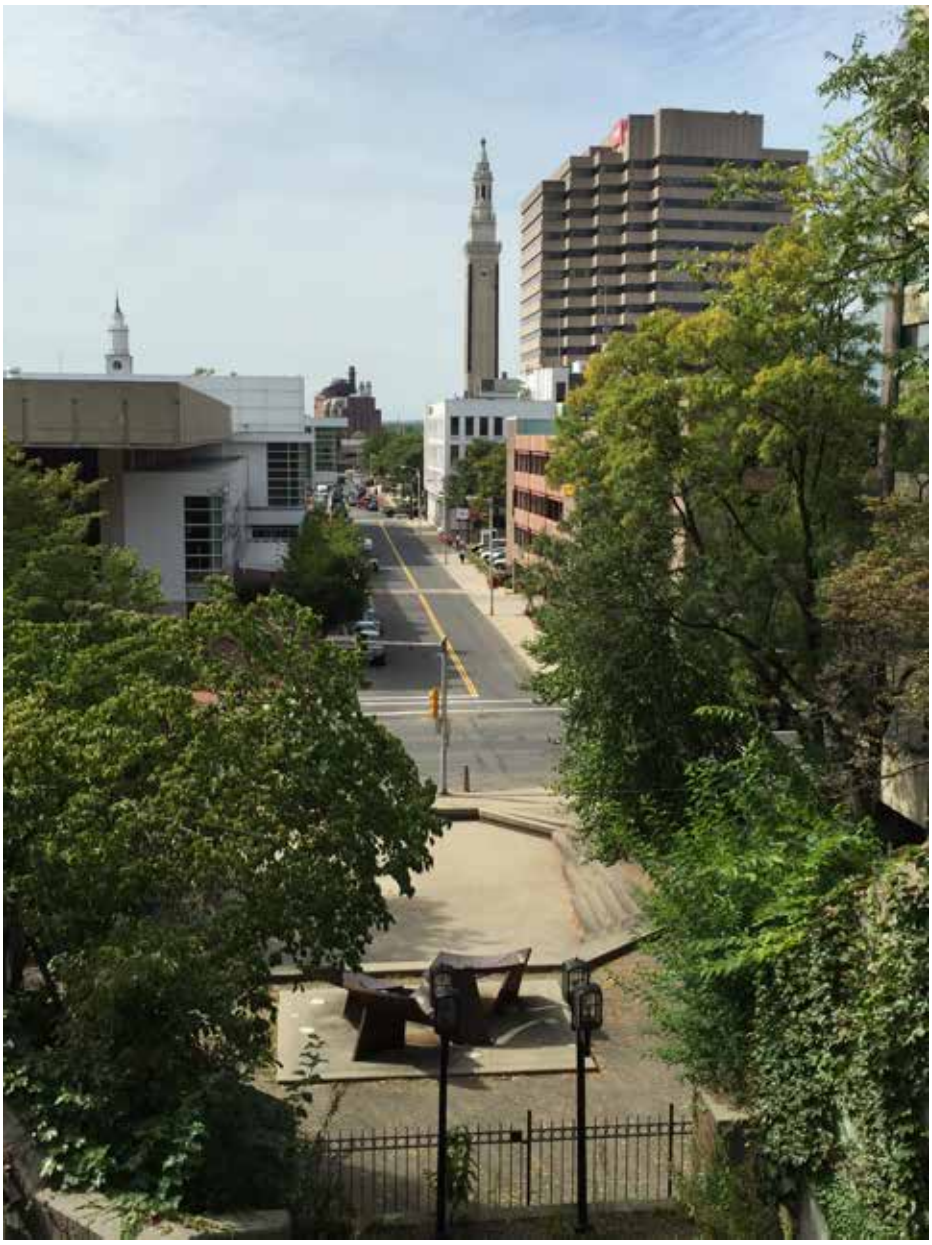
walkBoston®



Downtown/Cultural District Walk Assessment Springfield, MA

September 25, 2015

Massachusetts Department of Public Health
State and Local Public Health Actions to Prevent Obesity, Diabetes, and Heart Disease and Stroke (DP14-1422PPHF14)

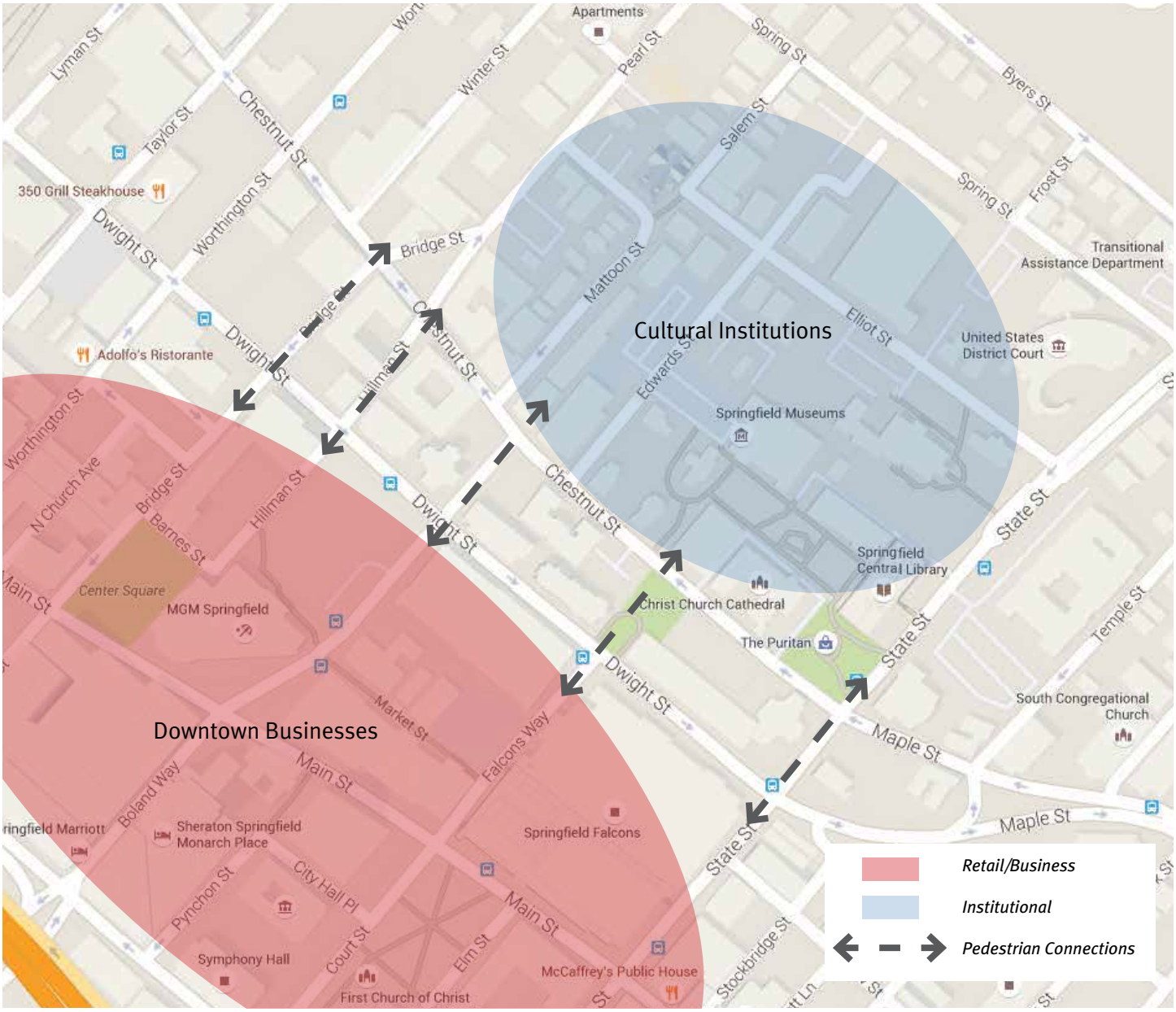
MAKING MASSACHUSETTS MORE WALKABLE

Old City Hall | 45 School Street | Boston MA 02108 | T: 617.367.9255 | F: 617.367.9285 | info@walkboston.org | www.walkboston.org

Purpose of Walk Assessment

Walkability, which is a measure of the level of connection and quality of the walking environment, contributes to an area's economic vitality, residents' physical health, and the level of community engagement. Neighborhoods with well-maintained sidewalks, safe crossings, streetscapes that contain benches and trees, and destinations accessible on foot have higher walkability and, consequently, better economic, physical and community health.

The purpose of this walk assessment was to identify ways to improve the walking connections between downtown businesses on Main Street and the historic neighborhoods and cultural institutions located around the Quadrangle, which is roughly bounded by Chestnut Street, State Street, and Elliot Street. Though physically close, the walkable connections between the two internally focused districts are in disrepair, challenging, and generally unfriendly to pedestrians. Traffic moves quickly on Dwight, Chestnut and State Streets, and pedestrian crossings are long and sometimes unprotected. In addition, there is an elevation change between downtown and the cultural institutions that further discourages connectivity between districts, particularly for pedestrians that are older, are pushing young children in strollers, or may face accessibility challenges.



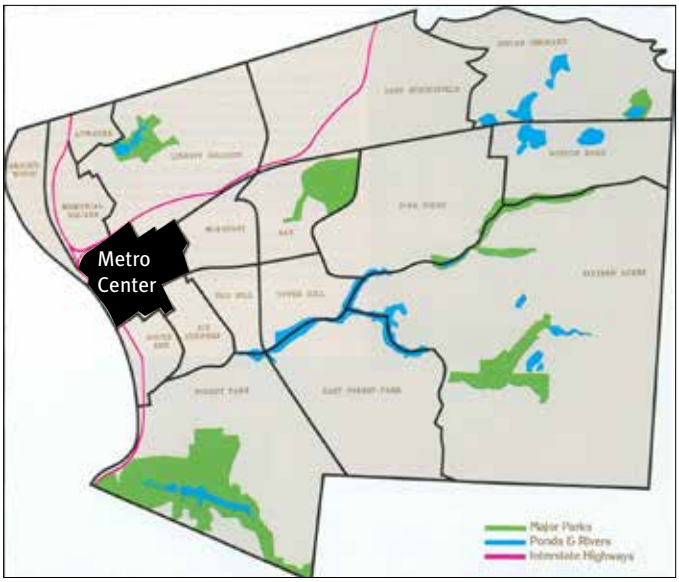
This assessment will help city staff set priorities as they move forward with pedestrian infrastructure improvements. This report will also be a resource as the city implements a wayfinding strategy, which seeks to promote utilitarian walking and to reveal the city's remarkable assets that are within walking distance of each other. For purposes of this report, wayfinding includes the traditional use of signage to help orient pedestrians to local destinations, as well as the use of streetscape improvements to create an identifiable sense of place.

Context

Springfield Massachusetts is a city of approximately 153,000 people located about 90 miles west of Boston. The third largest city in the Commonwealth, Springfield is the cultural and commercial center of the Pioneer Valley.

This walk assessment occurred in the Metro Center neighborhood of Springfield, which has been called the business, government, and cultural center of the city. Bounded by Route 291 to the north, Union and Howard Streets to the south, Federal Street to the east and the Connecticut River to the west, Metro Center is home to historic residential streets, high-rise apartment and office buildings, and a downtown retail district. The neighborhood contains several cultural institutions, including the Springfield Armory, Symphony Hall, and the Quadrangle, which houses several world-class museums and the Dr. Seuss National Memorial Sculpture Garden.

Archway to the museums on the Quadrangle



The Metro Center neighborhood has been called the business, government and cultural center of the city.
*Source: http://choosespringfieldmass.com/_Media/neighborhood_*

Despite these amenities, the Metro Center neighborhood still faces challenges to social and economic equality. Among Springfield neighborhoods, Metro Center had one of the lowest annual median incomes at $16,114 in 2012. Furthermore, Metro Center faces a poverty rate of 48.9%, significantly greater than the city's average poverty rate of 33.3%. Metro Center residents also face much higher rates of unemployment than the rest of the city; Springfield's unemployment rate is nearly 11% in comparison to 22.4% in Metro Center.

Housing at the corner of State and Chestnut

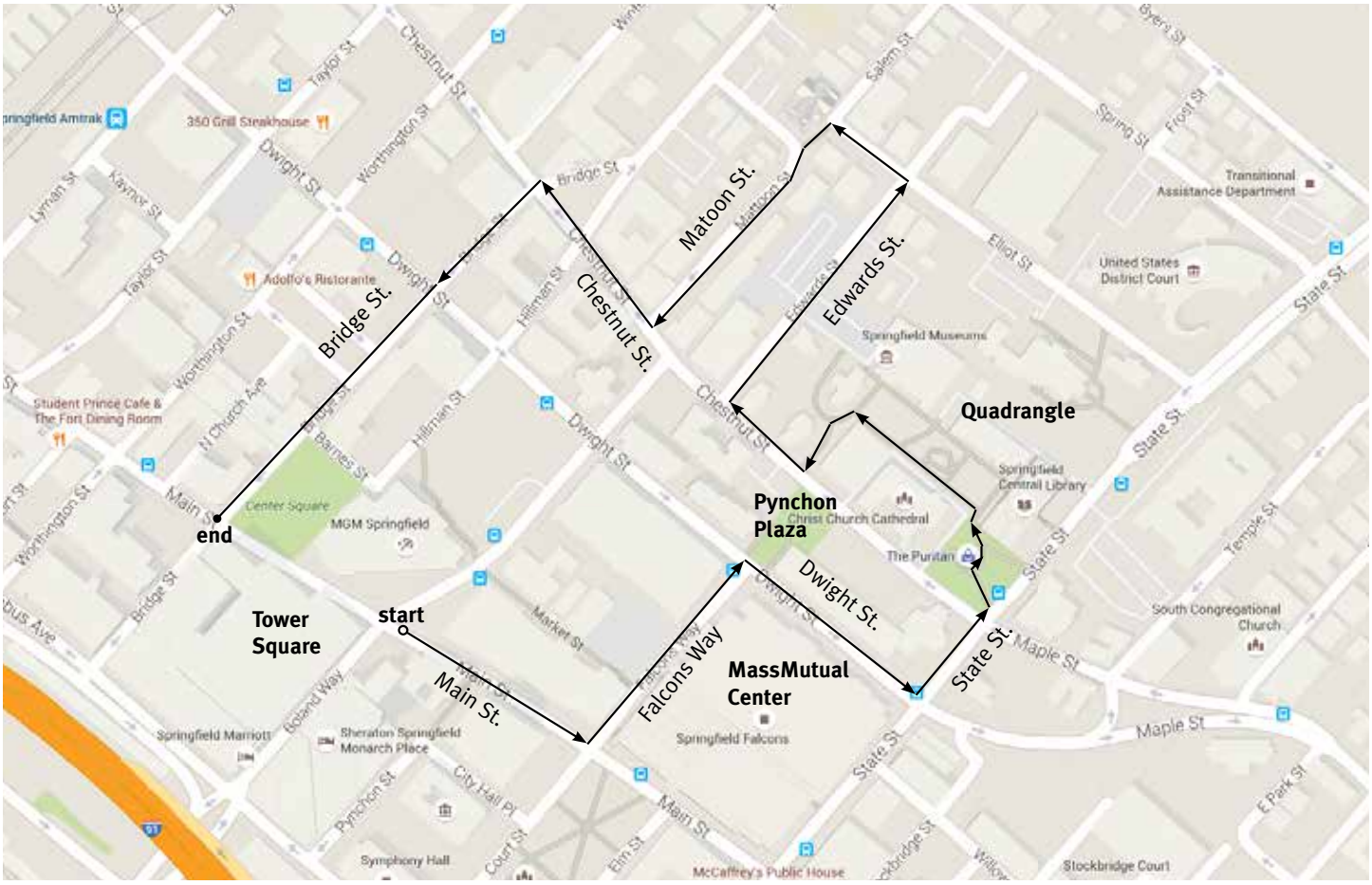
While these statistics may indicate a community in distress, the Metro Center community is continuing to evolve in more sustainable and equitable directions. The neighborhood already has one of the highest rates of sustainable transportation use at 42.4% (the Springfield average is 20.8%).

The walk assessment study area includes high-density residential development, a central business district, and neighborhood retail areas. The mix of uses and wide range of cultural destinations that can be reached on foot position the community favorably for high walkability.

Walk Assessment Route

The walk assessment began at Main Street and Boland Way in the downtown district. Participants continued north on Falcons Way near the MassMutual Center to Pynchon Park on Dwight Street. After heading east on Dwight Street to State Street, participants continued north on State Street to the Quadrangle. A walk through the Quadrangle led to a quiet residential community on Elliot Street and Mattoon Street. Once reaching Mattoon Street and Chestnut Street, the assessment continued down Chestnut Street to Bridge Street, and ended at the intersection of Bridge and Main Streets.

In addition to the traditional features that WalkBoston observes on all assessments, the CDC Worksite Walkability Tool was used to frame observations and recommendations for the assessment. Throughout the walk, participants used the tool to comment on different aspects of streetscape design, pedestrian safety, and overall walkability. A copy of the tool is available in Appendix A.



Map of walking route through the Metro Center neighborhood

Overall Observations

The following observations describe the general quality and characteristics of the walking environment seen during the assessment.

- The area north of Dwight Street and south of Chestnut Street is noticeably lacking in pedestrian facilities in comparison to the downtown business district and the Quadrangle
- Dwight Street and Chestnut Street are heavily travelled corridors and carry a significant amount of fast-moving traffic, which presents a potential threat to pedestrian safety
- Crosswalks are generally present, although the red and white color scheme used on the crosswalks in the downtown district are more vibrant and help create uniformity across the walking environment
- Sidewalks vary in condition; one of the major challenges is accessibility given the significant elevation change on State Street
- There are several underutilized green spaces in the assessment area, including Pynchon Plaza and Stearns Square, which have potential to serve as destinations and community gathering spaces
- Wayfinding signs are designed to direct drivers to destinations. Most signs are out of the line of sight of pedestrians, and are too high on existing street signs or utility poles

Wayfinding signage is designed primarily for drivers

Overall Recommendations

The following general recommendations suggest an approach to infrastructure improvements in the Metro Center neighborhood.

- Focus on pedestrian infrastructure improvements in the area bounded by Dwight Street and Chestnut Street to promote connectivity
- Consider pedestrian safety improvements on Dwight Street and Chestnut Streets, such as painting fog lines, adding curb bump-outs at intersections, and repainting crosswalks with the same red and white color scheme as the downtown district. See Gas Explosion Re-development study prepared for this area for additional recommendations
- Continue to study and promote the idea of converting Dwight Street and Chestnut Street to two-way traffic. Their conversion would contribute to traffic calming efforts and promote downtown economic revitalization.
- Revitalize parks and open space, both physically and programmatically, to serve as pedestrian gathering spaces. Pynchon Plaza in particular is a critical link between the museums and downtown.
- Develop a pedestrian scale wayfinding system linking the neighborhoods, museums and downtown districts

Renovation of Pynchon Park would restore a key connection between the downtown business district, residences, and the museums

CDC Walkability Audit Tool

The CDC walkability audit tool uses a ranking method to assess factors related to safety and aesthetics. Safety considerations are considered the most important, followed by aesthetics. Shade is considered the least important and is weighted the least in the audit tool formula.

The walk audit participants completed a walk audit tool worksheet for each road segment and/or intersection along the walk route. The worksheet evaluates the following 9 factors:

A. Pedestrian facilities
B. Pedestrian conflicts
C. Crosswalks
D. Maintenance
E. Path size
F. Buffer
G. Universal accessibility
H. Aesthetics
I. Shade

Each factor was given a numerical score between 1 and 5 (5 being the highest score). The formula below calculates a score for each road segment or intersection:

sum of high importance features (A-C): ___ x 3
sum of medium importance features (D-H): ___ x 2
sum of low importance features (I): ___ x 1

The scores are mapped on a walkability map using three categories:

Red - Higher risk; unattractive (70 or less)

Yellow - Moderate risk; reasonably attractive (71-85)

Green - Low risk; attractive (scores higher than 85)

Example of a high-risk, unattractive road segment

Example of a low-risk, attractive road segment

Downtown/Cultural District Walkability Map

	WALKING ROUTE SEGMENT											
	A	B	C	D	E	F	G	H	I	J	K	L
TOTAL	94	59	66	69	87	83	85	92	89	96	70	68
A. FACILITIES	5	4	3	3	5	5	5	5	5	5	4	3
B. CONFLICTS	5	3	3	3	5	5	5	5	5	5	4	3
C. CROSSWALKS	5	3	3	5	5	5	5	5	5	5	3	3
D. MAINTENANCE	3	2	4	4	4	3	4	5	4	5	3	4
E. SIZE	5	4	4	4	5	3	4	5	3	5	4	3
F. BUFFER	5	3	4	4	3	4	1	5	3	4	3	4
G. ACCESS	4	2	3	3	3	3	5	2	5	4	3	5
H. AESTHETICS	5	3	3	2	4	4	5	5	5	5	4	3
I. SHADE	5	1	3	2	4	4	2	3	4	5	3	3

SUM OF HIGH IMPORTANCE FEATURES (A-C): ___ X 3
SUM OF MEDIUM IMPORTANCE FEATURES (D-H): ___ X 2
SUM OF LOW IMPORTANCE FEATURES (I): ___ X 1

Site-Specific Observations and Recommendations

The descriptions below characterize the corridors and intersections along the walking route. Recommendations for specific infrastructure improvements follow the descriptions.

Appendix B defines many of the traffic calming techniques and pedestrian infrastructure elements suggested in this report.

Main Street corridor (Segment A)

Main Street is a highly walkable corridor with lots of shops, restaurants, and hotels. Crosswalks are short and painted with a red/white design at nearly all intersections along the corridor. Brick sidewalks are wide with trees and street furniture providing an adequate buffer between pedestrians and the roadway. There is an exclusive pedestrian signal at the intersection of Main Street and Falcons Way that provides adequate time for pedestrians to cross safely.

CDC Walkability Tool Score (out of 100): 94

Recommendations:

- Continue maintenance of sidewalks and street furnishings
- Repair loose bricks and dips near lampposts, trees and street signs

Falcons Way (Segment B)

Each side of the Falcons Way corridor presents a very different walking experience. The north side of the street offers few pedestrian amenities. Parking is the primary land use on this side of the street and the curb cuts at the parking entrance and exit are particularly long with wide curb radii. There is an entrance to a brick-paved alley along the former Market Street alignment that connects to Harrison Avenue. It is lined with street trees and pedestrian-scale lighting.

The south side of Falcons Way is more accommodating to pedestrians, as it offers wider sidewalks with planters serving as buffers from the street. There is a raised crosswalk on Falcons Way between the parking structure and the MassMutual Center. The condition of the sidewalks is fair with several deteriorating concrete panels near the garage and alley entrances.

CDC Walkability Tool Score (out of 100): 59

Recommendations:

- Plant trees and add street furnishings to improve the quality of the pedestrian environment. Trees can help to hide the parking lots and structure.
- Consider reducing the number and width of curb cuts
- Repair and/or replace crumbling sidewalk panels

While the Main Street sidewalks are generally in good shape, there are ongoing maintenance issues with brick sidewalks that can create tripping hazards

The combination of multiple, wide curb cuts, a singular large building facade, and parking as the primary land use compromises the pedestrian experience along Falcons Way

The Dwight Street crossing is long and not well-marked.

Falcons Way and Dwight Street Intersection (Segment C)

The crossing distance from Falcons Way to Dwight Street is long and marked with one faded crosswalk. Vehicles travel quickly down Dwight Street, a one-way three-lane collector with two parking lanes, which is approximatley 50' wide. Curb ramps are missing from the Dwight Street crossing (an apex ramp exists but does not line up with the crossing). The intersection is signalized, but not all approaches have pedestrian signals.

Pynchon Plaza is at the terminus of Falcons Way. The plaza is in need of reinvestment and is currently closed for public use. Its original design included a grand staircase and an outdoor elevator which helped people negotiate the significant grade change between Dwight Street and Chestnut Street. While the park is currently not operational, it has the potential to serve as a vibrant and lively community gathering space and reconnect the seemingly distant museum district from downtown.

CDC Walkability Tool Score (out of 100): 66

Recommendations:

- Consider installing curb bump outs at the Falcons Way/Dwight Street intersection to reduce the crossing distances
- Repaint the existing crosswalk and paint a second crosswalk on the northwest side of Falcons Way using a ladder design to increase the visibility of crossings
- Install curb ramps and detectable warning strips to comply with accessibility requirements

Pynchon Plaza was designed to bridge the elevation change between Dwight Street and Chestnut Street providing a key connection between downtown and the cultural institutions on the quadrangle

- Reinvest in Pynchon Plaza. Consider a phased approach, beginning with simple maintenance and park programming and studying alternatives for mitigating the grade change between Dwight and Chestnut Streets

Dwight Street Corridor Segment D)

Dwight Street is a one-way street with traffic moving east, and is one of the most frequently-traveled routes for getting into and out of the city. There were few pedestrians seen walking on Dwight Street. While there are some trees providing a buffer from traffic on the north side of the street, the fast vehicle speeds and tripping hazards on the sidewalk make walking difficult and unpleasant. Additionally, one of the primary land uses on this corridor is parking, which further detracts from the pedestrian environment.

CDC Walkability Tool Score (out of 100): 69

Recommendations:

- Repair and/or replace sidewalks along Dwight Street
- Continue to study possibility of instituting two-way traffic on Dwight Street

Dwight Street and State Street Intersection (Segment E)

The crossings at this intersection are well-marked with red/white paint, include curb ramps and detectable warning strips, and are protected with an exclusive pedestrian countdown signal. There are still some accessibility challenges. The elevation of State Street rises a fair amount when heading north, and there is a rock pit on a sloped sidewalk at the northwest corner of the intersection that could prove problematic if not well-maintained.

CDC Walkability Tool Score (out of 100): 87

State Street (Segment F)

The State Street corridor has seen recent investment in marked crossings, curb ramps and sidewalks.Trees and street furniture line the sidewalk. However, there are some tripping hazards, such as empty planters and uneven patches of sidewalk. The steep grade change from Dwight Street to Chestnut Street is a challenge on State Street; the elevation rises significantly as pedestrians travel north along this corridor. In terms of wayfinding, there is no signage present to indicate pedestrians are close to the Quadrangle and Springfield Museums.

CDC Walkability Tool Score (out of 100): 83

Recommendations:

- Repair sidewalks and remove tripping hazards along State Street
- Consider installation of wayfinding signs to the museums along Chestnut Street

This section of State Street has wide, smooth sidewalks and recent intersection enhancements that improve pedestrian safety

State Street and Chestnut Street (Segment G)

This intersection has had similar improvements as the intersection at State Street and Dwight Street. The crosswalks are painted with the same red and white pattern, and trees line the streets. The crosswalk across the northern side of Chestnut Street is outside the pedestrian desire lines and has a significant cross-slope given the elevation change along State Street. A bus stop shelter is located on the northwest corner of the intersection providing a covered waiting area for transit riders.

Signs announcing the museums are set back from the road and understated. Visitors and residents alike may miss them. The museum district and quadrangle are inward facing which keeps them hidden from those driving down State Street. Improved wayfinding signage would do a lot for advertising the location of the musuems and their close proximity to downtown.

CDC Walkability Tool Score (out of 100): 85

Recommendations:

- Consider re-locating the crosswalk and addressing the cross-slope on the northern side of Chestnut Street
- Improve wayfinding signage for walkers and drivers to better advertise the presence of the museums and quadrangle at this intersection

Institution and wayfinding signage should be improved to reveal the cultural assets along the State Street corridor to all

Springfield Museums and Quadrangle (Segment H)

The museums, quadrangle and sculpture park are hidden gems along the State Street corridor. Strolling through this area provides respite from the busy activity occuring along State and the other major city streets.

The park and paths within the quadrangle are well-maintained and a beautiful setting for the buildings and sculptures that frame and fill this space. Additional wayfinding signs would bring more visitors and residents who may not be aware of what lies just a short distance from their homes.

CDC Walkability Tool Score (out of 100): 92

Recommendations:

- Install additional wayfinding signs leading to the quadrangle and at its entrance

The Dr Seuss sculpture garden is just one of many surprise treasures found inside the quadrangle

Chestnut Street and Edwards Street (Segment I)

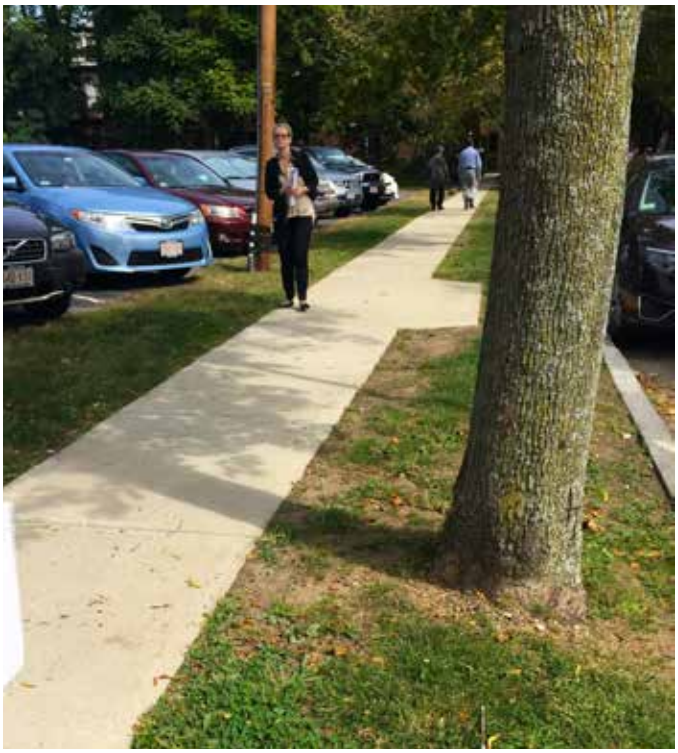
The intersection of Chestnut Street and Edwards Street is home to another entrance to the Springfield Museums, noted by a large archway at Edwards Street. Just east of this entrance is the school and group entrance to the museums. Here, the crosswalk is not in the pedestrian desire lines, nor is it very well marked. Additionally, the south side of the sidewalk at this location is quite narrow.

The main entrance to the Museums is on Edwards Street. There is a large parking lot to accommodate museum-goers that could benefit from a pedestrian path. The travel lanes on this street are narrow, and therefore traffic moves slowly, which is desirable. The sidewalks along this corridor are also narrow, which is not ideal given the numbers of people expected visiting the museums. A similar aesthetic continues to Elliot Street, where traffic volumes are low in this predominantly residential neighborhood.

CDC Walkability Tool Score (out of 100): 89

Recommendations:

- Consider widening the sidewalks to accommodate larger groups attending the cultural institutions



Widening the sidewalks is the only major recommendation along Elliot Street

Mattoon Street (Segment J)

Mattoon Street is a very walkable residential street. There is a pedestrian walkway that connects Mattoon Street and Elliot Street connecting this residential neighborhood to the nearby Springfield Museums. Mattoon Street reveals the charm and character of historic neighborhoods that were once more prevalent in the city. Its brick sidewalks and pedestrian scale lighting provide an excellent walking environment that is obviously well-cared for by its residents.

CDC Walkability Tool Score (out of 100): 96

The brick sidewalks and tree wells on Chestnut street need to be repaired. Particular attention should be made to maintaining the tree canopy

Chestnut Street (Segment K)

Chestnut Street is a one-way corridor that carries high volumes of traffic traveling to Route 291. The intersection of Mattoon Street and Chestnut Street is missing crosswalks, and there are some tripping hazards located on the sidewalk. There is a well-maintained triangular park located at the intersection of Chestnut Street, Bridge Street, and Pearl Street. While nearly all crosswalks are present at this intersection, they are only marked by two parallel lines.

CDC Walkability Tool Score (out of 100): 70

Recommendations:

- Consider painting crosswalks across Chestnut Street at the Mattoon Street intersection
- Remove tripping hazards and repair sidewalks along this section of Chestnut Street
- Continue to study possibility of instituting two-way traffic on Chestnut Street

Bridge Street (Segment L)

Bridge Street is a one-way corridor that carries traffic from the northern residential part of Metro Center to the downtown area. Like the intersection with Chestnut Street, the Bridge Street and Dwight Street intersection could be repainted with crosswalks that match the red and white scheme of the downtown area. Additionally, in order to enhance the connectivity between the downtown district and the Springfield Museums, this street would benefit from the addition of street trees, benches, and pedestrian-scale lighting. Filling the empty storefronts and revitalizing the park at Stearns Square as the pedestrian gathering space will further promote walking along this corridor.

CDC Walkability Tool Score (out of 100): 68

Recommendations:

- Consider painting crosswalks at the Bridge and Dwight street intersection
- Improve the overall quality of the streetscape along Bridge Street with street trees, smooth sidewalks, and pedestrian-scaled lighting
- Promote programming in Stearns Square and continue to encourage new businesses and restaurants to locate in this downtown area

Sources

http://www.springfield-ma.gov/planning/fileadmin/Planning_files/Springfield_Neighborhood_Profiles_PDF.pdf

http://www.pvpc.org/sites/default/files/Springfield% 20Data% 20 Atlas% 209-23-14-web-reduced.pdf

http://www.springfield-ma.gov/planning/fileadmin/Planning_files/Maps/Zoning_Map_0114.pdf

http://www.springfield-ma.gov/planning/fileadmin/Planning_files/Zoning_2013_Documents_Images/Article_3_Districts.pdf

Appendix A. Healthier Worksite Initiative Walkability Audit Tool

Location: _____ Date: _____

A. Pedestrian Facilities (High): presence of a suitable walking surface, such as a sidewalk or path.
1 No permanent facilities; pedestrians walk in roadway or on dirt path
2
3 Continuous sidewalk on both sides of road, or completely away from roads
4
5 Sidewalk on one side of road; minor discontinuities that present no real obstacle to passage

B. Pedestrian Conflicts (High): potential for conflict with motor vehicle traffic due to driveway and loading dock crossings, speed and volume of traffic, large intersections, low pedestrian visibility.
1 High conflict potential
2
3
4
5 Low conflict potential

C. Crosswalks (High): presence and visibility of crosswalks on roads intersecting the segment. Traffic signals meet pedestrian needs with separate 'walk' lights that provide sufficient crossing time.
1 Crosswalks not present despite major intersections
2
3
4
5 No intersections, or crosswalks clearly marked

D. Maintenance (Medium): cracking, buckling, overgrown vegetation, standing water, etc. on or near walking path. Does not include temporary deficiencies likely to soon be resolved (e.g. tall grass).
1 Major or frequent problems
2
3
4
5 No problems

E. Path Size (Medium): measure of useful path width, accounting for barriers to passage along pathway.
1 No permanent facilities
2 < 3 feet wide, significant barriers
3
4
5 > 5 feet wide, barrier free

F. Buffer (Medium): space separating path from adjacent roadway.
1 No buffer from roadway
2
3
4 > 4 feet from roadway
5 Not adjacent to roadway

G. Universal Accessibility (Medium): ease of access for the mobility impaired. Look for ramps and handrails accompanying steps, curb cuts, etc.
1 Completely impassible for wheelchairs, or no permanent facilities
2 Difficult or dangerous for wheelchairs (e.g. no curb cuts)
3
4 Wheelchair accessible route available but inconvenient
5 Designed to facilitate wheelchair access

H. Aesthetics (Medium): includes proximity of construction zones, fences, buildings, noise pollution, quality of landscaping, and pedestrian-oriented features, such as benches and water fountains.
1 Uninviting
2
3
4
5 Pleasant

I. Shade (Low): amount of shade, accounting for different times of day.
1 No shade
2
3
4
5 Full shade

Sum of High importance (A-C): _____ x **3** = _____
Sum of Medium importance (D-H): _____ x **2** = _____
Sum of Low importance (I): _____ x **1** = _____
Total Score: _____ / 100

Observations
1. What is the most dangerous location along this segment?

2. What is the most unpleasant element of this segment?

3. What improvements would make this segment more appropriate for pedestrian use?

4. Would it be possible to design a more direct route to connect the ends of this segment?

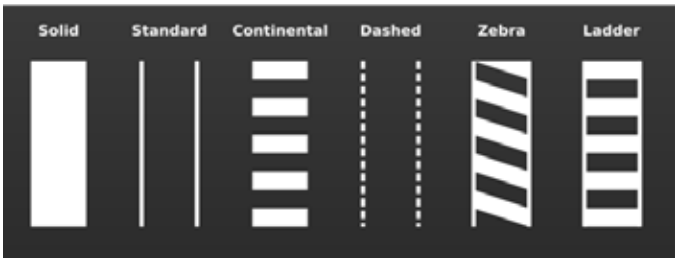
5. Are the conditions of this segment appropriate and attractive for exercise or recreational use?

Appendix B. Terminology

Below are images and definitions of the terms used to describe the walking environment in this report.

Crosswalk and Stop Line

Crosswalks can be painted in a variety of ways, some of which are more effective in warning drivers of pedestrians. Crosswalks are usually accompanied with stop lines. These lines act as the legally mandated stopping point for vehicles, and discourage drivers from stopping in the middle of the crosswalk.



Crosswalk patterns
Source: USFHA

Crosswalk and stop line
Source: http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/sys_impact_rpt/images/fig16.jpg

Curb Ramp and Detectable Warning Strip

Curb ramps provide access from the sidewalk to the street for people using wheel chairs and strollers. They are most commonly found at intersections. While curb ramps have improved access for wheelchair-bound people, they are problematic for visually impaired people who use the curb as an indication of the side of the street. Detectable warning strips, a distinctive surface pattern of domes detectable by cane or underfoot, are now used to alert people with vision impairments of their approach to streets and hazardous drop-offs.

Curb ramp and detectable warning strip in Woburn, MA

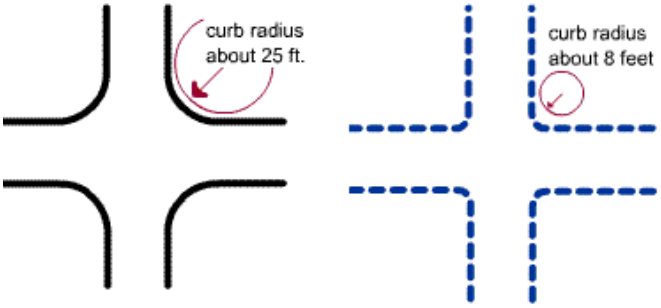
Curb Extension/Curb Bulb-out

A sidewalk extension into the street (into the parking lane) shortens crossing distance, increases visibility for walkers and encourages eye contact between drivers and walkers.

Curb extensions are often associated with mid-block crossings

Curb Radius

A longer curb radius (on the left in figure below) allows vehicles to turn more quickly and creates longer crossing distance for pedestrians. A shorter curb radius (on the right in the figure below) slows turning speeds and provides pedestrians shorter crossing distances.



There are two excellent examples of the shortening of curb radii in Woburn, MA. The first (A) is a low- cost solution using a gravel-filled zone between the original curb line and the newly established road edge. The second is a higher-cost solution using grass and trees and extending the sidewalks to the new curb. Both work to slow traffic.

Fog Line

A fog line is a solid white line painted along the roadside curb that defines the driving lane and narrows the driver's perspective. Fog lines are most often used in suburban and rural locations, but may be appropriate in some urban conditions.

Fog lines delineate the vehicular driving zone on wide roadways.

(A) Gravel-filled curb extension

(B) Grass, trees and extended sidewalk in curb extension

In-street Pedestrian Crossing Sign

In-street pedestrian crossing signs are used at the road centerline within crosswalks to increase driver awareness of pedestrians in the area. These signs are a relatively low-cost, highly effective tool in slowing traffic by the narrowing travel lanes. They are popular with road maintenance departments since they can be easily moved for snow removal.

Leading Pedestrian Interval (LPI)

A leading pedestrian interval gives pedestrians an advance walk signal before motorists get a green signal, giving the pedestrian several seconds to start walking in the crosswalk before a concurrent signal is provided to vehicles. This makes pedestrians more visible to motorists and motorists more likely to yield to them. Typical LPI settings provide 3 to 6 seconds of advance walk time.

Source: http://safety.fhwa.dot.gov/ped_bike/tools_solve/ped_scdproj/sys_impact_rpt/images/fig34.jpg