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Creating a benefit Index for Targeting Investment in Pedestrian Connectivity Improvements East Bayside Neighborhood: Portland, ME

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Creating a Benefit Index for Targeting Investment in Pedestrian Connectivity Improvements
East Bayside Neighborhood: Portland, ME

A Capstone Technical Report

By

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Abstract:

This project demonstrates how a GIS-based analysis of pedestrian accessibility to selected amenities from locations in and around the East Bayside neighborhood of Portland, Maine can help identify and guide decisions about public investment in improving such access. Two street network configurations are analyzed: the current (2011) condition, and a hypothetical configuration including several connectivity improvements currently under discussion or in the process of construction. The GIS tools are used to calculate the network distances between the centroid of the area's census blocks and two amenities: the nearest full-service grocery store, and an outdoor fitness station available to the public. The ratio between the network and Euclidian distances is used to calculate a Walking Permeability Distance Index, the WPDI (Allan, 2001). In addition, the difference in the network distance to the amenities between each network configuration for each census block was calculated and then used in analysis of the spatial distribution of revised access from the connectivity improvements. A new index was also developed, given the name here of Connectivity Improvement Benefit Index (CIBI), which factors in distance saved, total population, and estimated walking speeds, optionally normalized for distance. This alternate index technique has implications for use by communities in prioritizing scarce resources for investment in connectivity improvements to benefit the maximum desired segment or amount of their population. The East Bayside example serves especially as an example for any community seeking to reconnect urban street grids severed during the U.S. Urban Renewal period of the 1950s-1970s.

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Introduction

Street network design has been an integral element of human civilization since pre-history. It has certainly perplexed urban planners since the early days of the profession in the 19th century. Conflicting notions about what makes for good street network design – and the pitfalls of bad design – have left their mark throughout our urban landscapes. The change in our perspective on how to best configure street networks in our cities is perhaps one of the most emblematic of the sea change in public policy that has taken place since the early 1970s. The failure of hierarchical, poorly connected designs for urban neighborhoods was if nothing else a significant nail in the coffin of the modernist, rational model of urban planning. This helped launch the quiet revolution in planning that today is still processing, and in the best of cases seeking to rectify, the errors or the 1950s-1970s.

This paper applies theory to planning practice, moving from mathematical abstraction to discussion and analysis of connectivity and accessibility in an actual neighborhood. In doing so it connects theoretical network analysis to the task of improving street grid design. It begins with a discussion of network theory, which can be used to conceptualize abstractly the benefits and functionality of well-connected networks. Network theory is tied to the less abstract realm of contemporary physical planning principles, which argue for increased street grid connectivity with less reliance on hierarchical designs. Finally, theory is put into practice by demonstrating the use of GIS tools to model how increases in network connectivity can affect accessibility to amenities in the East Bayside neighborhood of Portland, Maine. The analysis shows how investments in improving connectivity can be targeted within a community by identifying what proportion or amount of the population benefits, such that scarce resources are used to their maximum utility.

The analysis discussed here is intended to provide a useful, topical discussion of a technique for estimating the benefit of connectivity improvements specifically for pedestrians.

This type of analysis could be used for other transportation modes, but for several reasons planning for pedestrian connectivity is emphasized. Considerable evidence exists that citizens will choose to employ active-walking or biking-transportation if streets are more well-connected (Dill, 2009). Pedestrian trips are perhaps the mode choice most requiring direct connections between destinations. Pedestrians simply do not have the time or patience for the circuitous routes auto-centric design has forced on our cities during the 20th century. Shortening the distance between citizens' homes and frequently visited amenities to a walkable distance has positive implications for reducing pollution, vehicle miles traveled, obesity, and a host of other benefits. According to the Federal Highway Administration (2010), 61% of trips less than one-half mile in distance take place by walking, but only 23% of trips between one-half and two miles are walked. With good planning, pedestrian travel distances can be ever-shortened and a higher percentage of future trips will be by walking.

Network Theory and Street System Design

In the most basic sense networks are composed of links connecting nodes where intersections may or may not take place. Travel between two or more destinations on a network is known as a path or route. The overall length of the path is referred to as network distance, which can be contrasted to Euclidian distance or the "straight line" type distance, outside the scope of the network. Networks occur throughout the natural world as well as in more abstract forms constructed by humans. A good example of a natural type of network is a river system, while perhaps the best known human built network is the internet. The functions of networks can be modeled as an abstraction by computer software and then studied. Transportation systems are inherently a form of network, and as such can be studied in abstraction by computer modeling. This project is concerned with modeling road network connectivity, although other transportation systems are frequently modeled by similar methods.

An important concept investigated in this study is the relative nature of adjacency. Adjacency refers to whether or not places, for example, are bordering. This idea, of functional adjacency, is an important concept relating the abstract idea of distance in real world transportation between points on a transportation network. Functional adjacency is the notion that the network distance between two points may be significantly larger than their Euclidian distance would otherwise indicate. This difference can be increased when modes of transportation do not share the same physical network. For example, a point on one side of an ocean bay may be physically close to a point on the other side, but to a bicyclist functionally quite distant because the road network connecting the points involves traveling all the way around the bay. To a ferry boat, conversely, the points may be functionally just as close together as they are spatially close. Adjacency is thus relative to transportation mode and network configuration.

There are many different reasons why otherwise adjacent areas can be functionally distant, both artificial and natural. Some common natural barriers include steep slopes, bodies of water, thick vegetation, and poor soils among others. Common artificial barriers include highways, fences, or simply bad design. In some cases, artificial barriers such as high speed motorways can greatly shorten the travel time between two regions. Two regions not spatially near could be thought of as functionally adjacent to an automobile driver passing between them on a high speed motorway. Indeed, this effect has been sought out in order to promote low density settlement patterns across the world. Unfortunately, such efforts are often mutually exclusive and greatly lengthen local pedestrian network distances where high speed motorways transporting suburbanites cut through urban neighborhoods. Pedestrian networks generally operate at close to the same speed throughout, and thus are dependent on direct connections between spatially congruent areas for efficiency.

The connectivity of a network is related to how many different links could be used to connect different network locations, and how direct the path between any two points on the network would be. In terms of road network connectivity, well-connected networks have few cul-de-sacs, many intersections, and numerous short links. As networks tend to be better connected, the network distance between two points decreases and the number of possible routes between points increases (Victoria Policy Institute, 2012). This increased redundancy increases the road network's resiliency to disruptions, for example the destruction of some proportion of links in a natural disaster. Increased connectivity can also increase a road network's capacity, decreasing congestion.

Geographers have developed indices of connectivity based on a mathematical abstraction of transportation networks. System scale meta-analysis type indices of connectivity include, for example, the ratio of number of street segments to the total number (sum) of cul-de-sac's and intersections. Another example would be the cul-de-sac to intersection ratio. Many other variations exist based on density of types of infrastructure per unit area, such as the number of intersections, number of streets, or number of blocks and so on (Berrigan et Al., 2010). These indices are most useful for studying connectivity over a wide area, as a whole system. They do not prove as useful at the neighborhood and pedestrian scale with which this project is concerned. So while the greater Portland area would perhaps be well suited for analysis using connectivity indices they were not deemed useful for a study at the neighborhood or sub-neighborhood scale as is the focus here.

An important reason for this problem stems from what is known in geography as the modifiable areal unit problem. The problem is that, depending on where geographic boundaries are drawn, an analysis will yield different results. In a connectivity analysis, for example, if one draws a boundary of a study area which is too small so that it includes an interstate highway but no crossings of that highway, the model would show no connectivity across the highway.

However, if the boundary of the study area were drawn just slightly larger, the connectivity resulting would improve considerably. This problem manifests in a multitude of ways when building abstract models of transportation networks.

The solution arrived at for this problem was to use applied indices, not based on the relative amounts of types of infrastructure in a given area, or its size. This type of index measures how accessible various amenities are over the pedestrian network in absolute terms, thus avoiding the modifiable areal unit problem by eliminating comparison across the entire study area. The first and most basic accessibility index is discussed in Maghelal & Capp (2011) and Allan (2001). This accessibility index, known as the Walking Permeability Distance Index or WPDI measures the ratio of network distance to Euclidian distance. This index quantifies how close in functional terms over a network a hypothetical point is to another, or how adjacent they are, and is a better measure of real world type connectivity.

The second index discussed in this project was developed by the author to show how changes in network configuration, specifically improvements in connectivity for pedestrians, provide benefit to the actual population of a given area. It has been termed the Connectivity Improvement Benefit Index, or CIBI, here. No index that this author found in the literature is based on calculating accessibility change over two network configurations (Maghelal & Capp, 2011; Berrigan et al, 2010). The CIBI, unlike other accessibility indices, also factors in residential population with the value of network distance improvement times the estimated walking speed from the literature (Levine, 1999). The index is optionally normalized for distance according to the user’s specifications. In the example of the index calculated for this project, the FHWA (2010) estimates for U.S. pedestrian travel rates for given intervals were used to attenuate probability of walking as distances increased.

Application of Theory to Study Area

While many different types of road networks exist, this paper will focus on the distinction between two primary and competing types found in the industrialized world today: hierarchical and non-hierarchical. Non-hierarchical networks are the type most used by humans before the invention of the automobile. Historically, road systems formed well connected networks featuring many intersections and short connecting roads. Because all traffic moved at nearly the same slow, constant speed the majority of roads were of small size and relative capacity by today's standards. Of course, many variations existed, for example between urban and rural areas, but in general a well-connected design was common. In the urban area analyzed in this paper and many like it throughout the U.S., the traditional well- connected design took the form of a regular grid, where streets intersect at perpendicular angles and form a rectangular block pattern of development.

Hierarchical networks, in contrast, are generally not well connected. They were at their most well-regarded in the United States when the interstate highway system was being constructed. Their design reduces theoretical travel times for automobiles at the expense of reducing the functionality if not absolute feasibility of non-motorized transportation types. Hierarchical transportation network designs more resemble a river system than a traditional street grid: at the most extreme many smaller roads with limited capacity connect to larger collector roads rather than to each other. The roads in such a network become larger, having more capacity, but do not connect well to each other. In the face of a blockage or temporary lessening of the capacity of one of these large connections, catastrophic failure of the network can result. In addition, the high capacity links in this type of design necessarily require higher speeds, and so are not compatible with non-motorized transportation. The largest of these roads, limited

access highways, generally require separation from smaller roads that are part of the more traditional non-hierarchical road system, cutting these networks wherever they pass through.

Modernist transportation planning theories tended to discount the importance of planning for short pedestrian travel times but often left traditional neighborhood structures intact. An example was the modern planned community in Radburn, New Jersey. It allowed for pedestrian connectivity while also incorporating a hierarchical structure of roadways for automobiles (Hall, 2002). Some theorists took the hierarchical view to extremes, however. One was Le Corbusier, who advocated planning for a world where the sole method of transportation between buildings or building projects was the automobile. These planning theories were widely well regarded in the United States during the 1950s – 1970s coincident with a period of urban decline and suburbanization. This period also saw a tendency for public agencies, including those involved with planning, to be extremely well funded by the federal government compared to today. The sort of U.S. Federal government policies that resulted during this era were thus inclined to plan very poorly for pedestrian friendly cities and had a lot of money with which to do it. This era featured the building of many large scale high speed motorways both between cities and through urban cores (Hall, 2002).

Not all planners agreed with these auto-centric theories. As early as 1960, as discussed by urban planning theorist Kevin Lynch argued in *The Image of the City* that networks (or paths) between places in a city can be thought of very differently depending especially on a traveler's mode of transit. Pedestrians were repeatedly demonstrated to think of the new large highways as imposing barriers to movement, not gateways to prosperity. Jane Jacobs also wrote of the benefits of well connected streets in her *Death and Life of Great American Cities* (Jacobs, 1961). Because of this and subsequent work (Alexander et al., 1977; Calthorpe, 1993) the importance of improving pedestrian network connectivity has greatly increased to urban planning professionals working in cities and new suburbs across the world.

The unfortunate consequences of poor planning for transit modes besides the automobile can be seen Portland, Maine in numerous locations. Perhaps the damage can best be summed up by the experience of the city's East Bayside neighborhood, shown in Map 1. This neighborhood has a long history. European settlement dates back to the colonial era, when the area saw a combination of residential and light industrial uses that is remarkably similar today (Conforti, 2005). Today the neighborhood features light industrial uses in its northern sections near Interstate 295 with public housing located just to the south and west of this area. Low to middle income private housing is located along the eastern and southern periphery. The neighborhood population in 2010 was 2,001, with an area of about 128 acres in populated census blocks. This yields a population density of approximately 15.6 persons per acre in the populated census blocks, which is much above average densities found in Maine (U.S. Census, 2010). This density is more than high enough to sustainably support public transit systems and pedestrian oriented development (Calthorpe, 1993).

The East Bayside neighborhood (Map 1) once had a normal, well connected street grid throughout, but this only remains on its eastern and southern borders. A high speed interstate highway, Interstate 295, is now located to its northwest. This highway forms a complete barrier for pedestrian access to the Back Cove area of the city, which is a tidal embayment which borders on East Bayside. Interstate 295 was built mostly with federal funds as part of the interstate highway program in the late 1960s and early 1970s. Historically, however, this neighborhood was economically and culturally linked to the body of water known as the Back Cove, which functioned as a second, better protected harbor for the city and even featured a place for young people to swim in the summer (Calhoun, 2005).

The study neighborhood's western border is also cut off by a large highway barrier. This is Franklin Arterial, a high speed urban access roadway more typical of suburban than urban

areas. Seen from the pedestrian point of view along the former Oxford St. (Picture 1) this street functions not as a high speed roadway but as a significant and unsafe barrier. Unfortunately, many residents of East Bayside who live closest to this area of poor connectivity are those of lowest income with the least access to automobiles. This area features many hundreds of units of public housing projects hemmed in tightly in the corner between these two major barriers (Franklin St. Arterial Study Committee, 2009).

Picture 1: Franklin Arterial at former Oxford Street. (Source: Damon Yakovleff, 2009)

Project Methods: Applying Accessibility Indices to Study Area

This analysis uses ArcGIS, MAPINFO, and the data management tool Alteryx to model accessibility in and around East Bayside. The first step was to conduct research as to which connectivity improvement projects and amenities to model. Then, the data needed to build a base map was either downloaded from the internet or created in the GIS. After that the two networks being modeled (unimproved and improved) were created from the data. The ArcGIS network analysis tool was used to compute the network distances between each census block and the amenity being modeled. The distances and differences between each network configuration were then analyzed.

The amenities modeled were selected early in this process. Both amenities are located across the barrier to pedestrian connectivity formed by Interstate 295 from the East Bayside neighborhood. The first amenity selected was the Hannaford grocery store (Picture 2), the nearest full service grocery store to the neighborhood (Map 1). This represents an important destination to the residents of East Bayside because it offers much lower prices than other grocery stores in the area for many items. Reducing travel distance for pedestrians to the store represents an important goal to the city, in order to facilitate the process of residents carrying groceries from the store to their homes. The second amenity is a component of an anti-obesity campaign carried out with federal grant money by the City of Portland (Picture 3). Facilitating improved access to this amenity would be consistent with the goal of promoting more frequent outdoor exercise for neighborhood residents.

Picture 2: Hannaford store, Forest Ave. (Source: Damon Yakovleff, 2012)

Picture 3: Fitness station, Back Cove Park. (Source: Damon Yakovleff, 2012)

The data used in this study were obtained through both downloading and manual digitization of aerial imagery. 2010 census block population data were downloaded in raw form from the U.S. Census website**.** Maine E911 road data as well as the spatial representation of census blocks in shapefile format was downloaded from the Maine Office of GIS website. Pedestrian trails, modern and future, were created from aerial imagery, fieldwork, and references to Google maps **(**2012**)**. The location of the fitness station and the Hannaford store were also identified through these methods.

Data preparation steps began with cropping all data to include only the City of Portland. While this step was optional, it simplified the data set and generally aided the modeling process. Land and water polygons for the modeling base map were then extracted. The census block fields where the area of land was equal to zero were exported to form a water layer. Then, using aerial photographs and local knowledge, Microsoft Bing data sets in Pitney Bowes MAPINFO software (30 day trials available) were used to create a polyline feature depicting the pedestrian networks not used in the e911 roads layer. These included bicycle/pedestrian trails as well as what is defined here as "improved sidewalks". These are sidewalks suitable for one to ride a bicycle on, and which include safety features for pedestrians where they cross roads, such as crosswalks.

I did not include such paths as the one depicted earlier (Picture 1) crossing Franklin Arterial in the model of present pedestrian networks. In many cases, such paths indicate a strong desire for pedestrian connectivity to be improved. Planners, sensitive to this, have included many of these areas in plans for pedestrian friendly transportation upgrades. The future networks were created using the same method (tracing aerial photographs in MAPINFO) based on information found in City of Portland planning documents pertaining to the area of analysis as well as through local on the ground research.

After all data were collected, they were then converted to the same datum and projection and displayed in ArcGIS. Map 2 shows the data used for this analysis. Interstate 295 specifically prohibits bicycles and pedestrians, so it was totally excluded from analysis. A modern pedestrian network for Portland, Maine was then created by merging the modern pedestrian routes created with the modern Interstate 295 subtracted road features.. A future network was created by then merging the planned network expansion polyline feature into the modern pedestrian network. These networks were then converted into network datasets and saved in a new ArcGIS geodatabase. The Integrate tool was then run for both network datasets to insure their integrity, and that vertices were located at each node as appropriate.

Modeling Process

Once the two different network datasets had been created, the network distances to each amenity could be calculated for each network condition (existing and improved). The Network Analyst tool in ArcGIS was used to accomplish this task. The results produced in Network Analyst had to be joined back to the census blocks afterwards using a spatial join because there is no option to do so built into the tool. Using the Alteryx program's formula tool, for each census block a number of indicators of accessibility were derived from the two network distances for each amenity.

The first new field for an indicator that was produced was the difference between the network distances for each condition (existing versus improved). This is expressed for the Hannaford amenity in Map 3 and for the fitness station in Map 4, both as a pure distance in miles. This difference is expressed as a percentage in Maps 5 and 6. The next indicators generated and added to the dataset as new fields produced the results for the Walking Permeability Distance Index, the WPDI. First, the spatial distance from each census block to the modeled amenity of interest was calculated. Then the ratio of the network distance, for each

condition, to spatial distance was calculated. The result is the WPDI for each network condition and for each amenity, displayed as Maps 7, 8, 9, and 10.

The next set of maps shows the additional index developed for this project, the Connectivity Improvement Benefit Index, or CIBI. This index is derived by first taking the change in network distance for each census block for a modeled amenity, in this case in miles. Then, it is multiplied by an average walking speed estimate. This varies considerably cross culturally and by age and gender, but according to the literature a useful figure to use for approximation is 17.6 minutes per mile (Levine, 1999). This is then multiplied by the distance saved, to arrive at an estimated time savings per one way trip. This is multiplied by the total population in each block, to arrive at a figure of total population time saved. This index is displayed in Maps 11 and 12.

As established by the Federal Highway Administration (2010) people are less likely to choose walking as their transportation mode as distances increase. Thus, the utility of accessibility improvements as measured by the CIBI would attenuate with increasing distance. As such, the index can optionally be normalized to more closely represent the true utility of a connectivity improvement by incorporating this attenuation. The normalizing factor used here was developed by calculating a regression equation based on the FHWA data on percentage of trips made by walking. This was done to approximate the tendency discussed in the literature (Calthorpe, 1993) for people being less willing to walk longer distances, especially over .5 miles. The probably of walking distances over 2 miles was considered to be approching zero.

Finally, Maps 15 and 16 display the results of ground truthing the model through a field verification opportunity that occurred during this study. While this project was being undertaken, one of the connectivity improvements discussed, the passage under Interstate 295 at Franklin Arterial, was constructed (Picture 4). The ground truthing maps display the difference between

using the old network configuration and the new configuration resulting from the constructed improvement.

Picture 4: New Underpass of Interstate 295 at Franklin Arterial. (Source: Damon Yakovleff, 2012)

Discussion of Results

This analysis demonstrates that the connectivity improvements either built or under consideration in and around East Bayside increase access to the two modeled amenities from the neighborhood. In particular, striking clusters appear in the region around the low income public housing, where network distance to amenities is reduced to a higher degree relative to the change for other locations in the neighborhood. The clustering of accessibility benefits for the low-income housing concentration appears throughout the different components of the analysis. The

results also demonstrate that the connectivity improvements have a time saving benefit for the neighborhood to the east of East Bayside, Munjoy Hill, although it is much reduced when normalized for distance for both amenities.

The connectivity improvements greatly improve access to the fitness station in particular. This is visible when one compares Maps 3 and 4, which show the difference in distance in miles to the two amenities. Many areas in East Bayside see a difference of approximately one-half mile shortened access for the improved distance to the fitness station. The distance saved to the Hannaford, while less, was still significant for the areas around the low income housing in the neighborhood, where some census blocks saw savings of up to .4 miles. Expressed as a percent change, as shown in Maps 5 and 6, the distance savings for trips to the fitness station ranged from 40% to as much as 100%, meaning the trip was now one-half the length. The overall change in percent for distance to the Hannaford did not exceed 40% in any census block, however.

The walking permeability distance index results for each amenity in each network configuration are shown in Maps 7-10. A WPDI index of 1.0 represents perfect connectivity, while higher values indicate much higher network distance to an amenity versus spatial distance. The WPDI definitively shows that walking permeability experiences several choke points around interstate 295 for access to the two amenities. However, along the several streets leading directly to crossings of 295 in the remainder of the city, the WPDI was much closer to 1.0., and in many areas is less than 1.5, considered a good result (Allan, 2001). It should be noted that the difference between the WPDI scores for each amenity between the two network configurations (existing and improved) is exactly the same as the difference in percentage between the total network distance since the spatial distance remains constant. Therefore, Maps 5 and 6 also show the percent improvement in WPDI scores for each condition.

The results of the Connectivity Improvement Benefit Index show how the reduction in network distance affects the residential population, adding more information than the WPDI measure does alone. There are significant differences between values normalized for distance and the non-normalized values, however the non-normalized index is included for an important reason. The non-normalized benefit index has the advantage that it can tell a municipality considering an improvement the total utility for improved pedestrian access to an amenity throughout the entire area under analysis. This is important because the CIBI only shows the utility gained from a single one way trip, and does not model how frequently citizens are likely to make that trip. Obtaining realistic values for the percentage of trips likely to be made by walking (which the normalization assumption attempts to take into account) especially at the more extreme walkable distances over one mile is difficult, but important. However, modeling all benefits in terms of variability of the populations' likelihood to walk different distances is a more complex modeling challenge, and beyond the scope of this present study.

The non-normalized index shows significant utility gained by both the East Bayside Neighborhood and by the Munjoy Hill Neighborhood. Particular clusters emerge in areas of high population. It is particularly notable that the clusters of highest utility emerge in both East Bayside and Munjoy Hill's areas of low income housing, even when the index is normalized for distance. This is likely due to their having a higher population, meaning the CIBI index has in this case accomplished its task of showing how connectivity improvements can benefit the greatest number of population, or even a targeted group within a population. In this case, the index shows how the improvement benefits lower income groups in the city.

The results of the CIBI are perhaps at their most useful as a starting point for further analysis. For example, the index could be combined with others, such as that developed by Giles Corti et. al (2011) exploring connectivity and its role in school neighborhoods. One could also, based on several assumptions, use the index as normalized for distance to estimate the total

benefit over the course of a year to the residential population in a given area for the connectivity improvement. One would have to make assumptions about, for example, how often a person who only travels by foot would go to the grocery store. A reasonable assumption might be three times a week conservatively. Or, one could calculate the benefit in time saved given a healthy population traveling to the fitness station 5 times a week. See Table 1 for a breakdown of the results of this analytical approach just described. The estimated yearly time saved per person is the normalized CIBI value, times trips per week, times 52 weeks in a year, divided by the total population in the study area, 2001.

CIBI: Yearly Hours Saved Estimate

Amenity	Normalized CIBI Value	Trips / Week	Estimated Yearly Minutes Saved per Person
Hannaford	1711	3	133
Fitness Station	6627	5	861

Table 1: This table depicts an example of how the CIBI index can be used to estimate yearly time saved per person in the study neighborhood.

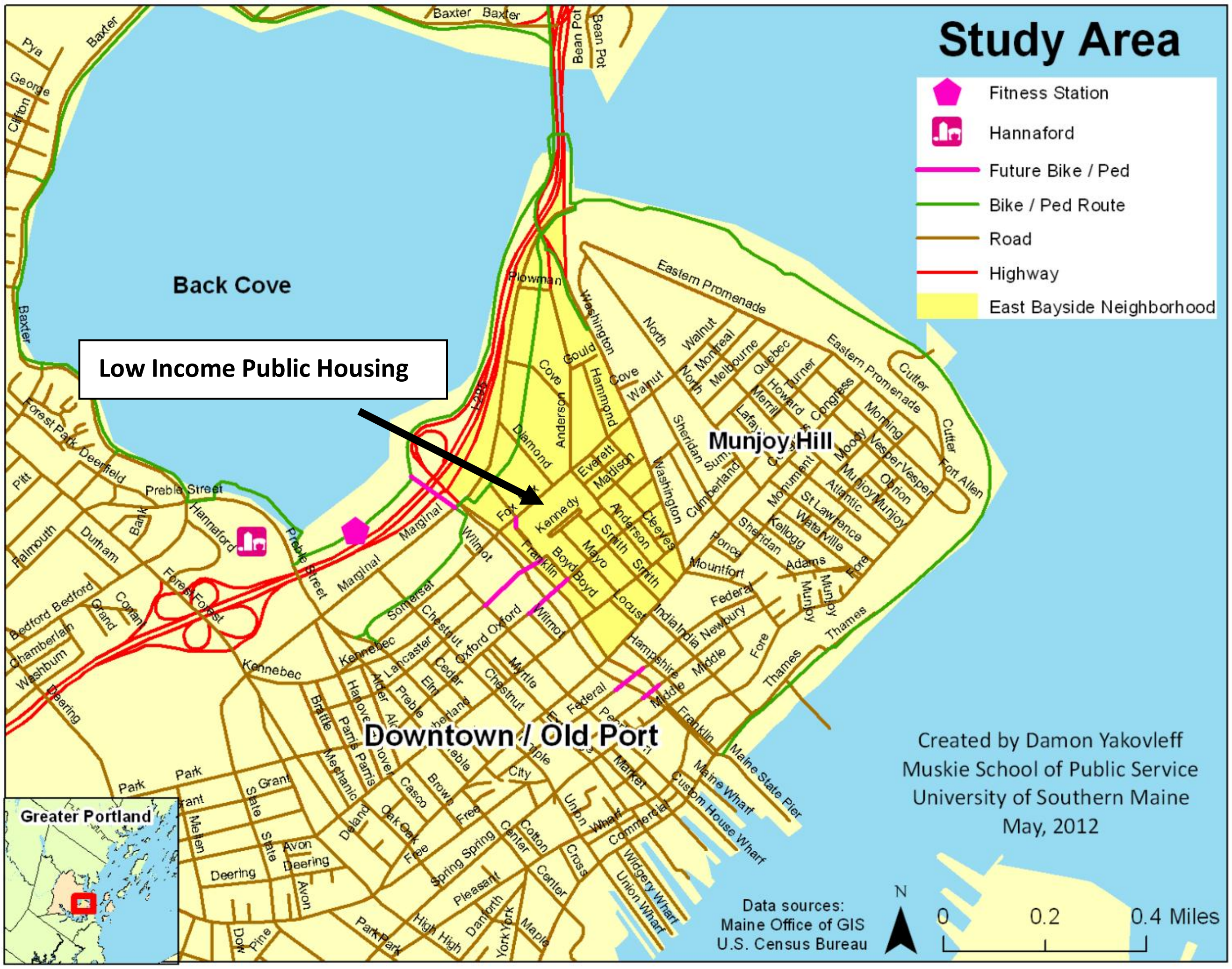
Conclusion

The results generated by this project demonstrate that simple and relatively inexpensive infrastructure projects that improve pedestrian connectivity can provide measurable improvements to the network distance between residential areas and targeted amenities. For example, especially in much larger cities than Portland, urban areas often feature “food deserts”. These are areas that lack any local healthy, nutritious food options. In many cases, these disadvantaged areas feature the same kind of auto-centric urban renewal projects seen in East Bayside. If this is the case, it may be that grocery stores are spatially near but not functionally near due to the high-speed motorways acting as a functional barrier. This kind of spatial analysis could, hopefully, help to target scare resources for building projects to improve those connections which provide the greatest benefit possible.

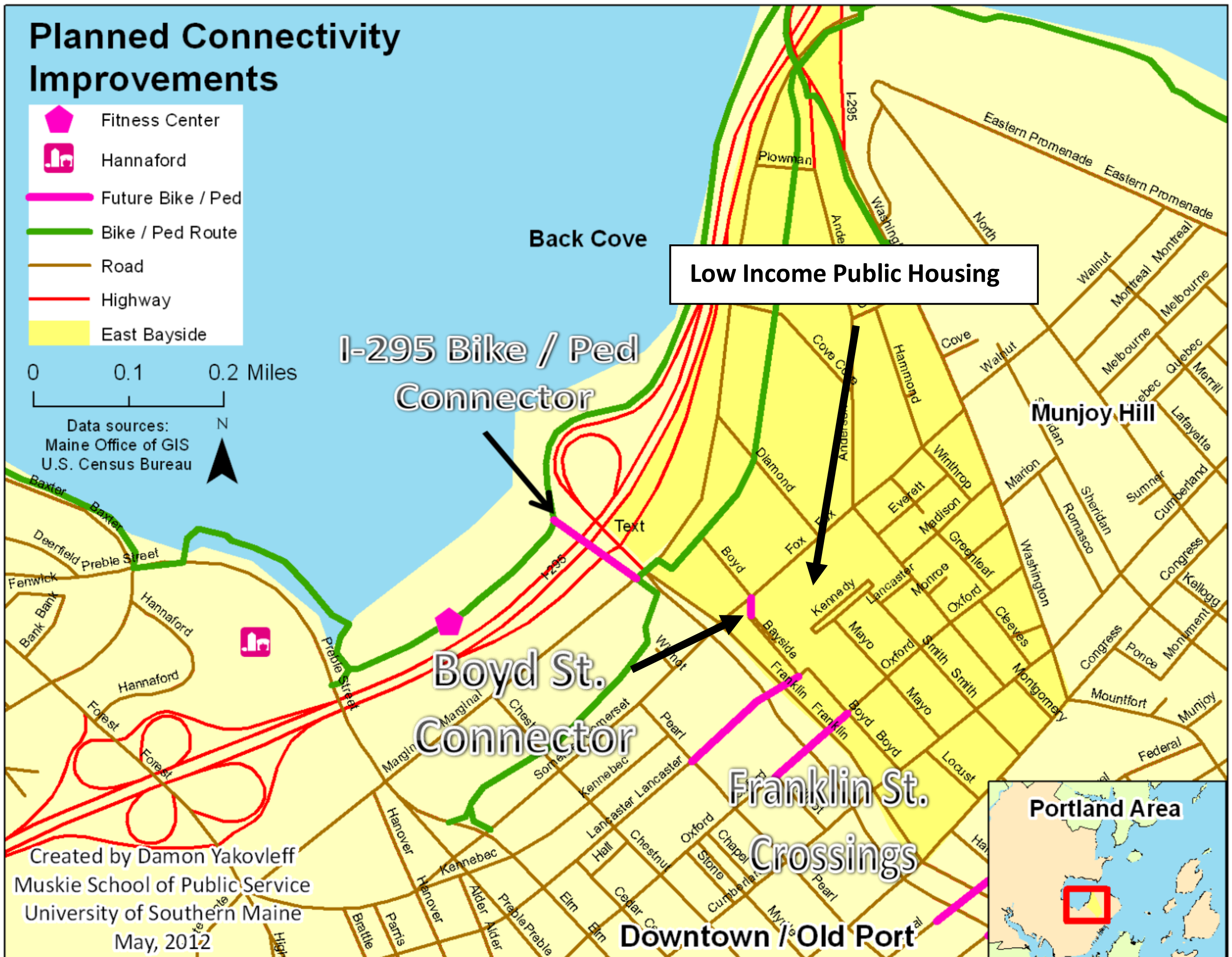
This indexing technique is intended to be both flexible and useful. It allows for municipalities to target their investments to either benefit the maximum number of the population or a select socioeconomic group with certain locational characteristics. Furthermore, variables used such as the normalization factor for distance and the estimated walking speed could be adjusted to the specific needs of a municipality. The amenities targeted are also extremely flexible, and need not necessarily constitute a point as in this study; they could be a line such as a greenway or bus route, or a polygon such as a park.

Future project work in East Bayside could expand this analysis both in breadth and in depth. The breadth could be increased by conducting an analysis of more amenities, over more network types. These network types could, for example, show a radical reorganization of the street grid with a reconnection of both bike/pedestrian access as well as vehicle access. It is possible that a future boulevardization of Interstate 295 could also be explored. The low cost of the techniques discussed here will very likely be of great use for planners building infrastructure through the rest of the 21st century.

Project Maps

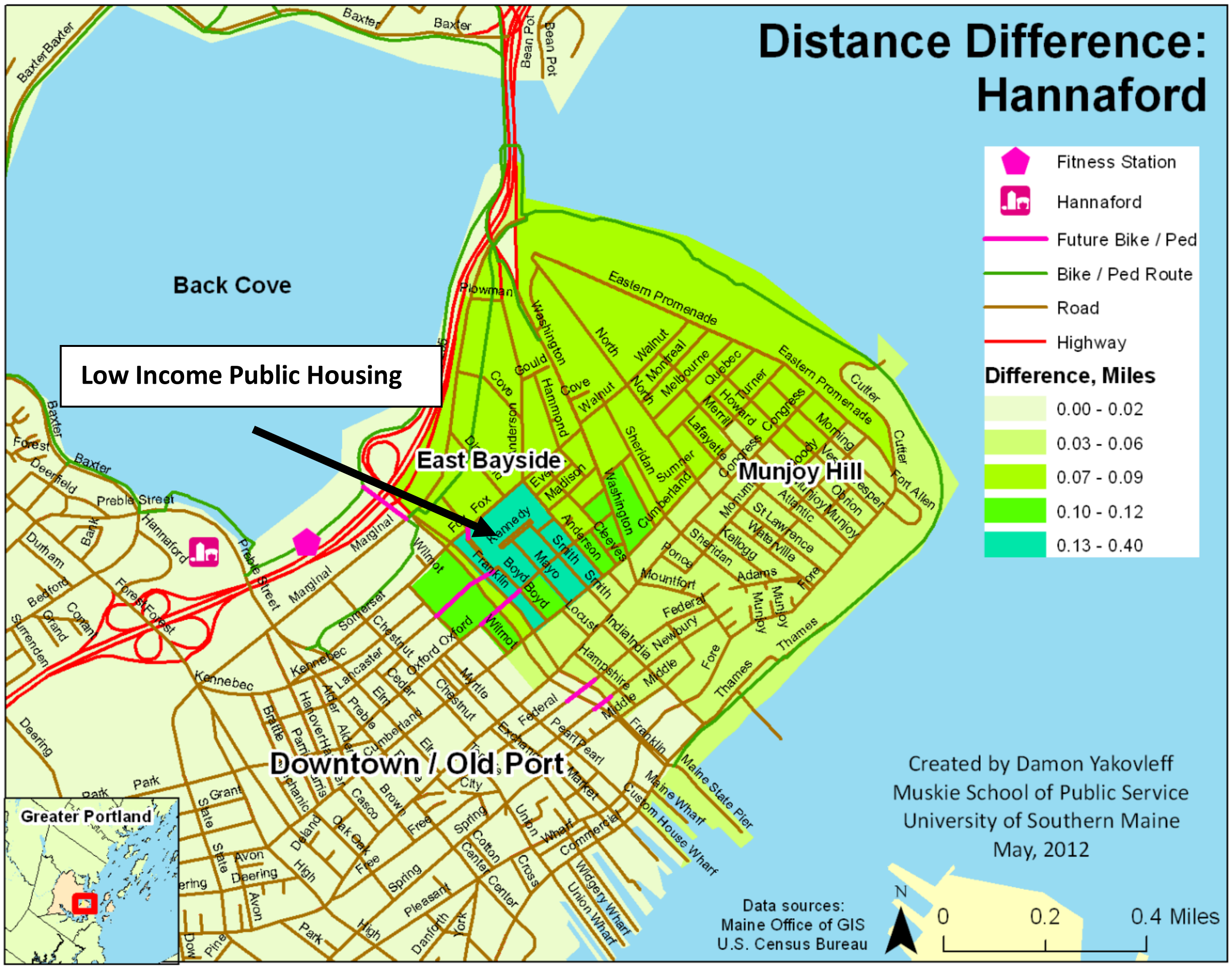


Map 1. Study Area in Portland, Maine

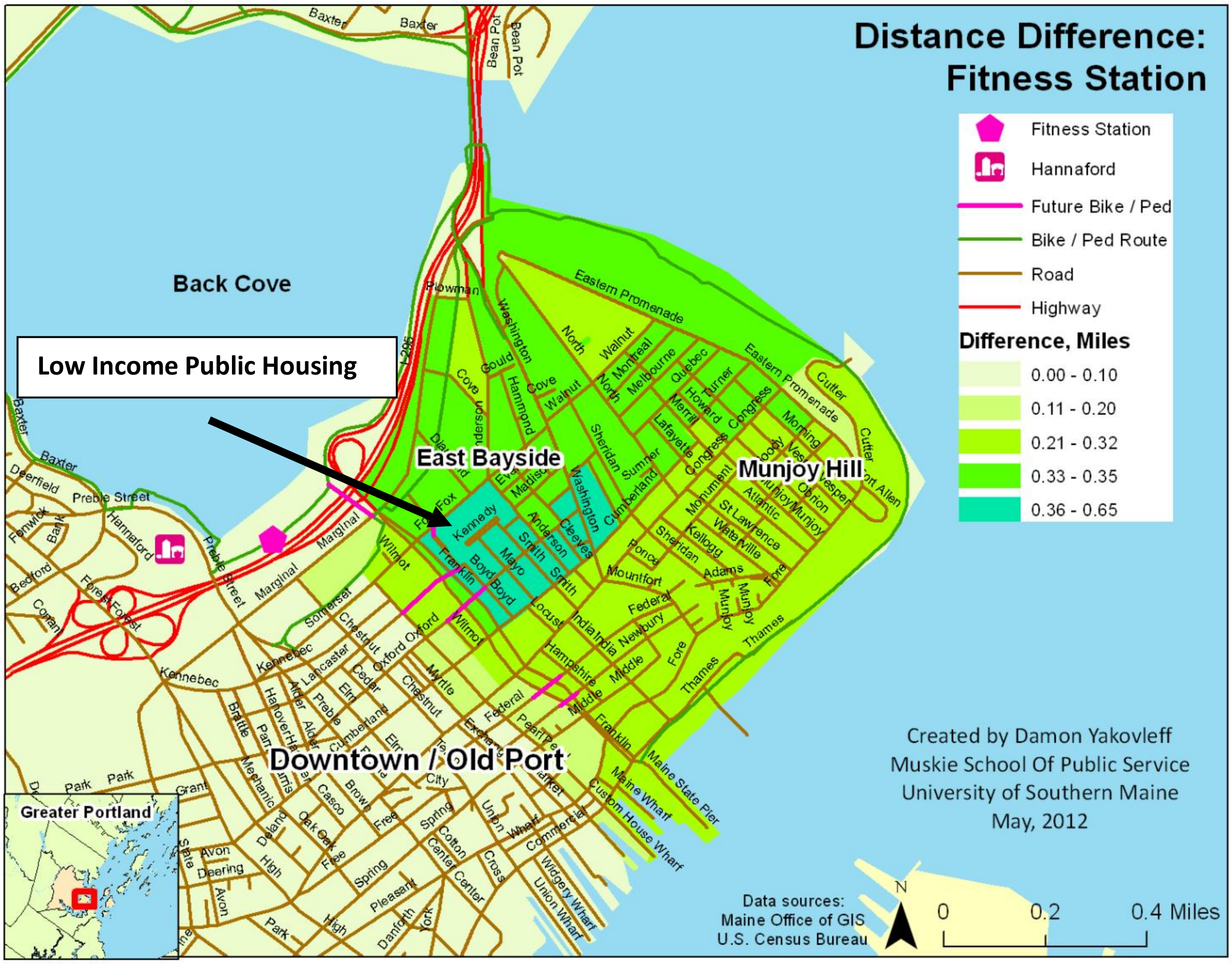


Map 2

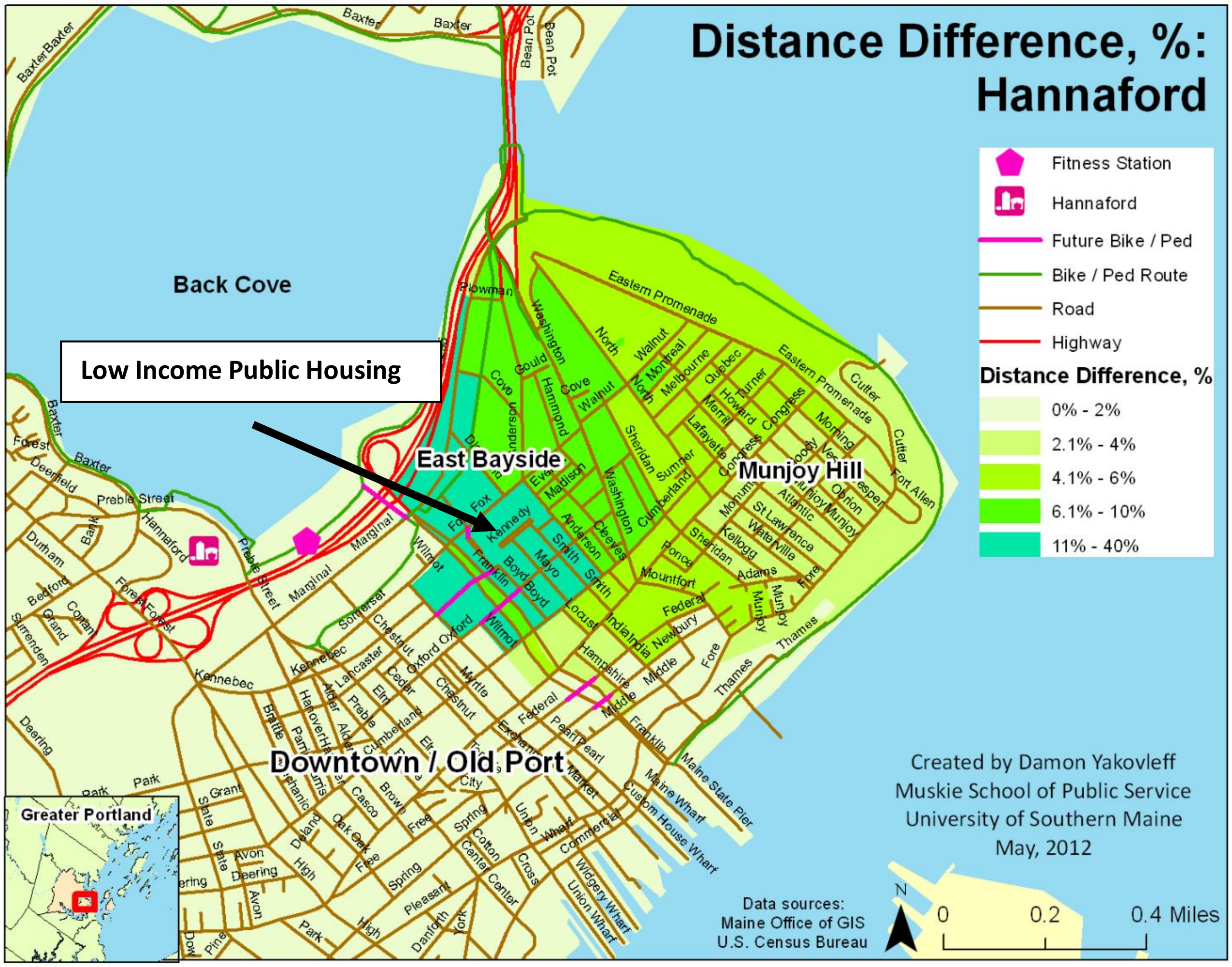
Map 2. Planned Connectivity Improvements Included in Modeled Analysis



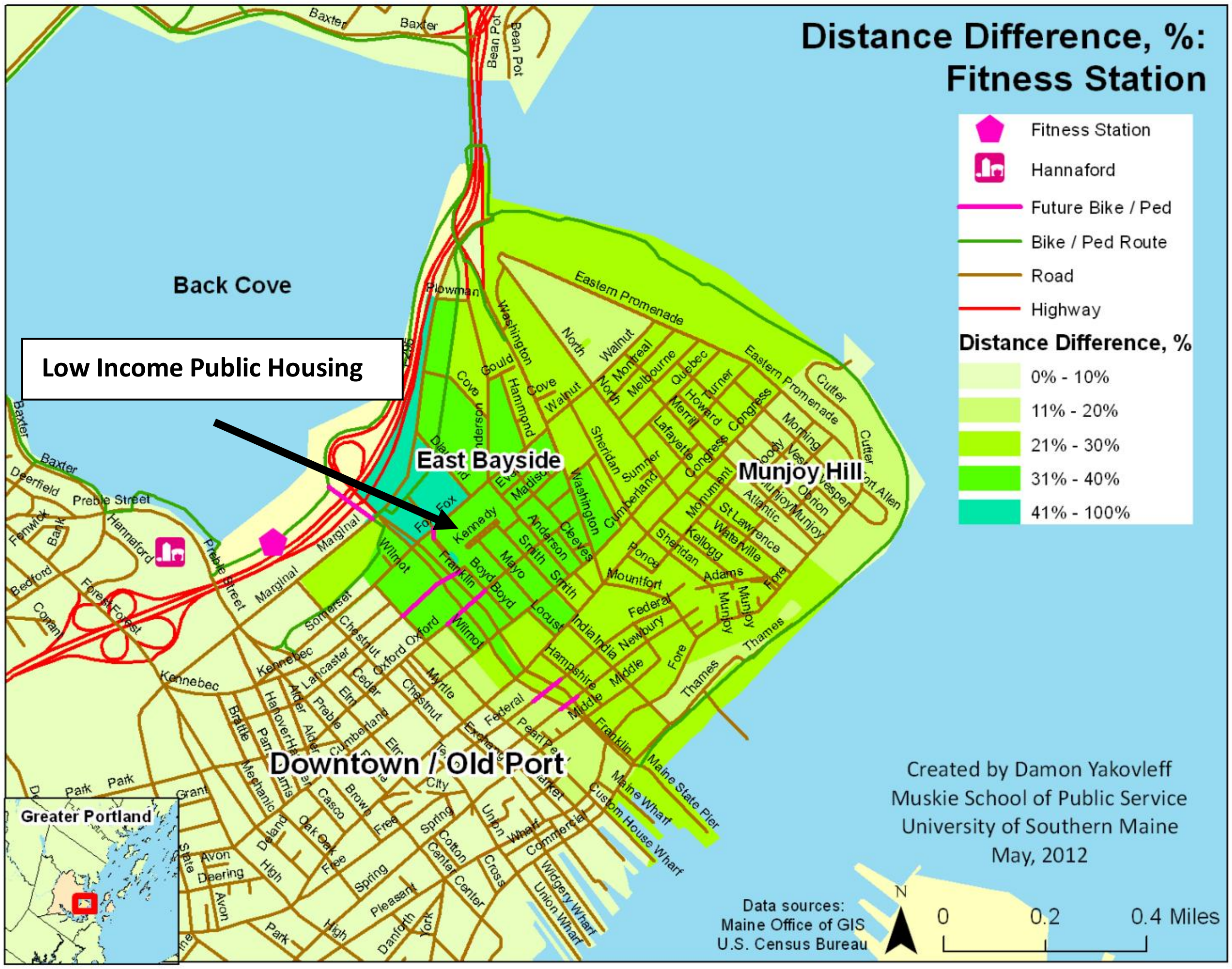
Map 3: Difference in distance between census blocks and Hannaford in modern and improved network configuration



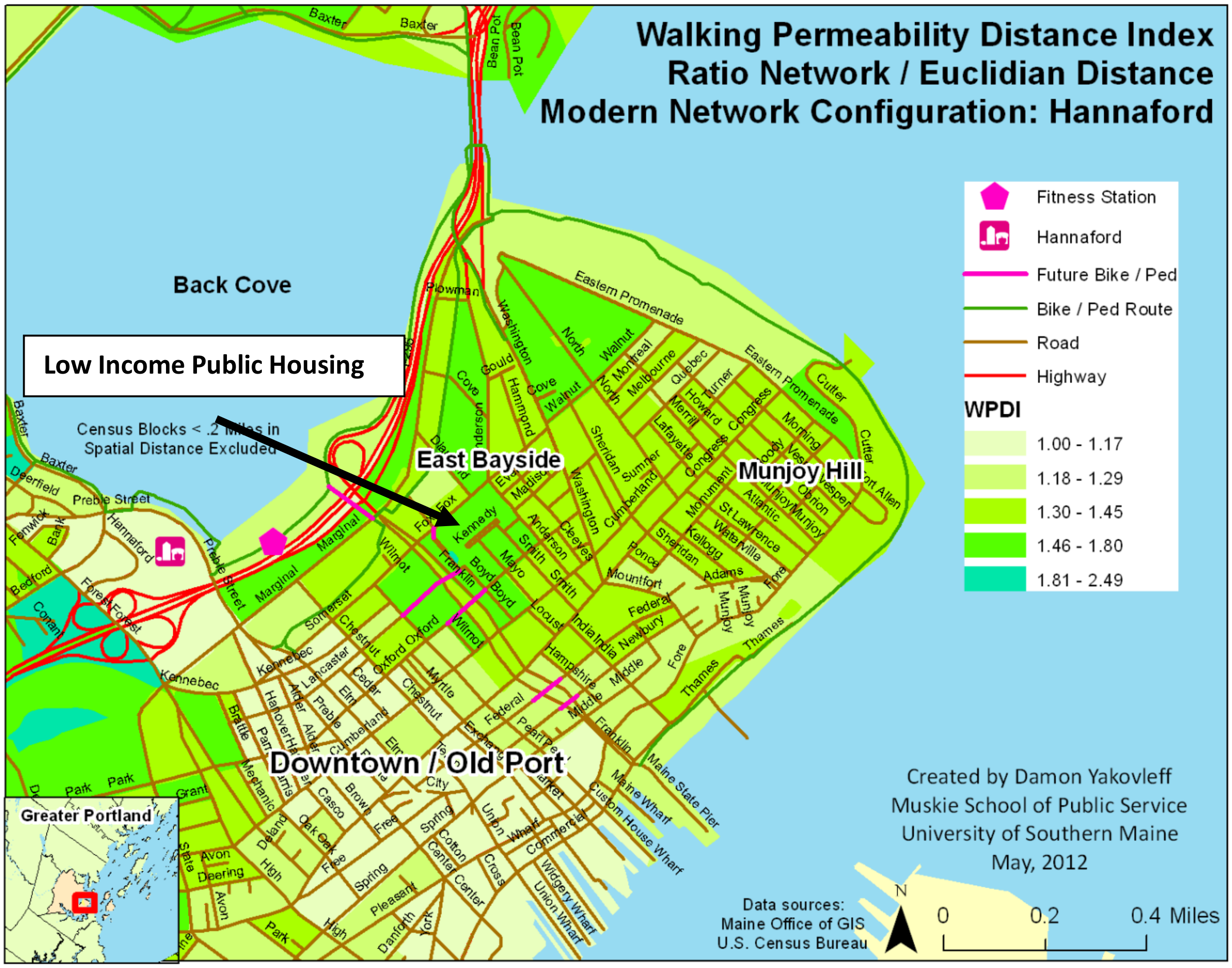
Map 4: Difference in distance between census blocks and fitness station in modern and improved network configuration



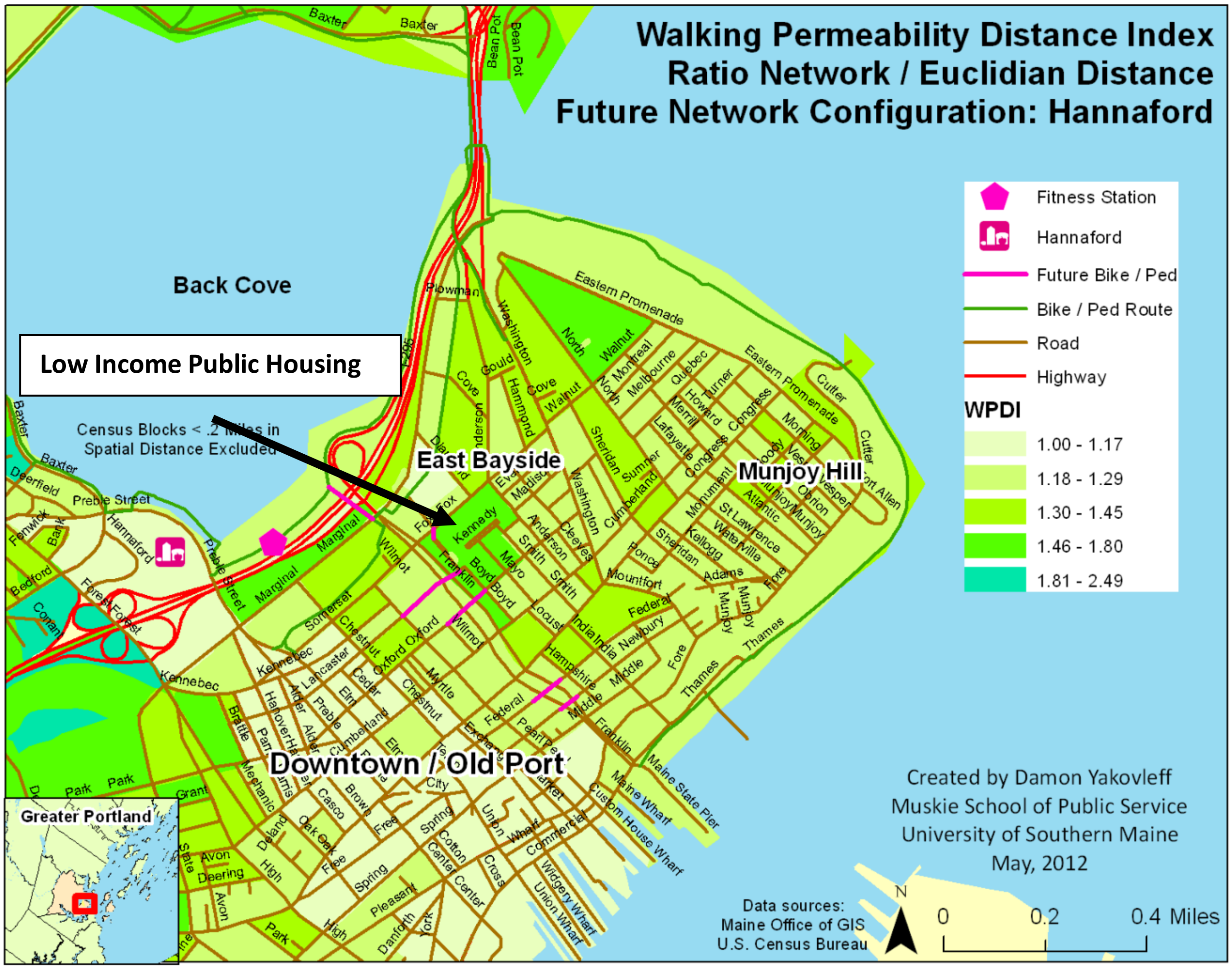
Map 5: Percentage of distance difference between census blocks and Hannaford in modern and improved network configuration.



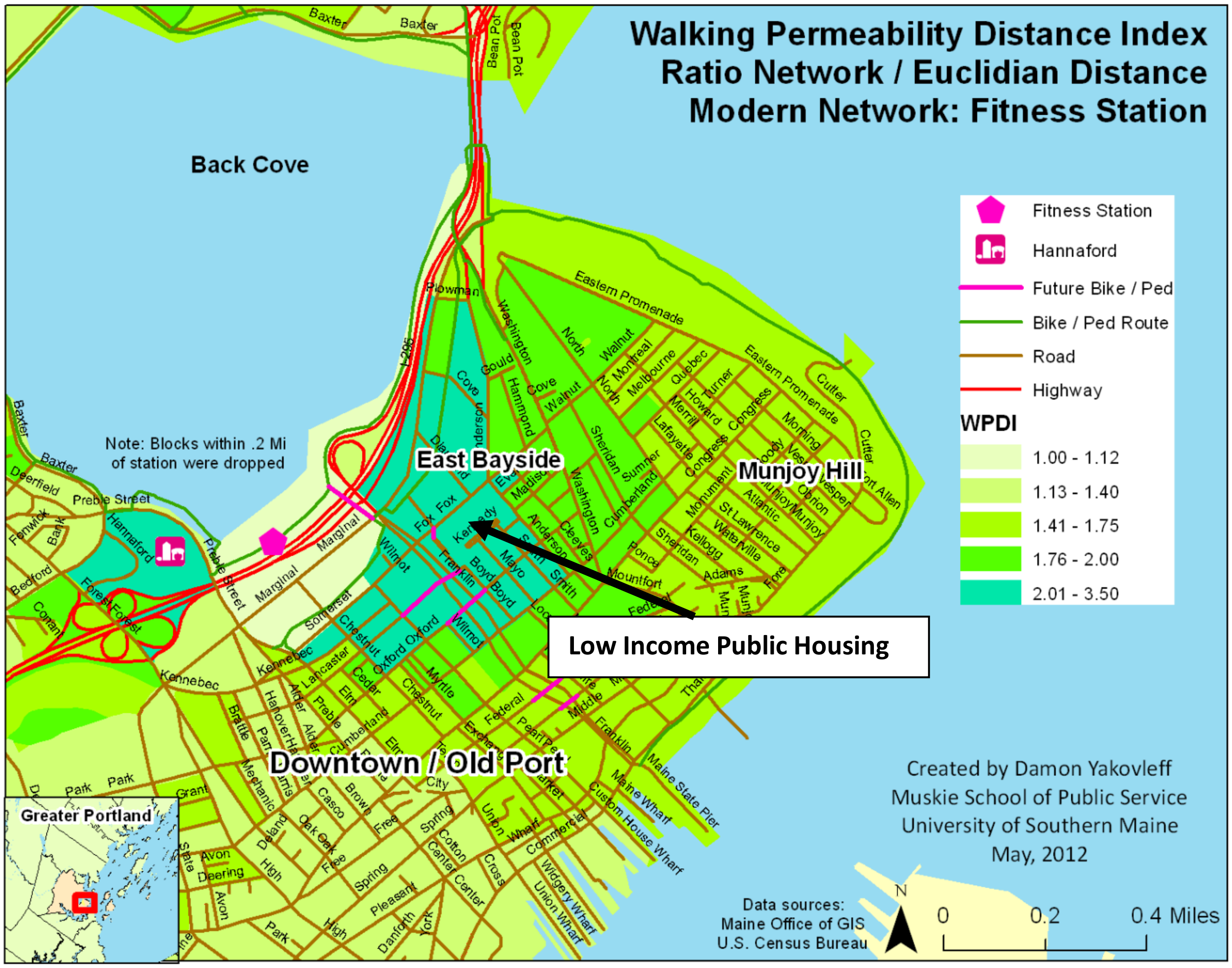
Map 6: Percentage of distance difference between census blocks and fitness station in modern and improved network configuration.



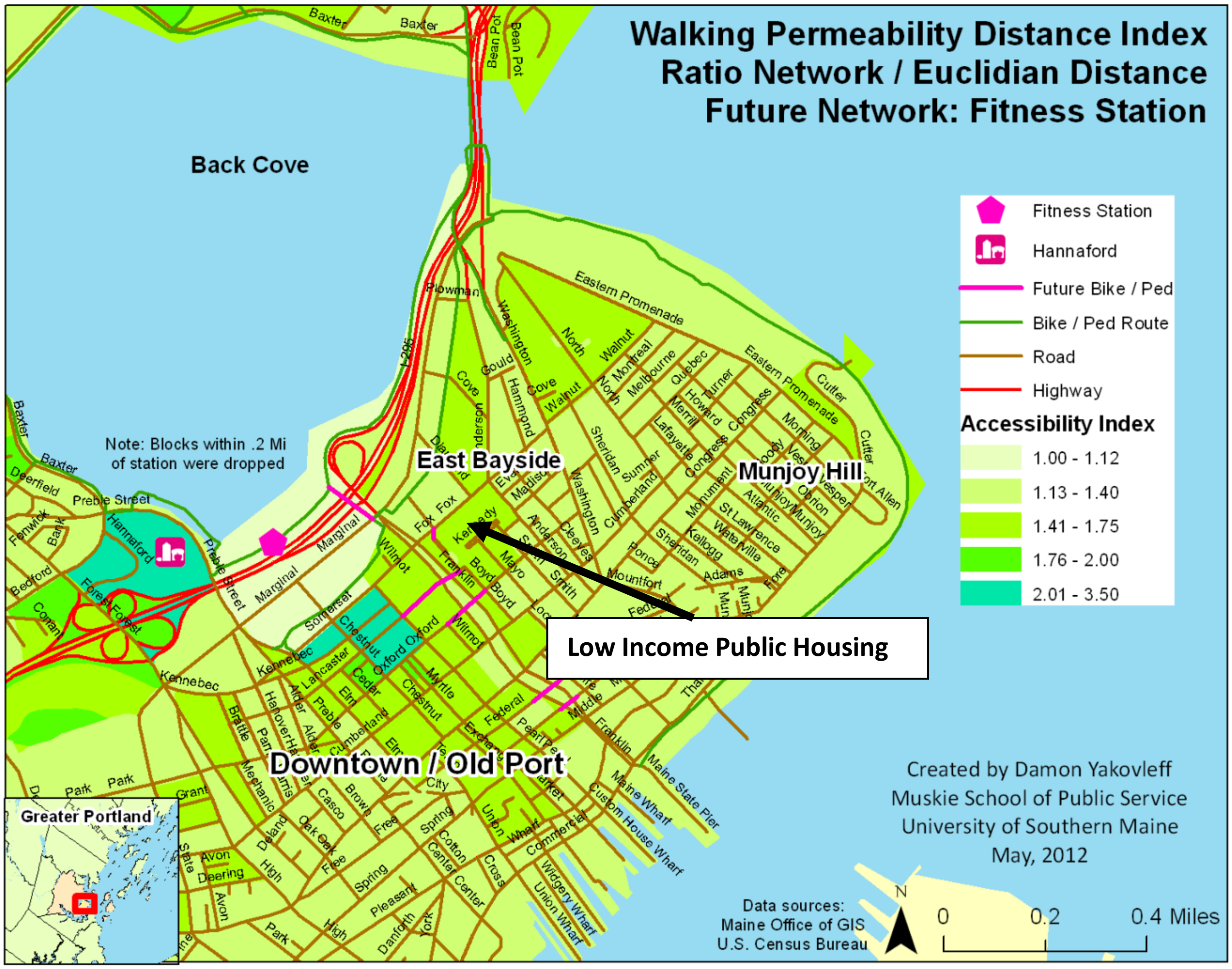
Map 7: Hannaford Walking Permeability Distance Index values, modern network configuration.



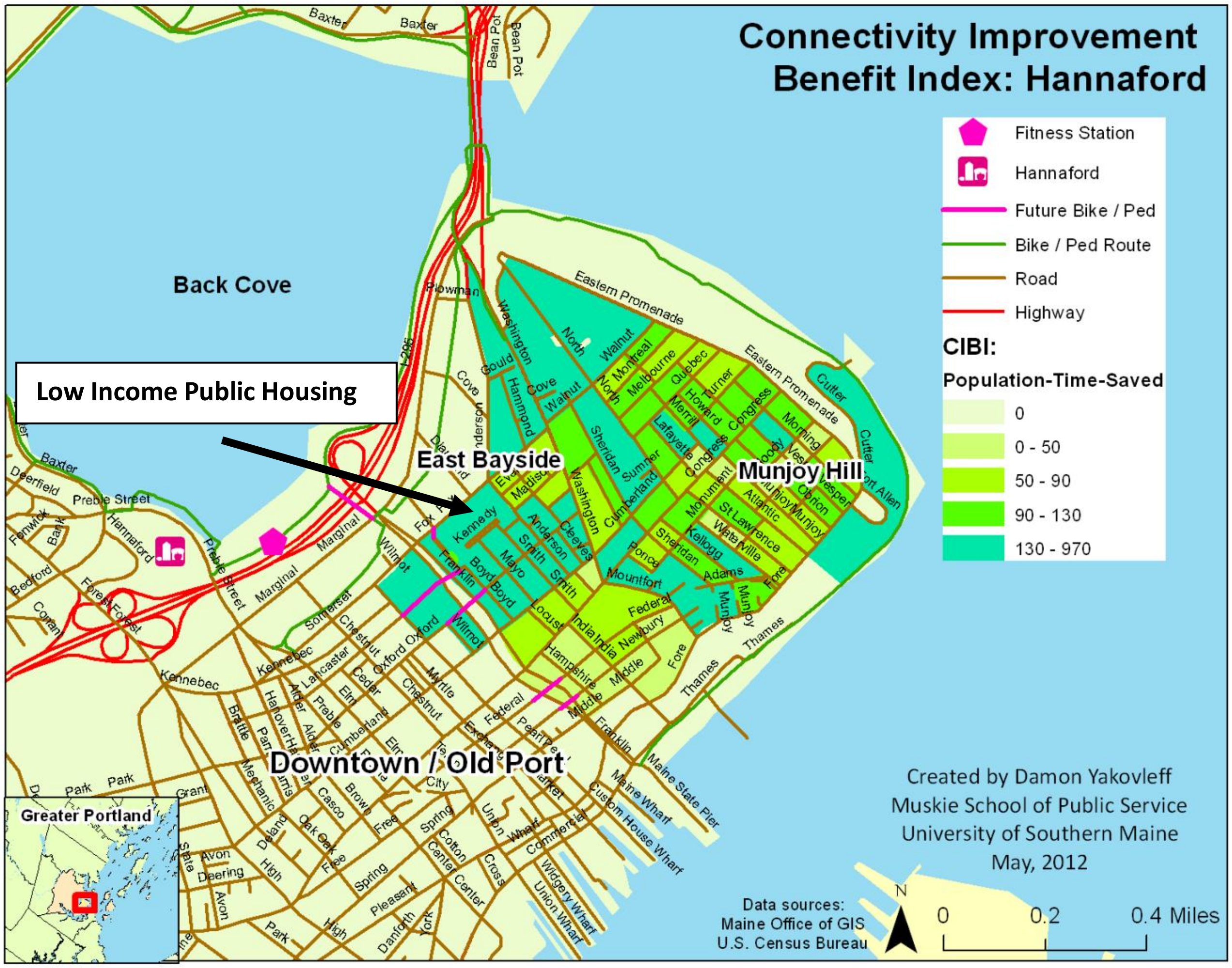
Map 8: Hannaford Walking Permeability Distance Index values, future network configuration.



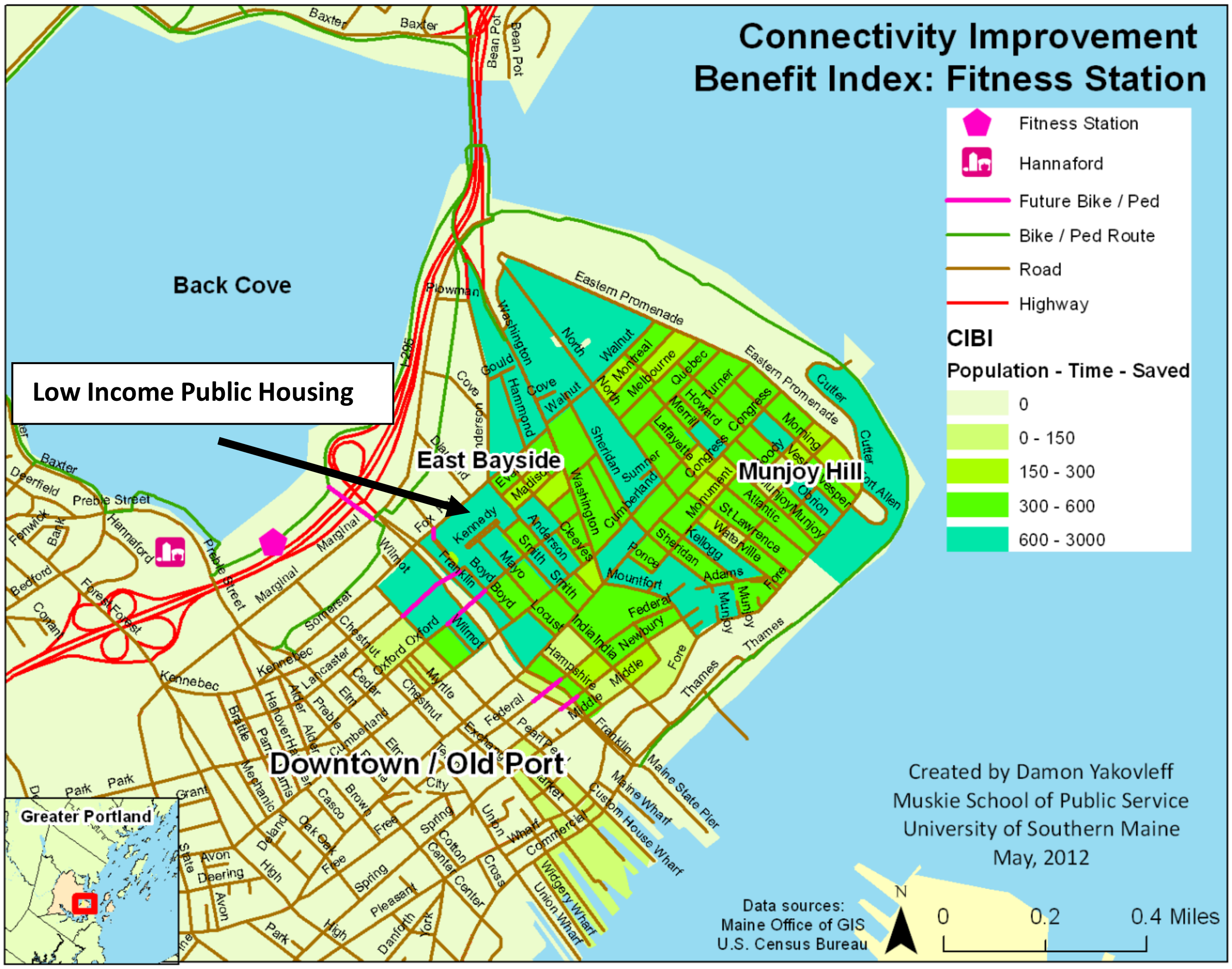
Map 9: Fitness station Walking Permeability Distance Index values, modern network configuration.



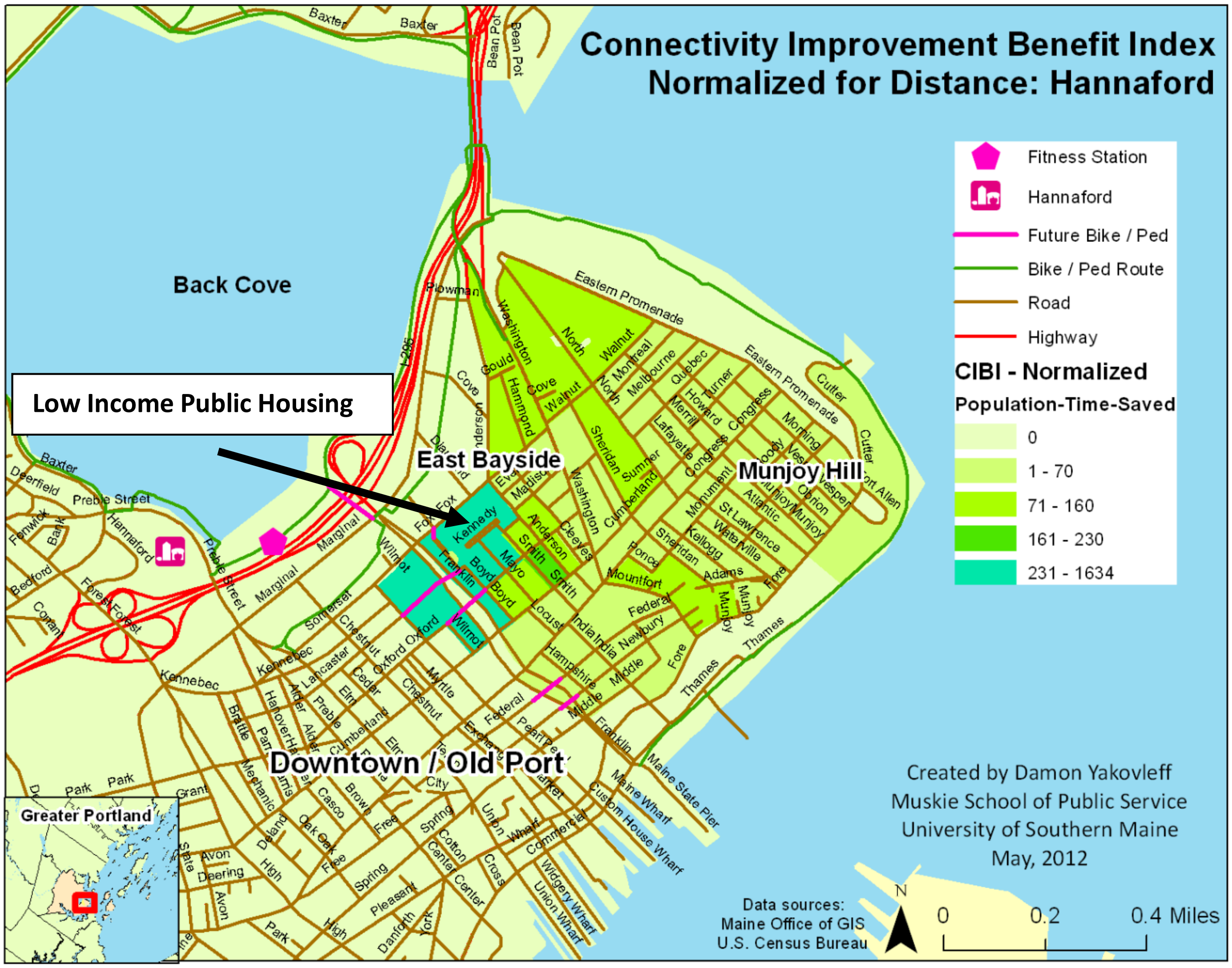
Map 10: Fitness station Walking Permeability Distance Index values, future network configuration.



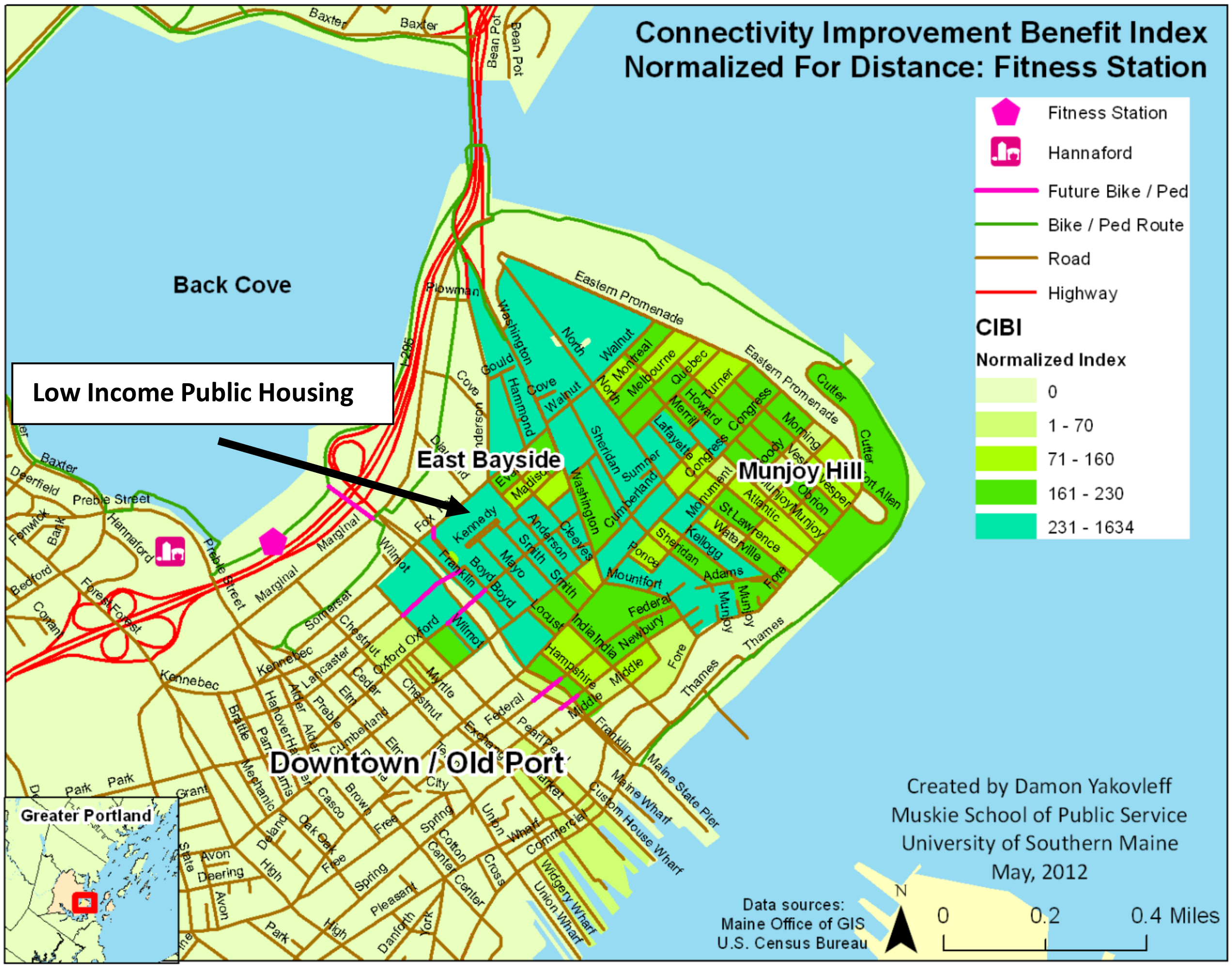
Map 11: Hannaford Connectivity Improvement Benefit Index values.



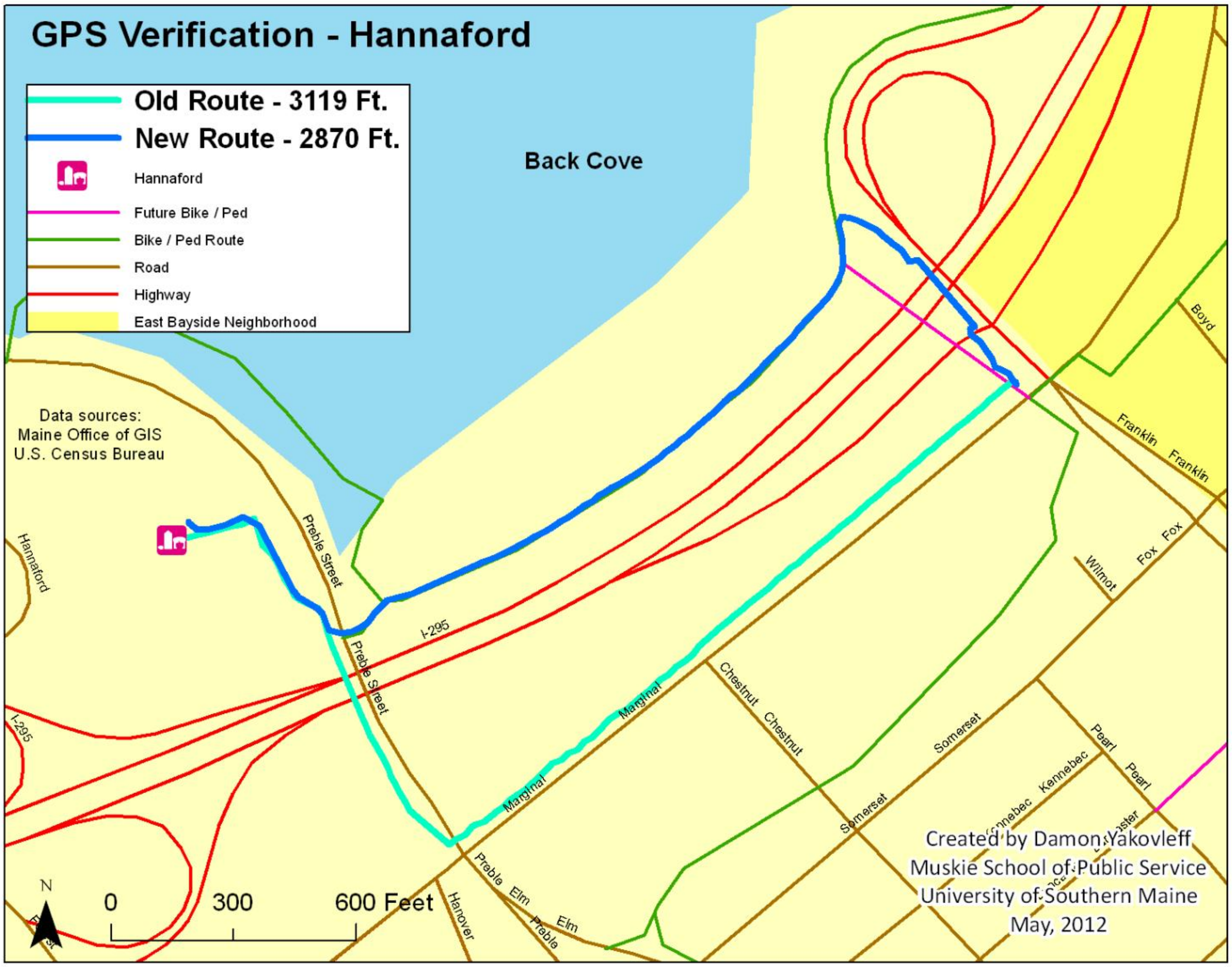
Map 12: Fitness station Connectivity Improvement Benefit Index values.



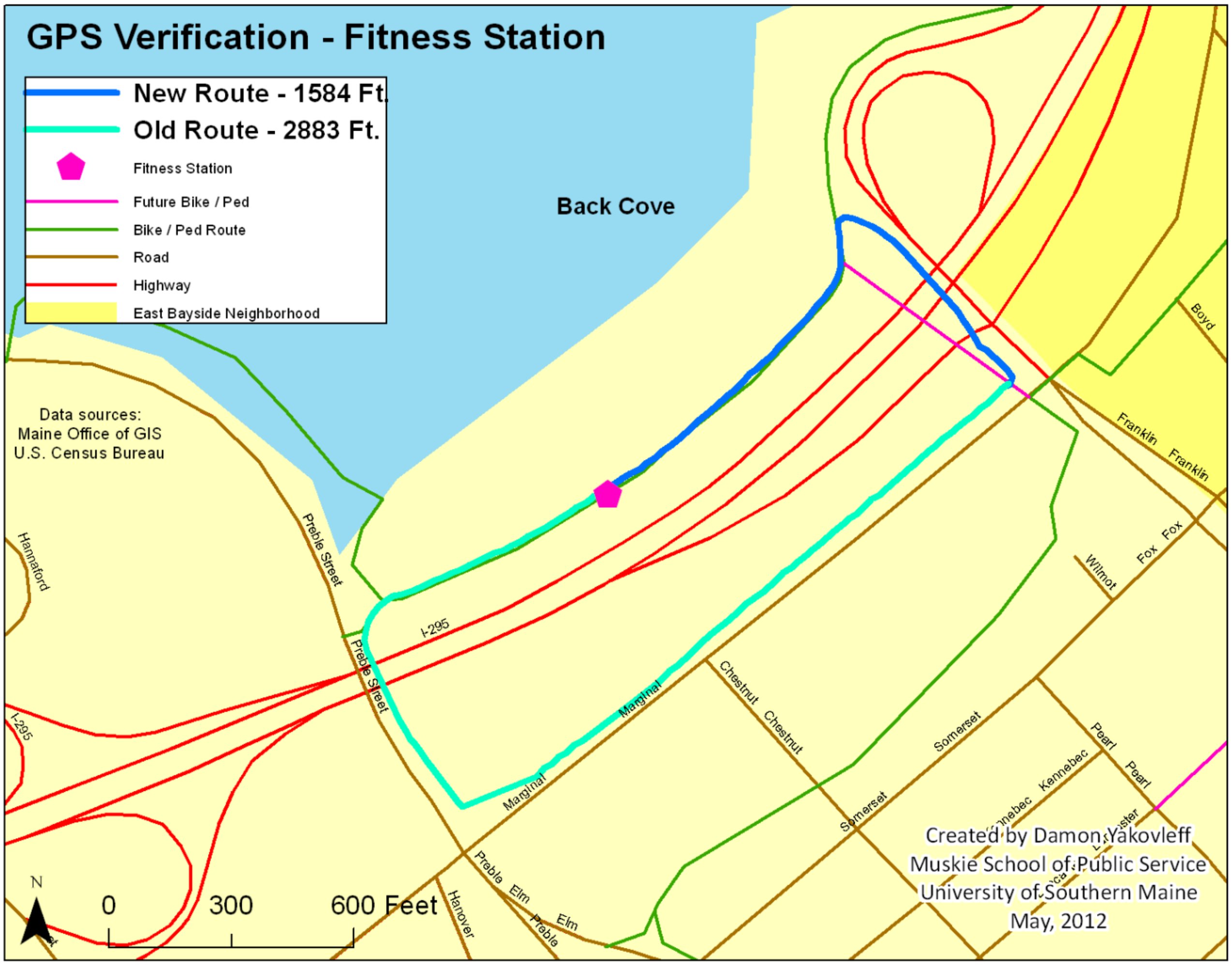
Map 13: Hannaford Connectivity Improvement Benefit Index values, normalized for distance.



Map 14: Fitness Station Connectivity Improvement Benefit Index values, normalized for distance.



Map 15: GPS verification of network distance, Hannaford.



Map 16: GPS verification of network distance, fitness station.

References

Alexander, C. 1977. A Pattern Language. Oxford University Press; New York.

Allan, A. 2001. Walking as a local transport model choice in Adelaide. *World Transport Policy Practice.* 7(2): 44-51.

Berrigan, D., Pickle, L., Dill, J. 2010. Associations between street connectivity and active transportation. *International Journal of Health Geographics.* 9(20)

Giles-Corti, B.,Wood, G., Pikora, G., Learnihan, V., Bulsara, M., Van Niel, K., Timperio, A., McCormack, G., Villanueva, K. 2011. School site and the potential to walk to school: The impact of street connectivity and traffic exposure in school neighborhoods. *Health and Place*. 17:545-550.

Calhoun, C, Conforti, J., ed. 2005.Creating Portland. "Longfellow's Portland". University of New Hampshire Press; Lebanon, NH.

Calthorpe, P. 1993. The Next American Metropolis. Princeton Architectural Press; New York.

Conforti, J. 2005. ed. Creating Portland. "Introduction". University of New Hampshire Press; Lebanon, NH.

Dill, J. 2009. "Bicycling for Transportation and Health: The Role of Infrastructure. *Journal of Public Health Policy*. 30:95-110.

Franklin St. Arterial Study Committee. 2009."Reclaiming Franklin St." http://www.trails.org/articles/09/AAA%20Franklin%20Street%20Report%20FINAL.pdf. Accessed 4/14/2012.

Federal Highway Administration. 2010. "2010 Status of the Nation's Highways, Bridges, and Transit: Conditions & Performance:". http://www.fhwa.dot.gov/policy/2010cpr/chap1.htm. Accessed 5/5/2012.

Googlemaps. 2012. http://googlemaps.com. Accessed 11/4/2011.

Hall, P. 2008. Cities of Tomorrow, 3rd edition. Blackwell Publishing; Malden, MA.

Jacobs, J. (1971). The Death and Life of Great American Cities. New York: Random House

Levine, R. 1999. "Pace of Life in 31 Countries". Journal of Cross Cultural Psychology. 30: 178.

Lynch, K. 1960. Image of the City. The MIT Press; Cambridge, MA.

Maghelal, P., Capp, C., 2011. Walkability: A Review of Existing Pedestrian Indices. *Journal of the Urban & Regional Information Systems Association*. 23(2): 5-19.

Maine Office of GIS. 2011. http://megis.maine.gov. Accessed 11/4/2011.

U.S. Census, 2010. http://census.gov. Accessed 11/3/2011.

Victoria Policy Institute. 2012. “Roadway Connectivity”. Online TDM Encyclopedia. http://www.vtpi.org/tdm/tdm116.htm. Accessed 4/21/2012