrix, which provides ranges to accommodate drivers, bicyclists, and pedestrians. Additionally, consideration is given to any transit or freight route information as an overlay. These matrix cell ranges for each context are then translated into a cross section alternative. An evaluation of alternative cross sections based on operational and safety analysis is also included.



Roadway Context

The following table provides the roadway context descriptions: density, land use, and setbacks.

Roadway context overview

Milepoint	Density	Land use	Setbacks	Expanded FCS
0.0–0.73	High density, multistory and high-rise buildings; highest density within the corridor	Commercial, institutional (court houses and government offices), and residential uses; off-street parking and parking structures	Small setbacks with wide sidewalks and enhanced pedestrian facilities (benches, street furniture and pedestrian plazas)	Urban Core

Roadway Type

W. Broadway Avenue is signed as US 150 and is classified as an urban principal arterial in Kentucky. US 150 provides direct access to Interstates 65 and 264 from the City of Louisville. Average daily traffic volume on US 150 is 25,200 vehicles per day (vpd). The speed limit on the corridor is currently 35 mph. While serving a significant volume of through traffic in the urban core and within the urbanized areas, it also serves high volumes of local traffic accessing the commercial, residential, and institutional areas near the corridor and the freeways. This use best fits the proposed principal arterial roadway type, which includes "corridors of regional importance connecting large centers of activity."

Urban Core (MP 0.0 to 0.73)

This is the urban core of the largest city in Kentucky; the city's 2014 population was 741,096, anchoring a metropolitan city–county area of 1,338,433 people.

Context / Roadway	Urban Core
Principal Arterial	L speed M mobility-M access
	LC: L separation; NC, CC: M separation
	P3: Wide; P4: Enhanced

The Expanded FCS matrix cell on the left defines the design considerations for the urban core–principal arterial section of the corridor. The roadway context is urban core due to the small setbacks, the mixed land use (residential, commercial, and institutional), and high density of buildings. Most of the buildings are high rise and multistory; there are enhanced-width sidewalks with street furniture and pedestrian facilities (benches and plazas); and there is on-street parking along most of the section. The roadway type is a principal arterial, because it supplies regional network connectivity to traffic through the town and facilitates access to the area centers of activity.

Urban Core Context

- Highest density (multistory and high-rise structures with integrated parking)
- Mixed commercial, residential, and institutional uses
- Small setbacks with sidewalks and pedestrian plazas

Driver Accommodation: According to the definitions for an urban core principal arterial, the roadway should be signed with low target operating speeds (<25 mph). Due to the principal arterial designation, the upper range of speeds is considered appropriate at 25 mph. This translates into medium mobility and medium levels of access.

Bicyclist Accommodation: The City of Louisville maintains a Bike Master Plan to direct investment and coordination of the city's bicycle facilities. A primary focus of the master plan is to extend bicycle connections into the outlying suburban areas of Louisville and complete the "Louisville Loop," an outer ring connection around the metro area. In addition, the master plan addresses the future bicycle network within the downtown urban core. The plan focuses on making strong east–west and north–south connections through the one-way street pair systems. W. Broadway Avenue is not identified as a future bike lane connection because of the extremely high volume of traffic on the roadway. However, parallel connection and cross street connections are present including the enhanced bike lane treatments on S. 6th Street (photograph on right), a primary southbound bicycle route. Due to the redundant bicycle connectivity provided by adjacent routes and the absence of the corridor as a future bikeway connection, bicycle priority is identified as low and shared-use facilities are proposed for commuting bicyclists who are comfortable riding in traffic. Other bicyclists may access the corridor from adjacent networks where bike lanes are planned and roadway volumes and speeds are lower.

Enhanced bike lane on S. 6th Street at Broadway.

Pedestrian Accommodation: The land use indicates high pedestrian activity with several pedestrian oriented destinations in the area (photograph below). This assessment of the land use is backed by the Louisville Pedestrian Master Plan, which conducted a latent demand analysis for pedestrian travel. The latent demand method predicts potential non-motorized trips based on characteristics of trip origins and destinations and their relative proximity and concentration/dispersion. As can be seen from this analysis, the downtown area, including Broadway, is identified as a Tier 1 area, meaning there is high potential to increase non-motorized transportation within the area. Based on the high number of transit stops and retail and pedestrian uses on the corridor, enhanced-width sidewalks are recommended. Street furniture and pedestrian plazas may also be considered to accommodate aggregating pedestrians in the area.

Pedestrian activity areas on W. Broadway Avenue.

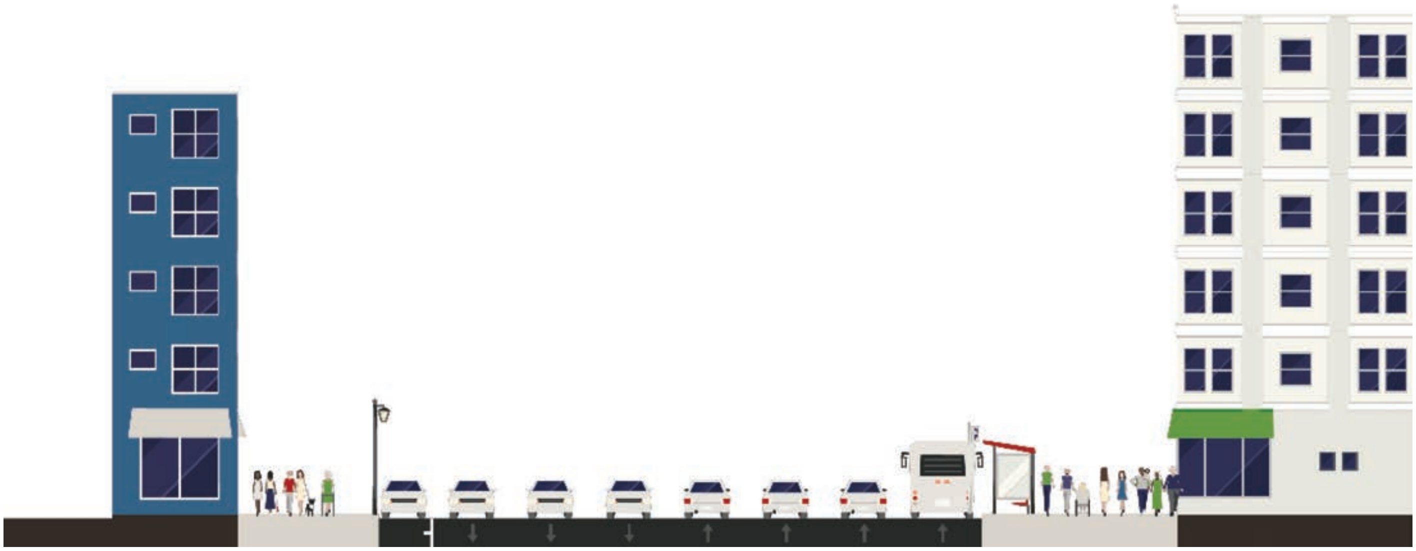
The Louisville Pedestrian Master Plan also provides guidance to direct the design of roadways on pedestrian corridors to reduce vehicle–pedestrian conflicts. Two objectives of the Pedestrian Master Plan are to (1) establish criteria and set priorities for constructing pedestrian facilities based upon condition, location, and proximity, as well as current and future demand, and (2) evaluate design speed as part of all corridor projects. Some of the goals associated with these include the following:

- Accommodate and improve pedestrian access to and across bridges, railroads, and state highways and through interchanges.
- Provide pedestrian access across arterial streets and state routes that divide high-demand pedestrian areas. Prioritize projects for improvement using Pedestrian Master Plan criteria. Implement through corridor projects and with other available resources. Seek grant funding as needed.
- Incorporate shortened pedestrian crossings into roadway designs by providing clear direction on curb bulbs and median islands, as well as other options that reduce the number of lanes a pedestrian must cross at an uncontrolled location (e.g., by eliminating peak-hour parking restrictions).
- Revise curb radii standards to create tighter turns to slow traffic in locations that do not have high volumes of truck or bus turning movement and in balance with emergency response needs.
- Use a combination of engineering, enforcement, and evaluation tools to reduce speeds along corridors within high-priority areas. Prioritize locations near parks, community centers, and neighborhood business districts. Where appropriate, add speed zone limits and signs (including radar speed signs), and expand the use of enforcement efforts (e.g., speed vans, red light cameras) in these areas.

Overlays: Broadway is also a heavily traveled transit route serving Express Route 23; Frequent Service Routes 2 and 31; and Local Routes 31, 49, 53, 64, 61, 66, 67, 68, and 78. The ZeroBus, a free-fare downtown route, also transits Broadway between 4th and 3rd Streets. The heavy transit demand along the corridor requires lanes designed to accommodate transit buses. There is also some freight demand (photograph on right), including small delivery trucks and large WB-53 trucks, and these must be considered during the final cross section design.

Freight traffic on W. Broadway Avenue.

Cross Section



Existing cross section.

The existing cross section on W. Broadway Avenue has two primary requirements: (1) automobile access providing a primary east–west route across Louisville traveling to Interstates 64, 65, and 264 and (2) east–west pedestrian movements as evidenced by the wide (25-foot) sidewalks. To serve automobile traffic, seven 10-foot travel lanes are provided, though the outside lanes do allow for time-of-day restricted parking. No turn lanes are present with four lanes eastbound and three lanes westbound. While the 25-foot sidewalks provide ample mobility for pedestrians along the corridor, the wide street makes crossings difficult and requires longer cycle lengths to direct pedestrian crossings, thus increasing delay to drivers and pedestrians. No bicycle allowances are present on the corridor.

Evaluating the operations of major intersections within this portion of the road demonstrates that all intersections maintain a high level of service (LOS A or B) with minimal vehicular delay.

Evaluating the Pedestrian Crosswalk Score (as computed by the *Highway Capacity Manual*, 6th edition) resulted in a LOS rating of C for all approaches. This LOS is based on pedestrian compliance (a function of delay and width of crossing).

Proposed cross section.

The proposed cross section reduces the number of lanes from seven to five, including a center two-way left-turn lane, allowing dedicated left turns at major intersections. Parking is removed except in localized areas which experience high drop-off/pick-up. The Brown Theatre is such a location (photograph below) and ample off-street parking opportunities exist within the corridor. Outside lanes are proposed at 13 feet to better accommodate the needs of transit. Additionally, the outside lane is striped as a shared bike lane, to allow riders comfortable riding with traffic to use the facility. It is also proposed that parallel streets W. Chestnut Street and Breckenridge Street be signed and striped as higher-order bicycle routes with separate facilities due to lower volumes of vehicular traffic on these routes. Rear access to all buildings fronting W. Broadway Avenue is available from these routes. It is also proposed that an expanded and improved tree lawn be provided along the sidewalk to increase separation from the vehicular traffic, as the existing sidewalk width is more than adequate to accommodate pedestrian demands. While the total pavement width is not reduced in this scenario, the opportunity exists to create curb extensions at major intersections or at pedestrian crossing points to reduce crossing width and to shorten traffic signal cycle lengths. Right-turn lanes are not provided to eliminate bicycle–vehicle interactions when entering right-turn lanes.

School bus drop off at Brown Theatre.

Vehicle LOS for the proposed alternative does degrade, with increased delays leading to LOS C/D, but all intersections are still shown to operate within capacity during the morning and afternoon peak hours.

Pedestrian crosswalk LOS is improved from LOS C to LOS B because of the reduced crossing times and delays.

Safety Evaluation

Application of the *Highway Safety Manual* procedures is not possible as there is no base model available for prediction of crashes for seven-lane sections. However, individual design elements and their effect on Crash Modification Factors (CMFs) or the base crash model for other conditions may be evaluated to identify potential trade-offs in the design. These are summarized in the table below.

Design Elements	Existing Cross Section	Existing CMF	Proposed Cross Section	Proposed CMF	Notes
Proportion of curb length with on-street parking	0.8	1.57	0.25	1.14	CMF
Median Width	0	23.5	10	13.2	Not a direct measure of median width, but rather change in segment crashes resulting from undivided to divided
Offset to roadside fixed objects	3	1.03	16	1	CMF
Number of Lanes Crossed by Pedestrian	7	0.042	5	0.039	Impacts the base conditions for pedestrian involvement
Number of Left Turn Lanes	2	0.81	4	0.66	CMF

As can be seen in the table, limiting on-street parking can reduce crashes by as much as 28 percent. Due to the current time-of-day restrictions, which place parking in a travel lane, it is possible that real-world safety gains would be even greater. The increase of offset from fixed objects from 3 feet to over 16 feet is shown to decrease crashes by 3 percent, though, improvements to pedestrian safety and pedestrian comfort are of significant benefits.

The current cross section does not provide any separation between travel directions, while the proposed cross section introduces a two-way left-turn median. This impact cannot be directly measured by the *Highway Safety Manual* application, though comparing a four-lane undivided section to a four-lane divided section shows a reduction in base crash conditions from 23.5 crashes to 13.2 crashes. Other studies have developed similar crash reductions factors for two-way left-turn lanes such as the FHWA TechBrief on two-way left-turn lanes, which estimated a Crash Reduction Factor of 29.1 percent on total crashes.

A primary contributor to the pedestrian crash model is the number of lanes the pedestrian crosses. When reducing the number of crossing lanes from seven to five, the pedestrian percentage of total injury crashes is reduced from 4.2 percent to 3.9 percent, an 8 percent reduction in pedestrian crashes.

Finally, the introduction of left-turn lanes on Broadway are directly shown in the CMFs to improve from 0.81 when left-turn lanes are present only on the side streets to 0.66 when they are introduced to the major street (a 20 percent reduction in crashes).

CASE STUDIES

Lessons Learned

The application of the Expanded FCS in the case studies demonstrated the following lessons learned:

1. Modal accommodation and balancing in the design could be achieved using the ranges provided in each cell of the Expanded FCS matrix. These considerations included the elimination of turn lanes in the urban core and urban contexts to accommodate bicycle and pedestrian traffic, widening lanes to accommodate buses, and reducing target operating speeds in suburban context to comply with the citywide connector for bicyclists.
2. Consistency of the cross section was also achieved with the use of 11 foot lanes throughout the corridor and wider lanes in the rural context.
3. The use of the Expanded FCS in determining the context and roadway type was easily implemented throughout the corridor. Context sections were easily discernable and the presence of 'major' intersections facilitated the clear distinction of the boundaries. Local knowledge of the facility also played an important role in the determination of the context boundaries.
4. Designating the context categories allowed for an easy transition in developing the design concepts and alternative for the design of the cross sections. These preliminary designs can be further developed to address specific location needs and issues. However, it should be noted that the initial development was easily completed by use of the ranges provided in the Expanded FCS cells.
5. An issue to be noted here is that local needs and constraints may affect these design choices and impact the final designs. Designers should become familiar with the existing and future context of the specific sections of the corridor and address their designs to reflect these concerns.
6. In these case studies, the context section boundaries occurred at major intersections and the transition from one section to the next was smooth. Designers should pay attention to these transition points and provide roadway users with adequate information to reach the target operating speeds by the time they enter the next context section.
7. Planning documents were critical to the identification of the network roles and future contexts of the study corridors.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TDC	Transit Development Corporation
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation

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