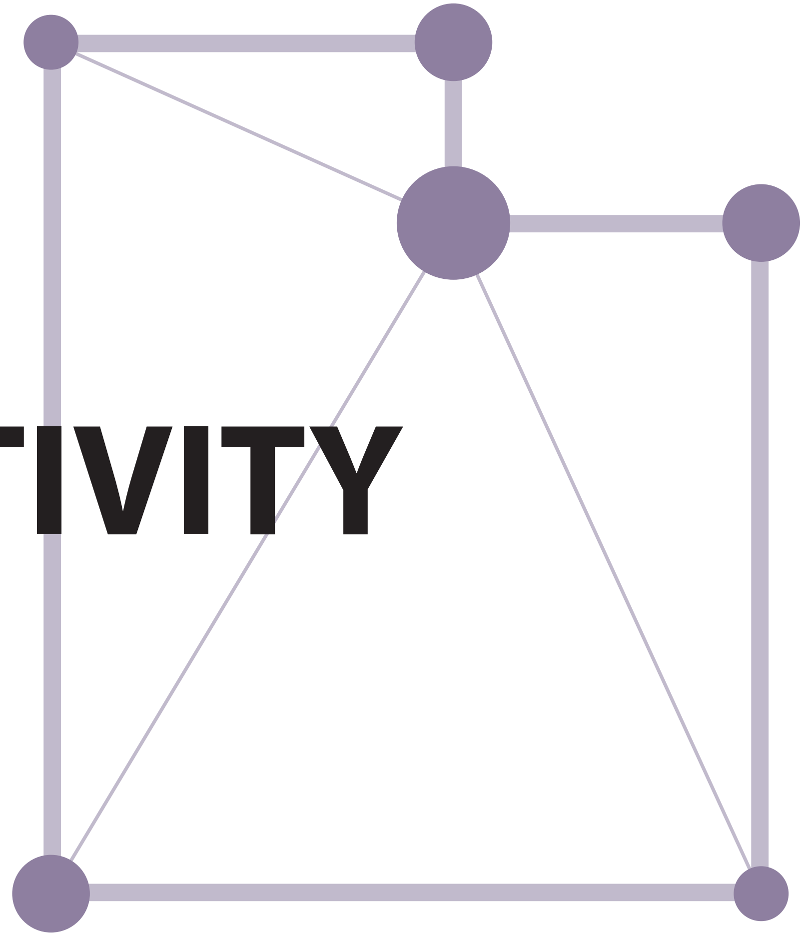
UTAH STREET **CONNECTIVITY** GUIDE



A RESOURCE FOR **WHAT** STREET CONNECTIVITY IS, **WHY** IT IS IMPORTANT - AND **HOW** TO INCREASE IT IN OUR COMMUNITIES

WASATCH FRONT REGIONAL COUNCIL

UTA

UDOT udot.utah.gov

MOUNTAINLAND ASSOCIATION OF GOVERNMENTS

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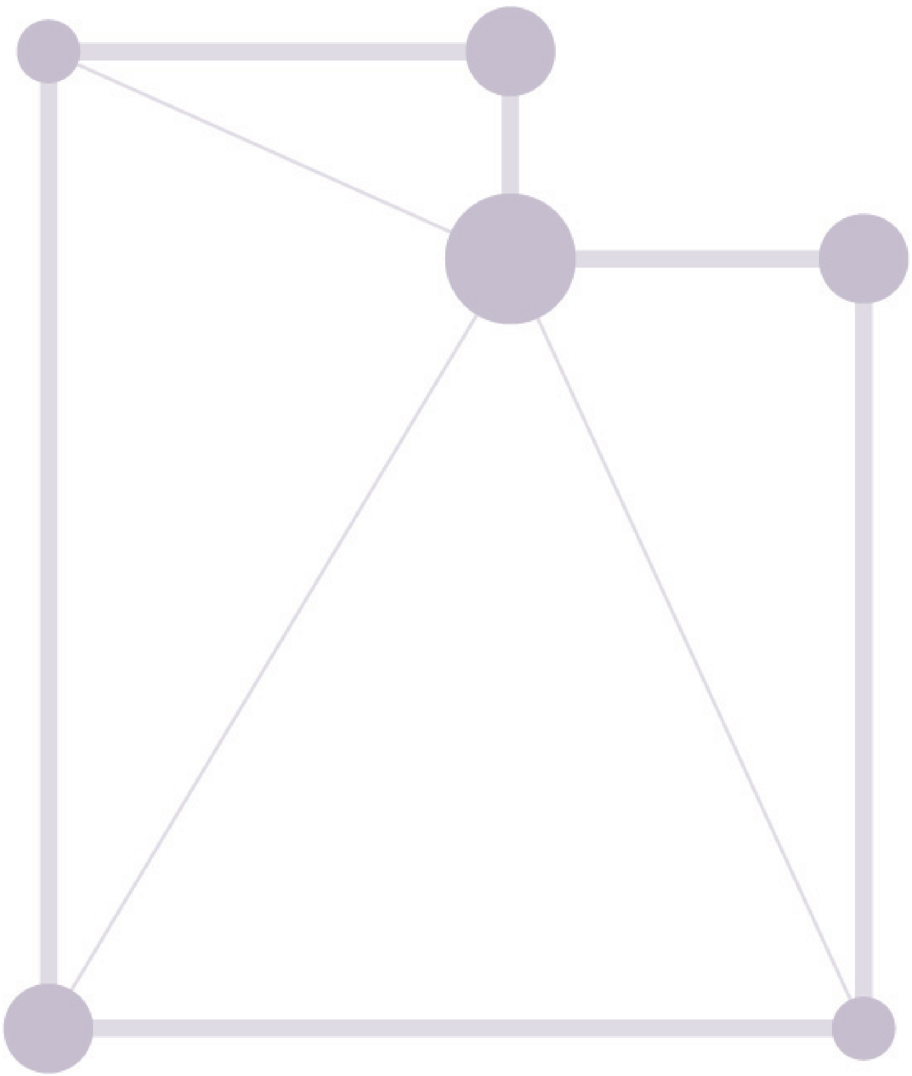
INTRODUCTION



The *Utah Street Connectivity Guide* is a comprehensive resource for improving street connectivity in communities throughout Utah.

This guide:

Identifies what street connectivity is. While most people have a general sense that “street connectivity” means the way our streets are connected to one another, this guide presents a clear yet comprehensive definition useful to practitioners and the communities they serve. The guide identifies a set of key aspects of street networks that constitute “connectivity.” These aspects can be measured both in existing street networks and in proposed street connections.

Makes the case for street connectivity. A high level of street connectivity creates several benefits. In addition to creating a more efficient transportation system, street connectivity can improve a wide range of community aspects reaching into safety, health, economic vitality, the environment, and quality of life. A series of community case studies undertaken as part of this project provides further demonstration of the quantified benefits of connectivity.

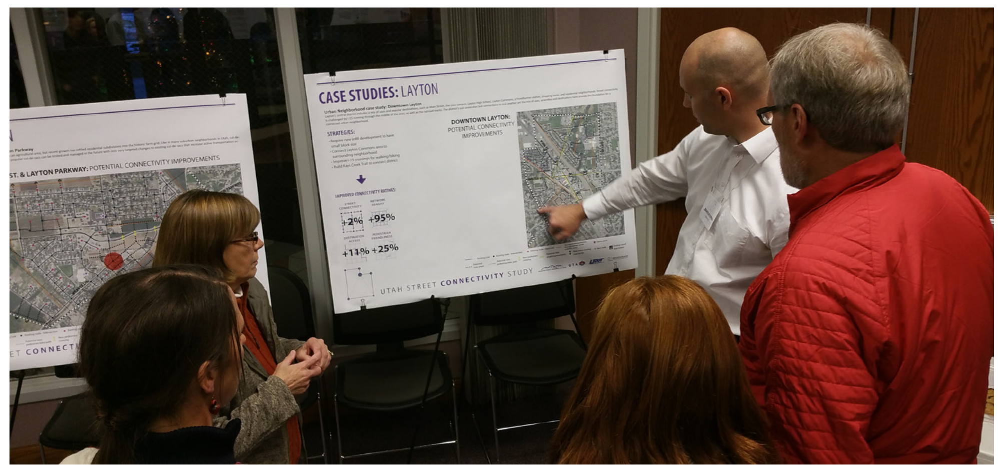
Provides ways to improve street connectivity. With the benefits of street connectivity in mind, this guide provides ways to realize those benefits in a range of communities. The guide identifies how different types of Utah communities – from urban to suburban to rural, and from neighborhoods to special districts – can improve their connectivity in ways appropriate to their context and character. Finally, the project’s case studies provide examples of how strategies can be implemented on the ground.

This guide is the result of a study undertaken by the Mountainland Association of Governments (MAG), Utah Department of Transportation (UDOT), Utah Transit Authority (UTA), and Wasatch Front Regional Council (WFRC). The study involved several subcomponents intended to explore street connectivity both academically and on the ground in Utah communities. These included:

- A **literature review** of the available studies from both academia and planning practitioners that explore the metrics, benefits, and strategies for street connectivity. See Appendix A for the complete Literature Review.
- A set of **surveys** that queried both local Utah jurisdiction and agency staff and Utah communities about issues related to street connectivity. See Appendix B for the complete surveys and summary of the results.
- **Case studies** in three Utah communities – Lehi, Layton, and Tooele County. These case studies involved the evaluation of street connectivity in areas within each community, recommendations for strategies to improve the connectivity in these areas, and the modeling of various benefits based on the improvements. See Appendix C for the full case studies.
- The development of **street connectivity context types**. This study took a context-sensitive approach to street connectivity and developed custom guidance for different scales – from the region to the neighborhood – and different land use types – whether urban or rural, residential or mixed use. These typologies are the basis for the guidance in Section 2.
- A series of **three public open houses** attended by approximately 35 local jurisdiction and agency staff, elected officials, and members of the public.
- A **Working Group** comprised of representatives of project partner agencies such as MAG, UDOT, UTA, WFRC, and the three case study communities met regularly and provided guidance for the development of the above elements of the study.

With this document, you will be able to:

- Understand the aspects of street connectivity – see *Section 1.2*.
- Understand why street connectivity matters to our Utah communities – see *Sections 1.1 and 1.2.*
- See the quantified benefits of improving street connectivity – see *Sections 1.3* and *Part 3*.
- Have the tools to make the case to your colleagues and constituents – see *Sections 1.1, 1.3*, and *3.3*.
- Understand how street connectivity applies to your specific community – see *Part 3*.
- Get tips for talking about street connectivity with your colleagues and constituents – see *Section 2.2* (page 26).
- Select appropriate strategies to improve the street connectivity in your community – see *Sections 2.2, 3.1, 3.3*, and *3.4*.



PART 1

The Case for Connectivity

1.1 Street Connectivity in Utah

Connection is an essential aspect of our communities. Public streets provide the function of connecting us to our jobs, neighbors, friends, and the places we visit. Streets are built to link us to one another and our community destinations.

But in recent decades, as cities and towns have grown, new street networks throughout Utah and the United States began to lose this connection. Living on a cul-de-sac, and the privacy and perceived safety that comes with it, became an attractive lifestyle. We realized that fewer street intersections allowed us to drive faster on bigger streets. Hierarchies of streets emphasized limited connections between neighborhoods and the collector and arterial streets that linked them to the surrounding region.

Because of these desires for mobility, safety, and security, our networks became so disconnected that a house that sits next to a school might require a mile trip along a looping street system to access it.

Yet a growing body of research shows the importance of reconnecting our communities with improved street networks. High levels of street connectivity actually do a better job of achieving many of the goals that many of our communities have in common – economic vitality, the effectiveness of infrastructure, health, and choice of how we travel around.

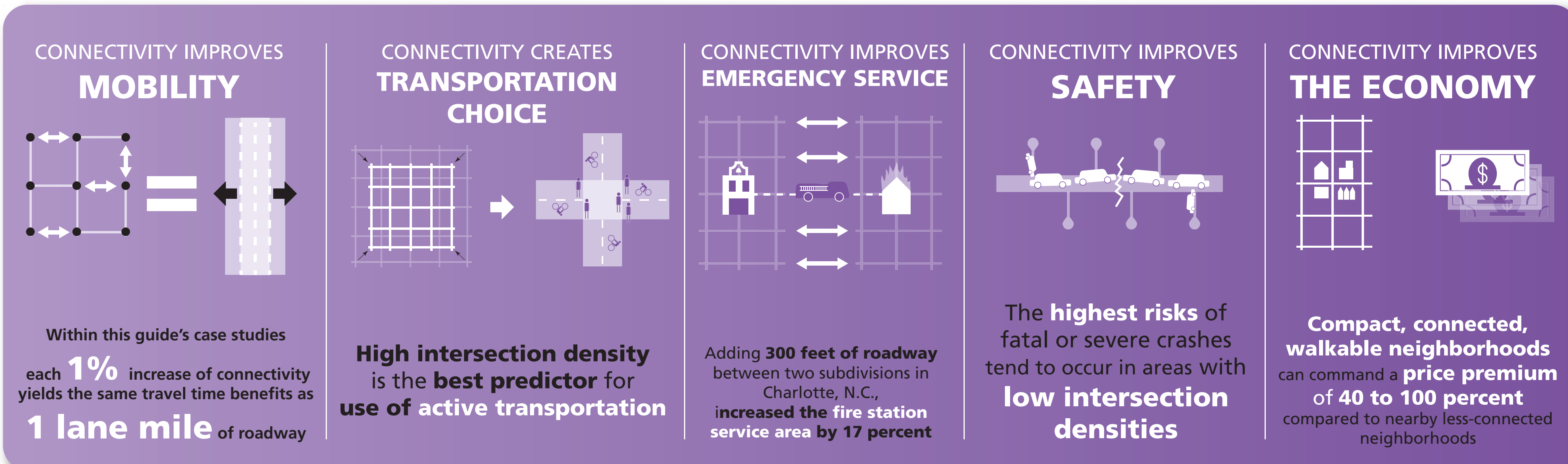
Street connectivity disperses traffic throughout the network, leading to a significant reduction in travel times, delays, and having to drive on larger streets. Unlike widening streets, the increase in street connectivity creates additional community benefits, such as increasing use of transit, bicycling, and especially walking. This increased ability to walk, bike and take transit leads to documented lifts in outcomes as diverse as property values, obesity prevention, and ecosystem conservation.

These benefits reach even to the aspects of street network that led city builders to disconnect streets in the first place – mobility, safety, and security. For example, the number one issue with respect to their neighborhoods for Utahns surveyed for this study is safety from traffic – and higher street connectivity has been shown to create more traffic safety.

We see a range of opportunities to increase street connectivity in Utah communities while also achieving the community goals important to different cities and neighborhoods. For example, good access to destinations is important to many Utahns. But increasingly, even neighborhood schools are inaccessible for Utahns. Yet the smallest of investments in street connectivity can yield major returns of accessibility. One link in a disconnected street network, for example, can put a school within walking distance for twice as many people.

Street connectivity is an idea useful to all Utah communities – and one that is flexible in how it is applied. This guide shows how all types of Utah communities can improve street connectivity in a way that is consistent with its core values.

In order to provide a comprehensive guide to street connectivity, this guide sets out to answer three main questions related to street connectivity: What is street connectivity? Why does it matter? And, finally, how do we improve it in our communities?



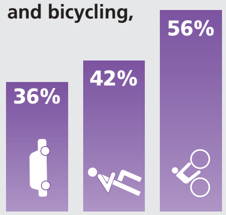
Sources: Utah Street Connectivity Case Study research; Ewing, R., and R. Cervero. Travel and the Built Environment: A Meta-Analysis. In Journal of the American Planning Association, Vol. 76, Issue 3, June 2010; Lehigh Valley Planning Commission. Street Connectivity Guidance Document, 2011; Marshall, W. E. and N. W. Garrick. Street Network Types and Road Safety: A Study of 24 California Cities. In Urban Design International, August, 2009.

UTAH STREET CONNECTIVITY SURVEYS

A set of **surveys asked** both Utah local jurisdiction and agency staff and Utah communities about opinions on street connectivity and existing connectivity-related policy but also opinions about broader topics such as neighborhoods and transportation. The community survey received 1,300 responses while the staff survey received nearly 100. Some key findings are summarized below.

Safety is the aspect of transportation most important to people.

For driving, walking and bicycling,

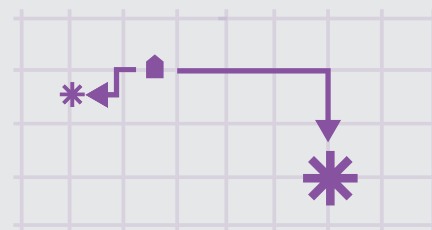


of survey respondents say safety is the most important issue - the top response for each mode.

Safety is often ***equated with disconnected streets*** (Our study has shown this not to be the case).

Yet the staff survey agreed that this perception is the No. 1 ***barrier to increasing connectivity.***

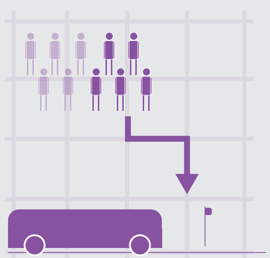
Access to destinations is very important to people.



One of the top barriers for walking is destinations are too far and ***"it takes too long to get where I want to go."***

Both ***neighborhood*** and ***regional*** destinations are important to access.

People want to use alternative transportation.

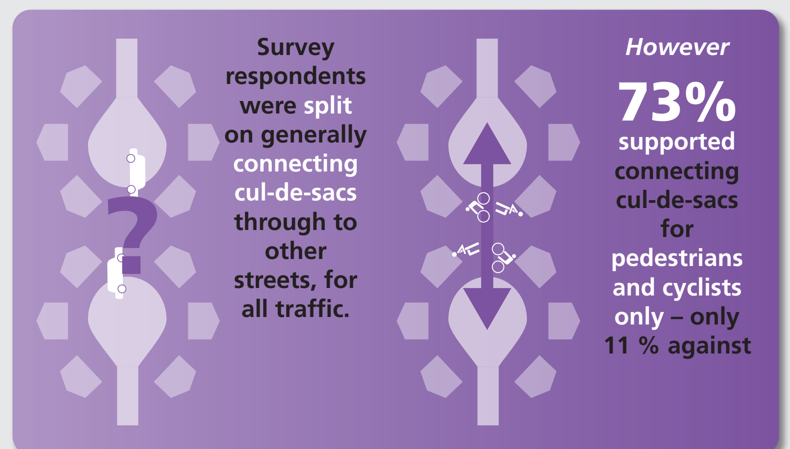


Over half of respondents agreed with the statement that

"I would be willing to ride transit more if bus stops or train stations were more easily accessible by walking or biking from my home."

30% of community survey respondents identified "good options for a wide range of transportation modes" as one of the most important neighborhood issues.

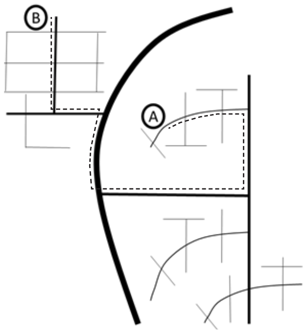
Cul-de-sac connection is a flash point for the street connectivity discussion.

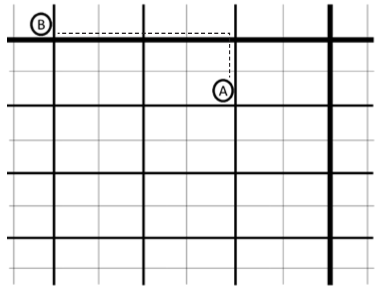


1.2 WHAT is connectivity?

Street connectivity is a simple idea – providing a network of public streets whose intersections allow for easy movement around it. However, this simple idea is more difficult to define.

Look at the two images below. The images show two street networks, and they are clearly different. But why are they different?



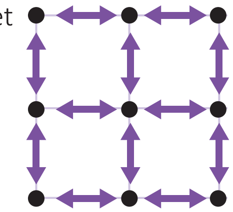


These two networks differ in many ways. The network on the left has fewer four-way intersections than the one on the right, and less of a grid pattern. It has larger, and less-defined blocks. It has fewer places to access a major street. It requires a longer path to get from Point A to Point B.

These differences all represent key aspects of street connectivity. After conversations with the study Working Group and extensive review of the academic literature and existing policy, the project team developed a working definition of street connectivity that has four aspects, two of them more general and "basic" and two others more specific and "secondary."

BASIC ASPECTS OF STREET CONNECTIVITY

The basic aspects describe the general qualities of connectivity of a network. These are good for understanding a network's high-level connectivity.



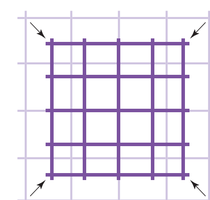
The relative level of connection. The most basic aspect of street connectivity is the degree to which streets are connected to one another at each intersection. One way to consider this idea is to look at how much "work" each intersection is doing. A six-point intersection is doing a lot of work, transferring traffic and other users among six different streets. But a cul-de-sac, with only one street coming off it, is doing the minimum amount of work. Essentially, the relative level of connection tells us how much work each intersection is doing – the more amount of work, the higher the level of connectivity. In the example below, the Downtown Salt Lake City grid has a higher level of connection because of its consistently 4-way intersections, while the eastern Salt Lake City example has mostly 3-way intersections and cul-de-sacs.

Downtown Salt Lake street grid

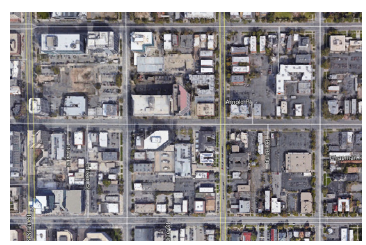
800'

East Salt Lake street grid

800'



Network density. However, the level of connection does not tell the whole story. Like in its name, "level of connection" is relative. Take the very connected network in downtown Salt Lake City and compare it to Salt Lake City's Avenues neighborhood. Because both are nearly perfect grids, they have the same relative level of connection. However, the Avenues network is noticeably different, and more connected. This is due to the second basic aspect of street connectivity – network density. With its approximately 330-foot blocks, the Avenues has much higher network density than downtown Salt Lake City, with its 660-foot blocks. The Avenues has more links and more nodes. So, it is also important to consider this "absolute" aspect of the network to provide this other critical dimension of connectivity.



Downtown Salt Lake street grid

800'

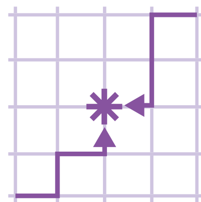
Avenues neighborhood street grid

800'

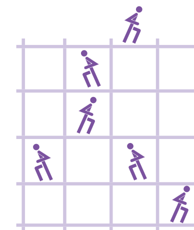
SECONDARY ASPECTS OF STREET CONNECTIVITY

The first two aspects of street connectivity give us a good understanding of the general connectivity of a street network. But a few things are missing. These two secondary aspects describe more real-world aspects of connectivity that one experiences on the ground in trips through the network.

Ability to connect to specific destinations. This aspect addresses the problem that all destinations along a network are not equally popular – and, therefore, are not equally valuable for a network to connect to. An elementary school receives more trips along a network than a single family home, for example. So it is important to understand how well a given network connects the community to these specific points along it. Often improvements to accessing a specific destination such as a school are the most effective ways a built-out community can improve its connectivity.



Quality of the network for all users – walkability. The other secondary aspect of street connectivity considers that, on the ground, streets are much different than lines on a map. Each street offers a different environment for all the transportation modes – private vehicles, public transit, freight, bicycling, and walking. Among these, this guide argues that it is particularly important to pay attention to the conditions for walking. Pedestrians are the most vulnerable users of the network, and everyone is a pedestrian at some point during their trip. The pedestrian environment is critical for transit access. Consequently, this guide identifies walkability as a key aspect of street connectivity. Walkability here means how well a street provides infrastructure for walking – both along it and at street crossings.



It is especially important that street networks connect to key community destinations like schools.

Walkable streets, with sidewalks or paths, buffers, amenities and safe roadway crossings, are an important aspect of street connectivity.

Each of these aspects is a vital aspect of connectivity, so that a truly connected street network that achieves the community goals outlined below should have all four of these. In this guide, each aspect is represented by a metric. The metrics are found in *Section 2.1* of this document.

1.3 WHY is connectivity important?

A highly-connected street network – one where a dense set of intersections each connect to several streets, that connects a community to its key destinations, and is walkable – provides a multitude of benefits for Utah communities.

This guide has quantified these benefits. Through a review of studies and literature available, as well as modeling of potential benefits in case studies of three Utah communities, we show how an increase in connectivity causes the achievement of benefits associated with commonly-found community goals. These include mobility, transportation choice, health and safety, infrastructure and growth management, economic vitality, and environmental conservation. The survey undertaken as part of this project confirms the importance of these objectives.

Below, we show how each one of these goals is benefited by improved street connectivity. The benefits come in four types:

Direct benefits describe a benefit that is conferred directly by street connectivity. For example, a dense, connected, walkable network directly increases the likelihood someone will choose a non-automobile transportation mode.

Indirect benefits describe a benefit that is conferred by a direct benefit. For example, a dense, connected, walkable network directly increases the likelihood someone will choose a non-automobile transportation mode, which in turn decreases the likelihood that person will be obese.

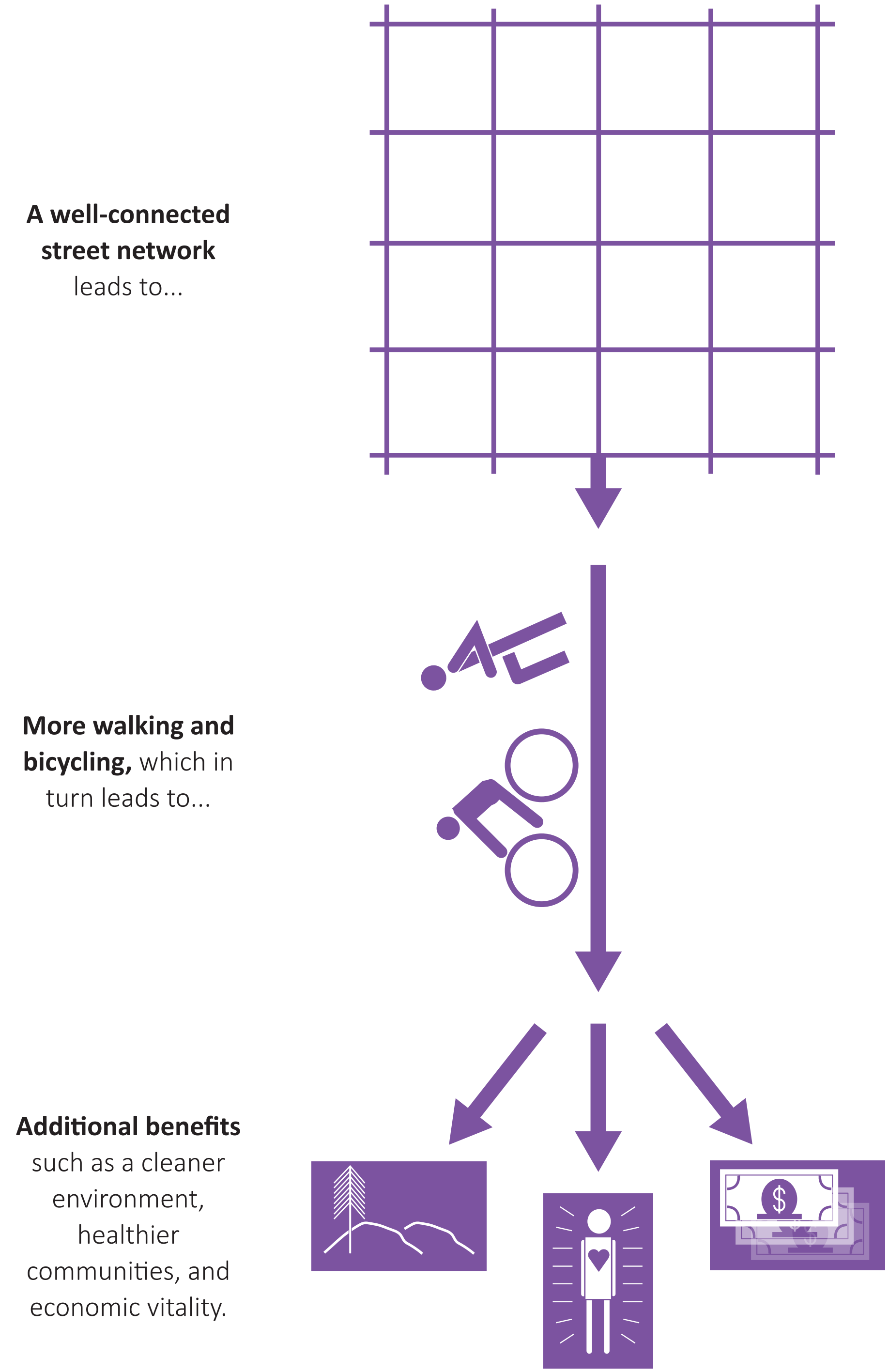
Inherent or implied benefits describe a benefit that is inherent in the nature of connectivity. For example, a more connected regional street network inherently helps its communities become more compatible with one another. However, these community goals have not been explored in the literature to a large extent.

Finally, **connectivity misconceptions** describe perceived dis-benefits of street connectivity that have been shown to be either untrue or less significant than perceived. For example, higher street connectivity actually increases a community's security and lowers crime.

Each of these benefits is influenced by one or more of the aspects of street connectivity described above. For some benefits, the deciding factor is relative level of connection; for others it may be network density. For many others, it is a combination of the four aspects.

Except where noted as part of this project's case studies, sources for the information contained in the following discussion are found in the literature review in the Appendix, which also contains more information about each benefit.

Direct and indirect benefits of street connectivity: an example



SUMMARY OF DIRECT BENEFITS

Regional and community mobility

Good street connectivity redistributes traffic among different routes in a network, providing more options and better accessibility for local traffic. This in turn frees some of the capacity on the adjacent arterial roads, which are mostly used by the non-local traffic.

- Modeling the effects of proposed street connectivity improvements in the cities of Lehi, Layton, and Tooele Valley led to some key conclusions including:
    - In urban and suburban community-scale networks, a **significant reduction in network travel times and delays** was observed.
    - A set of street improvements improving connectivity in three communities by an average of 32 percent would lead to an average of a **17 percent decrease in delay.**
    - **Vehicle miles traveled (VMTs) on larger streets** was, in most cases, **significantly reduced**, attributed to a more balanced distribution of traffic flows within the network.
- The literature confirms many of the conclusions of the case study modeling outlined above, and also indicates the following additional findings:
    - In general, the **average reduction in VMTs is about 10 percent** in networks with good street connectivity compared to those with poor connectivity. A greater reduction in VMTs is observed in less dense automobile-oriented urban areas.
    - In most cases, **greater connectivity reduces traffic volumes on arterial streets,** therefore improving mobility. The main factors that influence this are reduced trip distances, reduced number of local trips using arterials, multiple alternative routes, shifts from personal vehicles to other modes, and redistribution of traffic throughout the network which increases the network-wide capacity.
    - **Returns of mobility are highest** when a network goes from **low to moderate network density**, from about 10 to 16 connections per mile. These returns diminish for motorists when a network goes from this moderate level to a higher level of connectivity.

In general, 1 percent of increase in a city's street connectivity equals the network capacity of adding one lane-mile to an arterial street.

Transportation choice

Higher street connectivity provides travelers with greater choice of travel modes. In a well-connected network, active transportation modes and transit become more viable choices. This means that these types of networks are less automobile-dependent.

- Improved connectivity leads to **better mobility and access for cyclists and pedestrians**.
- Pedestrian and bicyclist benefits experience **increasing returns from medium to high connectivity.**
- Good street **connectivity increases the proportion of trips made by walking** by between 25 and 900 percent.
- **Short blocks and grid-like network structure** have been found to be influential characteristics for **higher use of active transportation**.
- Connectivity **improves the efficiency of bus transit** by providing more direct routes and providing a good collector street network that creates more options for routing bus transit closer to neighborhoods.
- A meta-study of 62 studies found that a **high intersection density is the best predictor for use of non-motorized** transportation modes.
- The same study also found that **use of transit was most closely related to a set of factors influenced by street connectivity**, including destination accessibility and the design of networks to maximize street connectivity and intersection density.
- This study's case study modeling projected that a set of street improvements improving connectivity by approximately 30 percent in two suburban communities could lead to a **bicycling mode share increase of 4 to 20 times and walking mode share by 4 to 6 times**.


Credit: vxla

High intersection density is a predictor for high use of non-motorized transportation modes.

Safety

In recent years, many studies have focused on how built environment factors (such as street connectivity and community) affect physical activity and health.

- Street network densities are correlated with roadway safety outcomes. The **highest risks of fatal or severe crashes** tend to occur **in areas with low intersection densities.**

- More **connected, multi-modal street design** can significantly **reduce traffic injury** and fatality rates. A study of 24 California cities showed that cities with better bicycle networks had on average between 10 and 17 times lower vehicle occupant crash fatality rates and between 3.8 and 4.5 times lower vehicle occupant crash severe injury rates.

- A local, well-connected network system **encourages slower and more cautious driving**, since drivers encounter various travel modes and more intersections.

Infrastructure and growth management

Higher street connectivity improves the investment in municipal infrastructure, such as utilities, and services, such as fire and emergency services.

- A 2008 study of municipal services conducted by Charlotte, N.C., found that the **citywide average response time** in subdivisions constructed since 2001 – when minimum street connectivity standards were enacted in the city – **dropped thirty seconds.**

- The 2008 Charlotte study found that **building 300 feet of street between two subdivisions provided a 17 percent increase** in service area for a fire station.

- The study also found that the typical **coverage area of a snowplow operator doubles in areas without prevalent cul-de-sac streets.**

- The Raleigh, N.C., Transportation and Planning Department studied fire and emergency management system efficiencies in three different neighborhood types and found that in all cases, the analysis showed **far greater service efficiencies for neighborhoods with greater street connectivity.**

- The Reason Foundation found that "increasing connectivity of the street network will help improve the efficiency of the transportation network, **allowing limited federal funds to be prioritized for pressing transportation needs** with less local traffic on overburdened roadways, reduced wear and tear may prolong the life of many critical infrastructure links. The costs associated with maintaining roadways have grown considerably over the last few years and measures to extend their lifespan may reduce the burden of public expenditure."

The highest risks of fatal or severe crashes tend to occur in areas with low intersection densities.

SUMMARY OF INDIRECT BENEFITS

Health

In addition to direct benefits, street connectivity has been shown to offer indirect benefits related to health, largely stemming from the health effects of increased physical activity.

- Connectivity is one of a few key ingredients of walkable neighborhoods that produce **positive body mass index (BMI) outcomes.** In one study, for example, high-walkability residential neighborhoods with higher residential density, land use mix, and street connectivity reported **70 minutes more physical activity** within a week than other neighborhoods. Other studies have found increasing levels of walkability decrease the risk of excess weight.

- Connectivity **limits time spent in the car.** Street connectivity impacts walking time and minutes spent in car, which consequently impacts BMI and population health.

- The World Health Organization (WHO) estimates that **regular use of bicycles** (for about three hours per week) can **reduce the mortality risk by about 28 percent.**

- Similarly, consistent **walking for about 30 minutes per day** can **reduce mortality risk by about 22 percent.**

- Physical activity also **reduces occurrences of cardiovascular diseases**, Type 2 Diabetes, and some cancers. These reductions are between 10 percent and 30 percent, according to the WHO reports.

- Our case study modeling projected that a set of street improvements improving connectivity by approximately 30 percent in three communities would on average lead to a **doubling of physical activity** and a **quadrupling of long-term health care cost savings.**

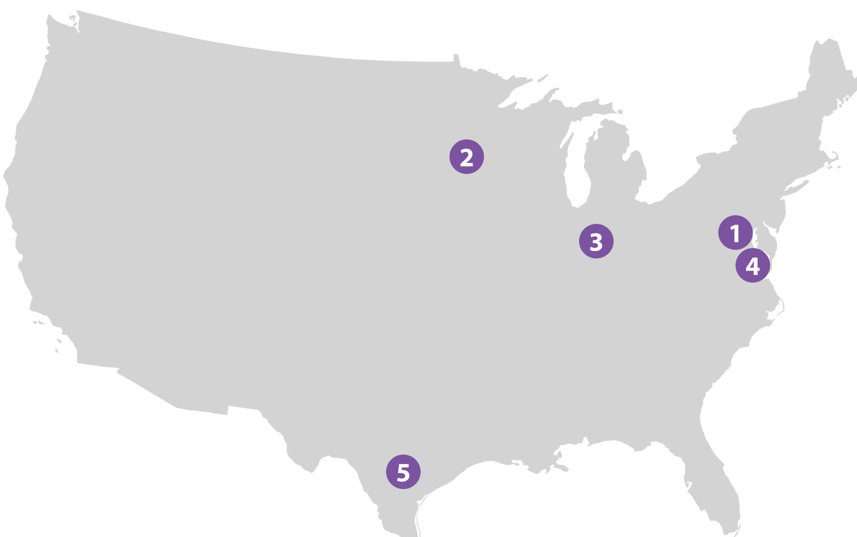
In one study, walkable, connected neighborhoods reported 70 minutes more physical activity per week than other neighborhoods.

Economic vitality

Increasing street connectivity has been found to have an impact on a community's economic vitality. Many of the benefits are measurable in the economy or in the fiscal well-being of households and governments. Some of the benefits are intangible such as increased personal time to spend with family and friends, improved overall health and well-being, and improved area air quality.

- **Compact, walkable neighborhood developments – in which connectivity is a key ingredient – can command a price premium.** This premium has found to be as much as 40 to 100 percent compared to houses in nearby single-use subdivisions. The homes at Kentlands, Maryland, 1 sell at a 25 percent premium over comparable large-lot developments in the same zip code. A 2003 study showed a $24,255 premium for Portland-area homes in New Urbanist areas compared to those in conventional suburban neighborhoods.

- Street connectivity also has a direct positive effect on bicycling and **bicycle networks can also have a positive impact on home values.** The median home values in Minneapolis-St. Paul 2 increased by $510 for every quarter of mile nearer to an off-street bicycle trail, while homes within half-mile of Indiana's Monon Trail 3 had an average of 11 percent increase in sale price when compared to similar homes further away. Additionally, regional economies can benefit as well. A case study of North Carolina's Outer Banks concluded that the one-time investment into the bicycle network resulted in an annual economic impact that is nine times greater, supporting more than 1,400 annual jobs.



- Improvements in **walkable street networks can also have an impact on retail rents.** A study of the Washington, DC, area 4 found that office and retail spaces in areas with good walkability rented for $8.88/sq. ft. and $6.92/sq. ft. more per year, respectively, compared to places with fair walkability, holding household income levels constant. Additionally, relative to places with fair walkability, places with good walkability scores, on average, bring in $301.76 more per month in residential rents and $81.54/sq. ft. more in for-sale residential property values. Another study showed that a 10 percent increase in walkability showed a 1 to 9 percent growth in property value.

- Because street connectivity has been shown to influence mode choice of transit, the **economic benefits of public transit are an indirect benefit of street connectivity.** These include creating jobs, stimulating development, boosting business revenue, increasing local and state revenues, saving employers money, decreasing pollution, and conserving energy. For example, in Bexar County, Texas, 5 a study estimated that the County loses approximately $307,000 in regional income and 8.4 jobs for every million dollars of expenditures switched to auto. The same million spent on bus operations will generate nearly $1.2 million in regional income and 62.2 jobs.

- There are also **benefits to hotels as a result of improved transit connectivity.** From 2006 to 2013, communities with direct access to airport terminals experienced a 10.9 percent increase in average daily rates and revenue per available room.

- **Worker productivity has been associated with bicycling.** Those who bike regularly saw a 32 percent decrease in sick days taken and a 55 percent decrease in healthcare costs, all while seeing a 55 percent increase in productivity.

The price premium for a walkable, connected neighborhood has been found to be as much as 40 to 100 percent.

- Motorized transportation benefits resulting from increased street connectivity lead to a variety of **community and regional scale economic benefits.** Models have found that increased street connectivity produces:
    - **Lower materials costs:** The reduction of travel time of trips on a regional level also results in lower materials costs because goods can reach their destinations quicker and in a shorter distance saving both wages and fuel.
    - **Increased sales:** For a local or neighborhood retailer, connectivity results in improved access to an area's customer base, generally resulting in higher sales per square foot.
    - **Lower household costs:** For local residential property owners, connectivity results in lower household transportation costs and increased personal time. Measures on the local level include job growth in all sectors including service and retail, as well as local tax benefits such as sales and property taxes. This leads to increase in job density which translates in to higher job accessibility lowering transportation costs for household.
- Our case study modeling projected that a set of street improvements improving connectivity in three communities by an average of 32 percent would lead to **small but significant increases in sales in different types of retail establishments.** These included a 0.9 percent increase in supermarkets and grocery stores, a 0.7 percent increase in warehouse clubs and supercenters, and a 0.5 increase in limited service restaurants.

Environment

Street connectivity has major impacts on the environment. Shifts towards transit and active transportation modes in a connected network reduce VMTs, delays, and usage of automobiles which reduces air pollution, noise, and energy consumption.

- This study's case study modeling projected that a set of street improvements improving connectivity by approximately 30 percent in two suburban communities would on average lead to a **500 percent reduction in carbon dioxide emissions due to increased walking and bicycling trips.**

Improving connectivity in two Utah suburban communities by 30 percent showed a likely 500 percent reduction in carbon dioxide emissions due to increased walking and bicycling.

Credit: Dean Derhak

SUMMARY OF INHERENT OR IMPLIED BENEFITS

Interlocal and regional compatibility

Connectivity inherently creates compatibility. Past research efforts have used the term “internal connectivity” and “external connectivity” for measuring the connectivity of specific region within itself, and “inter-local connectivity” of that region. Studies on inter-local connectivity are rare, but measures can be developed based on regional connections to arterials and other neighborhoods. Areas of interest are connections between state and local jurisdictions for issues such as transit access and freight.

Community access

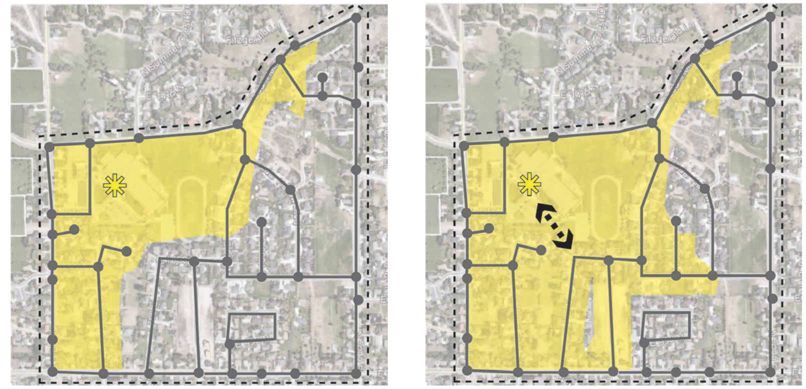
Connectivity inherently improves access. At a regional or community-wide scale, connectivity improvements can reduce bottlenecks and reduce distances that residents need to travel to jobs. At a neighborhood scale, where connectivity improvements can bring a school, park, or shopping area within walking or bicycling distance to more people. Access, in the context of street networks, also means interactions among people within a neighborhood.

- Studies have recognized good street connectivity **as the major prerequisite for accessibility and livability.**

- **Streets shape community interaction and community life.** Narrow streets with low traffic are friendlier for pedestrians, increasing interaction among people. Narrow streets also do not represent a barrier for the two communities on the opposite sides of the street.

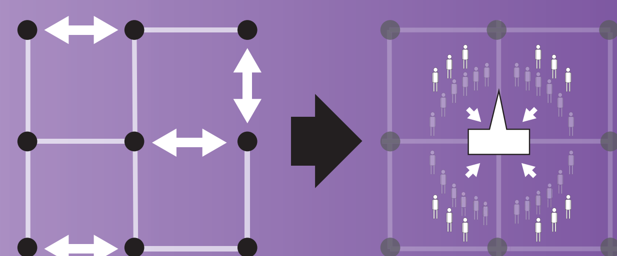
- **Natural features such as rivers and man-made features, like highways and freeways, often serve as or create barriers** to direct local travel, particularly for bicycle and pedestrian travel. This is a so-called “barrier effect,” which reduces accessibility for active transportation modes and forces a shift to motorized travel.

These inherent and implied benefits could benefit from increased study with regard to their relationship to street connectivity.



Even making one small connection can drastically improve the accessibility of destinations. While the diagram on the left shows the existing area accessible within walking distance to a neighborhood school (star marker), the diagram on the right shows the area accessible within the same distance if one strategic connection is made (black dashed arrow).

For every **degree street connectivity improves, Access to destinations** improves **two degrees**.



For example *- a neighborhood street network whose connectivity improves by **25 percent** on average makes its community destinations accessible to **50 percent** more of the neighborhood.*

CONNECTIVITY MISCONCEPTIONS

Cost

The perception is often that providing increased connections costs money, whether implemented by cities or developers.

- When it comes to utilities and their maintenance, it was observed that better connectivity actually can decrease these costs, since utility connections are improved, and, therefore, easier to access and maintain.
- There are strategies that communities can implement to avoid increase in costs, such as narrower street standards, limiting maximum block length, landscaping, and different treatments of cul-de-sacs.
- Developers may also argue that improved street connectivity decreases the amount of salable land they will have for development, since potential building lots may be used for transportation connections. However, incorporating appropriate walkability, traffic control, and security features into connected streets, as well as the opportunity to have more diverse contents, can offset the potential decrease in property values.
- In addition, the economic benefits of street connectivity because of walkability, bikeability, and transit-friendliness can also easily offset any short-term construction costs.

Residential traffic and safety concerns

Concerns about increased street connectivity are often related to increased traffic on residential streets. The community survey undertaken as part of this study found that the no. 1 reason people are hesitant to connect cul-de-sacs is concerns about traffic safety. The survey also found that traffic-related safety is important for all modes – it is the no. 1 issue for driving, walking, and bicycling. The staff survey, meanwhile, agreed that the no. 1 barrier to increasing connectivity in Utah communities is perception of connectivity negatively influencing traffic-related safety.

- While poor street connectivity may reduce traffic at a neighborhood micro-level, traffic usually increases on collector and arterial streets, creating more severe barriers for residents around their neighborhood.
- Our traffic modeling of some Utah neighborhoods found that improving connectivity in urban and rural neighborhoods does not seem to attract more through traffic, but at the same time provides a safer and better environment for non-motorized traffic modes.
- Overall safety in a community benefits more from a connected street network than a disconnected one – see findings under “Safety” heading.
- While increased traffic on residential streets has been observed in some studies, there are strategies that are implemented in the field to keep the traffic increase at a tolerant level.
- It is also important to provide good arterial and collector streets on the network borderlines that will provide more capacity and higher speeds for non-residential traffic, therefore minimizing the possibility that this traffic will use residential streets.

Crime and personal security

People often perceive that connected street networks invite crime and decrease personal security. Personal security is extremely important to Utahns – two-thirds of this project’s survey respondents identified safety from crime as one of the most important three aspects of their neighborhood. The desire to remain safe from crime was also a main reason survey takers did not want to connect cul-de-sacs as through-streets.

- The increase in crime rates in relation to street connectivity has not been quantified in practice. A study performed in Western Australia did not find that better street connectivity alone is not related to the increase in crime rate, although it correlated more walking and activity with increase in crime. Rather, the study found that the presence in local destinations is related to the increase in crime rate. Another London study found that the risk of crime is less in well-connected network with more activity, following the “safety in numbers” principle.
- That study also found that the high-tax properties on cul-de-sacs are more vulnerable to crime in small cul-de-sacs, and that dwellings on cul-de-sacs have twice as many burglaries as dwellings on connected streets.

PART 2

Tools for Street Connectivity

Now that we understand what street connectivity is and why it is important, we look to how we can make our streets connected within our current policy environments and while still meeting other community goals. Improving Utah communities' street connectivity is well within the reach of communities. There are many ways these improvements can happen.

This section and the section after it, the *Design Guide and Case Studies*, provide practitioners with the tools to understand the existing street connectivity in your community, develop ways to improve it, and see examples of applications of strategies.

The guide presents two reference sections:

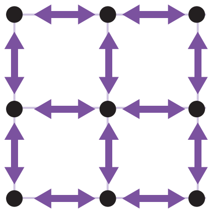
- *Measuring Street Connectivity*: a method for evaluating street connectivity; and

- *Strategies, Best Practices and Tools to Improve Street Connectivity:* A list of potential strategies to improve street connectivity.

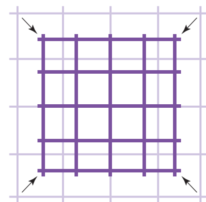
2.1 Measuring street connectivity

This guide offers a detailed method to measure the level of street connectivity in your community. The following offers the information you will need to evaluate the existing and improved connectivity in your community.

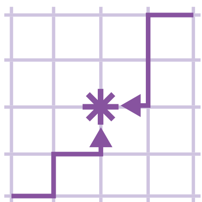
The ***What is Connectivity*** section identified four key aspects of street connectivity. They are:



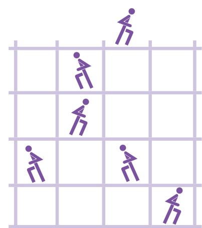
Relative level of connection



Network density



Ability to connect to destinations



Quality of the network for all users – walkability

For this guide, these four aspects translate into four metrics to use to evaluate a community's street connectivity. These are divided into Basic Metrics and Advanced Metrics.

Note that this section primarily introduces the metrics and describes how to measure them. For the standards for the metrics, please see the tables in *Section 3.1.4* as well as the context-based guidance in *Section 3.3*.

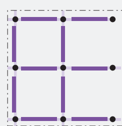
2.1.1 Basic Metrics

The Basic Metrics provide a basic understanding of the street connectivity in a community by measuring the levels of connectivity and density. They are relatively easy to calculate and convey.

Connectivity index

The relative level of connection is measured by the connectivity index, also known as the link-node ratio. The connectivity index is **the ratio of the links in a given area to the nodes in the same area**. It expresses how efficient the intersections are – the foundation of a well-connected network are intersections that connect to several links. The connectivity index measures this quality.

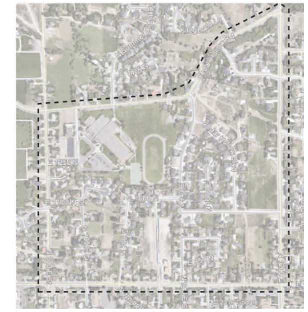
Connectivity index =
the number of *links*, or street lengths, ( )
divided by
the number of *nodes* - intersections/dead ends (•)
within a given area ( )



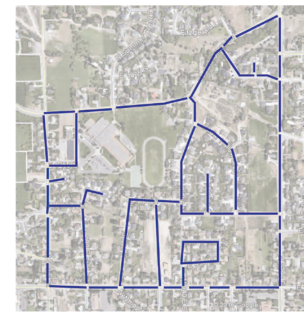
The connectivity index should be as high as possible.

Measuring the connectivity index is simple. Only a few points of information are needed, each of which is available using basic mapping tools.

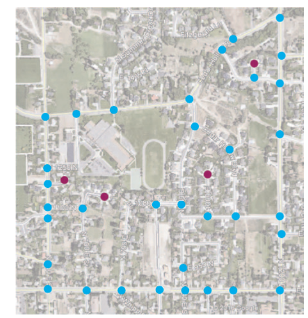
Area: The area is the area of your community you are evaluating. Whether using GIS or another mapping tool, draw or identify your area boundary and measure, in square miles, your area.



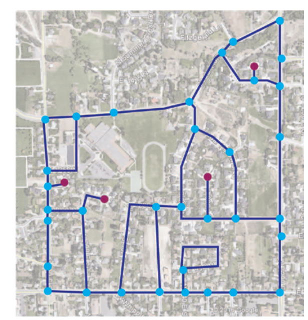
Links: Links are lengths of street between intersections or dead ends.



Nodes: Nodes are points where links meet. They come in two types, each of which you will have to identify and count: intersections and dead ends (cul-de- sacs count as dead ends).



Draw the area, the links and the two kinds of nodes on a map. To calculate the connectivity index, divide the number of links by the number of nodes (combined intersections and dead ends).



44 Links

34 Intersections + 4 Dead Ends

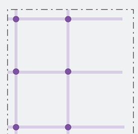
=

1.16 Connectivity Index

Intersections per square mile

Network density is measured by intersections per square mile, which is **the number of intersections per square mile within a given area**. As intersections are the basic unit of any street network, the network's density is measured by the density of the intersections. One of the benefits of the intersections per square mile metric is that it can be scaled to apply to a city-wide network or a regional network by limiting the level of street intersections being measured. For example, while a neighborhood network might take into account intersections of all streets, a regional network might take into account only intersections of arterial streets with other arterial streets, because these are those generally used by travelers making trips across the region.

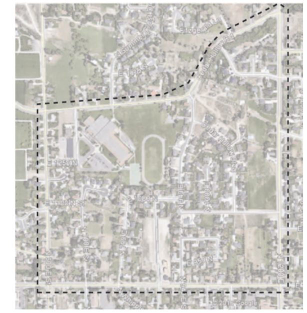
Intersections per square mile =
the number of intersections (•)
in a given area (⬚)
divided by
the square mileage of that given area



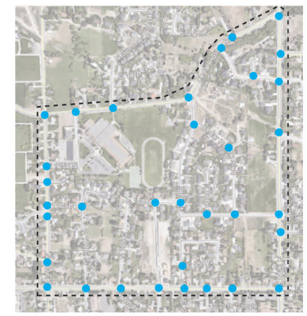
Intersections per square mile should be as high as possible.

Measuring the connectivity index is simple. Only a few points of information are needed, each of which is available using basic mapping tools.

Area: The area is the area of your community you are evaluating. Whether using GIS or another mapping tool, draw or identify your area boundary and measure, in square miles, your area.



Intersections: Intersections are points where links meet. They do not count dead ends, such as cul-de sacs.



Draw the area, the links and the two kinds of nodes on a map.

To calculate the intersections per square mile, divide the number of intersections (not including the dead ends) by the area, in square miles.

34 Intersections

.22 mile

=

155 intersections per square mile

How do these scores rate? Look in our standards for different types of neighborhoods in *Sections 3.1 and 3.3*.

2.1.2 Advanced Metrics

The Advanced Metrics provide understanding of additional dimensions of street connectivity – specifically, the ability of a network to connect to the most important destinations in a community and the ability of a network to accommodate pedestrians, its most vulnerable users.

Measuring the advanced metrics requires more work (and, in the case of the travel-sheds, mapping tools) but is relatively straightforward.

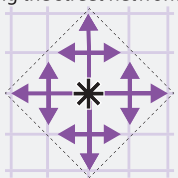
Travel-shed - accessibility rating

The ability to connect to community destinations is measured by generating a "travel-shed" for a specific destination or the average of a set of travel-sheds for a set of destinations. What is measured is the percentage of the travel-shed of a specific distance from the destination that can be accessed using the street network. The length of the radius being measured depends on the context. While, in a neighborhood-scale area, the radius is a half-mile, in a community-scale area the radius is two miles. The metric tells us how good of a job the street network is doing in accessing a particular destination.

We also recommend using travel-sheds as a metric for evaluating walkability at the scale of a city or region. Like with the evaluation of destination accessibility, the evaluator selects a set of destinations whose travel-sheds can be tested. But unlike the evaluation of destination accessibility, the network being evaluated is the pedestrian network. For how to define the pedestrian network, see the next Section 2.2.2 under Maximum Pedestrian Block Lengths.

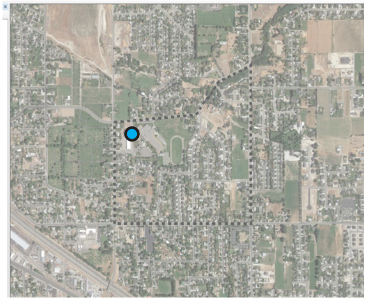
This technique is used for both the accessibility of key destinations metric for all scales and the pedestrian metric for the regional and community scales. The process for both is very similar.

Travel-shed =
the area reached ( )
within a given distance ( )
from a destination ( )
using the street network ( )



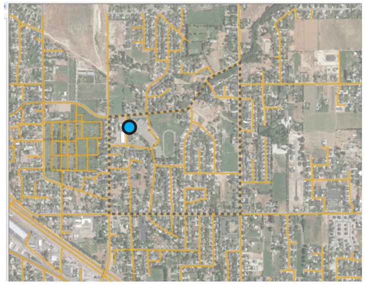
The travel-shed should be as large as possible.

First **select the destination** or destinations you will evaluate access to. We recommend choosing three destinations of significant importance for a neighborhood-scale area such as a school, grocery store, or church. You may want to choose destinations in different parts of your area in order to test accessibility to a range of locations. Represent each destination with a point feature in an ArcMap shapefile.



Study area and destination

Once the destinations are chosen and placed in a shapefile, using ArcMap or another GIS application, **generate your area's street network** using a street centerlines file or another shapefile that represents the network streets. Make sure the shapefile's network accurately represents the actual connections and barriers presented by the street network on the ground.



Street network

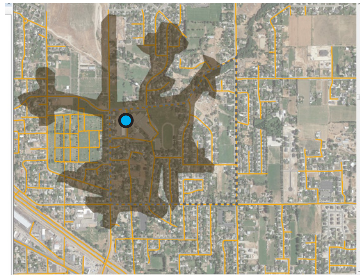
NOTE: For the destination accessibility metric, the network should represent connectivity for general purpose traffic, so include connections that allow general purpose traffic. For the pedestrian metric for the region and community scales, the network should represent the pedestrian network. To understand how to define the pedestrian network, see the next section, under Maximum Pedestrian Block Lengths.

Next, use the Network Analyst plug-in to **set up an analysis of how well the network serves each destination**. Network Analyst calls this a "service area" – for this metric we call it a "travel-shed." Each destination's travel-shed will have to be calculated separately.

The distance from the destination being analyzed differs depending on the specific metric and context. For the destination accessibility metric, use two miles for the community and region scales and a half mile for the neighborhood scale. For the pedestrian metric for the region and community scales, use a half mile.

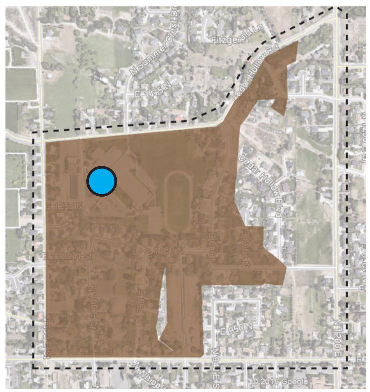
Run the service area analysis for each destination, which will generate a polygon of access.

Then, **determine the "ideal" travel-shed** within your study area. This area will represent the 100 percent access to the destination within the given distance, against which to measure your actual travel-shed. In some cases, the ideal travel-shed will be your entire study area, in others it will only be a part of it because a portion of the study area is beyond the ideal travel shed distance regardless of connectivity.



Network Analyst output: Service area / travel-shed

Finally, take the areas of both the actual Network Analyst travel-shed and the ideal travel-shed. Divide the actual travel-shed by the ideal travel-shed to **get the percentage of the surrounding area to which the destination is accessible** – the accessibility rating. If you are measuring the accessibility of a series of destinations within an area, generate the average accessibility rating.



Service area / travel-shed clipped to the study area

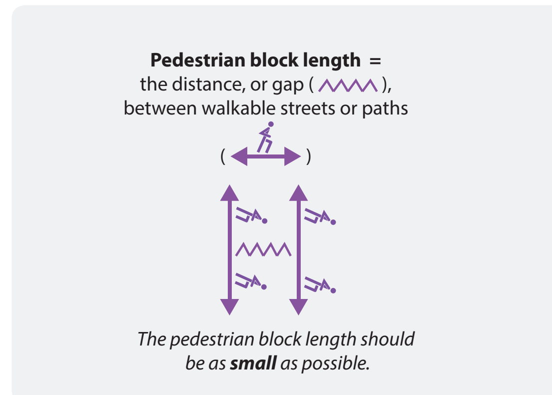
Note: It is also possible to generate this metric by hand, without ArcMap and Network Analyst. To do this, after you pick your destination, use a scaled map to measure all possible routes at the given distance (half mile for neighborhood-scale areas), then connect the endpoints of your routes to generate the shape of the accessible area.

$$\frac{.14 \text{ sq mi}}{.22 \text{ sq mi}} =$$

64% of study area is accessible to the destination

Pedestrian block length

The quality of the network for all users is evaluated through its support of pedestrians. This pedestrian support is evaluated by measuring the maximum "pedestrian block length" in an area. Pedestrian block length is the spacing between two parallel pedestrian routes. The larger a pedestrian block length, the more inconvenient and difficult a network is for pedestrians. Just a few very large "gaps" in spacing between pedestrian routes can render a neighborhood-scale network unusable for pedestrians, hence the measurement of the highest five pedestrian block lengths. The strength of this metric is not only understanding the value of these maximum block lengths but the type of gaps in the network – whether created by large properties or city blocks, infrastructure barriers like railroad tracks or freeways, or major streets without adequate pedestrian crossings.



Maximum pedestrian block lengths are used to evaluate the walkability aspect of connectivity in neighborhood-scale areas. This metric requires the evaluator to see the street network through the eyes of a pedestrian. First, review the street network for which streets do and do not reach a minimum standard of pedestrian support. This minimum level of pedestrian support is as follows:

On-Street Pedestrian Links: For links in the network, a sidewalk or other pedestrian facility must be present, or else the roadway must present enough of a traffic calmed environment that pedestrians are safe and comfortable walking in the roadway.

Intersections: At intersections where a pedestrian must cross a barrier street, an across-barrier connection must be provided. These barrier streets and across-barrier connections are defined as follows:

Barrier	Minimum across-barrier connection required
None: 25 mph or lower and two lanes or fewer	None required
Class I: Over 25 mph speed limit and/or three lanes or more	Marked crosswalk
Class II: Two of three are true: 35 mph or higher speed limit; five lanes or more; 20,000 average daily traffic (ADT)	Signalized crossing

Active transportation-only links: Find any trails or other paths that constitute links in the network that allow only walking, bicycling, and other active transportation modes.

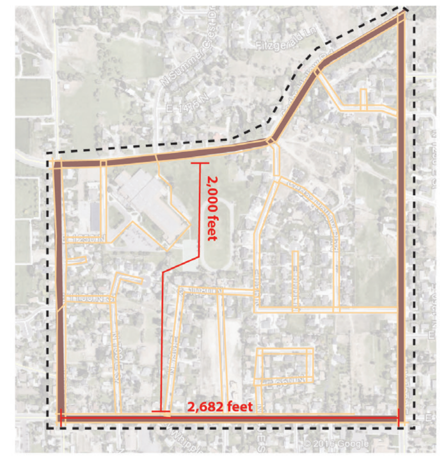
Then, draw this pedestrian network, shown in orange below:

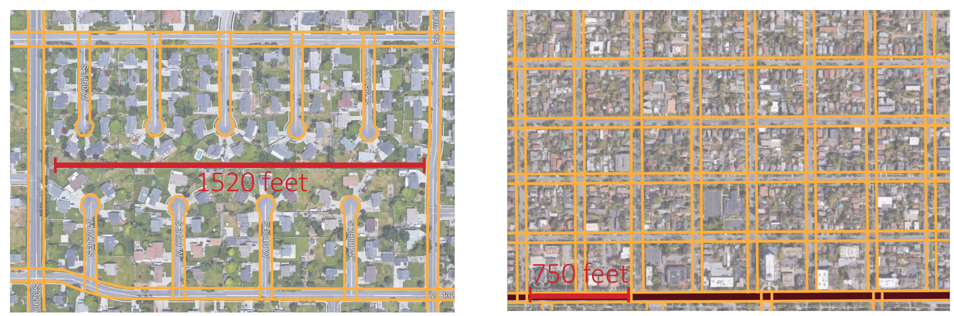
Pedestrian block length is the space between parallel-running pedestrian connections, whether these spaces are between links or between crossings of intersections.

Once you understand the key differences in the pedestrian network from the overall street network, **identify the places where the pedestrian links are farthest apart from one another.** These “gaps” could be the widths of large properties or city blocks, the lengths of infrastructure barriers like railroad tracks or freeways, or lengths of major streets without adequate pedestrian crossings. These are your maximum pedestrian block lengths. We recommend identifying the highest five pedestrian block lengths and taking the average.

The numbers which these metrics should reach depends on your type of community. These are explored in *Section 3.1: Contexts for street connectivity.*

The diagram on the right shows the measurement of two of the longest pedestrian blocks, or “gaps” between links in the pedestrian network.





These two examples show the different types of maximum pedestrian block lengths in different networks. In the example on the left, the longest gap in the spacing of pedestrian links is caused by the cul-de-sac streets, whose dead ends form one large “block” for pedestrians. In the example in the right, the longest gap is caused by a barrier street whose crossings are relatively far apart.

2.2 Strategies and best practices to improve connectivity

The end result of the use of this guide should be finding and implementing strategies to increase street connectivity in communities in ways that complement valued community characteristics.

This guide includes a wide range of different types of strategies to increase community character in order to provide practitioners with a choice of strategies that will best suit your specific community, as well as to provide the potential for synergy among different strategy types, for example long-range planning and development standards.

We have categorized the types of potential strategies to increase connectivity into four groups:

- **Plans and policies** are higher-level policies that create the foundation for good street connectivity.
- **Street and development standards** are concrete rules that implement the directives of the high-level policy.
- **Retrofit tools** are methods to improve the street connectivity of built-out areas.
- **Managing street connectivity** refers to tools that complement and maintain the functionality of connected streets and mitigate any negative side effects.

These tools are explained in more detail below.

See the guidance and case studies in Part 3 for ideas on how to apply these strategies.

2.2.1 Plans and policies

A jurisdiction's planning documents often create the foundations for good connectivity. While often not explicitly requiring types of street connections, plans can create the justification for street connectivity within a community's overall vision, and set forth the template for the large-scale connections that are important within a community.

EXPLICIT GENERAL PLAN POLICIES SUPPORTING STREET CONNECTIVITY

Including street connectivity in a community's general plan or other primary vision document creates the directive for connectivity in the foundation of policy.

POLICIES TO DESIGN FOR ALL USERS

Directing city staff to design places and networks with all users in mind inherently points these efforts toward better street connectivity. Addressing the needs of different modes leads to a finer network of connections.

EXAMPLE

Fort Collins, CO, requires that all local interconnected street networks be designed with all users in mind (automobile, transit, bicycle, and pedestrian).

POLICIES ENCOURAGING MULTIPLE AND DIRECT CONNECTIONS TO DESTINATIONS

Transportation master plans, area plans, and other planning documents can encourage and support the creation of multiple connections among destinations and neighborhoods. They can outline the street pattern and connectivity standards and emphasize that the local street system provides multiple direct connections between local destinations.

EXAMPLE

Portland, Oregon's right-of-way requirements and standards include pedestrian connectivity. The city's code requires direct routes for bicycles and pedestrians in residential areas and between neighborhood facilities. It also has specific standards and requirements for through streets and pedestrian connections which allow the most direct route.

CONNECTIONS TO OUTSIDE JURISDICTIONS

Planning documents, especially large-scale plans such as transportation master plans, can identify preferred connections among jurisdictions. These inter-jurisdictional connections can also be coordinated by larger agencies such as state departments of transportation and metropolitan planning organizations.

TYPES OF STREET NETWORKS

Planning documents can identify preferred patterns of streets that generally create good connectivity, such as grids of small blocks.

2.2.2 Street and development standards

Standards are the complementary piece to plans and policies – they are concrete rules that implement the directives of the high-level policy. In some cases, standards apply to public infrastructure such as streets designed and built by jurisdictions. In other cases, standards apply more to private developers who build streets and other connections as part of their projects.

MINIMUM CONNECTIVITY STANDARDS

Codes can require that developments achieve a minimum connectivity index (see metrics section), or reward developments that have a high connectivity index with various incentives.

MAXIMUM BLOCK LENGTHS / LOCAL INTERSECTION SPACING

Codes can also require maximum block lengths, which is essentially the spacing of local street intersections. Depending on context, best practices are generally average intersection spacing for local-streets of 300-400 feet, and maximum intersection spacing for local streets of about 600 feet.

EXAMPLE

Lehi, UT, has developed code language that requires new developments to meet a minimum connectivity index. Lehi also includes maximum block lengths in its code language; the exact maximum depends on the zone the street is located in (See pages 28-29).

MAXIMUM BLOCK SIZE

Another tool to create dense networks is to limit the size of whole blocks. Best practice is generally a block size that will maintain the desired intersection density while not creating large pedestrian block lengths.

CUL-DE-SAC MANAGEMENT

Eliminating, limiting, or otherwise managing cul-de-sacs is a direct way to increase street connectivity in new development. Development standards can:

- Prohibit cul-de-sacs.
- Limit cul-de-sacs to a certain percentage of total streets: for example, to 20 percent of streets.
- Limit the maximum length of cul-de-sacs: for example, to 200 feet.
- Provide specific exceptions: such as only when they can access land not otherwise accessible through a connected street pattern due to topography or other constraints.

EXAMPLE

The Pennsylvania Department of Transportation's guidelines for improving connectivity note that Cranberry Township in Pennsylvania does not recommend approval of cul-de-sacs, while Peters Township, PA, prohibits dead-end streets.

In residential neighborhoods, many of the benefits of cul-de-sacs can be created in a more connected environment using techniques such as loop streets whose connectivity is reinforced by active transportation paths and limiting cul-de-sacs to rare circumstances.

PEDESTRIAN CIRCULATION PLANS

Pedestrian circulation plans provide a concept of how pedestrians will move around and through a development.

MULTIPLE ACCESS TO DESTINATIONS

Jurisdictions can require developments to provide multiple routes to key destinations for most, if not, all places in the community.

EXAMPLE

The Kentucky Transportation Cabinet encourages proposed developments to provide multiple direct connections in its local street system to and between local destinations, such as parks, schools, and shopping.

TALKING ABOUT CONNECTIVITY

Much of the success of street connectivity improvements depends on broad community buy-in to the benefits of street connectivity. Whether talking to other city, county or agency staff, elected or appointed officials, or other stakeholders, here are a few ways to frame the discussion.

Start with community goals

Understand what goals are important to the larger community. Street connectivity has a wide range of positive effects and it is important to understand the fundamental things the community wants to achieve with its transportation policy and projects.

Describe the benefits

Discuss the specific benefits related to your community's goals, whether for mobility, the economy, the environment, safety, or others; see *Section 1.2*.

Emphasize the context

Point out that streets can be connected in ways that complement their surroundings, whether it be in a downtown, rural neighborhood or industrial area. Use our context-based guidance in *Section 3.3* to identify some of the considerations and ideas relevant to your community.

ACCESS TO ARTERIALS

In the same vein as providing multiple routes between a community and local destinations, city codes can require multiple access connections between a development and arterial streets.

NON-ARTERIAL ACCESS TO DESTINATIONS

Jurisdictions can require that new developments provide access from the community to destinations within it without the use of arterial streets, thereby preserving capacity on arterial streets for non-local traffic.

EXAMPLE

The Kentucky Transportation Cabinet encourages jurisdictions to require that a proposed development shall provide multiple direct connections in its local street system to and between local destinations without requiring the use of arterial streets.

MAXIMUM ARTERIAL OR COLLECTOR INTERSECTION SPACING

For large developments including several arterial streets, standards can create maximum amounts of space between arterial street intersections.

EXAMPLE

The Kentucky Transportation Cabinet recommends jurisdictions require a proposed development should provide a potentially signalized, full-movement intersection of a collector or a local street with Arterial Street at an interval of at least every 1,320 feet or one-quarter mile along arterial streets, and a proposed development should provide an additional non-signalized, potentially limited movement, intersection of a collector or local street with an arterial street at an interval not to exceed 660 feet between the full movement collector and the local street intersection.

MAXIMUM SPACING BETWEEN BIKE AND PEDESTRIAN CONNECTIONS

Standards can require a maximum spacing between pedestrian and bicycle connections through a development and across major barriers such as arterial streets. This closely parallels this guide's "pedestrian block length" metric.

LIMITS ON WIDTH OF STREETS

Limiting the width of new streets achieves connectivity (and mitigates its negative effects) in a number of ways, including facilitating pedestrian crossing, discouraging through traffic, reducing speeds, and helping to offset increased costs to developers of building more streets required to achieve better connectivity. Best practices limit local street pavement widths to 24-32 feet (varies with on-street parking restrictions).

RESTRICT PRIVATE AND GATED STREETS

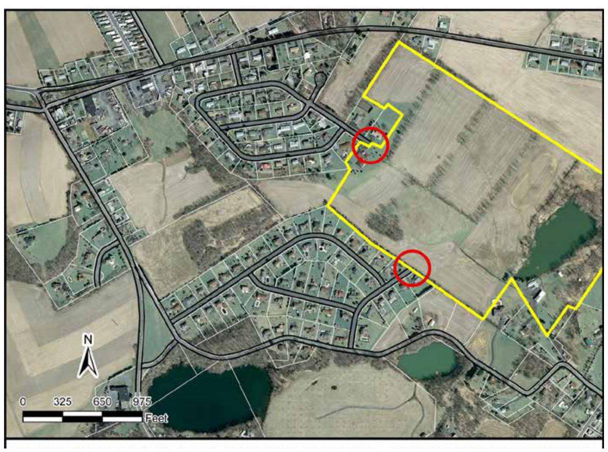
Jurisdictions can improve connectivity by limiting or discouraging gated communities and other restricted access roads.

STREET STUB REQUIREMENTS

Jurisdictions can require developments to create street "stubs," that is, streets that are initially dead ends but can be connected when adjacent parcels are developed in the future.

EXAMPLE

The Kentucky Transportation Cabinet's guidelines recommend that each development "shall incorporate and continue all collector or local streets stubbed to the boundary of the development plan by previously approved but unbuilt development or existing development."



An example of subdivision plans that left street stubs that will connect to the streets of a future development outlined in yellow.

LEHI'S STREET CONNECTIVITY STANDARDS

Lehi City recognized the importance of street connectivity and undertook 1.5-year process to create and adopt street connectivity standards.

In late 2014, staff began the process by researching connectivity metrics to determine the right fit for Lehi. Planning staff worked closely with Engineering to draft several versions of the ordinance until everyone agreed on a version that could be utilized during the subdivision approval process. Staff provided evidence to show the benefits of street connectivity and the Lehi City Council adopted the standards in April of 2016.

The adopted street connectivity ordinance utilizes a few primary metrics that resemble those used in the Utah Street Connectivity Study (USCS): a connectivity index (link-node ratio) and maximum block and cul-de-sac lengths. Minimum requirements for these metrics increase both connectivity and intersection density, the two basic aspects of street connectivity identified in the USCG. The adopted ordinance includes requirements and bonuses for pedestrian and trail connections between streets or at the end of cul-de-sacs. In practice, the connectivity standards have been effective in creating subdivisions that are more walkable, better disperse vehicular travel and increase accessibility for emergency response.

Section 37.050. Connectivity Standards
(New 04/26/16)

A. Purpose. These standards are intended to create a connected transportation system between neighborhoods and commercial areas within the City. The specific purposes of this Section include:

1. Promoting walkability through additional connections and shorter block lengths.

2. Improving emergency response time.

3. Increasing effectiveness of delivery access.

4. Providing better routes to schools and parks.

5. Reducing impacts of development on Master Planned arterial and collector roads by providing alternative routes.

6. Preventing isolated developments that increase dependency on automobiles.

B. Definitions.

1. Block Length – The distance along any given road frontage between two intersections with 3 or more connecting links (see Figure 25). Links that connect into a cul-de-sac shall not be considered the termination point of a block length.

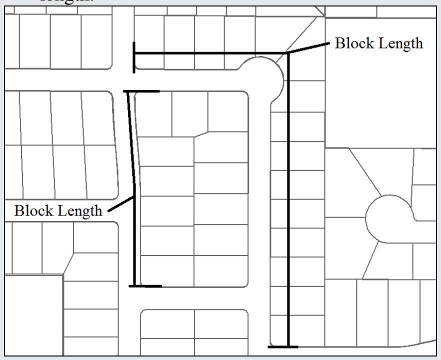


Figure 25. Example block length measurements.

2. Chicane – An extension of a curb typically on a local street to provide an element of traffic calming.

3. Connectivity Index – A ratio of roadway links and nodes that serves as a metric for measuring the level of connectivity.

4. Cul-de-sac Length – The distance from the street intersection to the throat of the cul-de-sac bulb (see Figure 26).

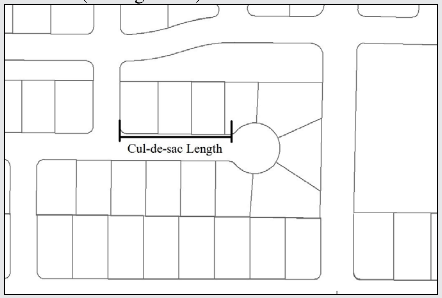


Figure 26. Example of cul-de-sac length measurement.

5. Curb Extension – An extension of a curb in a roadway to narrow the road at pedestrian crossings to provide additional safety for pedestrians and serves as a traffic calming measure.

6. Links – Streets that connect to nodes or external streets not included in the proposed development.

7. Node – Street intersection or cul-de-sac located within a proposed development. A street intersection exists where two or more named roads intersect.

C. Circulation Plan. A circulation plan shall be provided as part of a preliminary subdivision plat application.

1. The circulation plan must address street connectivity, pedestrian circulation, emergency access, and parking movements. In cases where cut-through traffic is likely, traffic calming measures such as curb extensions, chicanes, raised crossings, or other features may be required.

2. The circulation plan shall show the connectivity index, block length dimensions, cul-de-sac length dimensions, pedestrian facilities, and any proposed traffic calming features.

3. The circulation plan must take into account access and connectivity on adjacent parcels. On a case-by-case basis the Planning Director and City Engineer may require changes to stub road locations if it will increase the connectivity within an adjacent property.

4. A circulation plan will be required for proposed developments with more than one acre in project size or with more than ten (10) units. The Planning Director and City Engineer may waive the requirement for a circulation plan on a case-by-case basis.

D. Connectivity Index Calculation. The required connectivity index is calculated by dividing the total number of links by the total number of nodes (see Figure 27).

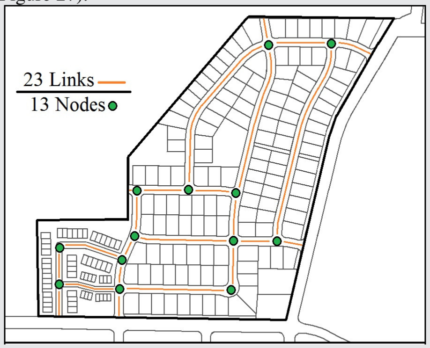


Figure 27. Example connectivity index calculation showing nodes and links. This example shows 23 links and 13 nodes which equates to a connectivity index of 1.77.

1. For the purposes of calculating the number of total links, one link beyond each node shall be included in the connectivity index calculation. Street stubs that provide future access to adjacent properties or streets that connect to existing streets are considered links.

2. An additional ½ link shall be included in the connectivity index calculation for each of the following:
   (a) Hard surface pedestrian connection through a cul-de-sac with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side (see Figure 28);
   (b) Hard surface master planned trail connection with a minimum width of (10) feet including an additional two (2) foot soft shoulder on each side (see Figure 29);
   (c) Internal hard surface trail segment connecting two roads with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side (see figure 30).

Figure 28. Cul-de-sac with a pedestrian connection to allow access to an adjacent open space.

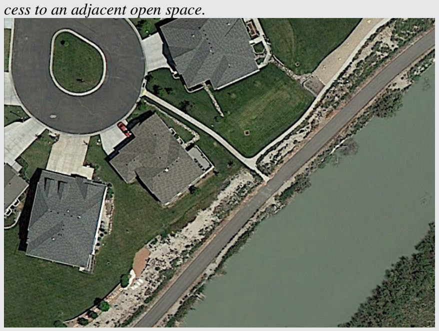


Figure 29. Pedestrian connection to a master planned trail.

Figure 30. Trails make pedestrian connections between multiple streets.

3. An additional ¼ link shall be included in the connectivity index calculation for each roadway segment where homes face an amenitized open space, park, or natural area (see Figure 31). The roadway segment shall have a minimum three hundred (300) feet of frontage along the said open space.

Figure 31. Park layout allows access from all sides with home fronts facing the park.

E. Residential Connectivity Standards. All new residential subdivisions with ten (10) or more units or more than one acre shall meet the following connectivity index, block length, and cul-de-sac length standards for public roads. Private roads shall be reviewed on a case-by-case basis: however, a public road may be required to prevent a private road in a subdivision from stubbing into a future or existing public road.

1. Required Connectivity Index. The minimum required connectivity index shall be required based on the project density as identified in the following table of minimum connectivity index scores:

Density	Minimum Index Score
0-2.5 DU/AC	1.5
2.6-4 DU/AC	1.6
4.1+ DU/AC	1.75

(a) Reduction in Required Connectivity Index. The required connectivity index may be reduced if the applicant provides clear and convincing evidence that it is impossible or impracticable to achieve due to the following limitations:

i. Topography;
ii. Natural features including lakes, rivers, designated wetlands;
iii. Existing adjacent development;
iv. Rail corridors;
v. Limited access roadways.

Reductions in the required connectivity index will be reviewed on a case-by-case basis and must require recommendations from the reviewing departments and Planning Commission and approval by the City Council.

The total allowed reduction to the required connectivity index will be based on an analysis of existing conditions that prevent connections. As part of the analysis, City staff will ensure the internal connectivity of the subdivision meets the required connectivity index and that connectivity is provided to adjacent properties where possible.

2. Maximum Block Lengths. Maximum block lengths allowed shall be required based on the project density as identified on the following table:

Density	Maximum Block Length
0-2.5 DU/AC	1,000 ft.
2.6-4 DU/AC	800 ft.
4.1+ DU/AC	600 ft.

(a) Increase in Block Length. The maximum allowed block length may be increased if the applicant provides clear and convincing evidence that it is impossible or impracticable to achieve due to the following limitations:

i. Topography;
ii. Natural features including lakes, rivers, designated wetlands;
iii. Existing adjacent development;
iv. Rail corridors;
v. Limited access roadways.

Increases in block length will be reviewed on a case-by-case basis and must require recommendations from the reviewing departments and Planning Commission and approval by the City Council.

3. Cul-de-sac Length Standards. Maximum cul-de-sac lengths allowed shall be required based on the project density as identified on the following table:

Density	Maximum Cul-de-sac Length
0-2.5 DU/AC	400 ft.
2.6+ DU/AC	250 .

(h) Cul-de-sacs shall not be allowed in the R-2, R-2.5 or R-3 zones unless the applicant provides clear and convincing evidence that a cul-de-sac is be necessary to develop the entire parcel due to the following limitations:

i. Topography;
ii. Natural features including lakes, rivers, designated wetlands;
iii. Existing adjacent development;
iv. Rail corridors;
v. Limited access roadways.

Requests for cul-de-sac within the R-2, R-2.5, and R-3 zones will be reviewed on a case-by-case basis and must require recommendations from the reviewing departments and Planning Commission and approval by the City Council.

F. External Street Connectivity Standards. In addition to the internal street connectivity standards, external connectivity shall be maintained.

1. Cul-de-sacs. In cases where cul-de-sacs have one (1) or two (2) rows of lots between the end of the cul-de-sac and an external road, a hard surface pedestrian connection with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side shall be utilized to connect to the external street (see Figure 32).

Figure 32. Sidewalk connection from cul-de-sac connects to an external collector road.

2. Pedestrian connections shall be utilized to connect proposed developments to master planned trails and adjacent existing or future developments where applicable. Connections shall be of a hard surface with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side.

2.2.3 Retrofit tools

Many Utah communities are built-out and lack good street connectivity. Yet, as with newly-built communities, improved street connectivity can help achieve many community goals in built-out communities as well. However, a different set of strategies is needed for this street connectivity retro-fitting.

PLANNING DOCUMENT GUIDANCE ON KEY CONNECTIONS

Planning documents, especially plans focusing on small areas or corridors, can identify key connections that will help make key destinations more accessible, improve walkability or bikeability, or distribute a neighborhood or district's traffic. If this connection is shown in an adopted planning document, it is easier for a community to require that it be made when a property is developed or if the community pursues it as a capital improvement.

COMPLETE STREETS

Making streets compatible with all modes improves connectivity in a few different ways. First, complete streets help ensure that street networks are complete for all users – not just vehicle traffic. Second, complete streets are also those that can be crossed by all modes, reducing barriers to the most vulnerable street users such as pedestrians.

The best ways to use complete streets to improve connectivity are to plan and build complete networks for all modes, and to identify key streets and corridors that are priorities for being complete streets. Both of these can be accomplished largely by retrofitting existing streets to serve all users.

PEDESTRIAN CROSSING IMPROVEMENTS

Similar to complete streets, pedestrian crossing improvements are a way to retrofit existing streets to improve the connectivity of the pedestrian network. Often, major streets pose the most challenging barriers for pedestrian connectivity in a community. In fact, a community may have small blocks and connected streets, but if a major street whose signalized pedestrian crossings are a quarter mile or half mile apart, the connectivity is poor for pedestrians.

An example of a high-visibility crosswalk in a neighborhood

There is a range of tools that can get pedestrians across a major street safely. Their use depends on pedestrian demand for the crossing, the traffic situation, and surrounding land use factors. These tools include full signals, mid-block half-signals activated by crossing pedestrians, hybrid beacon/stop signals, flashing beacons, grade-separated crossings, and high-visibility marked crosswalks.

CUL-DE-SAC CONNECTIONS – FULL STREET

Connecting the ends of cul-de-sacs to nearby streets or other cul-de-sacs is often the first strategy for retrofitting street connectivity that comes to mind. The elimination of a dead end and creation of a new intersection gets to the heart of our definition of street connectivity and likely helps people living on that street and in surrounding areas access destinations easier, especially on foot and on a bike. However, connecting cul-de-sacs is very difficult to do within most policy and community environments. Cul-de-sacs remain popular places to live, and connecting them, especially for a full street, usually involves property acquisition.

Situations exist where unbuilt lots at the end of cul-de-sacs exist; in those situations, connecting through can be slightly easier. However the best approach to cul-de-sacs is managing them and their effect on connectivity in the first place when a subdivision is planned, entitled, and built.

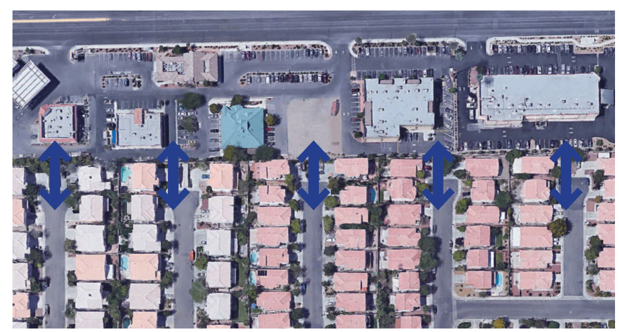
PEDESTRIAN PASS-THROUGHS TO ARTERIAL STREETS AND COMMERCIAL AREAS

A related type of connectivity retrofit strategy to the cul-de-sac connection is creating pedestrian pass-throughs from neighborhoods to commercial areas based on arterial corridors. Development patterns in many Utah communities have led to lack of access between residential street networks and adjacent arterial streets. In many cases, the potential exists to allow pedestrians to "pass through" the back of a commercial property to shorten the walk to a grocery store or other neighborhood store or business.

LARGE LAND USE PASS-THROUGHS AND ENTRIES

Many communities have large land uses that have limited entries. These land uses include shopping malls, office campuses, apartment complexes, and many others. These limited entries challenge the access to that land use but they also frustrate overall area connectivity. Allowing a connected network to run through these large land uses can improve overall neighborhood/district or even community-wide connectivity.

In the example on the right, residents of the neighborhood shown are very close to a commercial area, however due to the walled cul-de-sacs, they must travel a circuitous route to access these amenities. Simple connections through the dead ends can improve access to the commercial area.



CUL-DE-SAC CONNECTIONS – BIKE & PEDESTRIAN

Pedestrian and bike connections through existing cul-de-sacs present a more feasible alternative to full street connections. These active transportation connections require less width and do not present the traffic concerns that full street connections do. In addition, the Utah Street Connectivity Guide community survey found that 7 out of 10 respondents was generally comfortable with making active transportation connections through existing cul-de-sacs.

Making these connections benefits from planning ahead through the Planning Document Guidance on Key Connections described above. While less difficult than full street connections, even bike/pedestrian connections require significant effort and funds; targeting these efforts to connections that will gain the most connectivity improvements is important.

Sometimes streets dead end because of topographical barriers; pedestrian and bike paths can overcome these obstacles to connect communities.

Examples of pedestrian and bike connections through property barriers at the ends of cul-de-sacs or through a large block.

TRANSIT STOP AND DESTINATION TRAVEL-SHEDS

When the desire exists to improve connection to a specific destination such as a transit stop/station or other community or regional amenity, one way to prioritize potential improvements is to analyze the "travel-shed" of this destination – similar to the advanced metrics of this guide. Doing this analysis and exploring which connections create the biggest improvements in the size of the travel shed is one effective way to package a set of improvements.

LEVERAGE EASEMENTS FOR ACTIVE TRANSPORTATION

Easements exist throughout Utah communities – for canals, utilities, natural systems, Homeowners Associations, and many other uses. These easements are often sensitive and off-limits for other uses but there is sometimes the potential to run an active transportation trail.

The Murdock Canal trail uses a canal route to provide a valuable connection for walkers, cyclists, and other active transportation users.

2.2.4 Managing street connectivity

An additional set of strategies help maintain and implement the benefits of street connectivity and mitigate its drawbacks.

TRAFFIC CALMING MEASURES

Traffic calming measures (TCM) are means to force speed reduction in residential and dense downtown areas. As mentioned, enhanced connectivity increases the accessibility and path alternatives for each trip. Many of these paths may be located in residential areas. If not managed, multiple path alternatives could lead to increased congestion and decreased safety in these locations. TCMs can help prevent this situation, thus they are an important part of street connectivity.

Examples of traffic calming techniques in neighborhoods (from left): an exit-only street connection between a neighborhood and a major street; bulb-outs (which also create a shorter pedestrian crossing); and a traffic circle.

COMPLETE STREETS

Complete streets policies can support connectivity by ensuring that the links in the network cater to all types of users. See Retrofit Strategies section for more information of complete streets policies.

MARKET STRATEGIES FOR IMPLEMENTING CONNECTIVITY

A key strategy for implementing connectivity is to ensure that incentives and rewards accrue to the level of government or the private developer making the initial investment. These tools include private market incentives such as higher rents and property values through higher densities and public tools such as value capture, tax increment support, and special assessment districts.

TRANSIT-FRIENDLY DESIGN

Enhanced connectivity by itself may not be able to provide the desired impact on mode choice, and consequently on health, environment, and active transportation. Several other improvements must be made simultaneously to reach the expected results. One of these measures is transit-friendly design (TFD). TFD is a set of design guidelines that ease the integration of transit facilities into residential and non-residential areas. TFD improves the attractiveness of transit modes by increasing its utility. Consequently, TFDs improve overall transportation performance, improve air quality, and help provide the other benefits associated with street connectivity.

As mentioned above, TFDs increase the utility of transit modes. TFD guidelines focus on the following eight principles, adapted from the Calgary Transit Division, Transportation Department of the City of Calgary 2006:

- Provide appropriate community densities
- Minimize walking distance (Figure 3)
- Provide a mix of land uses
- Organize density, land use, and buildings to benefit from transit
- Create a pedestrian-friendly environment
- Route transit into the community
- Reduce transit travel time
- Build quality, user-friendly transit facilities

Examples of transit-supportive street treatments (clockwise from upper left): Bus-only lane; a red "queue bypass" lane to bypass intersection traffic; and island boarding for buses.

PART 3

Design Guide and Case Studies

Connectivity is not a one-size fits-all mandate. This guide has intentionally developed different ways to improve connectivity in a range of the contexts found in Utah's communities – both urban and rural, built-out and developing, and at the scale of the region, community and neighborhood.

This part of the guide explores these different contexts. It does this by 1) providing a design guide for street connectivity in different types of communities and 2) undertaking case studies for each context type. The design guide and case studies bring together the ideas from Part 1 and the tools from Part 2 to demonstrate how street connectivity can be evaluated and improved in different types of Utah communities- and how we can estimate the benefits our communities will receive as a result.

3.1 Contexts for street connectivity

Streets inhabit and serve different types of communities. These differences – whether in land uses, population density, levels of activity, demographics, the effect of natural systems, and other factors – create circumstances where the specifics of how a street network should interact with its surroundings are different.

This is the reason why this guide offers context-specific guidance for street connectivity – street connectivity cannot be a one-size-fits-all directive. We define these contexts both by scale – whether a region, city, or neighborhood. We also define them by land use type – whether residential, non-residential, mixed use, as well as how intense the use is. These differences have produced three levels of connectivity types, each with one to six sub-types addressing land use characteristics.

These contexts are for the help of the user – it is up to you, the user of the guide, to choose which context applies to your community.

It is important to note that good overall street connectivity depends on strong street connectivity for **all** scales. Regional, community and neighborhood/district street connectivity all reinforce one another.

3.1.1 Regional-scale connectivity

Regional-scale connectivity is street connectivity for travelers making trips across the region. Trips across the region are usually those over city borders. The most typical kind of regional trip is the work commute, but these trips are also made for social visits, recreation, and shopping.

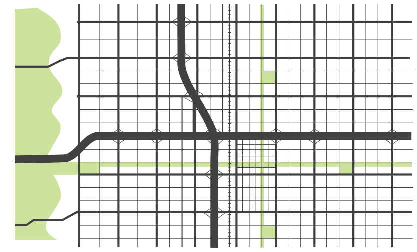
Areas in which to analyze regional-scale connectivity are groups of different cities or communities that contain regional-level trips. An example of this kind of area could be the entire Wasatch Front, but could also be a sub-area such as Salt Lake County, or the area covered by one of the Metropolitan Planning Organizations (MPOs) such as the Dixie MPO.

Regional-scale connectivity considers only those streets typically used by regional travelers – for this guide, these are defined as arterial and above level streets and roadways.

3.1.2 Community-scale connectivity

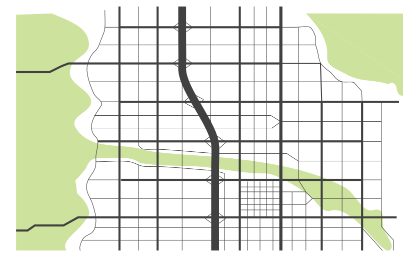
Community-scale connectivity is street connectivity within the borders of a local jurisdiction, most commonly a city. This guide defines three types of communities:

Urban: An urban community is a city or other local jurisdiction with:



- Higher overall density
- A high degree of intersecting regional transportation facilities and regional destinations
- A high degree of land use mix

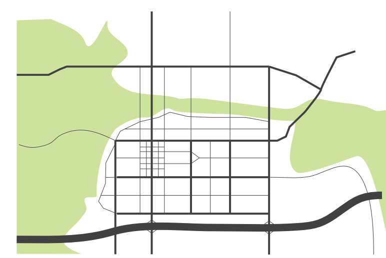
Suburban: A suburban community is a city or other local jurisdiction with:



- Medium overall density
- Fewer regional transportation facilities and regional destinations
- Lower degree of land use mix

Rural: A rural community is a city or other local jurisdiction with:

- Low density
- Relatively isolated from other communities
- High degree of agricultural, mountain land, or other natural open space within the community



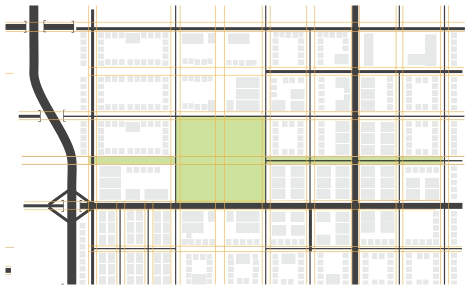
Community-scale connectivity considers only those streets typically used by citywide travelers – for this guide, these are defined as collector-and-above-level streets and roadways.

3.1.3 Neighborhood and district connectivity

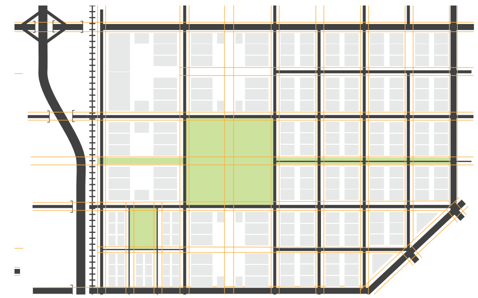
Neighborhood and district-scale connectivity is street connectivity within a neighborhood or district of common community character. These areas can range in size – as small as a single subdivision to as large as a several square mile subsection of a city.

This guide defines six types of neighborhoods/districts:

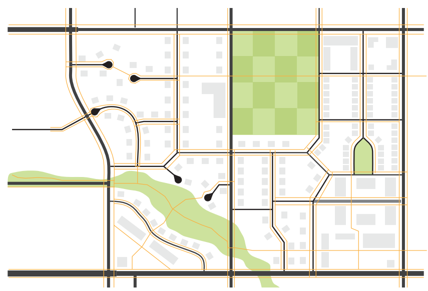
Urban residential neighborhood: An urban residential neighborhood is a higher-density residential area with a mix of civic, commercial, and office uses.



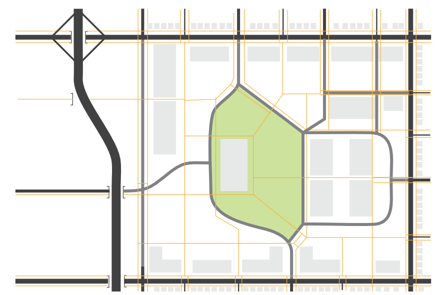
Downtown district: A mixed-use center of activity that attracts people from throughout the community and sometimes the region.



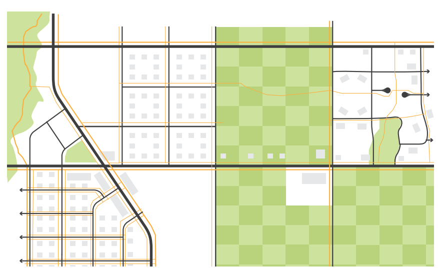
Suburban residential neighborhood: A lower-density residential area with other types of uses typically found on nearby arterial or collector corridors.



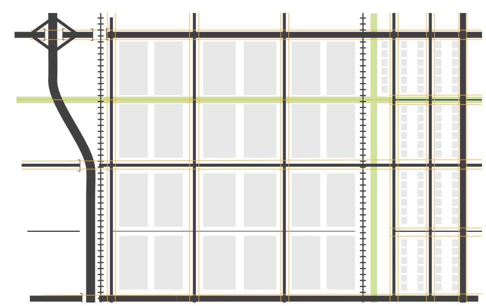
Campus district: A large land use such as an educational campus, shopping center, business park, or entertainment/lifestyle center.



Rural residential neighborhood: A very low density residential area with agricultural or natural space and few other uses present.



Industrial district: An area focused on production or distribution activities.



Neighborhood and district-scale connectivity considers all streets.

3.1.4 Metrics and street connectivity contexts

The street connectivity metrics described in the *Measuring Street Connectivity* Section 2.1 apply to all of the street connectivity contexts, but they are measured differently depending on the scale, and the specific context type determines the standard for each metric. For example, an urban neighborhood has much higher standards for the connectivity index and intersection density than a rural neighborhood.

The following tables provide a summary of how each metric applies to each street connectivity context type.

	REGION-SCALE METRICS	COMMUNITY-SCALE METRICS	NEIGHBORHOOD-SCALE METRICS
Basic connectivity metrics			
the relative level of connection	Connectivity index of arterial-level streets	Connectivity index of collectors and above-level streets	Connectivity index of all streets
network density	Arterial intersections per square mile	Collector or above intersections per square mile	Intersections per square mile of all streets
Advanced connectivity metrics			
ability to connect to destinations	Average travel-shed percentage for key destinations	Percentage of community travel-shed for key destinations	Percentage of neighborhood/district travel-shed for key destinations
quality of network for all users (walkability)	Percentage of potential half-mile walk shed from set of community destinations	Percentage of potential half-mile walk shed from set of community destinations	Average of highest 5 pedestrian blocks (spacing between pedestrian links)

	CONTEXT-BASED STANDARDS for CONNECTIVITY METRICS			
TYPOLOGY	*Relative level of connection*	*Network density*	*Ability to connect to destinations*	*Quality for all users (walkability)*
Regional typology	Connectivity index of arterial and above-level streets	Arterial or above intersections per square mile	Average travel-shed percentage for key destinations	Accessibility index for walking half mile from set of community destinations
Region	2	1	100 percent	100 percent
Community typologies	Connectivity index of collector and above-level streets	Collector or above intersections per square mile	Average travel-shed percentage for key destinations	Accessibility index for walking half mile from set of community destinations
Urban community	2	7	100 percent	100 percent
Suburban community	1.8	5	100 percent	100 percent
Rural community	1.6	3	100 percent	100 percent
Neighborhood / district typologies	Connectivity index of all streets	intersections per mile	Average travel-shed percentage for key destinations	Average of highest 5 pedestrian blocks (spacing between pedestrian links)
Residential neighborhood urban	1.7	225	100 percent	Maximum 500 feet
Residential neighborhood suburban	1.5	175	100 percent	Maximum 1000 feet
Residential neighborhood rural	1.5	50	100 percent	Maximum 1500 feet
Downtown district	1.7	225	100 percent	Maximum 350 feet
Campus district	1.5	50	100 percent	Maximum 500 feet
Industrial district	1.5	50	100 percent	Maximum 1500 feet

** Connectivity index for neighborhoods and districts should incorporate surrounding collector/arterial streets along the area boundary, if applicable.*

3.2 Introduction to case studies

Building on the context-based approach to this document, and to provide some Utah-based application of the tools presented and exploration of benefits, the project team undertook a series of case studies.

The case studies were based in three northern Utah communities: Lehi. Layton, and Tooele County. Representatives of each community were members of the project Working Group and provided input to this study along the process.

3.2.1 Area selection

The project team worked with each community to select areas to focus the case study analyses. Following the context types set out in the previous section, these areas include both the entire community and a series of sub-areas.

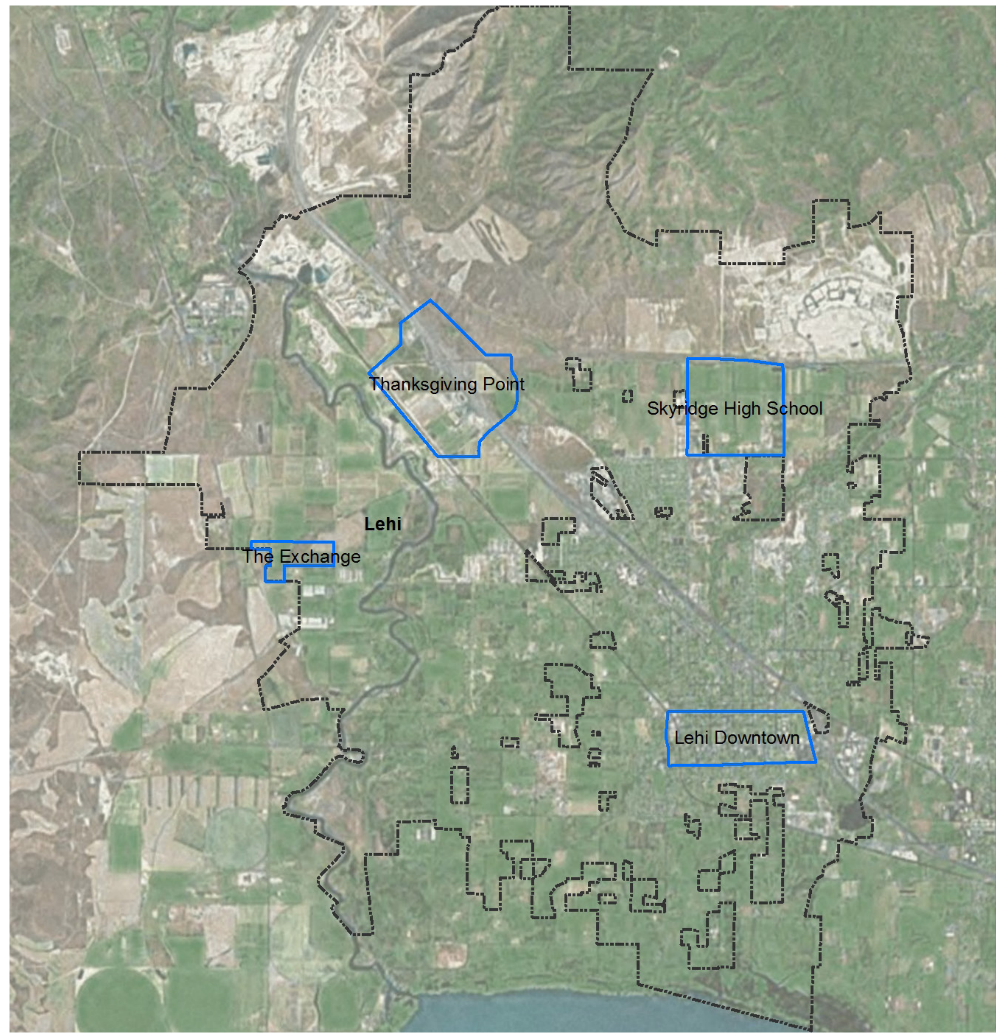
Selection of the case study neighborhood/district scale areas was based on a few factors:

- Locations where local jurisdiction staff have identified street connectivity issues or opportunities;
- Covering each of the context types set out in the previous sections in order to explore connectivity issues and solutions in the full range of Utah communities; and
- Covering the overall range of street connectivity issues and strategies.

Based on these factors, the team and the communities selected the following areas (with the context type in parentheses):

LEHI

- Full Lehi City (Urban Community)
- Downtown Lehi (Downtown District)
- Thanksgiving Point (Campus District)
- Skyridge High School (Suburban Neighborhood)
- The Exchange- development planned but not yet built (Suburban Neighborhood)

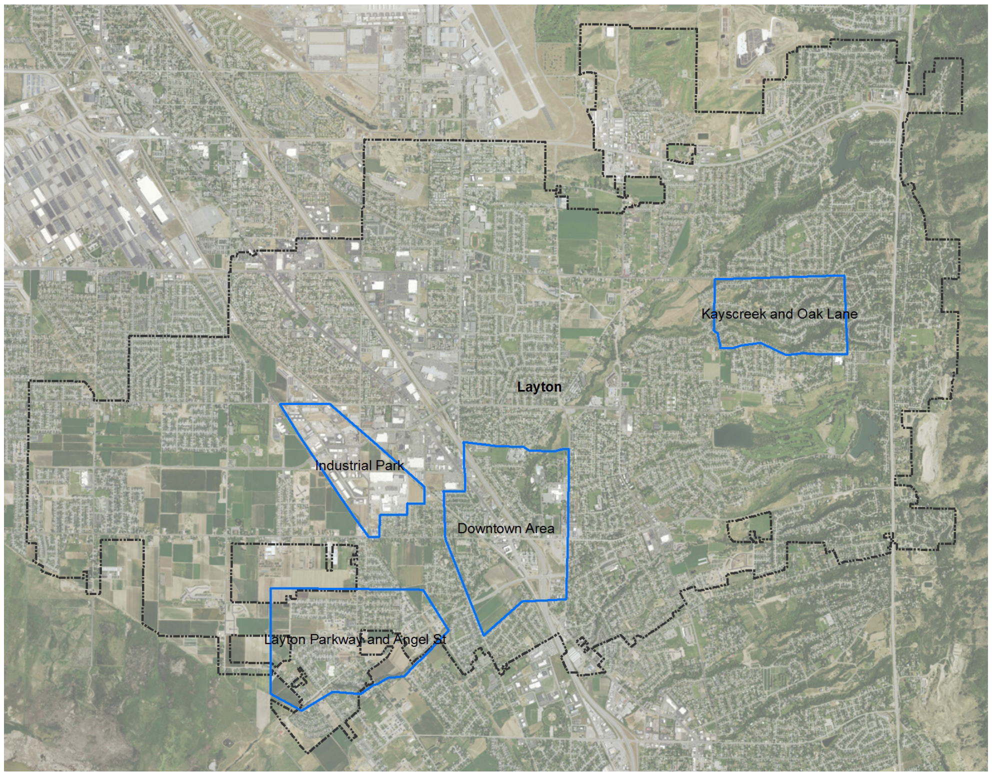


LAYTON

- Full Layton City (Suburban Community)
- Downtown Layton (Urban Neighborhood)
- Layton Parkway and Angel Street (Suburban Neighborhood)
- Kays Creek and Oak Lane (Suburban Neighborhood)
- Layton Industrial Area (Industrial District)

TOOELE COUNTY

- The central area of Tooele Valley including Erda, Stansbury Park, and Lake Point (Rural Community)
- West Erda (Rural Neighborhood)



3.2.2 Evaluation

The project team evaluated the existing street connectivity of each of the 12 case study areas according to the four Utah Street Connectivity Guide metrics described in *Section 2.1*. The street network was drawn on a map in terms of links, intersections, and dead ends. Each area was given a raw score for each metric as well as how it compares to the Utah Street Connectivity Guide standard for the context type.

3.2.3 Proposed connectivity improvements

Based on the evaluation, the project team determined the best opportunities for improving the street connectivity in each case study area. Generally, the team looked to improve the metrics for which the area scored most poorly. The team sought to apply a balanced set of the strategies described in *Section 2.2* – Plans and Policies, Street and Development Standards, Retrofit Strategies, and Managing Connectivity strategies. The team revised the case study area maps to reflect the strategies selected, and then re-measured each metric.

3.2.4 Benefits modeling

Once the proposed connectivity improvements and their impact on the connectivity metrics were established, the project team evaluated the potential benefits of these increases in connectivity. We used modeling techniques to investigate and quantify specific community benefits that the team believed would result from changes to the street network to increase connectivity.

Benefits in this guide are defined as changes resulting from increased street connectivity that achieve community goals. At the onset of the study, the project team worked together with the project's Working Group to identify community benefits potentially affected by increased street connectivity.

The Working Group came up with the following community goals:

- Regional and community mobility
- Transportation choice
- Accessibility to destinations
- Safety and health
- Effective infrastructure
- Community livability
- Economic vitality
- Environmental stewardship
- Interlocal and regional compatibility
- Overcoming geographic barriers
- Growth management

The project team identified benefits closely associated with these goals. For example, under the goal "regional and community mobility," the team found benefits such as arterial traffic reduction, vehicle miles traveled (VMT) reduction, and trip length reduction. Many of these can be quantified: not only in terms of traffic but also dollars or time saved, amounts of healthy behavior, number of people able to access a destination, or the values of property.

The benefit modeling seeks to quantify these benefits based on changes to the street network and the resulting street connectivity. Largely because of data needs, the benefit modeling was focused on the community-wide areas of each of the three case study areas (rather than the neighborhood/district areas).

The types of modeling undertaken are summarized below.

TRAFFIC MODELING

Vehicular traffic benefits were measured on several levels using different types of traffic models. The models captured changes in traffic volumes, vehicle-miles traveled (VMTs) and overall speeds.

The traffic modeling output measures of the following benefits:

- Traffic volume changes
- Vehicle miles traveled
- Travel times

ACTIVE TRANSPORTATION MODELING

The team undertook active transportation modeling to quantify the health-, environmental-, and transportation-related benefits associated with the estimated number of motor vehicle trips replaced by active transportation trips (bicycling and walking) through a series of economic multipliers that derived from the National Household Travel Survey (2009), local household travel surveys, and peer-reviewed journal articles. In order to estimate the number of motor vehicle trips replaced by active transportation, the team used data from walking- and bike-friendly peer cities with similar characteristics and connectivity as the case study communities.

The active transportation modeling output measures of the following benefits:

- Travel Behavior
    - Estimated annual bicycle and pedestrian trips
    - Estimated annual motor vehicle trips reduced
    - Estimated annual vehicle miles traveled reduced
- Environmental Benefits
    - Estimated annual metric tons of particulate matter (PM2.5 and PM10) reduced
    - Estimated annual metric tons of nitrous oxides (NOx) reduced
    - Estimated annual metric tons of sulfur oxides (SOx) reduced
    - Estimated annual metric tons of volatile organic compounds (VOC) reduced
    - Estimated annual metric tons of carbon dioxide (CO_2) reduced
    - Estimated annual environmental benefits from reduced greenhouse gases and criteria pollutants ($USD)
- Health Benefits
    - Estimated average annual newly active persons (number of persons meeting the CDC's minimum level of physical activity per week from active transportation)
    - Estimated annual healthcare cost savings ($USD)

ECONOMIC MODELING

The team also estimated economic benefits of improved connectivity, specifically changes in taxable sales resulting from increased connectivity. Depending on the type of connection made, along with the type of uses that connection is bringing together, the team assigned an increased value ratio from the literature.

A more detailed summary of the benefits modeling methods and results are in the Appendix.

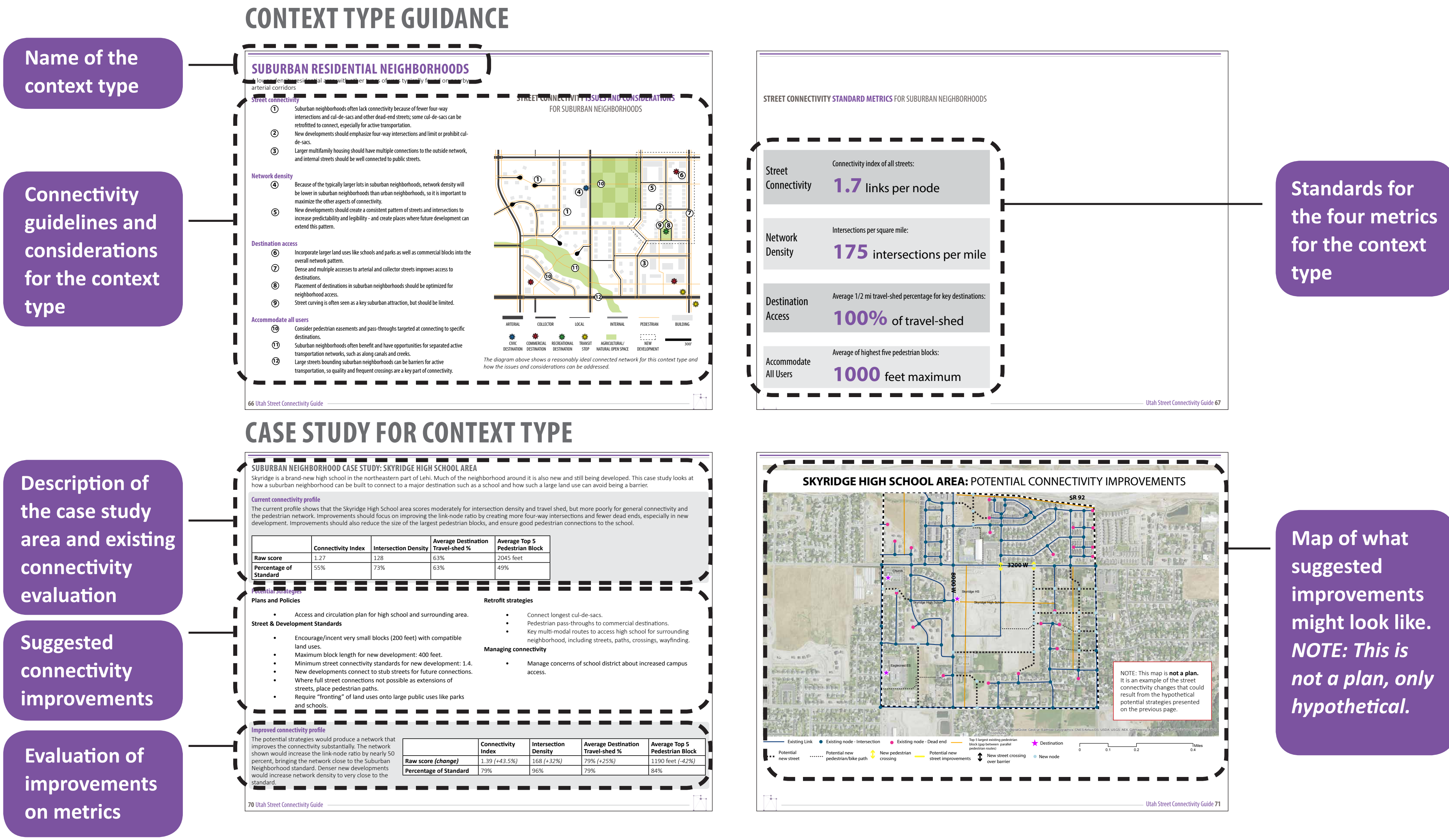
3.2.5 Results

The results of the case studies, both the potential connectivity improvements and the modeling for each community, are summarized in the following *Section 3.3: Street Connectivity Design Guide and Case Study Results.*

3.3 Street Connectivity Design Guide and Case Study Results

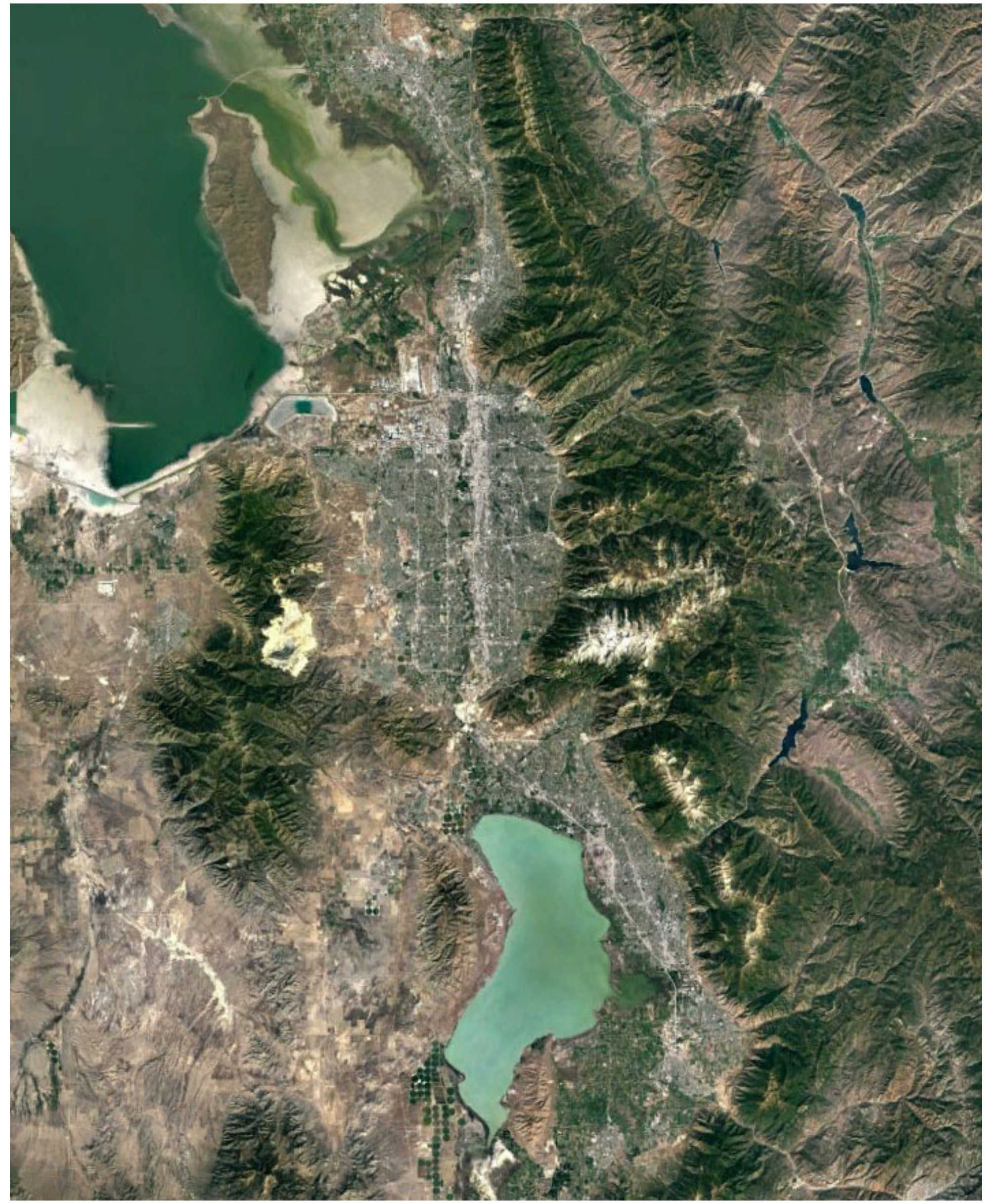
This section illustrates how you, the user, can put together the information in this guide to improve street connectivity in your community. The guidance in this section is based on the different community contexts. Each context type contains a section that provides a set of considerations that may apply in your type of environment and the set of standards for each of the four metrics to measure street connectivity.

Meanwhile, each case study results page contains an explanation of the area; the evaluation of the area's connectivity according to the Utah Street Connectivity Guide metrics in Section 2.1; suggested potential strategies according to the four types of strategies identified in Section 2.2; a map showing how the suggested strategies might look; and a re-evaluation of the metrics with the strategies incorporated. For the three community-scale case studies a summary of the benefits modeling is included. An example is below:



REGIONAL-SCALE STREET CONNECTIVITY

While this guide does not explore regional-level connectivity as much as community- and neighborhood-level connectivity (in the following pages), here are some considerations for planning for street connectivity at the regional level:



Street connectivity:

- Regional street networks are almost always connected – there are very few dead-end arterials or freeways. However, it is helpful when arterials form four-way intersections.
- One very important aspect of regional aspect of regional networks is their ability for modes to complement one another – specifically roadways, passenger rail, and freight. This includes planning how each will serve the same destinations, if needed, and complement one another in a set of corridors.
- Regional networks must contend with large scale geographic features such as mountains and bodies of water. At this scale, network connectivity should often be subordinate to the health of natural systems such as habitat and watersheds.

Network density

- Network density is critical for regional networks. When regional networks are not dense enough, the streets carrying regional traffic through an area becomes a major barrier for the community and a bottleneck for mobility along it.

Destination Access

- Regional networks become denser and more complex the closer they get to key destinations – such as employment, education or entertainment hubs. The closer to these hubs regional networks get, the more important it is to accommodate all modes of transportation.

Accommodate all users

- One of the aspects of a regional network is its ability to scale down to a community, neighborhood or district
- Regional networks must balance moving people long distances with not becoming barriers to connectivity at the community and neighborhood/district scales.

Community-scale connectivity

URBAN COMMUNITIES

An urban community is a city or other local jurisdiction with higher overall density, a high degree of intersecting regional transportation facilities and regional destinations, and a high degree of land use mix.

Street connectivity

1. Community-scale networks (collectors and above) in urban communities in Utah often reflect historic grid patterns put in place before the automobile.
2. Community-scale networks in urban communities are generally more connected than suburban or rural communities. Urban communities in Utah typically have a grid of collector and arterial level streets with four-way intersections.
3. Regional transportation facilities like freeways, other highways, or railways can be a barrier to community scale connectivity in urban communities - efforts should be focused to overcome these, especially for pedestrians and bicyclists.
4. Urban communities, as the homes of regional destinations, often must move high amounts of traffic, creating the need for large streets that can challenge community connectivity.

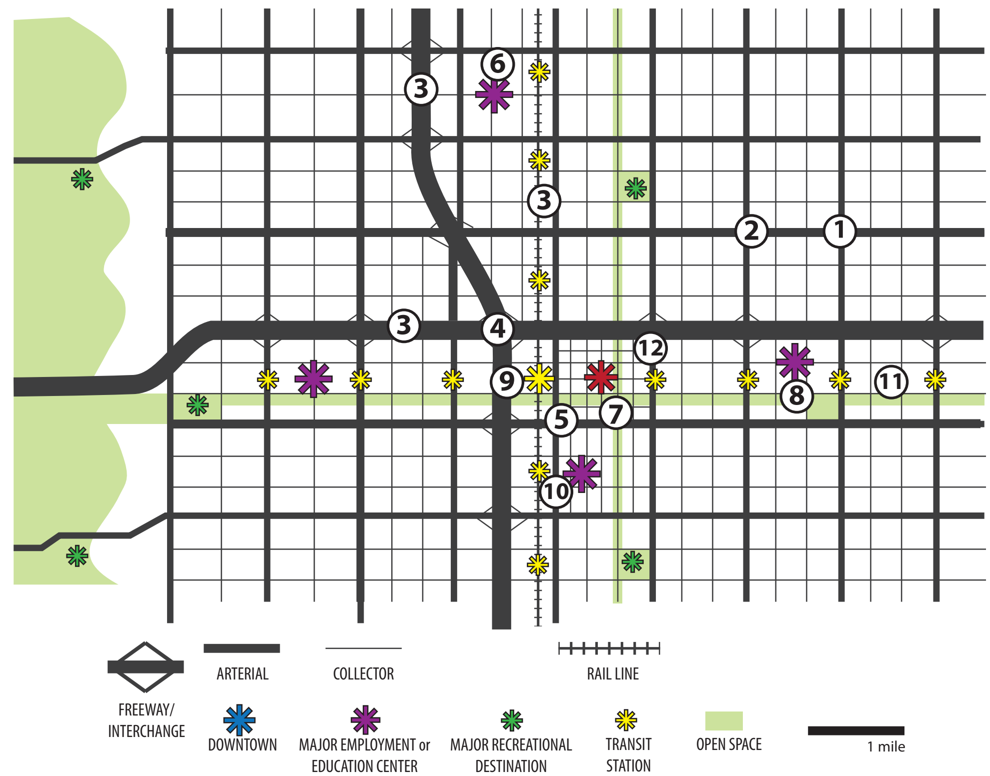
Network density

5. Urban communities generally have a higher degree of mix of land uses, and consequently have less hierarchy in their street networks than suburban or rural communities, so that more streets are classified as collector-level and above. This means more community-scale network density.
6. Some areas of urban communities – such as those around campus districts like secondary education institutions, hospitals, and shopping centers – can reduce overall network density.

Destination access

7. Urban communities generally possess more regionally-attractive destinations than other types of communities – such as downtowns, educational campuses, shopping areas, sports and entertainment, and cultural attractions.
8. The highly connected networks in urban communities generally lead to good destination access for the community.
9. Transit stops and stations are important urban community destinations.
10. It is important to pair regional destinations and regional transportation facilities to maximize connection to these destinations.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS
FOR URBAN COMMUNITIES



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

Accommodate all users

11. Urban communities are in a good position to create complete streets for all modes.
12. The high network density of community-level streets provides opportunities for emphasizing different modes on parallel streets. For example, while one street may emphasize moving traffic, another nearby parallel route may be a slower street for bikes – but they are part of the same general "corridor."

STREET CONNECTIVITY STANDARD METRICS FOR URBAN COMMUNITIES

Street Connectivity	Connectivity index of all streets: **2.0** links per node
Network Density	Intersections per square mile: **7** intersections per square mile
Destination Access	Average 2-mile travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Percentage of 1/2 mile walk-shed from key destinations: **100%** of walk-shed

URBAN COMMUNITY CASE STUDY: LEHI

Lehi is a fast-growing city in Utah County with several developing centers of activity- especially the Thanksgiving Point area. Lehi would currently likely be a Suburban Community, but Lehi's potential growth, its activity hubs, and location could put it in the Urban Community category. The Wasatch Front's central transportation corridor, including I-15 and rail lines, splits the city. The east-west corridor of S.R. 92 is a growing transportation corridor.

Current connectivity profile

For the Lehi community, the basic metrics were evaluated, as well as one of the advanced measures (travel-sheds). For Suburban Community standards, Lehi would score very well, however, against an Urban Community standard, it has some room for improvement, especially with regard to overcoming major barriers like I-15 and connecting its evolving activity centers together.

	Connectivity Index	Intersection Density
Raw score	1.70	4.88
Percentage of Standard	70%	70%

Potential Strategies

Plans and Policies

- Explicit general plan policies supporting street connectivity.
- Policies to design for all users.
- Policies encouraging redundant and direct connections to destinations.
- Connections to outside jurisdictions.
- Key connections plan for city.
- Plan for greater SR-92 corridor that emphasizes connections between Thanksgiving Point and points east to allow movement across SR-92.
- Preferred network types for undeveloped areas: In the west, balance the buildout of the grid with the preservation of Jordan River. In the north, balance the grid connectivity with topography constraints.

Street & Development Standards

- Maximum major street spacing (arterials, collector or similar) – 2,000 feet.

Retrofit strategies

- Connect all dead-end streets in community-wide network (collectors and above).
- Increased connections among the activity centers in and along Downtown, 2100 North, and Thanksgiving Point.
- Create additional pedestrian crossings on SR-92.

Managing connectivity

- Traffic Calming Measures.
- Transit-Friendly Design – use network to increase transit speed and accessibility.
- Complete Streets policy – ensure networks for all modes.

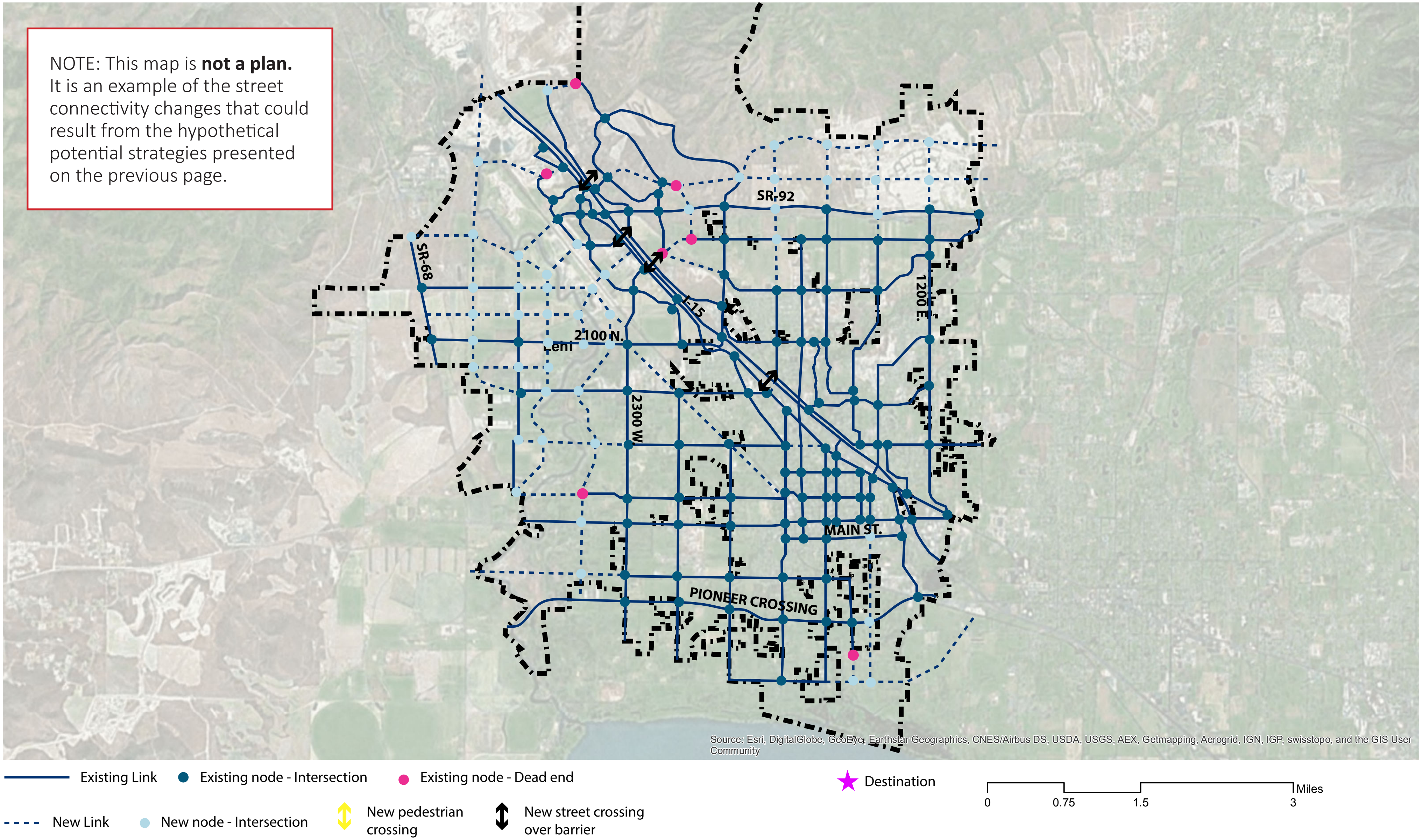
Improved connectivity profile

The potential strategies could produce a network that improves the connectivity substantially. The network shown would improve both the overall connectivity and the network density of Lehi by 30 and 42 percent respectively, nearly bringing Lehi to the Urban Community standards.

	Connectivity Index	Intersection Density
Raw score *(change)*	1.89 *(+30%)*	6.94 *(+42%)*
Percentage of Standard	94%	99%

LEHI: POTENTIAL CONNECTIVITY IMPROVEMENTS

NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.



Benefit modeling results

Using modeling techniques, the project team estimated the likely benefits of the potential Lehi Community street connectivity improvements resulting from the strategies shown on page 46 and shown on the map on page 47.

Traffic performance

The existing Lehi street network was modified with the added connections shown in the map. To make a comparison to the existing condition, the same origins and destinations were used for traffic assignment in the new network. Using outputs from VISUM traffic models, the networks were compared for the total length (both directions), 3-hour traffic volumes, free-flow and actual network travel times, as well as delays and vehicle-miles traveled (VMT). A comparison of traffic volumes and VMTs for some of the main arterials and collector streets was also performed.

The project team concluded the following about the traffic performance of potential connectivity improvements:

- Connectivity improvements increased the total length of the Lehi network for 30 percent, but the actual travel time reduced in the improved network by 13 percent. This is attributed to more direct, faster connections between points in the network, and also by the introduction of new connections over the freeway.
- Total delay, computed as the difference between the free flow and actual travel times, reduced 24 percent in the better connected network.
- Total volumes traversing the network and VMTs are slightly reduced in the connectivity improvement scenario.
- A significant decrease in volumes and VMTs was observed in the connected scenario. The volumes were distributed to other connections, relieving the arterials a giving a better distribution of traffic flows in the network.

The connectivity improvements' impact on traffic performance was also compared to a road widening scenario:

- The 25 percent lane-miles increase in the street connectivity scenario was about twice as much as in the street widening scenario.
- Street widening resulted in about the same actual travel time as improved connectivity, but the delay reduction was higher in the street connectivity scenario (24 percent vs. 17 percent).
- The increase in the average street and total network capacity in the street widening and connectivity scenarios was the same, about 13 percent.
- The widened streets attracted between 8 and 31 percent more traffic, with a similar increase in VMTs.

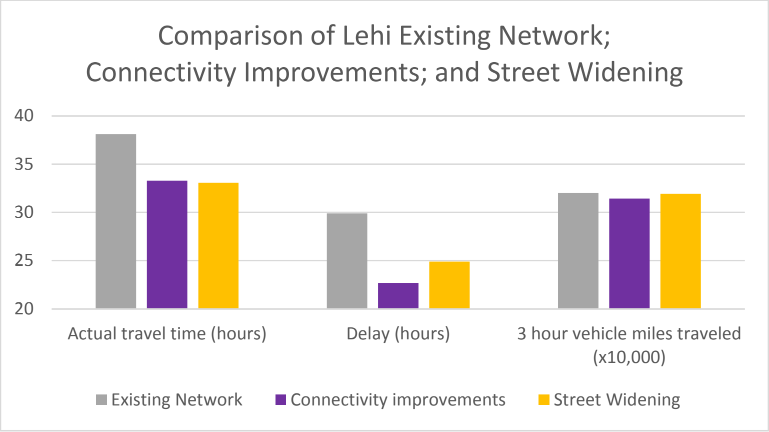
Active transportation and associated benefits

The active transportation modeling analysis estimated the number of bicycle and walking trips that would result from an increase in bicycle and pedestrian mode share, approximated the corresponding reduction in vehicle trips and vehicle-miles traveled (VMT), and assessed the potential health, environmental, and transportation-related benefits. These benefits include bike and walk trips, hours of physical activity, recommended physical activity minimum met, healthcare cost savings, CO2 and other emissions reduced, vehicle emission costs reduced, annual VMT Reduced, reduced traffic congestion costs, reduced vehicle crash costs, reduced road maintenance costs, and household vehicle operation cost savings.

The estimates of active transportation benefits were generated by analysis of a set of peer cities to Lehi that have connectivity levels similar to the potential improvements shown for Lehi as well as high walking and bike mode shares. These cities included Beaverton, OR; Bellevue, WA; Menlo Park, CA; Palo Alto, CA; Redmond, WA; Salt Lake City, UT; and West Sacramento, CA.

Based on these peer cities, implementing connectivity improvements could lead to increases in biking mode shares from a current base of .25 percent to between 1.1 and 5.2 percent; and increases in walking mode shares from a current base of .85 percent to between 3.2 and 5.3 percent.

If levels of connectivity similar to the peer cities are reached and these active commute mode shares increase to the estimates based on peer cities' mode shares, the study area could experience between $2,477,000 and $8,254,000 in additional health, environmental, and transportation-related benefits every year.



Sales

Economic modeling measured the impact of the potential connectivity improvements for Lehi on sales. In the west side of the city, where many of the potential improvements were located, there is very little development currently and limited retail. However, this area is poised for new development and these connections will be vital to the economic success and quality of life of the area. Additional connections were made in the center of the city, providing quicker access to retail establishments. Improvements were also made in the northern part of the study area, while there isn't much retail here, quicker access to existing nodes was improved.

From the connectivity improvements, potential impacts to retail sectors were calculated. Grocery stores have the potential to increase sales by 0.8 percent, while warehouse clubs and supercenters could see a similar impact of 0.7 percent. Gas stations could experience an increase of 0.5 percent in sales. Limited service restaurants could see an additional 0.8 percent increase while full-service restaurants could see a slight increase of 0.1 percent.

For context, if these percentages were applied to actual sales for Lehi in 2015, an additional $2.6 million in sales could have occurred. Warehouse clubs and supercenters could experience and additional $1.2 million in sales, while grocery stores and restaurants could both experience close to $650,000 in additional sales. Gas stations could experience and additional $98,000 in annual sales.

Modeling showed that these improvements could:

- **Reduce traffic delay by 24 percent**
- **Increase the amount of walking by up to 20 times**
- **Increase retail sales by $2.6 million**
- **Add up to $7.4 million of transportation, health, and environmental benefits**

SUBURBAN COMMUNITIES

A suburban community is a city or other local jurisdiction with medium overall density, fewer regional transportation facilities and regional destinations, and a lower degree of land use mix.

Street connectivity

① Community-scale networks in suburban communities often build on historic rural grids or other patterns, which can have high levels of connectivity.

② Many suburban communities have historic downtowns and neighborhoods with dense, connected street grids. Community street connectivity can be increased by extending these connected street patterns to newer development areas adjacent to the historic areas.

③ Community-level suburban streets often have not been built to connect among subdivision projects. New developments should provide stub streets for collector-level (and local-level) streets so these connections can be made.

④ Similarly, apart from historic roads, streets often do not connect among different jurisdictions. Regional and inter-jurisdictional planning efforts should identify and encourage these connections.

⑤ Regional transportation facilities that bisect suburban communities can be major barriers to connectivity – efforts should be focused to overcome these.

Network density

⑥ Because of an unplanned pattern of growth in formerly rural areas, suburban communities often have few community-scale streets that connect over long distances. This tends to concentrate community and regional traffic on a small number of streets.

Destination access

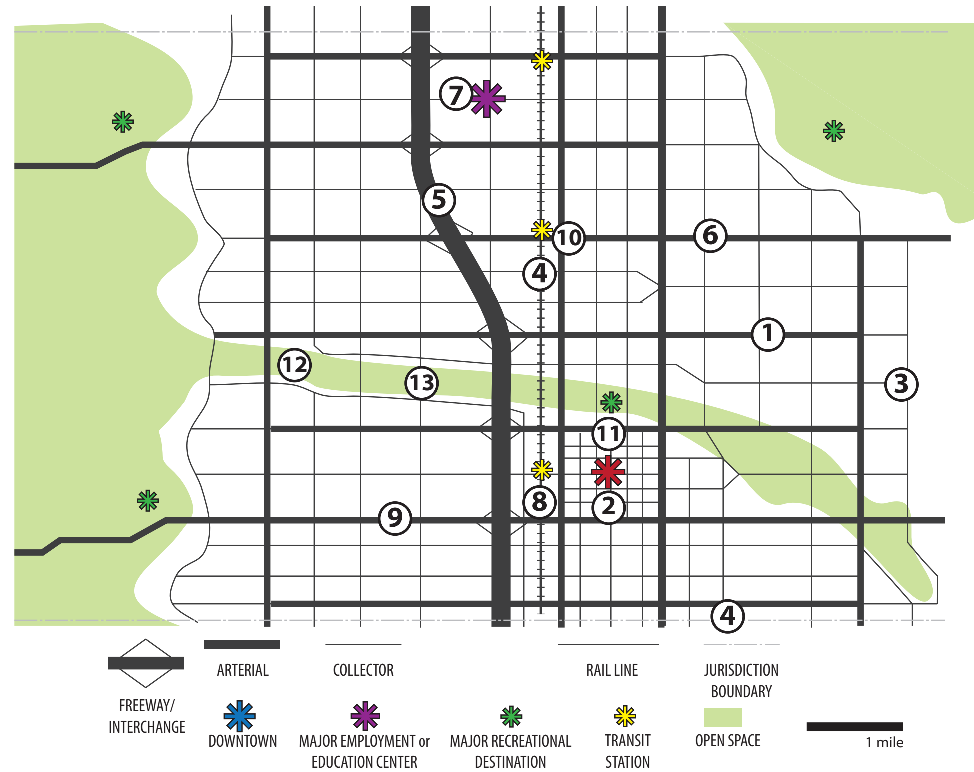
⑦ Suburban communities often contain regional-level destinations such as educational campuses, employment centers, and shopping and entertainment centers.

⑧ Suburban communities often feature a central light rail or commuter rail station that should be a focal point for community multi-modal access.

Accommodate all users

⑨ The often-widely spaced community-level streets and the concentration of traffic onto them presents a challenge for active transportation users. Suburban communities should seek to make these major streets safe and convenient for all users, and/or to provide parallel routes that have the same level of community connection and access the same destinations.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS FOR SUBURBAN COMMUNITIES



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

⑩ Transit users should be able to cross and walk along major streets to access transit services running on them.

⑪ Care should be taken to provide complete streets or networks around key community destinations.

⑫ In suburban communities, active transportation connections can raise the effective connectivity of otherwise disconnected places.

⑬ In suburban communities, major land features such as creeks, canals, agricultural preserves, and hilly or mountainous areas can be opportunities for community-wide active transportation corridors.

STREET CONNECTIVITY **STANDARD METRICS** FOR SUBURBAN COMMUNITIES

Street Connectivity	Connectivity index of collector-or-above streets: **1.8** links per node
Network Density	Collector-or-above intersections per square mile: **5** intersections per square mile
Destination Access	Average 2-mile travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Percentage of 1/2 mile walk-shed from key destinations: **100%** of walk-shed

SUBURBAN COMMUNITY CASE STUDY: LAYTON

Layton is a suburban city in Davis County just south of Ogden. Layton has both established neighborhoods in the eastern, hilly areas against the Wasatch Mountains, and newer neighborhoods in growth areas near the Great Salt Lake shorelands to the west. The Wasatch Front's central transportation corridor, including I-15 and rail lines, splits the city.

Current connectivity profile

For the Layton community, the basic metrics were evaluated, as well as one of the advanced measures (travel-sheds). Layton has room for improvement in all the metrics evaluated, especially in the hilly eastern area of the city and the growing western area. In general, intersection density is more of a need than general connectivity – improving both of these will likely improve destination access.

	Connectivity Index	Intersection Density
Raw score	1.62	3.42
Percentage of Standard	77%	68%

Potential Strategies

Plans and Policies

- Explicit general plan policies supporting street connectivity.
- Policies to design for all users.
- Policies encouraging redundant and direct connections to destinations.
- Connections to outside jurisdictions.
- Key connections plan for city.

Street & Development Standards

- Maximum major street spacing (arterials, collector or similar) – 2,000 feet.

Retrofit strategies

- Connect all dead-end streets in community-wide network (collectors and above).
- Create a north-south connection in eastern Layton between Fairfield Road and Church Street.
- Increase the density of the network in the historic downtown/ FrontRunner area.
- Create connections between Layton Commons area and Mall area.
- Connect the different network types: build out the diagonal and orthogonal grids to connect streets.

Managing connectivity

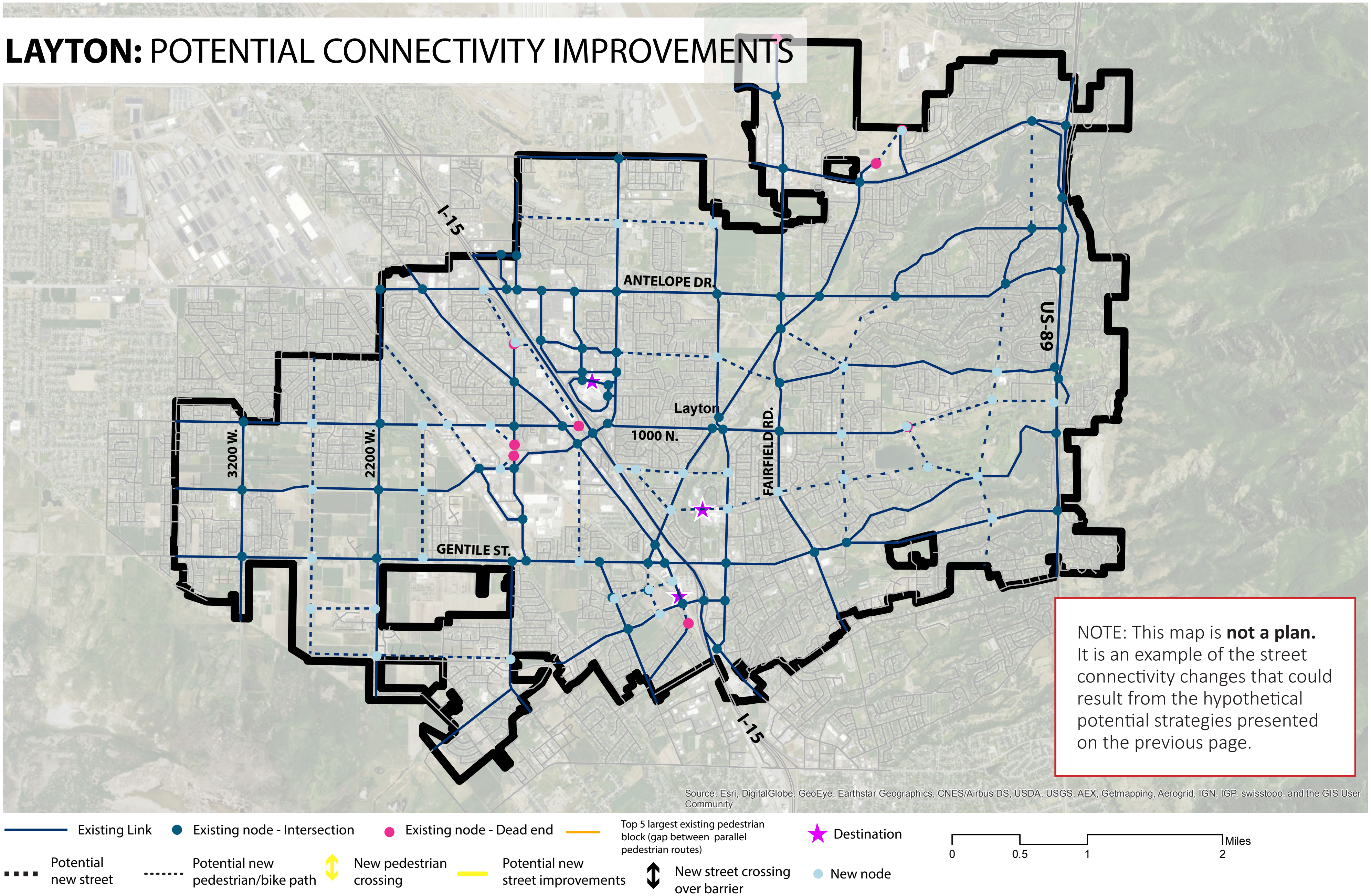
- Traffic Calming Measures.
- Transit-Friendly Design – use network to increase transit speed and accessibility.
- Complete Streets policy – ensure networks for all modes.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity substantially. The network shown would improve both the overall connectivity and the network density of Layton by 26 and 47 percent respectively, bringing Layton to near the Suburban Community standards.

	Connectivity Index	Intersection Density
Raw score *(change)*	1.78 *(+26%)*	5.05 *(+47%)*
Percentage of Standard	97%	101%

LAYTON: POTENTIAL CONNECTIVITY IMPROVEMENTS



NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

Benefit modeling results

Using modeling techniques, the project team estimated the likely benefits of the potential Layton Community street connectivity improvements resulting from the strategies shown on page 52 and shown on the map on page 53.

Traffic performance

The existing Layton street network was modified with the added connections shown in the map. To make a comparison to the existing condition, the same origins and destinations were used for traffic assignment in the new network. Using outputs from VISUM traffic models, the networks were compared for the total length (both directions), 3-hour traffic volumes, free-flow and actual network travel times, as well as delays and vehicle-miles traveled (VMT). A comparison of traffic volumes and VMTs for some of the main arterials and collector streets was also performed.

The project team concluded the following about the traffic performance of potential connectivity improvements:

- The actual travel times, as well as the total delays, were reduced 4 percent and 9 percent respectively, showing the benefits of better connectivity on network mobility.
- A small reduction in VMTs was also observed on the network level.
- A reduction in volumes was also observed along most arterials, except 700 South and Layton Parkway.
- The VMTs along all arterial are reduced, ranging from very small reductions of 1% to significant ones of more than 20 percent.

The connectivity improvements' impact on traffic performance was also compared to a road widening scenario:

- Street widening resulted in about the same actual travel time and delay reduction as improved connectivity.
- Although the average street capacity reduced 7 percent in the street connectivity scenario, the total network capacity increased more than 10 percent.
- The increase in the average street and total network capacity in the street widening scenario was the same, about 4 percent.
- The widened streets attracted more traffic, changing the traffic distribution in the network.
- Improved street connectivity reduced volumes and VMTs along analyzed streets by 8 to 10 percent, more than the street widening scenario (2 to 3 percent).

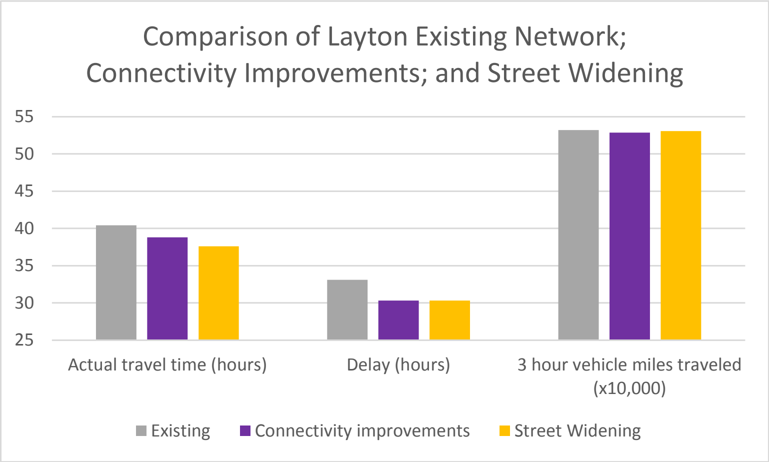
Active transportation and associated benefits

The active transportation modeling analysis estimated the number of bicycle and walking trips that would result from an increase in bicycle and pedestrian mode share, approximated the corresponding reduction in vehicle trips and vehicle-miles traveled (VMT), and assessed the potential health, environmental, and transportation-related benefits. These benefits include bike and walk trips, hours of physical activity, recommended physical activity minimum met, healthcare cost savings, CO2 and other emissions reduced, vehicle emission costs reduced, annual VMT Reduced, reduced traffic congestion costs, reduced vehicle crash costs, reduced road maintenance costs, and household vehicle operation cost savings.

The estimates of active transportation benefits were generated by analysis of a set of peer cities to Layton that have connectivity levels similar to the potential improvements shown for Layton as well as high walking and bike mode shares. These cities included Albany, OR; Claremont, CA; Edina, MN ; Goshen, IN; Portage, MI; Redmond, WA; and West Sacramento, CA.

Based on these peer cities, implementing connectivity improvements could lead to increases in biking mode shares from a current base of .17 percent to between .75 and 1.7 percent; and increases in walking mode shares from a current base of 1.26 percent to up to 2.9 percent.

If levels of connectivity similar to the peer cities are reached and the active commute mode shares increase to low, mid, or high estimates based on peer cities' mode shares, the study area could experience between $1,610,000 and $5,671,000 in additional health, environmental, and transportation-related benefits every year.



Sales

Economic modeling measured the impact of the potential connectivity improvements for Layton on sales. There were major improvements throughout Layton, especially on the east side of the city. Major connections were made inside residential neighborhoods. Additionally, some of these connections directly improved access to retail nodes. As a result of these improvements, study retail sectors saw major increase in market accessibility within the 7-minute drive time.

From the connectivity improvements, potential impacts to retail sectors were calculated. Warehouse clubs and supercenters have the potential to increase their sales by 1.4 percent. Supermarkets and grocery stores could see an increase of 0.9 percent, gas stations could see similar impacts with the opportunity to increase sales by 0.8 percent. Limited and Full service restaurants saw almost no change.

For context, if these percentages were applied to actual sales for Layton in 2015, an additional $4.9 million in sales could have occurred. The largest impact was seen in Warehouse clubs and Supercenter retailers such as Wal-Mart/Target. These types of retailers could have seen an additional $3.7 million in sales across the city. Grocery store could see an additional $800,000 while restaurants could experience an additional $200,000 in sales and gas stations an additional $163,000.

Modeling showed that these improvements could:

- **Reduce traffic delay by 8.5 percent**
- **Double the amount of walking**
- **Increase retail sales by $4.9 million**
- **Add up to $4.2 million of transportation, health, and environmental benefits**

RURAL COMMUNITIES

A rural community is a city or other local jurisdiction with low density, relatively isolated from other communities, and a high degree of agricultural, mountain land or other natural open space within the community.

Street connectivity

1. Community-level networks in rural areas generally consist of regional highways and historic farm roads. These links are often highly connected, with four-way intersections.
2. However, subdivisions that branch off these major streets are often only connected at one point, which prevents community-level connectivity from evolving with the community growth. This new development should be planned for multiple connections to the larger network.
3. In rural areas, it is important to understand the community's plan for future growth and preservation, so that the right level of connections among subdivisions and among jurisdictions can be made.

Network density

4. The low density of rural communities can lead to low community-level street network density. However, with planning, the development of properly-spaced and connected collectors and arterials can be coordinated with community growth.

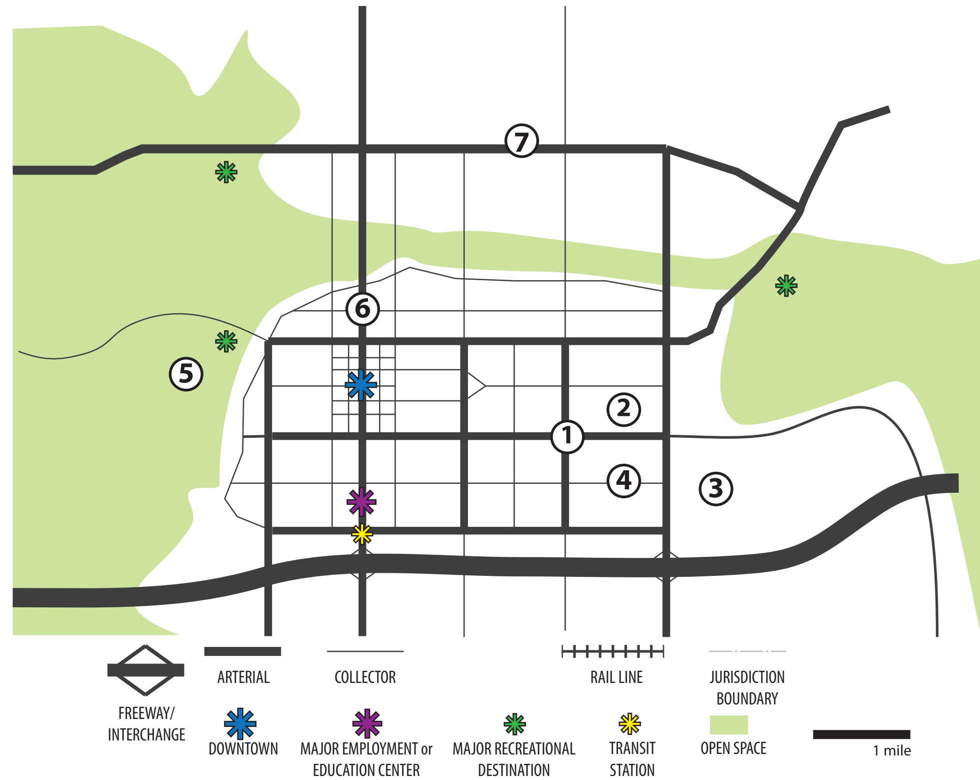
Destination access

5. Rural communities often contain regional recreational destinations such as ski areas, trail systems, and sports parks. The network should prioritize connections to these destinations.

Accommodate all users

6. The often-widely spaced community-level streets and the often-high speed traffic on them presents a challenge for active transportation users. Rural communities should seek to make these major streets safe and convenient for all users, and/or to provide parallel routes that have the same level of community connection and access the same destinations.
7. Rural highways often present barriers to active transportation users, requiring safe, visible and convenient at-grade or grade-separated crossings of active transportation paths or routes across these highways.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS FOR RURAL COMMUNITIES



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

STREET CONNECTIVITY **STANDARD METRICS** FOR RURAL COMMUNITIES

Street Connectivity	Connectivity index of collector-or-above streets: **1.6** links per node
Network Density	Collector-or-above intersections per square mile: **3** intersections per square mile
Destination Access	Average 2-mile travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Percentage of 1/2 mile walk-shed from key destinations: **100%** of walk-shed

RURAL COMMUNITY CASE STUDY: TOOELE VALLEY COMMUNITY

Tooele Valley is a broad Great Basin valley on the other side of the Oquirrh Mountains from Salt Lake Valley. The area of Tooele Valley being evaluated in this case study contains much of the valley's population outside the unincorporated communities of Tooele and Grantsville and covers the area roughly between Tooele City and Interstate 80. These unincorporated communities include Erda, Stansbury Park, and Lake Point. The area is predominantly rural but is growing steadily with housing development.

Current connectivity profile

For the Tooele Valley community, the basic metrics were evaluated. The evaluation reveals that Tooele Valley's existing network is very well connected but has a low intersection density, so improvements should focus on densifying the network while still maintaining a high link-node ratio (connectivity index).

	Connectivity Index	Intersection Density
Raw score	1.74	1.09
Percentage of Standard	124%	36%

Potential Strategies

Plans and Policies

- Explicit general plan policies supporting street connectivity.
- Policies to design for all users.
- Policies encouraging multiple/ direct connections to destinations.
- Connections to outside jurisdictions.
- Key connections plan for city.

Street & Development Standards

- Maximum major street spacing (arterials, collector or similar) – Half mile.

Retrofit strategies

- Connect all dead-end streets in community-wide network (collectors and above).

Managing connectivity

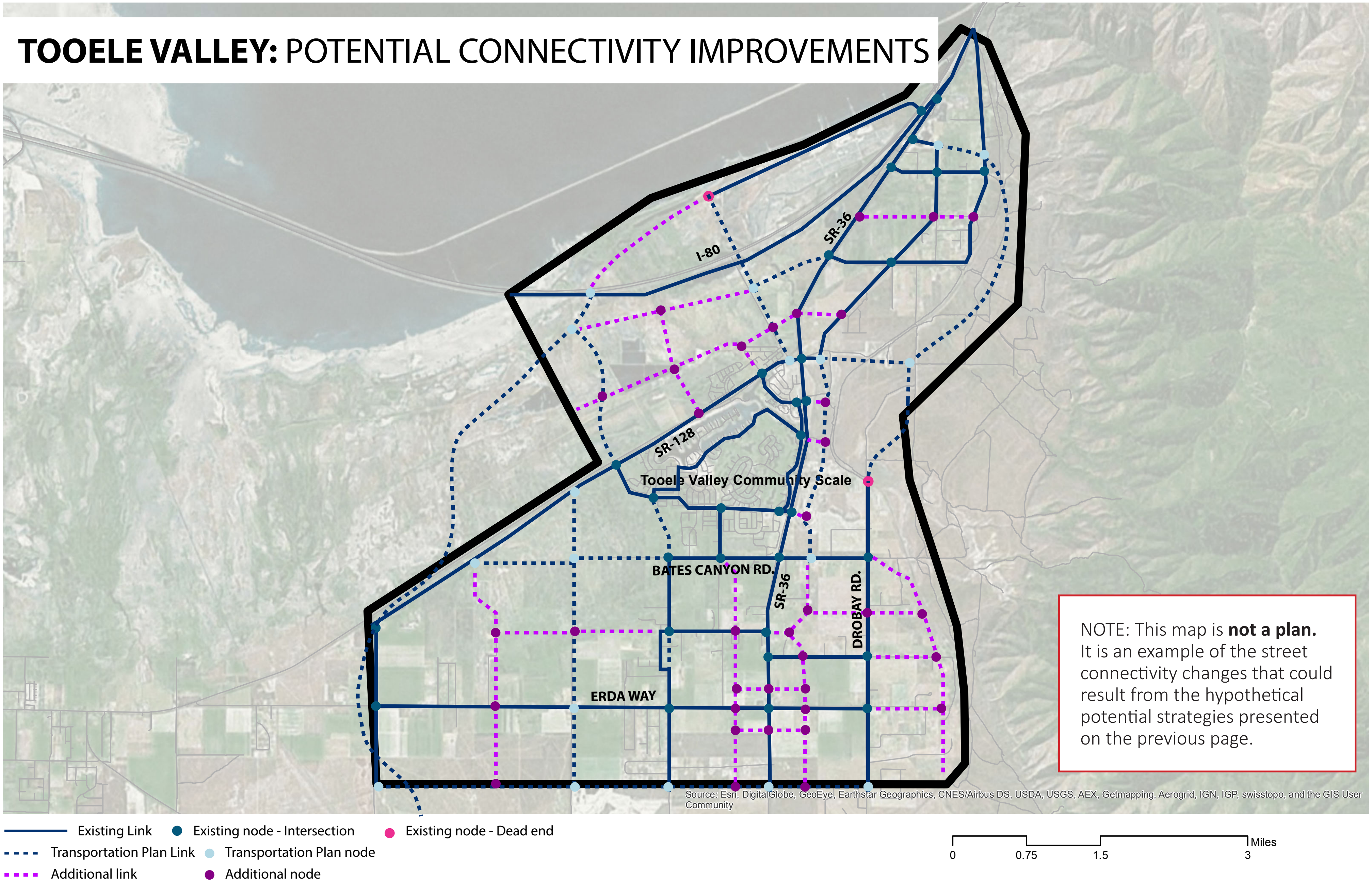
- Traffic Calming Measures.
- Complete Streets policy – ensure networks for all modes.

Improved connectivity profile

For Tooele Valley, both a near-term plan and a long-term plan were assessed in terms of the basic connectivity metrics. Over the combined time frames, the potential strategies would produce a network that improves the connectivity substantially. With the network already achieving link-node ratio standards for the Rural Community context, the improvements largely focus on increasing the network density without losing the level of connectivity. The networks shown would improve the network density in the near term and long term, eventually bringing Tooele Valley to the Rural Community standards at build-out.

		Connectivity Index	Intersection Density
Near Term	**Raw score *(change)***	1.68 *(-8.2%)*	1.77 *(+62.1%)*
	Percentage of Standard	105%	59%
Long Term	**Raw score *(change)***	1.76 *(+2.3%)*	3.12 *(186.2%)*
	Percentage of Standard	110%	104%

TOOELE VALLEY: POTENTIAL CONNECTIVITY IMPROVEMENTS



NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

Benefit modeling results

Using modeling techniques, the project team estimated the likely benefits of the potential Tooele Community street connectivity improvements resulting from the strategies shown on page 58 and shown on the map on page 59. Only the first phase of improvements were analyzed.

Traffic performance

The existing Tooele street network was modified with the added connections shown in the map. To make a comparison to the existing condition, the same origins and destinations were used for traffic assignment in the new network. Using outputs from VISUM traffic models, the networks were compared for the total length (both directions), 3-hour traffic volumes, free-flow and actual network travel times, as well as delays and vehicle-miles traveled (VMT). A comparison of traffic volumes and VMTs for some of the main arterials and collector streets was also performed.

The project team concluded the following about the traffic performance of potential connectivity improvements:

- In this case, the actual travel time in the new network increased from the existing network, but the total delay reduced about 18 percent.
- About 10 percent higher volumes, with a slight increase in VMTs, were also observed in this network. This is due to the major changes in the network layout, much more than in the other two case studies, since the total network length increased more than 50 percent.
- This caused major changes in traffic flow patterns, including significant reductions in traffic volumes and VMTs for almost all arterials and major collectors.

The connectivity improvements' impact on traffic performance was also compared to a road widening scenario:

- The total delay in both scenarios was comparable.
- The average street and the total network capacity increased 5 and 11 percent respectively in the street connectivity scenario, compared to a 3 percent increase in both cases in the street widening scenario.
- The improved street connectivity scenario saw reduced total volumes and VMTs along analyzed streets by 9 to 10 percent, compared to a 2 percent increase in volumes in the widening scenario. This again shows a much better distribution of traffic flows in a better connected network.

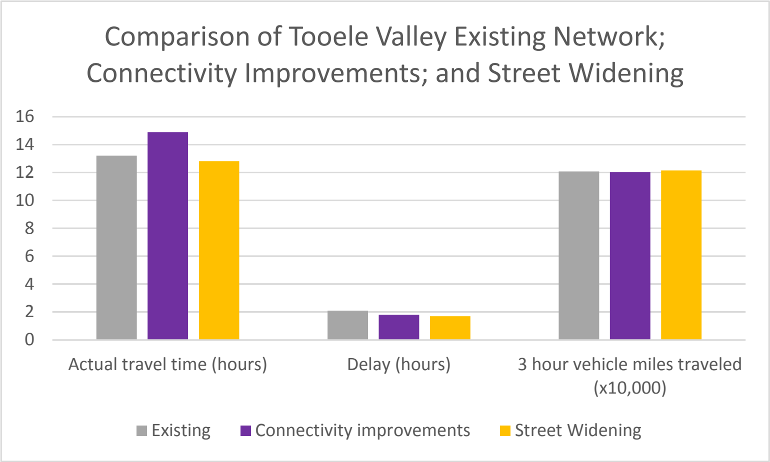
Active transportation and associated benefits

The active transportation modeling analysis estimated the number of bicycle and walking trips that would result from an increase in bicycle and pedestrian mode share, approximated the corresponding reduction in vehicle trips and vehicle-miles traveled (VMT), and assessed the potential health, environmental, and transportation-related benefits. These benefits include bike and walk trips, hours of physical activity, recommended physical activity minimum met, healthcare cost savings, CO_2 and other emissions reduced, vehicle emission costs reduced, annual VMT Reduced, reduced traffic congestion costs, reduced vehicle crash costs, reduced road maintenance costs, and household vehicle operation cost savings.

The estimates of active transportation benefits were generated by analysis of a set of peer cities to Tooele Valley that have connectivity levels similar to the potential improvements shown for Tooele Valley as well as high walking and bike mode shares. These cities included Summit County, UT; Garfield County, CO; Grand County, UT; Driggs, ID; and Teton County, ID.

Based on these peer cities, implementing connectivity improvements could lead to increases in biking mode shares from a current base of .33 percent to between 1.3 and 2.4 percent; and increases in walking mode shares from a current base of 2.5 percent to up to 5.3 percent.

If levels of connectivity similar to the peer cities and counties are reached and the active commute mode shares increase to low, mid, or high estimates based on peer cities and counties' mode shares, the study area could experience between $1,321,000 and $4,421,000 in additional health, environmental, and transportation-related benefits every year.



Sales

Economic modeling measured the impact of the potential connectivity improvements for Tooele Valley on sales. The majority of unincorporated Tooele Valley's retail businesses are located near Tooele City limits to the south and near I-80 to the north. As seen in Figure 5, the majority of the connections were made in the middle of the study area with little to no retail. However, this increased the market accessibility of existing retail located along SR-36 to those living further away from exiting major arterials.

From the connectivity improvements, potential impacts to retail sectors were calculated. Combined, full and limited service restaurants could see an increase of 4 percent in annual sales. While this may seem drastic, it is important to understand that the majority of these establishments are located along a single corridor. Additionally, there are only 33 establishments in the City. With such a small market, any improvements to traffic flow and market accessibility have significant impacts. Warehouse Clubs and supercenters saw no change because there is only one of these in our study area. Grocery stores could see an increase of 0.9 percent, while gas stations could experience a minimal impact of 0.2 percent.

For context, if these percentages were applied to actual sales for Tooele Valley in 2015, an additional $1.9 million in sales could have occurred. Full and limited service restaurants have to potential to add an additional $1.5 million in annual sales, while grocery stores have the potential to add over $300,000 annually. Gas stations could see minimal increase in sales, adding just over $20,000, and because there is only one warehouse club/supercenter establishment, there are no impacts.

Modeling showed that these improvements could:

- **Reduce traffic delay by 17 percent**
- **Double the amount of walking**
- **Increase retail sales by $1.9 million**
- **Add up to $2.5 million of transportation, health, and environmental benefits**

URBAN RESIDENTIAL NEIGHBORHOODS

An urban residential neighborhood is a higher-density residential area with civic, commercial, and office uses mixed in.

Street connectivity

1. Because of the historic pre-automobile nature of many urban neighborhoods, these areas present favorable conditions for optimizing connectivity. Four-way intersections are common and dead ends/cul-de-sacs are rare.
2. New development should preserve pre-existing gridded networks (block consolidation should be discouraged) and connect to street networks on most or all sides of the development.
3. Ensure connections to areas outside of the neighborhood across barriers such as large roads or rails.

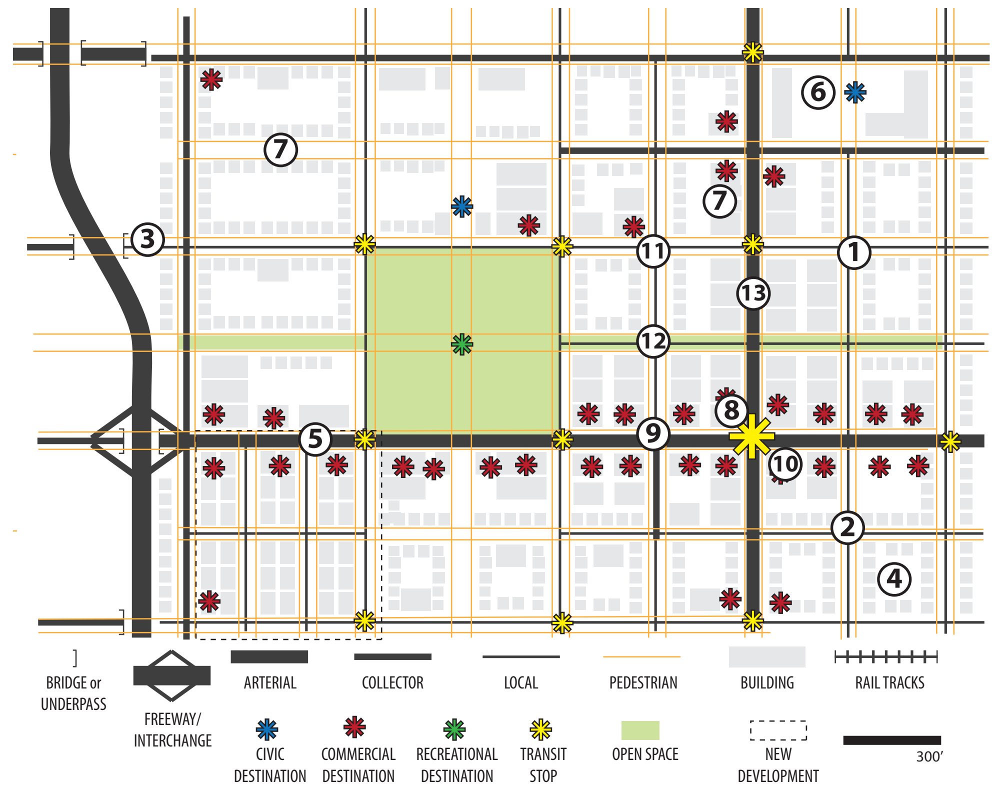
Network density

4. The smaller lots often found in urban neighborhoods are conducive for higher network density.
5. Urban neighborhoods throughout Utah are increasingly taking on more residential and employment density; street networks in these areas should emphasize access and connection rather than mobility. For example, intersections should be frequent even across large arterial streets to emphasize access across them.
6. Incorporate larger land uses like schools, parks, and commercial centers into the overall dense network pattern, preserving streets and intersections.
7. In Utah, even highly connected urban street networks can have low network density because of large blocks (such as in central Salt Lake City); some of these historic grids can be made more dense with additional street or active transportation connections.

Destination access

8. Urban neighborhoods should provide multiple routes to access destinations by all modes.
9. Commercial corridors often provide a focal point of destinations within an urban neighborhood. Ensure that these "Main" streets and connections to them have an especially high degree of connectivity and network density.
10. Transit stops and stations are especially important destinations in urban neighborhoods and all modes should connect well to transit, especially larger stations.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS FOR URBAN NEIGHBORHOODS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

Accommodate all users

11. Network density in urban neighborhoods is most vital for pedestrians – a dense, connected network for people on foot is the highest connectivity priority here.
12. Pedestrian ways, greenways, and linear parks can enhance networks in urban neighborhoods, but be careful that pedestrian ways do not take energy and vibrancy away from streets.
13. The major barriers for pedestrians in urban neighborhoods are often large streets; care should be taken to provide frequent, convenient, and safe crossings across arterial streets.

STREET CONNECTIVITY **STANDARD METRICS** FOR URBAN NEIGHBORHOODS

Street Connectivity	Connectivity index of all streets: **1.7** links per node
Network Density	Intersections per square mile: **225** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Average of highest five pedestrian blocks: **500** feet maximum

URBAN NEIGHBORHOOD CASE STUDY: LAYTON DOWNTOWN

Layton's central district includes a mix of uses and popular destinations, such as Main Street, the civic campus, Layton High School, Layton Commons, a FrontRunner station, shopping areas, and residential neighborhoods. Street connectivity is challenged by I-15 running through the middle of the area, as well as the railroad tracks. The district's sub-areas also lack connections to one another yet the mix of uses, amenities, and destinations here provide the foundation for a connected urban neighborhood.

Current connectivity profile

The current profile shows how Downtown Layton is relatively well-connected to its key destinations, but otherwise scores poorly. Improvements should focus on increasing the density of the general street network and the pedestrian network in particular.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.36	60	73%	2486 feet
Percentage of Standard	51%	27%	73%	20%

Potential Strategies

Plans and Policies

- Develop a "key connections" plan for the area as an amendment to the Downtown Plan that includes identifying 3-way intersections to convert to 4-way intersections, the creation of new access points to Civic Campus and Park from the west, and identifying a desired connection at FrontRunner station across the tracks.
- Implement Kays Creek trail plan.
- Build on Downtown Plan to create complete streets.

Street & Development Standards

- Standards for high network density in infill areas (300 foot minimum block lengths).
- Standards for very high connectivity index (1.7).
- Streets in new developments to align with existing streets to create 4-way intersections.

Retrofit strategies

- Work with school districts for pedestrian paths through large campuses.
- Build paths through park to connect civic center to neighborhoods to south and west.
- Leverage existing I-15 overpasses by improving them for all modes.
- Where full streets not possible over barriers or between different sub-districts, build pedestrian pass-throughs.

Managing connectivity

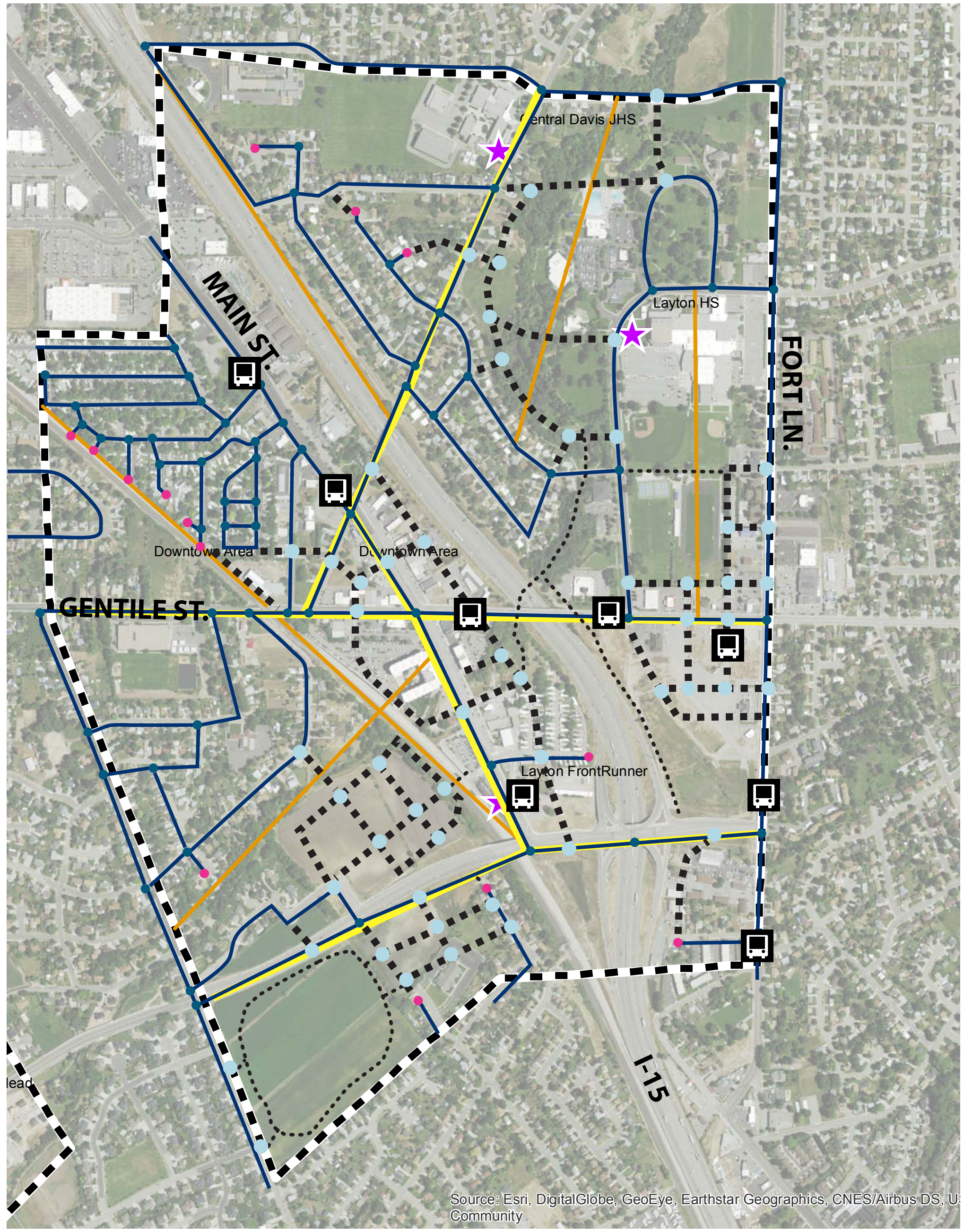
- Create complete streets in Downtown Layton area and in I-15 crossings.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity substantially, yet, because the standards for an urban neighborhood are so high, the network changes to downtown Layton would only get it to about 50 percent of the standards for the basic metrics. The improvement was nearly all in the realm of intersection density, while maintaining a similar level of connectivity.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.36 *(+2%)*	117 *(+95%)*	81% *(+11%)*	1855 feet *(-25%)*
Percentage of Standard	52%	52%	81%	27%

DOWNTOWN LAYTON: POTENTIAL CONNECTIVITY IMPROVEMENTS



- Existing Link
- Existing node - Intersection
- Existing node - Dead end
- Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
- Destination
- Potential new street
- Potential new pedestrian/bike path
- New pedestrian crossing
- Potential new street improvements
- New street crossing over barrier
- New node
- Existing transit stop/station

NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

SUBURBAN RESIDENTIAL NEIGHBORHOODS

A lower-density residential area with other types of uses typically found on nearby arterial corridors

Street connectivity

1. Suburban neighborhoods often lack connectivity because of fewer four-way intersections and cul-de-sacs and other dead-end streets; some cul-de-sacs can be retrofitted to connect, especially for active transportation.
2. New developments should emphasize four-way intersections and limit or prohibit cul-de-sacs.
3. Larger multifamily housing should have multiple connections to the outside network, and internal streets should be well connected to public streets.

Network density

4. Because of the typically larger lots in suburban neighborhoods, network density will be lower in suburban neighborhoods than urban neighborhoods, so it is important to maximize the other aspects of connectivity.
5. New developments should create a consistent pattern of streets and intersections to increase predictability and legibility - and create places where future development can extend this pattern.

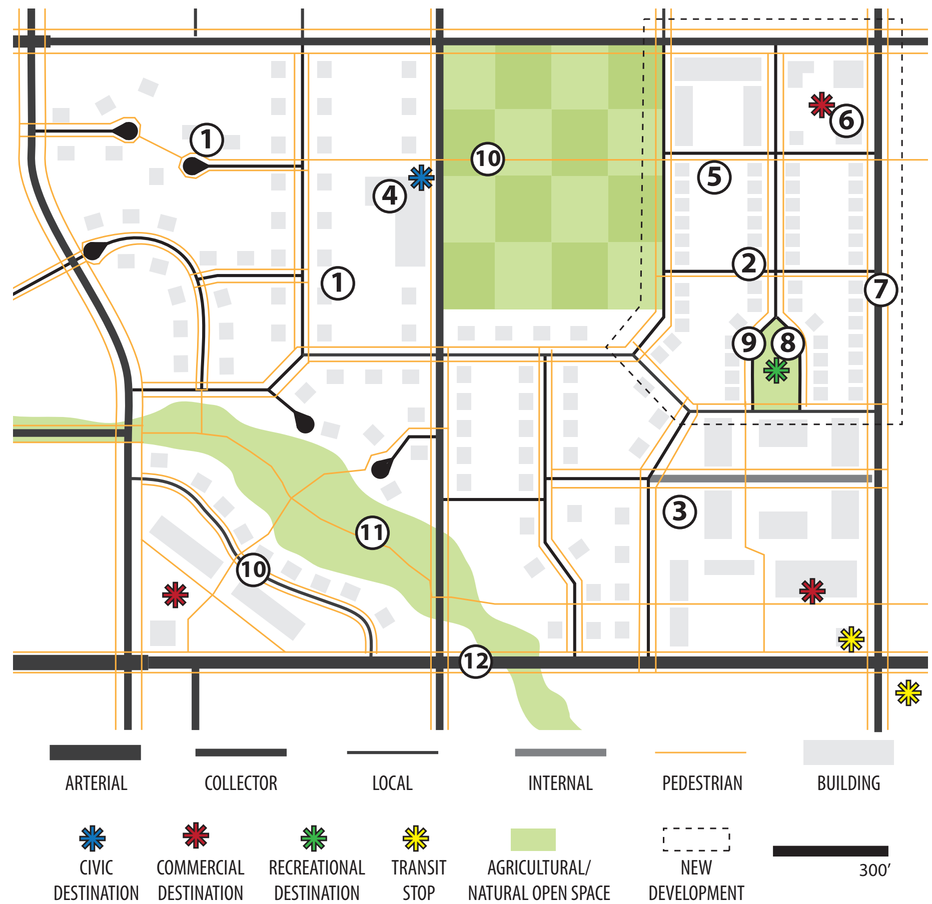
Destination access

6. Incorporate larger land uses like schools and parks as well as commercial blocks into the overall network pattern.
7. Dense and multiple accesses to arterial and collector streets improves access to destinations.
8. Placement of destinations in suburban neighborhoods should be optimized for neighborhood access.
9. Street curving is often seen as a key suburban attraction, but should be limited.

Accommodate all users

10. Consider pedestrian easements and pass-throughs targeted at connecting to specific destinations.
11. Suburban neighborhoods often benefit and have opportunities for separated active transportation networks, such as along canals and creeks.
12. Large streets bounding suburban neighborhoods can be barriers for active transportation, so quality and frequent crossings are a key part of connectivity.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS FOR SUBURBAN NEIGHBORHOODS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

STREET CONNECTIVITY STANDARD METRICS FOR SUBURBAN NEIGHBORHOODS

Street Connectivity	Connectivity index of all streets: **1.5** links per node
Network Density	Intersections per square mile: **175** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Average of highest five pedestrian blocks: **1000** feet maximum

SUBURBAN NEIGHBORHOOD CASE STUDY: LAYTON PARKWAY AND ANGEL STREET

This area of Layton is located in the southwestern part of the city. It was traditionally an agricultural area, but recent growth has infilled residential subdivisions into the historic farm grid. Cul-de-sacs are a common subdivision feature. However, this case study looks at how these popular cul-de-sacs can be limited and managed in the future with only very targeted changes to existing cul-de-sacs that increase active transportation access to destinations.

Current connectivity profile

The current profile shows how Downtown Layton is relatively well-connected to its key destinations, but otherwise scores poorly. Improvements should focus on increasing the density of the general street network and the pedestrian network in particular.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.27	84	62%	2832 feet
Percentage of Standard	53%	48%	62%	35%

Potential Strategies

Plans and Policies

- Plans and policies to coordinate streets to connect with Kaysville.
- Policy for preferred types of street networks for new developments.
- Implement Parks Plan proposed trails.
- Locate future community/commercial/mixed-use centers at connected places – such as 3-way intersections.

Street & Development Standards

- Minimum connectivity standard of 1.5.
- Minimum block lengths of 400 feet, including arterials.
- Manage cul-de-sacs:
    - Limit cul-de-sacs to 20% of streets.
    - Limit the maximum length of cul-de-sacs to 200 feet.
- Require a pedestrian/bike connection for each cul-de-sac.
- Multiple new development accesses to arterial/collector streets.
- Street stub requirements.

Retrofit strategies

- Pedestrian/bike connection from cul-de-sac to school.
- Pedestrian connections across Layton Parkway and into neighborhoods – e.g. pedestrian connection to Weaver Lane.
- Better connections to Prospector rail trail and western spur to neighborhoods.
- Integrate the farm street pattern into the new urbanized street pattern.

Managing connectivity

- Traffic calming strategies.

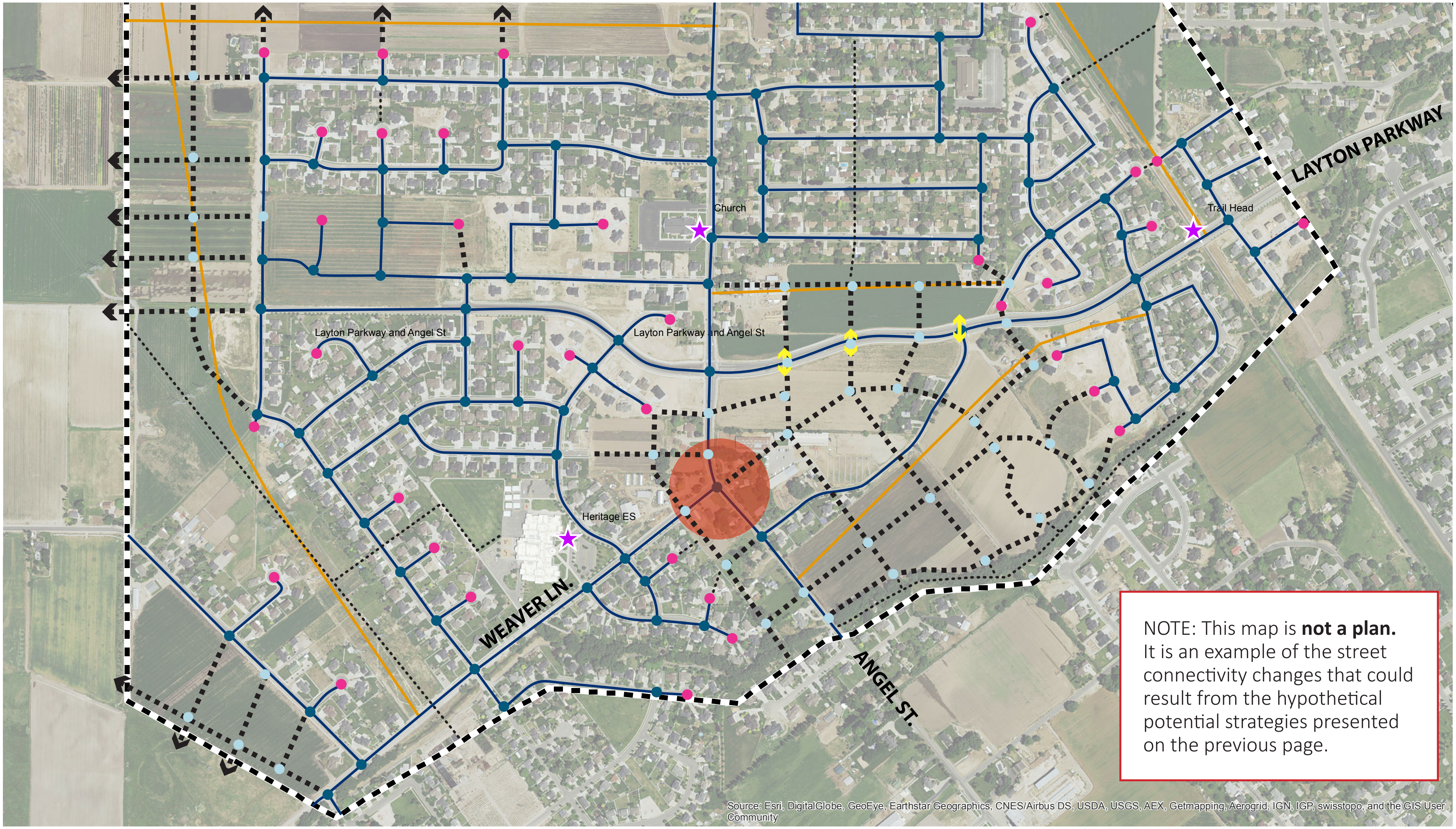
Improved connectivity profile

The potential strategies would produce a network that improves the connectivity substantially. The network shown would over double the connectivity, implementing streets in new development that reduced the number and effects of cul-de-sacs. One lesson of this case study is that a neighborhood can keep its cul-de-sacs to come degree and still meet street connectivity standards if the cul-de-sacs are limited and designed well.

This case study also demonstrates how the network also improves in the advanced metrics – new development and key connections reduced the pedestrian block size by half and the travel-sheds of key destinations increased by 35 percent.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.59 *(+121%)*	131 *(+56%)*	84% *(+35%)*	909 *(-194%)*
Percentage of Standard	117%	75%	84%	103%

ANGEL ST. & LAYTON PARKWAY: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node
Potential future commercial center

0 | 0.1 | 0.2 | 0.4 Miles

SUBURBAN NEIGHBORHOOD CASE STUDY: SKYRIDGE HIGH SCHOOL AREA

Skyridge is a brand-new high school in the northeastern part of Lehi. Much of the neighborhood around it is also new and still being developed. This case study looks at how a suburban neighborhood can be built to connect to a major destination such as a school and how such a large land use can avoid being a barrier.

Current connectivity profile

The current profile shows that the Skyridge High School area scores moderately for intersection density and travel shed, but more poorly for general connectivity and the pedestrian network. Improvements should focus on improving the link-node ratio by creating more four-way intersections and fewer dead ends, especially in new development. Improvements should also reduce the size of the largest pedestrian blocks, and ensure good pedestrian connections to the school.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.27	128	63%	2045 feet
Percentage of Standard	55%	73%	63%	49%

Potential Strategies

Plans and Policies

- Access and circulation plan for high school and surrounding area.

Street & Development Standards

- Encourage/incent very small blocks (200 feet) with compatible land uses.
- Maximum block length for new development: 400 feet.
- Minimum street connectivity standards for new development: 1.4.
- New developments connect to stub streets for future connections.
- Where full street connections not possible as extensions of streets, place pedestrian paths.
- Require “fronting” of land uses onto large public uses like parks and schools.

Retrofit strategies

- Connect longest cul-de-sacs.
- Pedestrian pass-throughs to commercial destinations.
- Key multi-modal routes to access high school for surrounding neighborhood, including streets, paths, crossings, wayfinding.

Managing connectivity

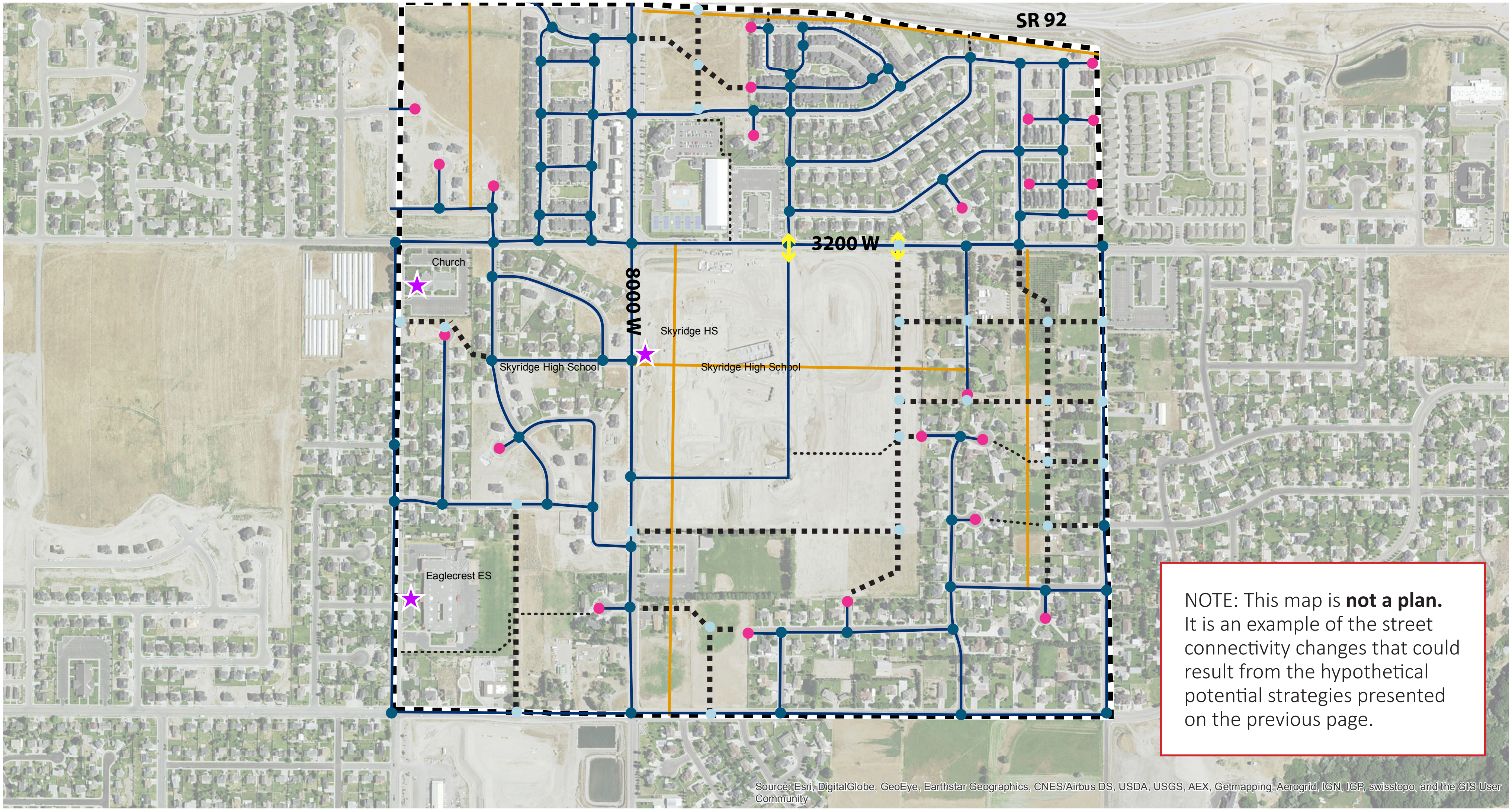
- Manage concerns of school district about increased campus access.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity substantially. The network shown would increase the link-node ratio by nearly 50 percent, bringing the network close to the Suburban Neighborhood standard. Denser new developments would increase network density to very close to the standard.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.39 *(+43.5%)*	168 *(+32%)*	79% *(+25%)*	1190 feet *(-42%)*
Percentage of Standard	79%	96%	79%	84%

SKYRIDGE HIGH SCHOOL AREA: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node

0 0.1 0.2 0.4 Miles

SUBURBAN NEIGHBORHOOD CASE STUDY: KAYS CREEK AND OAK LANE

This area is located in the foothills and ravines of the east side of Layton. The topography and the cul-de-sac-heavy street pattern currently restricts movement around the neighborhood; residents in different parts of this small area must travel in long circuitous paths to reach neighborhood schools and churches on the other side of the steep ravines. However, the potential exists for better pedestrian connections via an improved trail network.

Current connectivity profile

The current profile shows how this neighborhood scores poorly for every measure. However, the topography and built-out nature of the neighborhood makes changes difficult. The most feasible changes are likely in reducing the size of gaps in the pedestrian network by connecting areas of the neighborhood by trails.

	Connectivity Index	**Intersection Density**	**Average Destination Travel-shed %**	**Average Top 5 Pedestrian Block**
Raw score	1.14	85	43%	3172 feet
Percentage of Standard	29%	48%	43%	32%

Potential Strategies

Plans and Policies

- Pedestrian circulation plan for the area.
- Key connections plan for connecting some of the cul-de-sacs.
- Implement Parks Plan proposed trails.

Street & Development Standards

- Multiple access points for new developments.

Retrofit strategies

- Consider small street connections that improve neighborhood destination access.
- Trails between rows of homes – use Mid-Fork Trail as trunk which side connector trails can branch off.

Managing connectivity

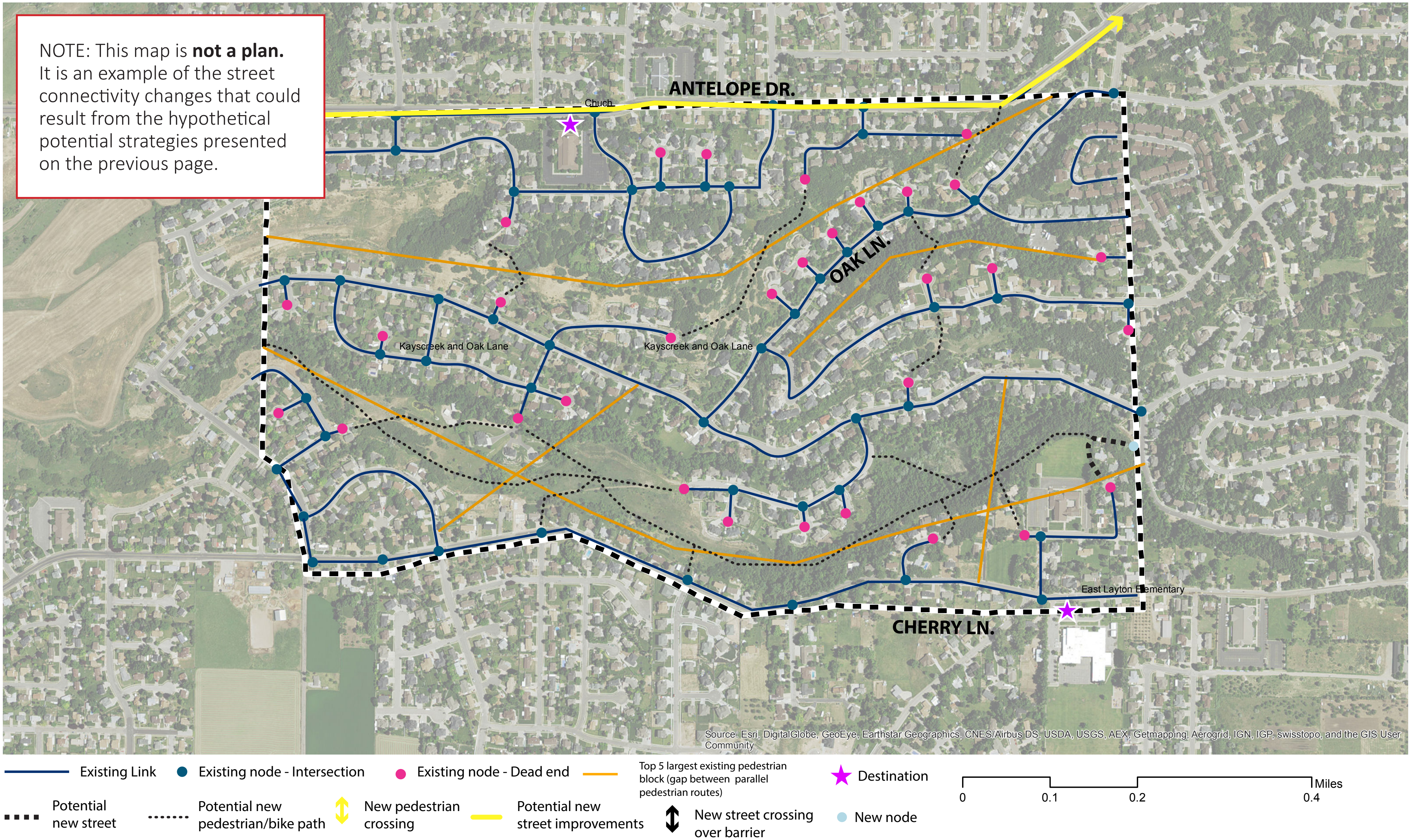
- Improve sidewalks/paths on arterials like Antelope Drive.

Improved connectivity profile

The potential strategies would do little to change the basic metrics but would reduce the pedestrian block sizes, improving pedestrian connectivity in the area. One lesson from this case study is that in some cases, especially in built-out challenging areas, fewer aspects of connectivity can be improved.

	Connectivity Index	**Intersection Density**	**Average Destination Travel-shed %**	**Average Top 5 Pedestrian Block**
Raw score *(change)*	1.16 *(+9%)*	87 *(+2%)*	43% *(+0%)*	1568 feet *(-51%)*
Percentage of Standard	31%	49%	43%	64%

KAYS CREEK & OAK LANE: POTENTIAL CONNECTIVITY IMPROVEMENTS



SUBURBAN NEIGHBORHOOD CASE STUDY: THE EXCHANGE

The Exchange, a planned development on the growing west side of Lehi, presents a unique opportunity for a case study. The Exchange was entitled under Lehi's new street connectivity standards, which require a minimum street connectivity index and maximum block length. The development was tested against this guide's metrics and it scored very well. The Exchange provides a real-world example of how street connectivity standards can produce a much more connected street network and neighborhood. The Exchange has some cul-de-sacs but they are connected for pedestrians and cyclists; its other dead-end streets are planned to connect to adjacent developments.

Current connectivity profile

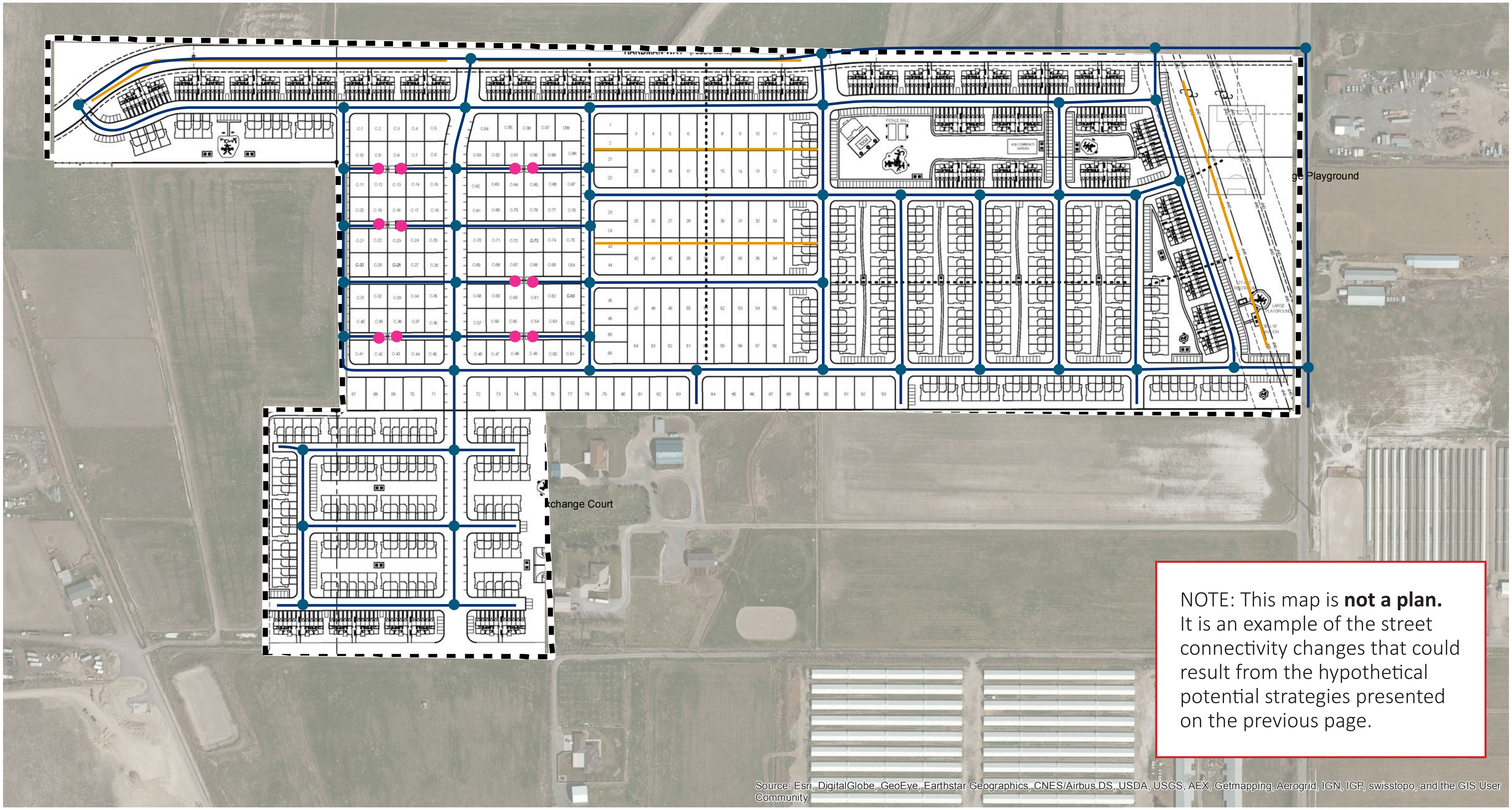
The current profile shows how, largely due to Lehi's new standards for street connectivity, the Exchange scores very well on all aspects of connectivity. It either meets, exceeds, or very nearly meets all the standards for a Suburban Neighborhood.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.49	390	84%	909 feet
Percentage of Standard	98%	223%	84%	110%

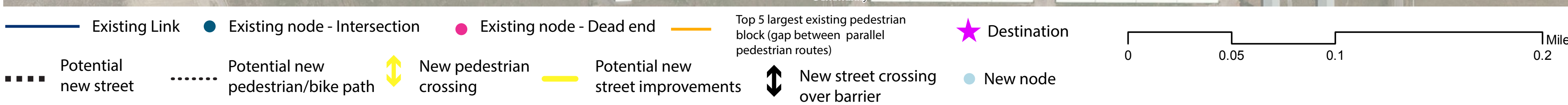
Potential Strategies

- The only improvements would be to increase the number of pedestrian paths/pass-throughs in the longer blocks.

THE EXCHANGE: POTENTIAL CONNECTIVITY IMPROVEMENTS



NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.



RURAL RESIDENTIAL NEIGHBORHOODS

A very low density residential area with agricultural or natural space mixed in and few other uses present.

Street connectivity

1. Rural neighborhoods can be just as connected as suburban or even urban neighborhoods. Many rural areas are built on grid networks.
2. Many uses prevalent in rural areas, such as open space and agriculture, can provide barriers to connectivity, and must often be planned around.
3. Ensure new subdivisions are connected on multiple sides, not just to the nearest major street.
4. Stub streets should be built to connect to future adjacent growth.
5. A long-term growth plan can identify where land uses will change and intensify and where open space and agriculture will be preserved. This allows the appropriate future connections to be anticipated.
6. In rural neighborhoods, more informal dirt roads and trails can be important links in the network and raise connectivity – ensure public access to these.

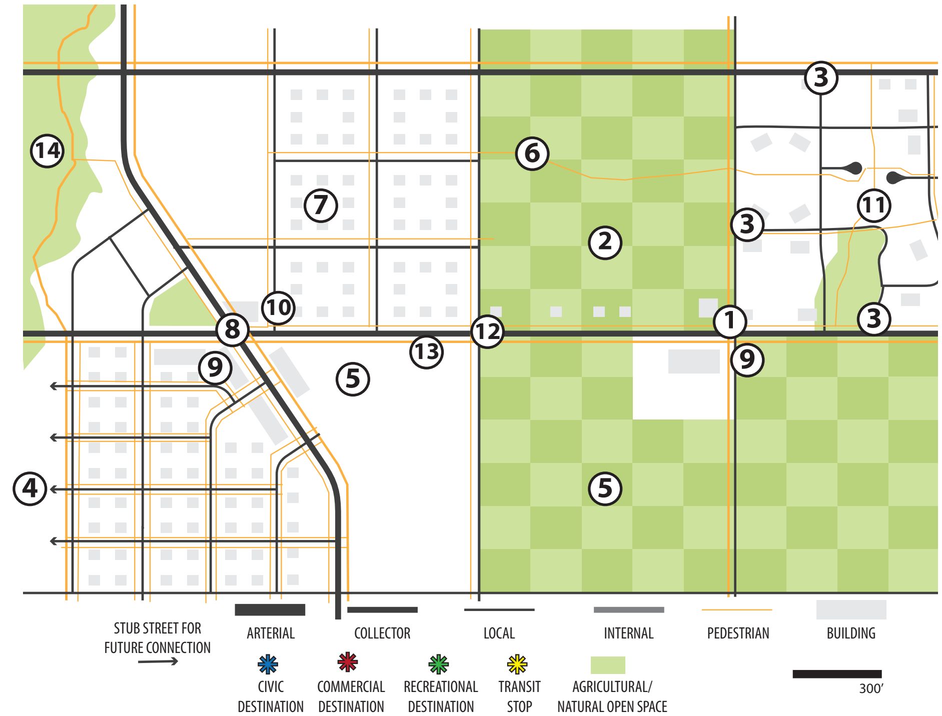
Network density

7. Rural areas typically have low network density due to a variety of factors, including large lots, low levels of infrastructure, and large farms and open space resources. Consequently, it is important to maximize the other aspects of connectivity.

Destination access

8. Because of low network density, rural neighborhoods should focus connectivity on access to specific destinations.
9. Destinations should be concentrated as much as possible and located to maximize connectivity, i.e. at key intersections.
10. Destinations should emphasize multi-modal access by ensuring non-arterial or highway routes that lead to them.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS
FOR RURAL NEIGHBORHOODS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

Accommodate all users

11. It is rare to have sidewalks on rural neighborhood streets, but new subdivisions should have an overall plan to account for pedestrian movement through them, whether via sharing the streets with slow-moving vehicles or a system of multi-use paths connecting homes to destinations.
12. In rural neighborhoods, highways can be a barrier to pedestrian and bicycle access. Ensure safe and convenient crossings of these large roads.
13. Active transportation paths can provide trunk routes among communities and destinations in rural areas.
14. Open space resources such as stream corridors can be opportunities for pedestrian and bike connections within or among rural communities.

STREET CONNECTIVITY STANDARD METRICS FOR RURAL NEIGHBORHOODS

Street Connectivity	Connectivity index of all streets: **1.5** links per node
Network Density	Intersections per square mile: **50** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Average of highest five pedestrian blocks: **1500** feet maximum

RURAL NEIGHBORHOOD CASE STUDY: WEST ERDA

West Erda is one of Tooele Valley's fastest-growing areas. Over the past several years, it has seen new subdivisions that are not always well-connected to the existing rural street network or to one another. Yet an area that is largely not built-out presents a major opportunity to create a well-connected network of new neighborhoods while retaining the agricultural character of the area. This case study looks at the potential future of the West Erda street network in two phases – the near-term adjustment and connections of projects currently in the planning stage; and the long-term build-out of the area.

Current connectivity profile

The current profile shows how West Erda scores poorly for all the metrics. Strategies should seek to improve all aspects of connectivity – both through near-term key connections and new developments that are better connected and planned to connect to one another.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.17	21	51%	3650
Percentage of Standard	34%	43%	51%	41%

Potential Strategies

Plans and Policies

- Implement Tooele County Transportation Plan network
- Develop a long-term master transportation network – with key connections and grid types

Street & Development Standards

- Minimum connectivity index (link-node) standard: 1.5
- Maximum block length of 750 feet
- Requirement for multiple accesses to arterial street for developments above a certain size
- Cul-de-sac management standards:
  - Limit cul-de-sacs to 20% of streets.
  - Limit the maximum length of cul-de-sacs to 200 feet.
- Requirement for pedestrian circulation plan
- Stub street requirements for future connections

Retrofit strategies

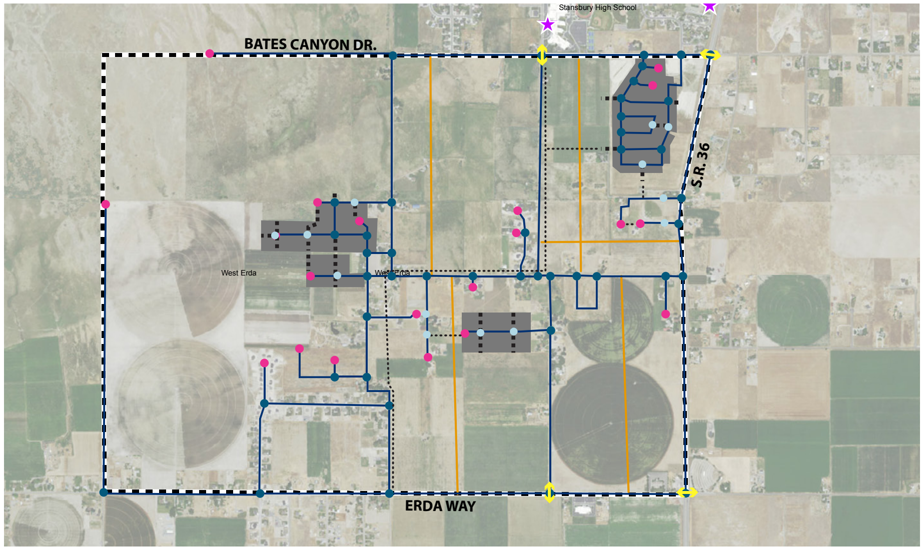
- Create pedestrian crossings across major streets
- Connect longest cul-de-sacs
- Develop active transportation "spine" through the area onto which future active transportation links can connect
- Create pedestrian easements/pass-throughs to key connections – that could eventually become new streets

Improved connectivity profile

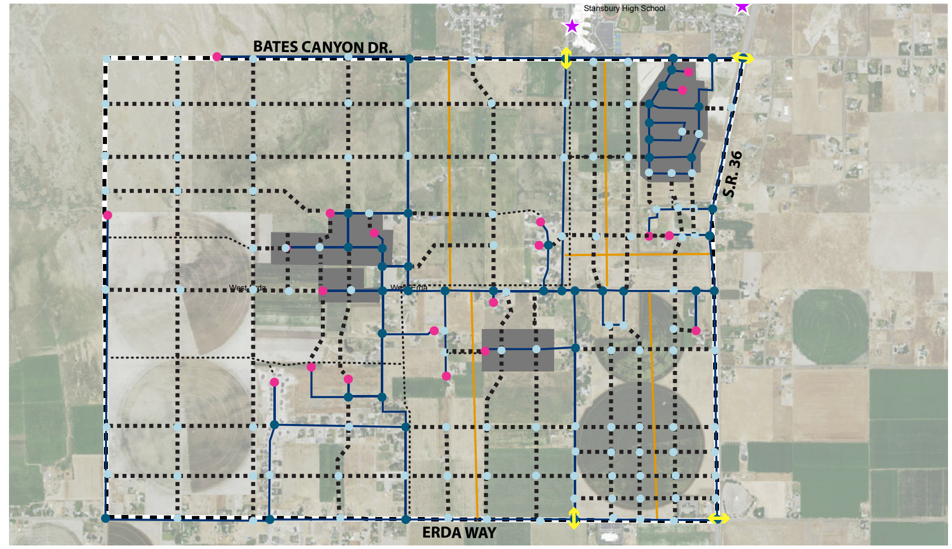
The potential strategies would produce a network that incrementally improves the connectivity to the point in the long-term scenario where the standards for both basic metrics are exceeded. The different types of strategies combine to completely change the network over a long period of time to one that emphasizes the best aspects of connectivity.

		Connectivity Index	Intersection Density	Avg. Destination Travel-shed %	Average Top 5 Pedestrian Block
Near Term	**Raw score *(change)***	1.33 *(93.9%)*	26.31 *(+22.7%)*	55% *(+6%)*	3150 feet *(-14%)*
	Percentage of Standard	67%	53%	55%	48%
Long Term	**Raw score *(change)***	1.64 *(+269%)*	51.21 *(138.9%)*	83% *(+61%)*	1505 feet *(-59%)*
	Percentage of Standard	127%	102%	83%	100%

WEST ERDA: POTENTIAL CONNECTIVITY IMPROVEMENTS (SHORT TERM)



WEST ERDA: POTENTIAL CONNECTIVITY IMPROVEMENTS (LONG TERM)



Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node

NOTE: These maps are **not plans.** They are an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

DOWNTOWN DISTRICTS

A mixed-use center of activity that attracts people from throughout the community and sometimes the region.

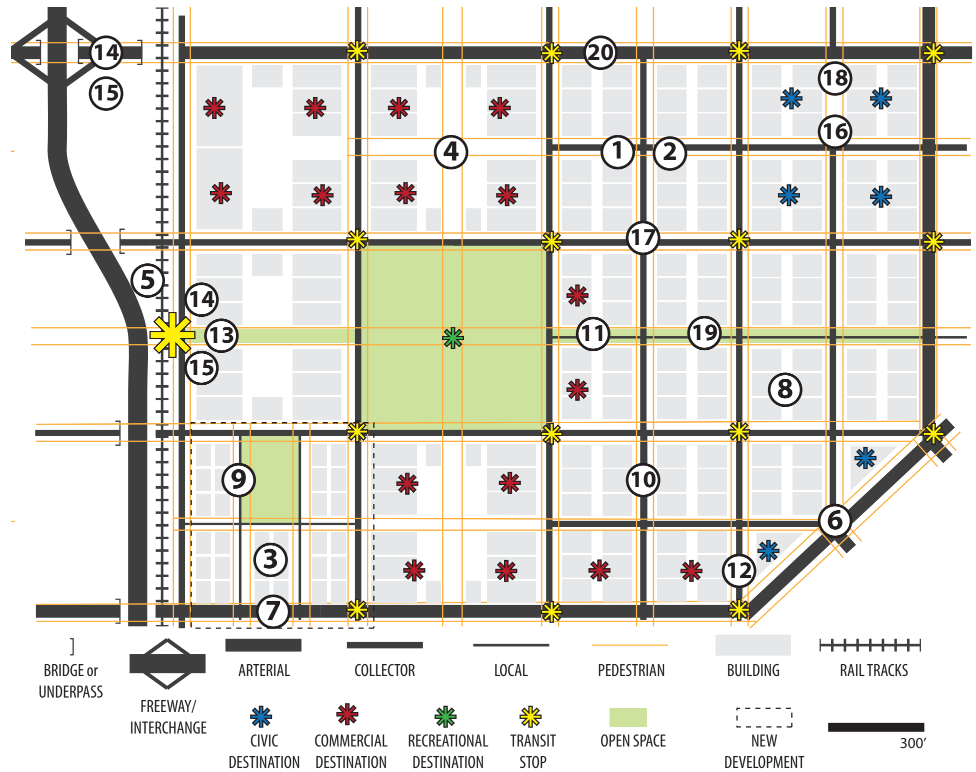
Street connectivity

1. Downtowns are the most connected of the six neighborhood-scale context types.
2. Because of historic pre-automobile nature of many downtowns, these areas present favorable conditions for optimizing connectivity. Four-way intersections are common, and dead ends and cul-de-sacs are rare.
3. New development should preserve pre-existing gridded networks (block consolidation should be discouraged) and connect to street networks on most or all sides of the development.
4. In the case of some larger land uses, large blocks are unavoidable, but active transportation connections can increase connectivity.
5. Downtowns are often adjacent to major transportation facilities such as rails, freeways, and other larger roads. The high degree of connectivity found in downtowns should continue across these potential barriers as much as possible.
6. Downtowns are often where different types of street networks come together. The places where these different networks come together can be designed to be key connection points for the whole community, such as gateways, public spaces, or transit centers.

Network density

7. Many downtowns throughout Utah are increasingly taking on more employment density and diversifying land use into housing; street networks in these areas should increasingly emphasize access and connection rather than mobility. For example, intersections should be frequent even across large arterial streets to emphasize access across them.
8. In downtowns, all land uses should fit into the overall dense network pattern, preserving streets and intersections.
9. In Utah, even highly connected urban street networks can have low network density because of large blocks (such as in central Salt Lake City); some of these historic grids can be made more dense with additional street connections.
10. In some cases, downtowns have networks of one-way streets, which can reduce network density for cyclists. In some cases, "contraflow" lanes can be striped on these streets to allow cyclists to ride both ways on them.
11. Network density is most vital for pedestrians – a dense, connected network for people on foot is the highest connectivity priority here.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS
FOR DOWNTOWN DISTRICTS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

Destination access

12. In downtowns, land uses are mixed, so destinations are spread across them. Because of this, high street connectivity and network density tend to be the best tools to provide good destination access.
13. Downtowns should provide multiple routes to access destinations by all modes.
14. A downtown can be considered one big destination in and of itself; how the downtown is connected to the neighborhoods and districts around it is one of the most vital connectivity issues.

15 One key issue for downtown destinations access is how travelers from outside the district – in many cases from far outside it – can make a longer trip to access the area and then transition to making shorter walking trips to access specific destinations within the downtown. This raises the following considerations:

- One of the most important destinations in downtowns is parking – destinations in downtown are oriented to community and regional visitors, many of whom drive to them, park once and can walk from there. Networks should emphasize connectivity between regional roadways and large parking lots or structures.
- Intermodal transportation centers and transit stations are also important destinations in downtowns. These transportation centers should be connected to the networks of all modes, especially for pedestrians, cyclists and other transit.
- Freeway interchanges are vital nodes to consider in downtowns, because they must balance moving traffic from the freeway to the downtown with maintaining a walkable environment for the downtown and its relationship with surrounding neighborhoods and districts.

Accommodate all users

16 Streets in downtowns accommodate all types of users, ensuring high connectivity and density of networks for pedestrians, cyclists, transit vehicles and riders, motorists, and truck deliveries.

17 While all downtown streets should be walkable, drivable and rideable for all modes, downtown networks may have to prioritize different streets for different modes – for example one street may focus on moving traffic through the downtown, while another is a pedestrian promenade, while another is a transit mall concentrating transit service and another features a hallmark protected bike facility.

18 Pedestrian ways can enhance networks in downtowns, but care should be taken that pedestrian ways do not take energy and vibrancy away from streets.

19 Greenways/linear parks can provide a unique way to connect downtowns for pedestrians, while providing an open space resource.

20 The major barriers for pedestrians within downtowns tend to be large streets; care should be taken to provide frequent, convenient, and safe crossings across arterial streets.

STREET CONNECTIVITY STANDARD METRICS FOR DOWNTOWN DISTRICTS

Street Connectivity	Connectivity index of all streets: **1.7** links per node
Network Density	Intersections per square mile: **225** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations: **100%** of travel-shed*
Accommodate All Users	Average of highest five pedestrian blocks: **350** feet maximum

DOWNTOWN DISTRICT CASE STUDY: DOWNTOWN LEHI

Downtown Lehi is a classic Utah small town downtown, with a relatively consistent, dense grid of streets and blocks. While the connectivity in this area is better than most other case study areas this guide explores, there is plenty of room for improvement – and this area has a higher standard to achieve in the downtown context type.

Current connectivity profile

The current profile shows how Downtown Lehi is generally a very well-connected place, yet because the standards for a Downtown District are so high, there is room for improvement. This is especially true for the Pedestrian Block metric – even though the Lehi grid is made of blocks 430 feet long, there are five places where the pedestrian block averages out to nearly a quarter mile. Improvements will focus on improving the pedestrian network and also increasing the network density with opportunities for redevelopment.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.49	145	86%	1238 feet
Percentage of Standard	70%	64%	86%	28%

Potential Strategies

Plans and Policies

- Develop a plan to restore/complete the grid.

Street & Development Standards

- Grid repair/enhancement standards, including requirements that new development restores/completes the 430-foot block grid and incentives to infill the grid (215-foot blocks or mid-block pedestrian ways).

Retrofit strategies

- Create more pedestrian crossings across the eastern segment of Main Street.
- Fill in missing sidewalks.
- Create pedestrian connection between Main and 100 South by Kohler's grocery store.
- Change drive aisle into full street: Extend the cul-de-sac of pool drive to 500 East.

Managing connectivity

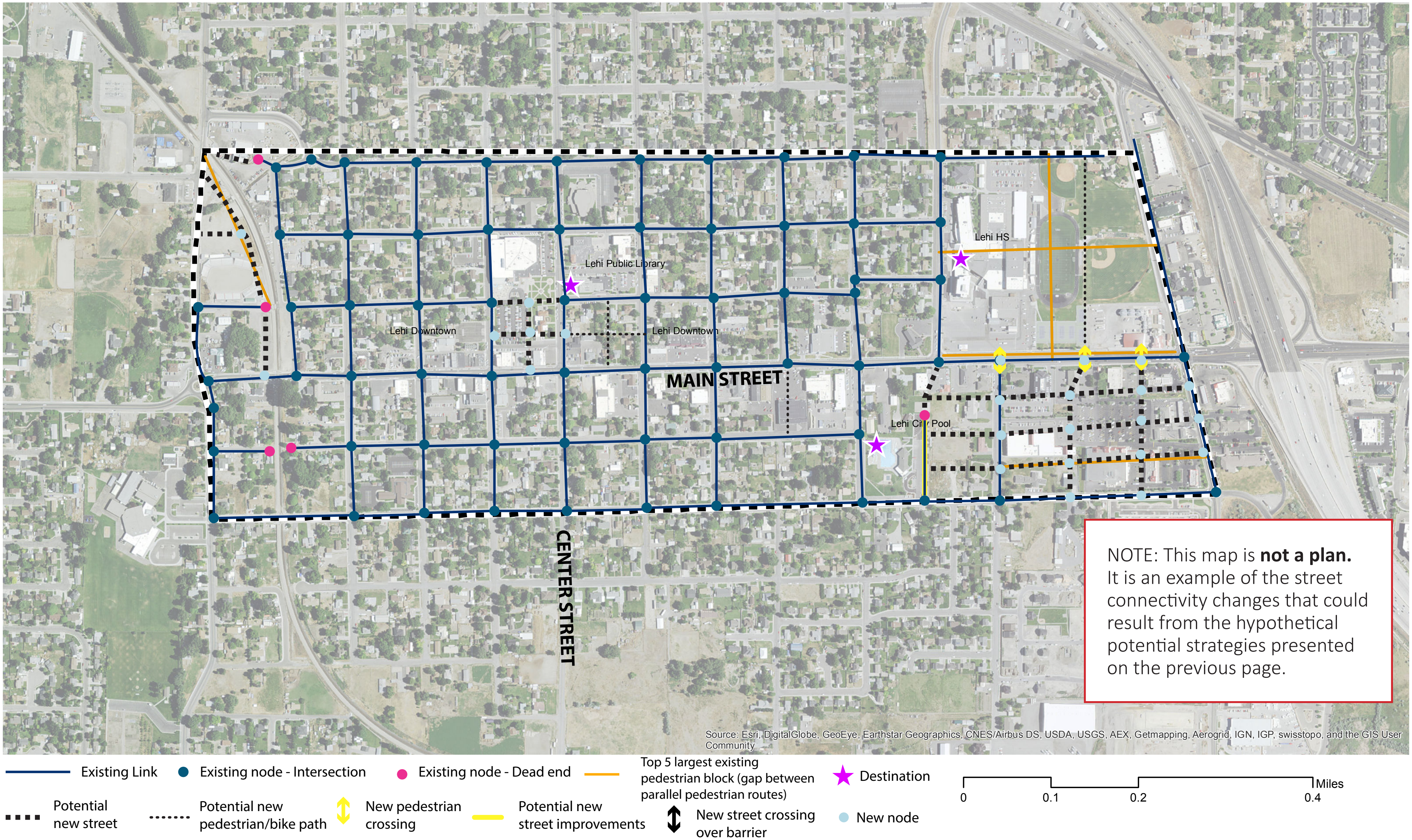
- Develop complete streets standards.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity on all counts. The network shown would improve especially the network density by 41 percent, while increasing the link-node ratio by 15 percent. The improvements to the pedestrian network would also substantially reduce the pedestrian block size.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.57 *(+15%)*	204 *(+41%)*	87% *(+1%)*	1006 feet *(-19%)*
Percentage of Standard	81%	91%	87%	35%

DOWNTOWN LEHI: POTENTIAL CONNECTIVITY IMPROVEMENTS



CAMPUS DISTRICTS

A large land use such as an educational campus, shopping center, business park, or entertainment/lifestyle center.

Street connectivity

1. Streets in campus environments are often private internal streets and drive aisles.
2. Campus environment streets often have lower levels of connectivity within the campus because they are designed to lead to specific destinations and parking areas.
3. It is important that a campus district's internal network is well connected to the surrounding networks; internal and external streets should align.
4. A well-connected pedestrian network is as vital in a campus as it is in a downtown, since many people, even if they drive to the campus, access their destinations by parking once and walking. In a campus, nearly everyone is a pedestrian.

Network density

5. Because of the size of many of the uses typically located in campus environments, such as educational buildings, office buildings, and large stores, the density of the street network is often low in campuses. However, a dense, connected pedestrian and bike network is important to make up for this lack of street network density.
6. It is often possible to fit a campus type environment into the pattern of a dense, connected neighborhood around it.

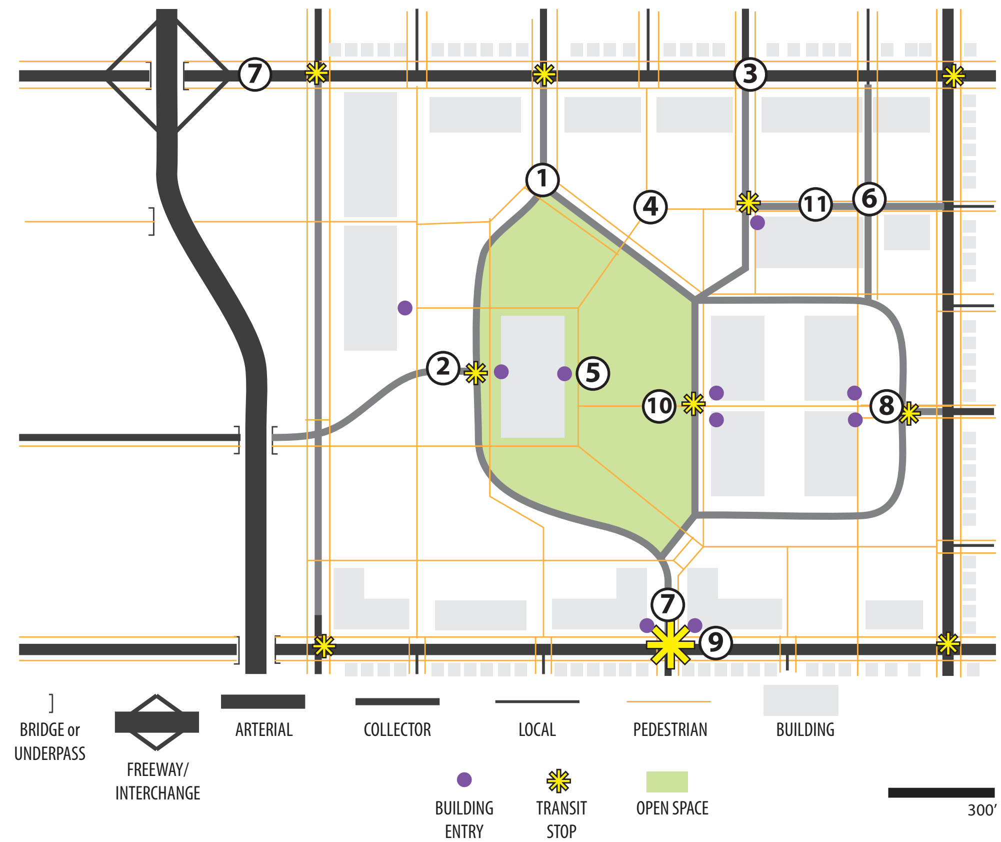
Destination access

7. Like downtowns, campus environments are often community-wide and regional destinations, so good access to them from regional transportation facilities such as freeways and rail stations is vital.
8. Care should be taken to connect pedestrian paths to building entries and provide efficient and safe connections among campus buildings.
9. It is often advantageous to have building entries fronting onto walkable streets in a campus district in order to maximize access to destinations and a pedestrian-supportive environment.

Accommodate all users

10. Campus districts, as major destinations, should all be highly multi-modal. The level of importance for walking, bicycling, and transit depends on the specific use – secondary educational institutions, for example, should especially emphasize connected, dense networks for pedestrians, bicyclists, and transit riders.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS
FOR CAMPUS DISTRICTS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

11. An important part of street connectivity in campus is ensuring that the network is comprised of streets and not "drive aisles" of parking lots. Building a network of streets, even internal streets, helps the network to support all modes.

STREET CONNECTIVITY **STANDARD METRICS** FOR CAMPUS DISTRICTS

Street Connectivity	Connectivity index of all streets:	**1.5** links per node
Network Density	Intersections per square mile:	**50** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations:	**100%** of travel-shed
Accommodate All Users	Average of highest five pedestrian blocks:	**500** feet maximum

CAMPUS DISTRICT CASE STUDY: THANKSGIVING POINT, LEHI

Thanksgiving Point is a fast-growing office park with some cultural and entertainment elements and presents a good opportunity to study a campus-type environment. The area is split by Interstate-15, which creates a barrier for movement within it. It has the benefit of a UTA FrontRunner rail station but the rail tracks also present another barrier to the west of the area. Thanksgiving Point has few public streets connecting its large properties, creating a low-density network that also poses a challenge to connectivity.

Current connectivity profile

The current profile shows how Thanksgiving Point, while well-connected, has a lower network density than it should and a very poor ability to connect people to its key destinations and move pedestrians around. Improvements will focus on these latter three areas, especially improving the pedestrian network and overcoming the I-15 barrier to improve the travel-sheds of key destinations such as Adobe.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.42	29	36%	2690 feet
Percentage of Standard	83%	57%	36%	19%

Potential Strategies

Plans and Policies

- Street connectivity plan addressing street densification/infill; pedestrian circulation; I-15 barrier connections; and specific improvements enhancing access to key destinations.
- Explore a special district or a Transportation Management Association to pay for street connectivity improvements.

Street & Development Standards

- Require maximum block length of 800 feet.
- Require maximum pedestrian pathway spacing of 350 feet.

Retrofit strategies

- Convert drive aisles/gated streets to full streets – i.e. south of Vivint and adjacent to Electric Park and throughout Thanksgiving Point entertainment area.
- Create pedestrian/bike bridge at Adobe campus.
- Create more direct street connection from Executive / Ashton through parking lots to FrontRunner station.
- Explore pedestrian and bicycle greenway connecting key destinations: Thanksgiving Point entertainment, Ashton corridor, food and shopping, and the FrontRunner station.

Managing connectivity

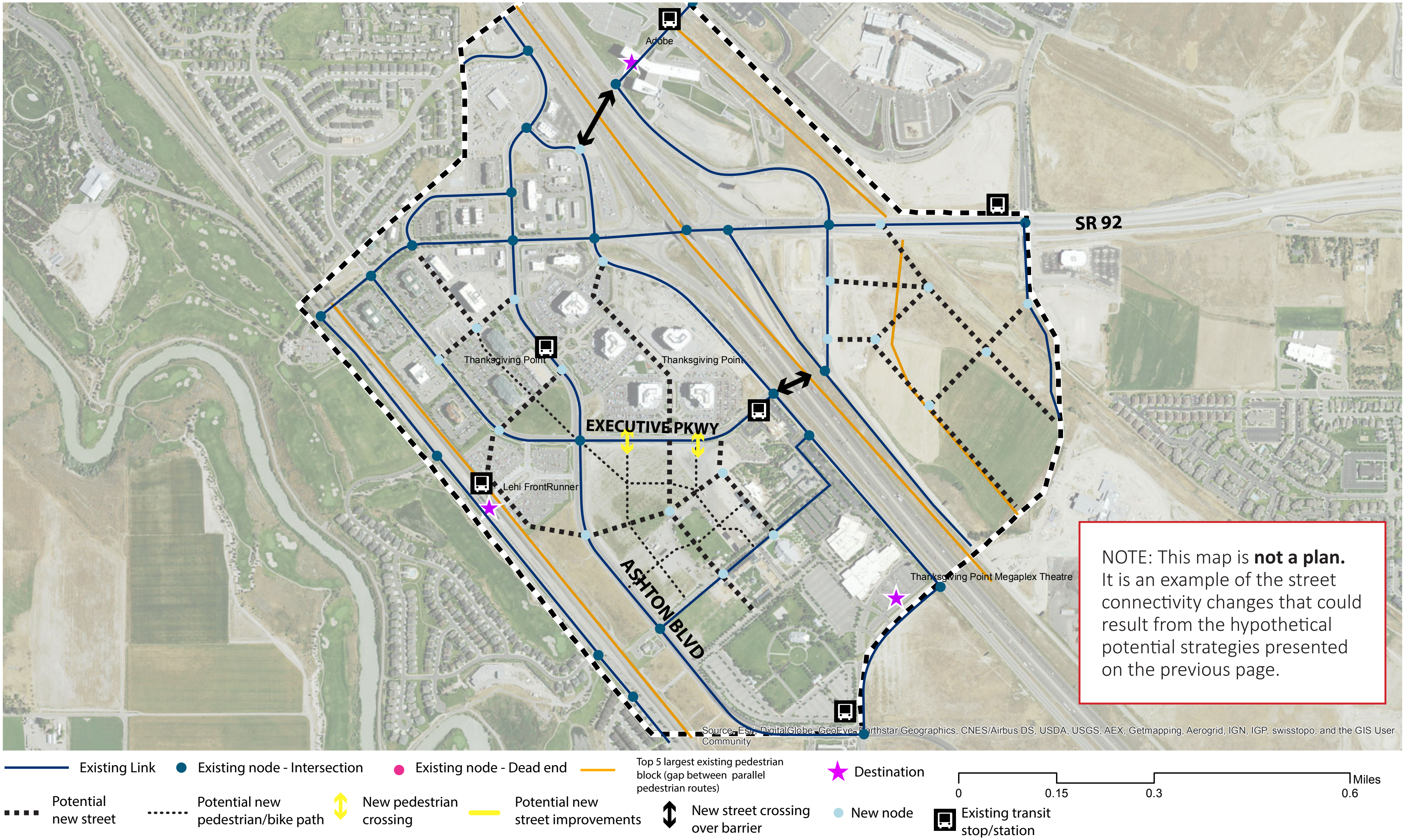
- Special District / Transportation Management Association ongoing management of connectivity issues.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity substantially. In this network, the link-node ratio and the intersection density have increased beyond the standard for campuses.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.52 *(+25%)*	52 *(+83%)*	56% *(+56%)*	2068 feet *(-23%)*
Percentage of Standard	105%	105%	56%	24%

THANKSGIVING POINT: POTENTIAL CONNECTIVITY IMPROVEMENTS



NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

INDUSTRIAL DISTRICTS

An area focused on production or distribution activities.

Street connectivity

① Industrial districts are often located adjacent to major transportation facilities such as rail yards and railroads, major collectors and arterials, and ports (dry or water). Because of these transportation facilities and large land parcels found in industrial districts, street connectivity can sometimes be limited.

② Older industrial districts may have streets that do not accommodate the geometric design needed for 53-foot trucks and large combination vehicles (LCVs).

③ Adequate turning radii at interchanges, intersections, and business entrances are needed for 53-foot trucks and LCVs.

④ Longer turn lane lengths and signal timing, particularly left turn signals, need to be adjusted for high levels of truck traffic at intersections and interchanges.

Network density

⑤ New industrial development should promote a grid street network with collector streets placed every four to six blocks and arterial streets every one mile.

⑥ Access management should be controlled with one to two major accesses to large land parcels.

Destination access

⑦ It is often the first and last mile of freight that is most difficult for mobility of freight vehicles.

⑧ Arterial roadways such as freeways and parkways are necessary access to industrial districts because of the large truck volumes associated with such development.

⑨ Multiple accesses to industrial districts are important for freight mobility.

⑩ Sufficient space is needed for the expansion of freight land uses in industrial districts. Therefore, additional roadways and land are needed for future use.

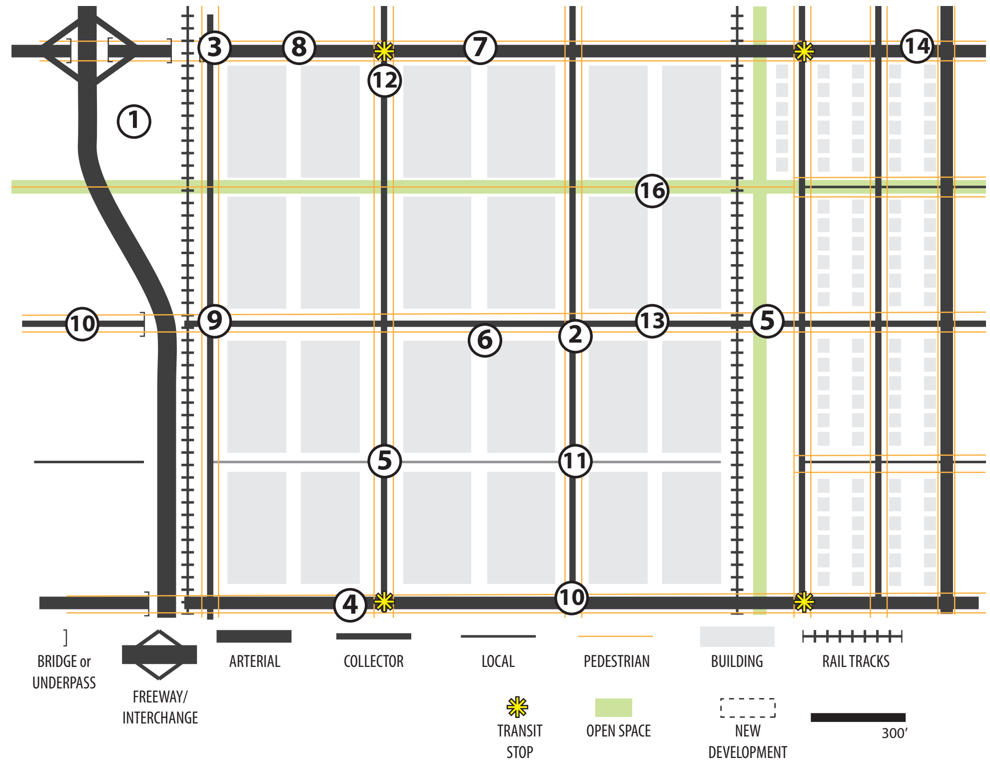
Accommodate all users

⑪ If geometric roadway designs work for trucks, they will work for automobiles.

⑫ Industrial districts are usually major employment centers and access to transit is needed in industrial districts.

⑬ Bike lanes and routes also provide employment access to industrial districts.

STREET CONNECTIVITY ISSUES AND CONSIDERATIONS FOR INDUSTRIAL DISTRICTS



The diagram above shows a reasonably ideal connected network for this context type and how the issues and considerations can be addressed.

⑭ Establish truck routes in non-industrial districts for the following reasons:

- Help trucks avoid inappropriate residential streets.
- Reduce traffic congestion throughout the municipality and the region.
- Increase logistics operations that will benefit businesses, transportation providers, and consumers.
- Improve the economic competitiveness and attractiveness of industrial districts.
- Provide a major benefit to the municipality's economy.

STREET CONNECTIVITY **STANDARD METRICS** FOR INDUSTRIAL DISTRICTS

Street Connectivity	Connectivity index of all streets: **1.5** links per node
Network Density	Intersections per square mile: **50** intersections per mile
Destination Access	Average 1/2 mi travel-shed percentage for key destinations: **100%** of travel-shed
Accommodate All Users	Average of highest five pedestrian blocks: **1500** feet maximum

INDUSTRIAL DISTRICT CASE STUDY: LAYTON INDUSTRIAL AREA

The industrial area in Layton oriented along Hill Field Road contains major distribution centers for companies such as the grocery chain Smith's. Issues raised in this case study include how well the area is connected for the freight trucks that must access it from I-15 and circulate within it, as well as the ability of the area to not be a barrier to citywide travelers moving through it.

Current connectivity profile

The current profile shows how the Layton industrial area already scores well on the metrics relative to the standards for an industrial area. The largest area needing improvement is the reduction in the pedestrian block size, so improvements will largely focus on that.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score	1.58	48	62%	3019
Percentage of Standard	117%	95%	62%	50%

Potential Strategies

Plans and Policies

- Identify key community-wide bike and pedestrian routes through the area.
- Leverage and maximize for all modes the existing rail crossings - especially the grade-separated crossing.
- Identify potential new streets crossing the rail trail westward if industrial land uses will expand to the west.

Street & Development Standards

- Future industrial development should align streets to create 4-way intersections.
- Manage cul-de-sacs in industrial area and adjacent development.

Retrofit strategies

- Fill in sidewalk gaps on Hill Field Road.
- Create more east-west pedestrian/bike corridors through the industrial area based on routes identified in policy.
- Consider long-term east-west connection in southern area to leverage rail crossing and avoid trucks going through adjacent neighborhood.

Managing connectivity

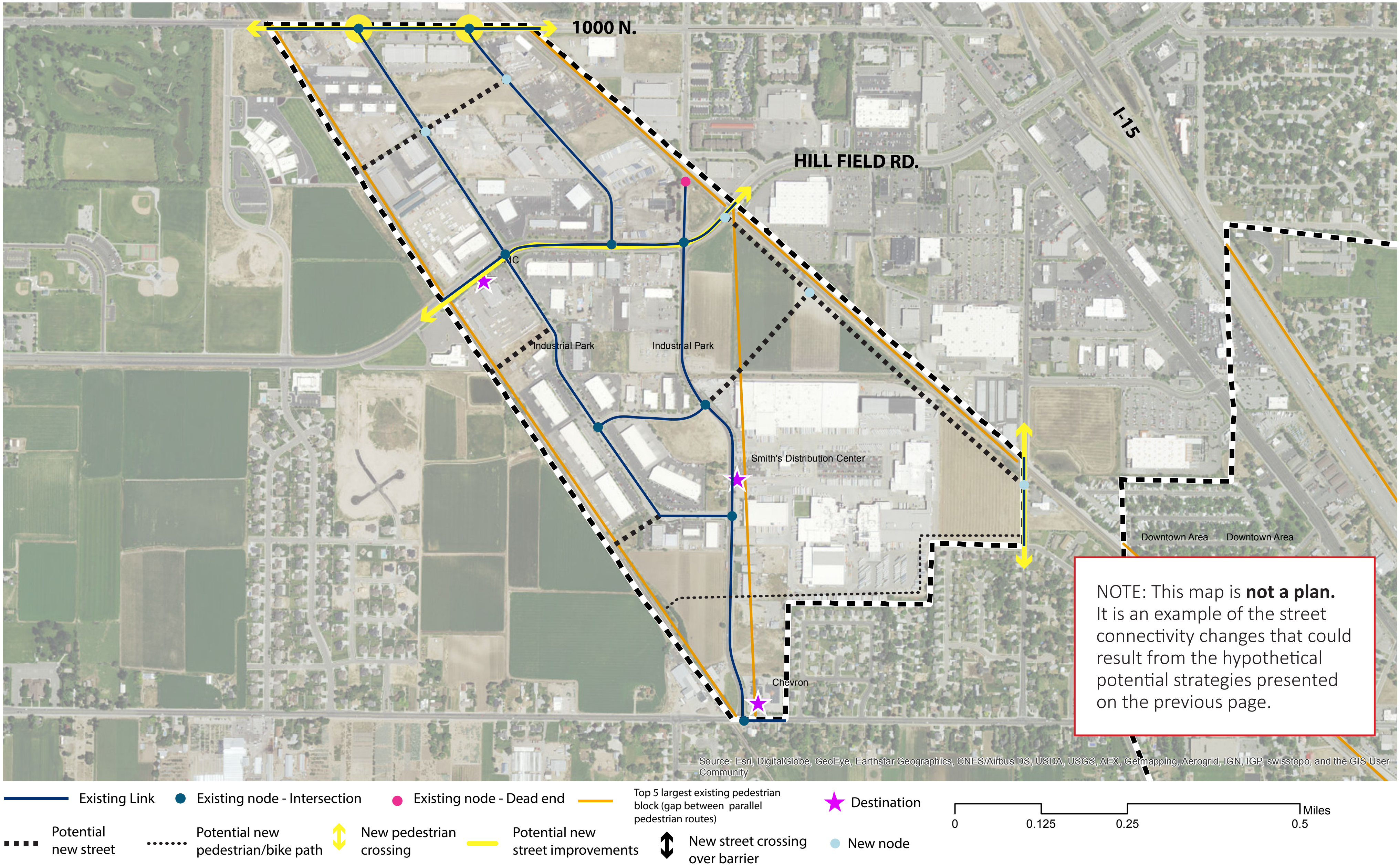
- Ensure ability of streets and intersections to handle truck movements.
- Balance freight and other modal use of Hill Field Road.

Improved connectivity profile

The potential strategies would produce a network that improves the connectivity, increasing the link-node ratio and intersection density modestly.

	Connectivity Index	Intersection Density	Average Destination Travel-shed %	Average Top 5 Pedestrian Block
Raw score *(change)*	1.69 *(+18%)*	58 *(+22%)*	83% *(+33%)*	2390 feet *(-21%)*
Percentage of Standard	138%	116%	83%	63%

LAYTON INDUSTRIAL: POTENTIAL CONNECTIVITY IMPROVEMENTS



NOTE: This map is **not a plan.** It is an example of the street connectivity changes that could result from the hypothetical potential strategies presented on the previous page.

3.4 Connect your community in 3 Steps

The following three steps walk you, the practitioner, through how to evaluate the street connectivity in your community, and then how to employ appropriate strategies to improve street connectivity.

STEP 1: EVALUATE YOUR COMMUNITY

Define your area. The street connectivity evaluation depends on defining a clear area to measure. This area can be as small as a few blocks and as large as the entire Wasatch Front. Start by identifying the area on a map and measure its area in square miles. Be sure to exclude any areas that present constraints for building, such as protected natural open space, steep slopes, or water bodies.

Note that the Utah Street Connectivity Guide's standards are set up to incorporate streets that may also define the study area's boundaries. For example, if the border of your study area on one side is a collector street, incorporate that collector and its intersections as part of your study area.

Identify your context type. How connected your community should be, and the strategies you should use to improve the connectivity, is based on what kind of community it is.

Two primary questions inform this step:

- What scale are you analyzing – a neighborhood, a city, or an entire region or county?
- What is the character of the area you are analyzing – is it a primarily residential neighborhood? If so, is it more urban, suburban, or rural? Or if it is not residential, is it a downtown, an industrial area, or a campus-type environment?

To answer these questions, reference the ***Contexts for Street Connectivity*** *Section 3.1* as well as the typology descriptions in the *Design Guide and Case Study Results Section 3.3*. Note that the connectivity type is up to you – however, the standards for the different types will direct you toward higher or lower connectivity as well as different context-appropriate strategies.

Measure connectivity in your community. Use the metrics identified in the ***Measuring Street Connectivity*** *Section 2.1* to assess your area.

You have the choice of using just the two basic connectivity metrics, which are relatively quick to measure, or the basic metrics plus the two advanced metrics. While the advanced metrics take more time to measure than the basic ones, they form a more complete picture when combined with the basic measures.

For a ready-made place to calculate your community's street connectivity, download the **Connectivity Calculator** *on the Wasatch Front Regional Council website.*

Calculating the measures involves obtaining some basic information about your area for the basic metrics. The advanced metrics require more information and potentially specialized software. Enter your information into the Connectivity Calculator. Depending on the type you entered, the Connectivity Calculator will automatically give you your area's score for each of the metrics that you measured.

See how your area rates. Take the results of your measurements and compare them against the standards given for the type you identified. These standards are found in the descriptions for each type as well as *Section 3.1*. Where is your community weak or strong? How far are you from the standards for each type?

If some of the aspects of connectivity in your area are so far from the context type standard, consider choosing a different type. If, for example, you have identified your community as an urban neighborhood, but the network density is much closer to the standard for a suburban neighborhood, then perhaps your area is more of a suburban neighborhood.

STEP 2: DEVELOP STRATEGIES

Build a list of strategies. Reference your area's type description, which contains a list of considerations organized by the different aspects of connectivity. This list of considerations will point you to issues to consider in the aspects you need to improve in your area, and help you brainstorm opportunities. Look through the list of strategies in the ***Strategies, Best Practices, and Tools to improve Connectivity*** *Section 2.2*.

Compile a list of strategies that you think will improve the aspects of connectivity that you have identified. It is a good idea to have a blend of different types of strategies that complement one another. For example, Plan and Policy strategies provide a foundation for improving a community's connectivity and should be complemented by strategies that can implement those plans such as Street and Development Standards or capital improvement projects. It is good to understand that if you need strategies for a built-out community, the Retrofit Strategies may be more effective while if you are addressing connectivity in new developments, standards may be more effective.

Calculate the street connectivity metrics once the strategies are implemented. Update your map of links and nodes (and the advanced metrics if you did those to reflect the physical street connectivity changes you expect when your suite of strategies is implemented. For example, if you have an undeveloped area and plan to enact a minimum street connectivity index, draw a new street network that reflects that index.

Then, re-count your links, nodes, and other elements and re-calculate your metrics. Enter your improved connectivity metrics into the Connectivity Calculator, which will automatically determine your estimated improved metrics.

In addition, you can use the re-calculate technique to measure the effect of a transportation master plan or another planned network on street connectivity.

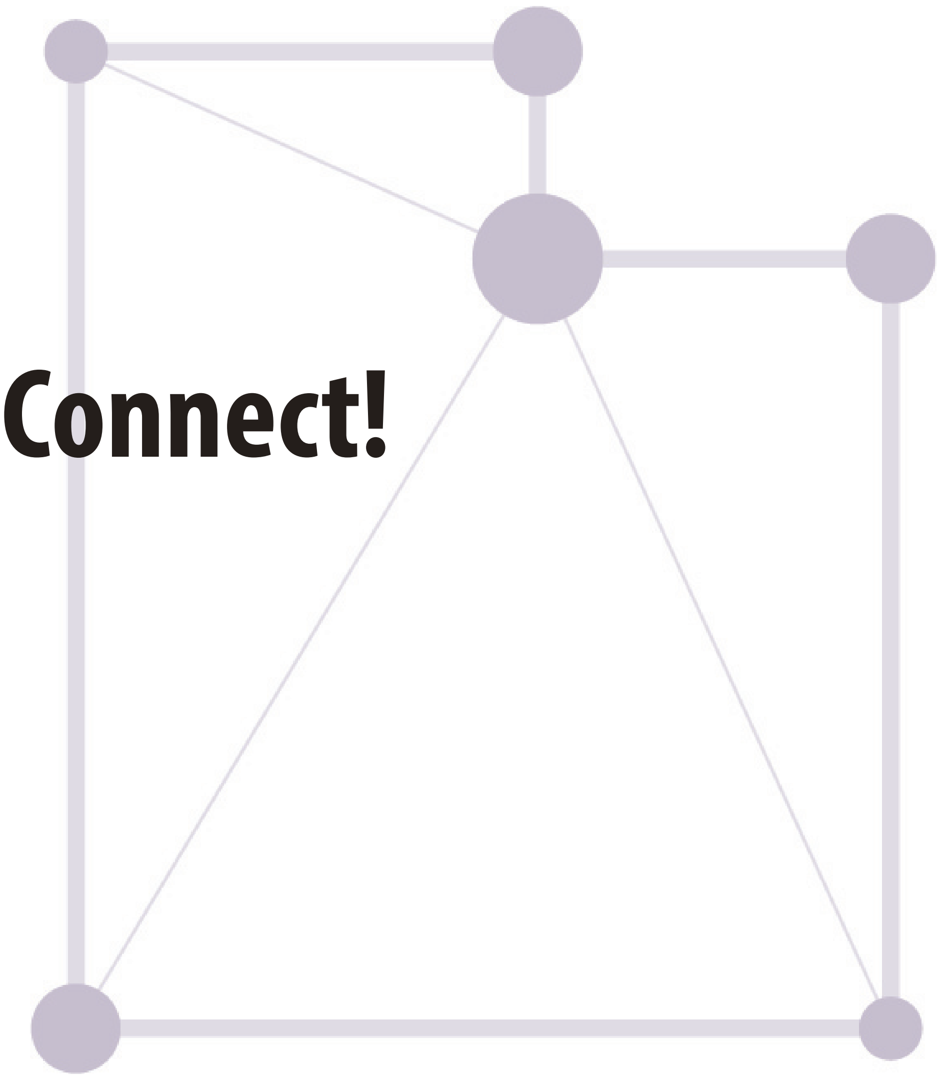
Make a list of the benefits of your connectivity improvements. Use the ***WHY is connectivity important?*** *Section 1.3* to estimate the benefits that will result from implementing your connectivity strategies. Focus on the benefits that will be most compelling to your community.

STEP 3: IMPLEMENT STRATEGIES AND MONITOR PROGRESS

Implement your strategies. Refine your suite of strategies and make policy arguments to other local jurisdiction or agency staff and officials for the strategies that you think will be most effective. Work with colleagues and stakeholders to implement the strategies.

Monitor progress. In the years after you implement your strategies, use the street connectivity metrics to monitor the improvement of street connectivity in your area. This ongoing monitoring is valuable for you to fine tune your community's policies, but it is also adds to the knowledge base in the planning and engineering communities with regard to street connectivity. A relative dearth of data related to roadways, active transportation usage, and other factors that weigh heavily on determining the success on increased connectivity means that some of these measures have room for improvement in their precision and predictability.

CONCLUSION



Thank you for reading the Utah Street Connectivity Guide. This guide has provided you with a top-to-bottom, A to Z rundown of everything street connectivity. You have learned what street connectivity is and the range of benefits it brings to Utah communities. Especially compared to street widening, street connectivity provides equal or better mobility benefits with a multitude of community benefits that widening does not create. You have learned how to measure street connectivity. You have learned of a range of ways to increase street connectivity in communities, from high-level policies to detailed street development standards to capital improvement projects retrofitting built-out areas. You have reviewed the series of case studies that apply these tools in specific Utah communities and result in specific benefits. Finally, you have learned that the best street connectivity improvements depend on the type of community, neighborhood or district you are planning.

Perhaps most importantly, we hope that this guide has conveyed that street connectivity can benefit your community regardless of what type of city, town, county or region you are – there are ways to increase connectivity and network density, to link people to destinations, and improve the pedestrian network that respect your community character and values.

Now, it is up to you to use these tools and connect your streets in a way that is appropriate for your community. Good luck!

Additional resources for you:

- Utah Street Connectivity Guide Appendices:
  - Public Outreach Summary
  - Literature Review
  - Staff and Community Surveys
- Connectivity Calculator: a Microsoft Excel spreadsheet that provides shortcuts for calculating the four street connectivity metrics used in this guide.
- Lehigh Valley Planning Commission Street Guidance Document: another connectivity guide that complements this guide.
- Lehi City street connectivity standards: Lehi, a city that participated in this stud, created a set of connectivity standards highlighted on pages 28 and 29. Contact the city or go on its website for the full standards: www.lehi-ut.gov.

UTAH STREET **CONNECTIVITY** GUIDE

APPENDIX

APPENDIX

Literature Review

STREET CONNECTIVITY STUDY

Literature Review: Final Report

Authored by:
Utah Traffic Lab, University of Utah
and
Parametrix

Date of Research: March – April 2016

Report Date: June 20, 2016

INTRODUCTION

Street connectivity refers to the ways in which our streets are linked to one another. Numerous studies and projects have proven the benefits of better street connectivity when it comes to accessibility for all users, reduction in congestion and improvement in travel times, improvements in safety and security for all users, environmental benefits, economic development, community resiliency, and better livability.

This literature has explored the impacts of several built environment features on transportation behavior. Various facets of street connectivity have been identified as some of the most important features of a built environment, and thus have a major impact on travel behavior. By changing travel behavior, street connectivity makes a direct or indirect impact on many aspects of daily life such as a person's choice of ways to travel and to the ability to move about the community and region, access to his or her community, and his or her safety, health, and economic well-being.

In addition, street connectivity influences the effectiveness of a community's infrastructure, emergency access, its compatibility with other jurisdictions and the region as a whole, its ability to manage its growth, and its relationship to the environment. Thus, understanding different ways to define and measure street connectivity and how it shapes and impacts these aspects of communities will help to plan and design informed policies.

At the onset of the Utah Street Connectivity Study, a working group including representatives of public agencies and cities in the region gathered and developed a refined list of these community goals potentially achieved by better street connectivity. This list includes:

- regional and community mobility;
- transportation choice;
- accessibility to destinations;
- safety and health;
- effective infrastructure;
- community livability
- economic vitality;
- environmental stewardship;
- interlocal and regional compatibility;
- overcoming geographic barriers; and
- growth management.

These goals will be the framework of the Utah Street Connectivity Study, informing the benefits we explore and the strategies that could achieve those benefits.

This document is structured to explore three key questions:

- WHAT is street connectivity?
- WHY does street connectivity matter?
- HOW can we achieve street connectivity in our Utah communities?

Each of the following sections will explore one of these questions.

WHAT IS STREET CONNECTIVITY? WAYS TO MEASURE HOW STREETS ARE CONNECTED

While simple in idea, street connectivity is complex to measure. Street connectivity can refer to a number of aspects of the street network, including the measure of density of network connections and directness of paths. Good street connectivity has many short links, numerous intersections that connect joining roadways, and avoid cul-de-sacs (Victoria Transport Policy Institute (VTPI), 2015) (Figure 1). Street connectivity includes both the quantity and quality of connections (Scoppa, 2015). In its core, street connectivity reverts to the main function of streets, which is connecting spatially-separated places and enabling movement between them. It relates to the number of intersections along a segment, and asserts the overall connectivity of an area to the system (Lehigh Valley Planning Commission (LVPC), 2011). In such a network, travel distances decrease, numerous shortest paths exist between each origin and destination, more destinations become accessible within the given time budget, active transportation becomes a viable choice, and the response time for emergency services reduces.

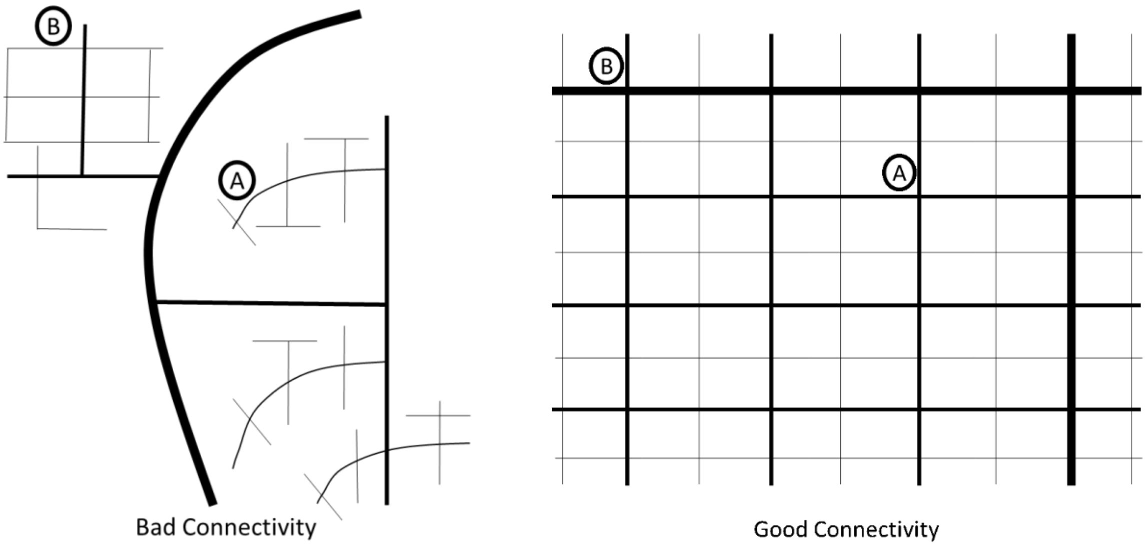


Figure 1: Connectivity Impacts on Accessibility

The two networks in Figure 1 differ in a number of ways:

- **They have different levels of connection:** In the network on the right, the intersections are individually more efficient – i.e., they are doing more work – than in the network on the right.
- **They have different network densities**: Assuming they are the same scale, the network on the right has a higher number of connections and links than the network on the left.
- **They have different abilities to connect to specific destinations**: The network on the right offers a higher number and more direct routes to connect between points A and B, and from the rest of the network to these destinations.
- **They vary in quality for different modes**: The network on the right offers several streets of similar type, meaning that crossing these streets for pedestrians and bicyclists will be

easier than in the network on the left, which offers lots of smaller local streets and one major wide street that is probably difficult to cross on foot or by bike. A well-connected network provides travel options for all types of mobility, such as automobile, transit, walking, and biking. In this sense, street connectivity means more than just a connected series of lines, by looking at how the lines function on the ground.

- **They are different styles of networks:** The most obvious difference between the two networks is that the one on the right is a grid pattern while the one on the left is a branching pattern with many cul-de-sac ends. Different street patterns are directly related to street connectivity (VTPI, 2015). In a grid street system, streets are usually highly connected, straight, and parallel and intersections are usually 4-legged and perpendicular. In a modified grid system, streets are usually well connected, but many are short and there is significant number of T-intersections. In a hierarchical network, streets are less connected, with many cul-de-sacs and connections to arterials. The less-connected network shown in Figure 1 is an example of a hierarchical network. A hierarchical network emphasizes mobility along high-speed and high-capacity arterials. On the other hand, the grid network in Figure 1 emphasizes accessibility by supporting all transportation modes and traffic dispersion.

These differences combine to affect travel behavior and other aspects of life. In Figure 1, points A and B are approximately the same distance apart on the map, but the trip distance in a poorly-connected network is almost three times longer than in a well-connected network. Consequently, bad connectivity tends to increase total vehicle travel, traffic congestion, and accident risk. The poorly-connected route also requires entering and exiting the arterial route (high speed) which can increase the risk of an accident. In a network with bad connectivity, walking and biking are not viable transportation choices due to crossing high-speed and high-volume roads.

The following section explores how these differences can be measured.

Street Connectivity Measures

There are many studies that address measuring street connectivity. A good measure should characterize the street connectivity accurately, and be determined easily (applicable). Most connectivity measures link travel behavior to urban form.

Generally, all measures can be given on the network level, but they are categorized based on the parameters needed for calculation:

- the level of connection (such as connected intersection/node ratio, connectivity index),
- densities (block length, size and density, street length and density, intersection density),
- ability to connect to specific destinations (areas, route directness, accessibility index, effective walking area),
- quality of routes (lengths and sizes among others), and
- types of street and intersection configurations (percentage of four side blocks, percentage of four-way intersections, percentage of cul-de-sacs, connected intersection/node ratio).

Table 1 presents some of the most widely-used measures, classified by the predominant level (network, block, street, and intersection) (Dill 2004, Berrigan et al. 2010, Zhou et al. 2014, Tasic et al. 2015, Scoppa 2015, VTPI 2015).

TABLE 1 Street Connectivity Measures

Measure	What does it measure	Description
Connectivity index/Link-node ratio	Level of connection	Number of links divided by the number of nodes in an area
Connected node ratio	Level of connection	Number of street intersections divided by the number of intersections plus cul-de-sacs
Connected intersection ratio	Level of connection	Number of connected intersections divided by the total number of intersections
Total blocks	Network density	Number of blocks within a network
Block length	Network density	Length from the curb of one side of the block to the curb on the other side of the block (or between intersection mid-points)
Block size	Network density	Area of the block (mi^2)
Block density	Network density	Number of blocks per mi^2
Street network length	Network density	Total length of streets within a network (mi)
Street density	Network density	Street network length divided by total network area
Total intersections	Network density	Number of intersections within the area
Intersection density	Network density	Number of intersections per unit of area
Effective walking area	Specific destinations	Number of parcels within 5 min walking time (¼ mi walking distance) from origin
Accessibility index	Specific destinations	Actual travel distances divided by direct travel distances
Pedestrian route directness	Specific destinations	The ratio of physical route distance to straight line distance between two points
Percentage of one-way streets	Qualities of routes	Length of one-way streets divided by street network length
Percentage of four side blocks	Network configuration	Percentage of area with four side blocks
Percentage of cul-de-sacs	Level of connection/network configuration	Number of Cul-de-Sacs/Number of nodes
Percentage of four-way intersections	Network configuration	Percentage of area with four-way intersections (shows the grid pattern of a network)

There are many additional measures used for street connectivity in the literature and practice (Tresider 2005, Yi 2008, Scoppa 2009, Berrigan et al. 2010, Zhou et al. 2014, Scoppa 2015). The presented table shows the most common ones that are easier to calculate and can be applied to any network. Among these measures, block length, block size, block density, intersection density, 4-way intersection density, and connectivity index are easy to calculate and have impact on many different aspects including: accessibility, active transportation, land use mix, public health, emergency access, and walkability. Therefore, they are the most-widely used measures in policies. However, the block measures may not be appropriate for the analysis of small-scale neighborhoods. On the other hand, link-node ratio and connected node ratio don't consider the block size, spacing of intersections, and length of the links (Zhang and Kukadia 2005). It is important to know that each street connectivity measure has its advantages and disadvantages. For a large-scale analysis, the density measures are more widely used and expected to perform better.

The measures presented in Table 1 are selected as the most applicable for Utah conditions, based on the previous studies that considered street connectivity issues and their importance to local agencies. Additional measures for including public transit and biking should be considered and added to the list – these fall into the "qualities of routes" category, which is the most under-represented on the list. The measures should be classified for suburban and urban, as well as regional, community and neighborhood levels to capture street connectivity for different typologies and levels that will be analyzed in this study.

Roadway Functional Classification and Relation to Connectivity

When discussing street connectivity, it is important to consider that perhaps the major driver of the design of street networks over the last half-century has been the Functional Classification System. The Federal Highway Administration (FHWA) functional classification of highways (FHWA Functional Classification Guidelines 2011, AASHTO Green Book 2011, LVPC 2011) is based on the hierarchy of movements (such as the main movement, transition, distribution, collection and local access), as well as trade-off between mobility and accessibility. Arterials have the highest mobility and lowest destination accessibility, local streets have highest accessibility to destinations but lowest mobility, while collectors are in between and they provide links between arterials and local streets (Figure 2). Mobility is a measure of moving efficiently and comfortably, and is characterized by high speeds, lower travel times, and small delays. Access is the ability to approach a desired trip destination and is needed at both ends of any trip. Based on the function that a roadway needs to perform, a set design criteria for different functional classes are established, such as speed, lane width, and alignment. The Functional Class system aims to improve the effective connectivity for motorists by providing both mobility and accessibility. It has been this focus on vehicle mobility and access that has driven the shape of our street networks over the last half century.

However, the Functional Class system has been criticized for lacking in its effectiveness of serving the mobility and access of other modes, as well as a wider range of community goals such as safer streets for all users, less traffic congestion, savings in costs, and reducing the need to provide more capacity on arterial streets. Therefore, connectivity principles should be applied both internally (streets within an area) and externally (connections with arterials).

FIGURE 2 Relationship between Mobility and Land Access in FHWA Classification

WHY DOES STREET CONNECTIVITY MATTER? EXPLORING THE BENEFITS

This section summarizes the literature's findings on how street connectivity achieves benefits associated with the community goals identified in the introduction. These include:

- regional and community mobility;
- transportation choice;
- accessibility to destinations;
- traffic safety
- public health;
- effective infrastructure;
- community livability
- economic vitality;
- environmental stewardship;
- interlocal and regional compatibility;
- overcoming geographic barriers; and
- growth management.

The degree to which the literature supports the existence of benefits associated with these goals varies. Much of the literature has been focused on a few of these goals. The literature points to both direct and indirect benefits of street connectivity. Direct benefits are straightforward outcomes of street connectivity, such as increased mobility, increased use of transit and non-motorized modes, destination accessibility, and community livability. Indirect benefits are added values of street connectivity resulting from direct benefits, such as safety and health, security, economic vitality, and growth management.. In addition, other goals appear to have benefits that on one hand seem to be inherent but also have not been explored to a major degree in the literature.

DIRECT BENEFITS

Regional Mobility

Good street connectivity redistributes traffic among different routes in a network, providing more options and better accessibility for local traffic. This in return frees some of the capacity on the adjacent arterial roads, which are mostly used by the through traffic.

The literature shows the following regional mobility-related benefits are associated with increased street connectivity:

VMT, trip lengths, and travel time:

McNally et al. (1992) analyzed vehicle miles traveled (VMT), average trip lengths, and congestion at links and intersections for two hypothetical networks which tried to replicate the characteristic of neo-traditional (enhanced connectivity) and conventional suburban community (low connectivity). The results showed a significant reduction in VMT and travel time within the network with enhanced connectivity. There are several similar studies with similar types of results (Portland Metro 2004, Zhou et al. 2014).

A reduction in VMTs is usually one of the most easily observed parameters that result from applying street connectivity measures. Summarizing the results from the presented studies (VTPI 2015, Portland Metro 2004, McNally 1992) it can be seen that the implementation of different street connectivity strategies reduces VMTs from about 2% to close to 70% in some cases. In general, the average reduction in VMTs is about 10% in networks with good street connectivity. A greater reduction in VMTs is observed in less dense automobile-oriented urban areas. In grid-type networks, an increase of 10% in relative connectivity for pedestrians is associated with a 23% decrease in VMTs on the local level (VTPI 2015). A reduction in VMTs is directly related with safety and environmental impacts.

Reduction in arterial traffic volumes:

Alba et al. (2005) explored the impact of street connectivity of local residential areas on traffic volume of neighboring arterials. Tallahassee, Florida, was selected as the case study network. The results showed enhanced connectivity can reduce the traffic volume of arterials significantly when the travel speed between arterial and local streets is small, and the capacity of the arterial is small or fully utilized. Tasic et al. (2015) studied the effects of enhanced connectivity on traffic operation in West Valley City, Utah. They simulated and compared twelve different scenarios including enhanced connectivity, street widening, and traffic calming measures for the study area. The results show that enhanced connectivity scenarios accommodate more traffic than the scenarios with street widening, and benefits both traversing and local traffic.

The existing research and practice on street connectivity in most cases supports the findings that greater connectivity reduces traffic volumes on arterials. The main factors that influence this are reduced trip distances, reduced number of trips, multiple alternative routes, shifts from personal vehicles to other modes, and redistribution of traffic throughout the network which increases the network-wide capacity. This increased accessibility in turn increase mobility throughout the network. In general, enhanced connectivity tends to decrease travel time and congestion, and therefore increases the regional mobility. On the other hand, through traffic on local streets must be controlled to prevent deterioration of conditions in local neighborhoods.

Overall network capacity

"Street Connectivity: An Evaluation of Case Studies in the Portland Region," by Portland Metro, found that improved street connectivity decreases overall vehicle traffic demand. However, the same study also found that a side effect of increased connectivity is that additional connecting intersections reduce the overall capacity of regional streets.

As an important side note to the benefits identified above, the Portland Metro study found that returns of connectivity are highest when a network goes from low to moderate density, from 10 to 16 connections per mile. These returns diminish for motorists when a network goes from this moderate level to a higher level of connectivity.

Transportation Choice

Wasatch Front Regional Council (WFRC), Mountainland Association of Governments (MAG) and towns and local communities in Utah are developing plans to promote the ability to shift from personal vehicle usage to other modes of transportation, such as transit and active transportation modes. Many efforts have been made in this direction in recent years. Better street connectivity provides travelers with greater choice of travel modes. In a well-connected network, active transportation modes and transit become more viable choices largely because they reduce walking and bicycling distances among origins and destinations. This means that these types of networks are less automobile-dependent.

The literature shows the following transportation choice-related benefits are associated with increased street connectivity:

Bike and pedestrian mobility

The Portland Metro study found that improved connectivity leads to better mobility for cyclists and pedestrians. Furthermore, the study notes that in contrast to motorist benefits, pedestrian and bicyclist benefits experience increasing returns from medium to high connectivity.

Pedestrian and bike mode share:

A study of urban neighborhoods in Seattle found that the highest proportion of pedestrian trips occur in areas where paths are relatively more direct to nearby destinations on foot than by car (Canada Mortgage and Housing Corporation (CMHC) 2008). Higher values of pedestrian network areas and effective walking areas generate greater increases in walking and reduction of driving. Berrigan et al. (2010) found statistically significant correlation between aggregate measures of street connectivity on one side and walking and biking on the other.

Studies found that the biggest proportion of pedestrian trips (close to 18%) is achieved in networks with good connectivity and pedestrian-focused designs, compared to about 10% of pedestrian trips in networks with poor connectivity (CMHC 2008). According to the same study, a grid-like, well connected network, contributes to about 26% increase in the odds that the residents will meet the recommended level of physical activity through local walking. A study of 24 California cities explored how different network designs impact transportation mode share

(Marshall and Garrick, 2010). The study found that increased street connectivity was highly associated with increased walking and biking mode shares (or with decreased driving mode shares). Between hierarchical networks and more connected networks, walking and biking mode shares tripled from about 6% of trips (combined) to almost 18%. This shows that well connected networks have much higher shares of non-automobile modes.

Better transit performance
Connectivity improves the efficiency of bus transit by providing more direct routes (LVPC 2011). The collector street network plays a major role in improving transit efficiency in suburban areas by providing a connection between arterials (where the bus lines mostly run) and local network for local access, usually by walking. A good collector network creates more options for routing bus transit closer to neighborhoods, eliminating the need for automobile use and having positive environmental impacts.

Selection of non-auto modes:
Ewing and Cervero (2010) performed a meta-analysis of the past literature on the impact of built environment on travel. In this study, built environment measures were organized into five categories called D variables (Density, Diversity, Design, Destination Accessibility, and Distance to transit), which are in direct correlation with street connectivity measures. The results of the study confirm that street connectivity characteristics have significant impacts on transportation mode choice. Berrigan et al. (2010) explored correlation between different connectivity characteristics and measures and active transportation (such as walking and biking). The study found statistically significant correlation between aggregate measures of street connectivity and active transportation. Short blocks and grid-like network structure were found to be the predominant characteristics that lead to active transportation.

Transit ridership:
Transit use is also related to the measures of design, destination accessibility, distance to transit, and demographics (Ewing et al. 2011, Tian et al. 2015). Trip distance for automobile trips is related to development scale, diversity, destination accessibility, and demographics.

Access to Destinations
There is a strong correlation between street connectivity and accessibility. Many studies have used these terms almost as equal, meaning that high street connectivity leads to high accessibility to destinations and otherwise.

The literature shows the following accessibility-related benefits are associated with increased street connectivity:

Pedestrian and bike accessibility:
Yi (2008) explored street connectivity and pedestrian accessibility for typical cul-de-sac and grid networks. He concluded that the grid network provides better accessibility to destinations for pedestrians, but by providing separate pedestrian trails, the accessibility of cul-de-sacs can be improved up to a point where it is comparable with a grid network. Tal and Handy (2012) explored various measures of network connectivity and pedestrian accessibility for non-motorized trips.

They showed that pedestrian network continuity is an important part of non-motorized accessibility, and often neglected in past studies.

One major finding of the Portland Metro case studies (2004) was that pedestrian and bike access to destinations was greatly improved with better connectivity. The study considered three scenarios of different connectivity, and in each, access to a town center from a neighborhood (defined as the percentage of the neighborhood within 1/4 to 1/2 walking/bicycling distance) was measured.

The study found that increased connectivity yields increased access so that 74 percent of the neighborhood was accessible from selected locations in the moderate connectivity scenario, while 99 percent of the neighborhood was accessible in the high connectivity scenario. Access increased due to the decreased distance that pedestrians and bicyclists have to travel to a town center. The ratio of "actual walk distance" to "straight line distance" dropped from 1.4 in the low connectivity scenario to 1.18 in the high connectivity scenario. Finally, walking distance among key origins and destinations dropped 9 percent from the low to moderate scenarios, and 18 percent from the moderate to high scenarios.

Safety and Health

In recent years, many studies have focused on how built environment factors (such as street connectivity and community) affect physical activity and health.

The literature shows the following safety and health-related benefits are associated with increased street connectivity:

Traffic safety:

Street connectivity measures, in combination with traffic calming strategies, have a significant potential to improve traffic safety (LVPC 2011). A local, well-connected network system encourages slower and more cautious driving, since drivers encounter various travel modes and more intersections. As discussed earlier, in a more connected network, the total VMTs will decrease, which reduces exposure and improves safety. Marshall and Garrick (2008) studied different cities in California with different street network shapes and densities. They found that connectivity densities are correlated with road safety outcomes. The highest risks of fatal or severe crashes occurred within low intersection densities. They found that street networks that combine high network density with low connectivity, or low density with high connectivity, significantly increase risks of severe crashes. In another study, Marshall and Garrick (2011) found that more connected, multi-modal street design can significantly reduce traffic injury and fatality rates.

Eyes on the street

The Utah Foundation's "Roads Less Traveled" Research Report points to a potential benefit that could be worth researching further. One consequence of connectivity, the report notes, is "more natural surveillance created by the opportunity of more eyes on the street adds a benefit of safety." This recalls the observations of Jane Jacobs in *The Death and Life of Great American Cities* that two of the most important aspects of good urban neighborhoods are "eyes upon the street," or natural surveillance by inhabitants and proprietors, and a fairly continuous level of sidewalk activity (Jacobs, 1961). Jacobs implies this connection between eyes on the street and a connected network of public streets. The "public peace," wrote Jacobs, is "kept by an intricate, almost unconscious network of voluntary controls and standards among the people themselves." Jacobs' observations led to the Crime Prevention through Environmental Design (CPTED) movement, which sought in particular to make housing projects safe, and also found one cause of unsafe spaces in housing projects was the "superblock" structure where public streets were cut off in favor of open spaces for each apartment complex.

Effective infrastructure
Better street connectivity improves the investment in municipal infrastructure such as utilities and services such as fire and emergency services.

The literature shows the following effective infrastructure-related benefits are associated with increased street connectivity:

Faster service response times and larger service areas
As a study produced by the Lehigh Valley Planning Commission notes, good street connectivity provides "greater, quicker and more direct access to an incident." A 2008 study of municipal services conducted by Charlotte, N.C., found that the citywide average response time rose from 4.5 minutes in the mid-1970s to 5.5 minutes in 2002, as neighborhoods with less-connected street networks were built. But in subdivisions constructed since 2001, the average response time had dropped thirty seconds, to 5 minutes. Cities in North Carolina such as Charlotte and Cary added street connectivity minimums into subdivision ordinances about that time, which required new developments to obey minimum street connectivity standards.

The Raleigh, N.C. Transportation and Planning Department studied fire and emergency management system efficiencies in three different neighborhood types:

(1) older, traditional, gridded development;

(2) neighborhoods built in the 1970s and 1980s with limited connectivity; and

(3) developments from the late 1980s and 1990s with very limited connections and many cul-de-sacs and dead-ends.

They noted that "In all cases, the analysis showed far greater service efficiencies for those older neighborhoods with greater street connectivity. Even when discounting the density of development in these areas, the raw acreage covered in each case confirmed the greater efficiency in fire response coverage for areas with better street connectivity."

The 2008 Charlotte study found that building 300 feet of street between two subdivisions provided a 17 percent increase in service area for a fire station. It saved the city of Charlotte from having to build a fire station to serve the same area. The study also found that the typical coverage area of a snowplow operator is 12 to 15 miles of streets but was six to eight miles in areas with prevalent cul-de-sac streets.

Protection of public investment
Studies have also found that street connectivity protects public investment in infrastructure. The Reason Foundation published a report called "Transportation for America and Taxpayers for Common Sense titled The Most for Our Money: Taxpayer Friendly Solutions for the Nation's

Transportation Challenges," which found that "increasing connectivity of the street network will help improve the efficiency of the transportation network, allowing limited federal funds to be prioritized for pressing transportation needs…with less local traffic on overburdened roadways, reduced wear and tear may prolong the life of many critical infrastructure links. The costs associated with maintaining roadways have grown considerably over the last few years and measures to extend their lifespan may reduce the burden of public expenditure." (Zimmermann et al., 2011)

Community livability

According to Partners for Livable Communities, livability is "the sum of the factors that add up to a community's quality of life." These include the built and natural environments, economic prosperity, social stability and equity, educational opportunity, and cultural, entertainment and recreation possibilities. Consequently, livability is influenced by many of the other benefits discussed in this literature review such as accessibility and walkability. For example, there are several studies showing enhanced connectivity increases walking, biking, and transit use, which are all factors that impact the characteristics of livable communities. Still, livability has its own distinct benefits produced from good street connectivity.

The literature shows the following livable communities-related benefits are associated with increased street connectivity:

Community accessibility:

Twaddell and Toth (2010) discuss the role of mobility, accessibility, livability and sustainability for livable communities, and the importance of each of these factors. They recognize good street connectivity as the major prerequisite for accessibility and livability.

Community walkability:

The ability to be a pedestrian in a neighborhood is related to livability in a number of ways (better mobility and accessibility, lower pollution, safety, public health, the quality of natural and built environment and similar). Straight streets, short block length, and good street connectivity indicate walkability (Calthrope and Poticha 1993, Ewing 1997).

Community life:

Streets shape community interaction and community life (Southworth and Ben-Joseph 1997), and streets have significant physical and social impacts on environment. Narrow streets with low traffic are more friendly for pedestrians, increasing interaction among people. Narrow streets also do not represent a barrier for the two communities on the opposite sides of the street. If the space is not devoted to vehicular use only, different street scaping strategies can be applied, making the environment nicer and healthier (less pollution and noise). However, most of the urban land is devoted to vehicular use (such as streets, highways, parking lots), which in the U. S. is close to one half of the total developed urban land.

INDIRECT BENEFITS

Safety and Health

In addition to direct benefits, street connectivity has been shown to offer indirect benefits related to health, largely stemming from the health effects of increased physical activity.

Obesity:

In the United States, obesity rates have steadily increased from the 1980s in all states. There are several other countries that are experiencing growth in obesity among their population. Several studies have linked levels of street connectivity and obesity and body mass index (BMI) outcomes:

- *Connectivity is one of a few key ingredients of walkable neighborhoods that produce positive BMI outcomes:* Lawrence et al. (2004) surveyed body mass index (BMI) and travel pattern of about 11,000 participants in the Atlanta, Georgia region, between 2000 and 2002. They estimate the impact of land use mix, net residential density, and street connectivity on BMI, time spent in car, and obesity. The results show a strong relation between land use mix and obesity. Saelens et al. (2003) compared 107 adults in two neighborhoods in terms of built environment and physical activity. High-walkability residential neighborhoods with higher residential density, land use mix, and street connectivity reported higher safety and 70 minutes more physical activity within a week than other neighborhoods. More connected networks lead to more walking, and thus healthier weight. Brown et al. (2009) explored the impact of land use measures on BMI, overweight, and obesity in Salt Lake County, Utah. They found that the presence of walkable land uses (defined by walking accessibility or intersection density), relates to healthy weight. Smith et al. (2008) measured neighborhood walkability by population density, intersection density, block length, and land-use diversity in Salt Lake County, Utah, from 2000 to 2006. They found increasing levels of walkability decrease the risk of excess weight. Pedestrian-friendly streets also reduce the risk of obesity and overweight. Frank et al. (2006) evaluated the association between a single index of walkability that incorporated land use mix, street connectivity (intersection per square kilometer), net residential density, and retail floor area ratios, and health-related outcomes in King County, Washington. They found that enhanced connectivity can increase walkability and consequently increase physical activity and decrease BMI, obesity, and even NOx emissions.
- *Connectivity limits time spent in the car:* Lawrence et al. concluded that street connectivity impacts walking time and minutes spent in car, which consequently impacts BMI and population health.

Mortality and disease prevention

The World Health Organization (WHO) estimates that regular use of bicycles (for about three hours per week) can reduce the mortality risk by about 28%. Similarly, consistent walking of about 30 minutes per day can reduce mortality risk by about 22%. Physical activity also reduces occurrences of cardiovascular diseases, type 2 diabetes, breast cancer, color cancer and similar. These reductions are between 10% and 30%, according to the WHO reports. Transit use also has significant advantages on people’s heath through increase in physical activity (walking to and from transit). About 29% of people walking to and from transit achieve the recommended level of 30 minutes of daily physical activity (Besser and Dannenberg, 2005).

Economic Vitality

Inter-regional, regional, and local connectivity has been the subject of several studies and the development of economic impact models that combine transportation benefits with dynamic economic impact analysis. The models generally focus on the following measures of economic activity:

- Increases in productivity
- Job growth
- Reduced transportation/materials costs
- Increased customer base/revenue

Most of the models are built on economic input/output models that measure the relationships between various sectors of the economy of a country, state, region, county, or metropolitan area.

Other measures of economic vitality related to transportation projects, including intermodal accessibility, include access-related measures and geo-spatial measures such as geographic customer base and financial measures (for instance, sales per square foot and real property values). Benefits from improved connectivity vary based on the scale, geography, and land use type. Many of the benefits are measurable in the economy or in the fiscal well-being of households and governments. Some of the benefits are intangible such as increased personal time to spend with family and friends, improved overall health, and well-being and improved area air quality.

The literature shows the following economic vitality-related benefits are associated with increased street connectivity:

Increased market accessibility

On a regional level, improved connectivity reduces travel times of trips, resulting in increased market accessibility. Several models have been developed to measure regional benefits to improved transportation networks. These include the Transportation Economic Development Impact System (TREDIS) model, developed by the TREDIS Software group, that measures total economic impact by industry and productivity impacts for a region and estimates increases in employment and population for an area and impacts on overall competitiveness. The TREDIS model combines the Regional Economic Models, Inc (REMI) economic model with travel demand and geospatial modeling.

Lower materials costs

The reduction of travel time of trips on a regional level also results in lower materials costs because goods can reach their destinations quicker and in a shorter distance saving both wages and fuel.

Increased sales

For a local or neighborhood retailer, connectivity results in improved access to an area's customer base, generally resulting in higher sales per square foot.

Lower household costs

For local residential property owners, connectivity results in lower household transportation costs and increased personal time. Measures on the local level include job growth in all sectors including service and retail, as well as local tax benefits such as sales and property taxes. This leads to increase in job density which translates in to higher job accessibility lowering transportation costs for household.

Walkable communities command price premiums

Street connectivity is a key ingredient in walkable communities, which has its own set of benefits, including economic ones. As researcher Keith Bartholemew writes, "Consumers seem willing to pay a premium to locate in New Urbanist developments that feature higher-than-average densities, a mix of housing types, commercial centers, interconnected streets, and prominent public spaces" (Bartholomew, K. and Ewing, R. 2011) Compact developments can command a price premium of as much as 40 to 100 percent compared to houses in nearby single-use subdivisions, according to Chris Leinberger of the Brookings Institution (2008). The homes at Kentlands, Maryland sell at a 25 percent premium over comparable large-lot developments in the same zip code (Eppli and Tu 1999a). Song and Knaap (2003) show a $24,255 premium for Portland-area homes in New Urbanist areas compared to those in conventional suburban neighborhoods. The hedonic price literature confirms that the market shifts in favor of pedestrian- and transit-design development indicated by survey data and demographic analyses are, indeed, being capitalized into real estate prices" (Bartholomew and Ewing). In addition, when comparing walkability across the Portland metro area, those neighborhoods with above average walkability tend to attract a premium between $4,000 to $34,000 when compared to rest of the region (Cortright 2009).

Walkable areas can also have major impacts on socioeconomic factors. Residents of places with poor walkability are generally less affluent and have lower educational attainment than places with good walkability. (Leinberger, et. al. 2012). Places with more walkability features have also become more gentrified over the past decade (Leinberger, et. al. 2012). Less walkable places also tend to have lower incomes, higher unemployment, and lower education levels. This could provide a barrier for households wishing to move to more walkable areas where there may be a supply of suitable jobs and educational opportunities (Litman 2012).

Improvements in street design can also have an impact on retail rents. Redevelopment of plazas, and redesigns of sidewalks to make it more convenient and safer to walk has coincided with a doubling of rents near Times Square since improvements were made in 2009 (NYC DOT 2013). A Brookings study of the Washington, DC area found that office and retail spaces in areas with good walkability rented for $8.88/sq. ft. and $6.92/sq. ft. more per year, respectively, compared to places with fair walkability, holding household income levels constant. Another study showed that a 10 percent increase in walkability showed a 1 to 9 percent growth in property value and made the point that walkable property types generated higher income and therefore have the potential to generate returns as good as or better than less walkable properties, as long as they are priced correctly (Pivo 2010). More than 5,600 property sales in Jefferson County, Alabama were analyzed between 2004 and 2008, finding that there is a premium for walkability and that this impact reverses as neighborhoods become more car-dependent in the suburbs (Rauterkus 2011)

Transit-related economic benefits:

As discussed earlier, street connectivity has significant impacts on trip mode choice. Many studies looked into economic benefits of public transit (APTA 2012, 2009, Tri-Met 2010, Detroit Transit 2006). The economic benefits of public transit include creating jobs, stimulating development, boosting business revenue, increasing local and state revenues, saving employers money, decreasing pollution, and conserving energy. Encouraging non-motorized modes of transportation and coordinating these modes with public transit, accessibility and, thus, efficiency is increased multiplicatively (Litman).

There are benefits to hotels as a result of improved transit connectivity. From 2006 to 2013, communities with direct transit access to airport terminals experienced a 10.9 percent increase in Average Daily Rates and Revenue per available room (American Public Transportation Association 2013)

Improved transit connectivity can result in improved regional economic capture. In Baxter County, Texas, a study estimated that the County loses approximately $307 thousand in regional income and 8.4 jobs for every million dollars of expenditures switched to auto. The same million spent on bus operations will generate nearly $1.2 million in regional income and 62.2 jobs. General household consumption is positively affected by $426 thousand with an increase in 17 jobs (Miller 1999).

Bicycling related economic benefits:

Street connectivity increases active transportation. Increases in biking and walking will boost economic growth in several major ways (Urban Land Institute 2016, Gotschi 2011):

1. Increasing revenue for bicycle-related industries
2. Fueling redevelopment to boost real estate values
3. Helping companies attract talented workers
4. Making workers healthier and more productive
5. Increasing retail visibility and sales volume
6. Increasing tourism

Many studies have also explored the economic benefits of Traffic Calming Measures (TCM), and reported the same benefits mentioned above (Sermons and Seredich 2001, Local Government Commission's Center for Livable Communities 2002, Burden 2001, Kohl 1999, Boarnet and Greenwald 2001). In TCM section, we will show that TCMs are important part of enhanced connectivity.

Bicycle networks can have a positive impact on home values. The median home values in Minneapolis-St. Paul increased by $510 for every quarter of mile near an off-street bicycle trail, while homes within half-mile of Indiana's Monon Trail had an average of 11 percent increase in sale price when compared to similar homes further away (Alliance for Biking & Walking 2013). Additionally, regional economies can benefit as well. A case study of North Carolina's Outer Banks concluded that the one-time investment into the bicycle network resulted in an annual economic impact that is nine times greater, supporting more than 1,400 annual jobs (North Carolina DOT 2004).

Worker productivity and numerous health benefits have been associated to biking, those who bike regularly saw a 32 percent decrease in sick days taken and a 55 percent decrease in healthcare costs, all while seeing a 55 percent increase in productivity (US Department of Health and Human Services 2002).

The past literature shows the significant impact of non-motorized transportation on economic benefits. Street connectivity is one of the many factors that encourage non-motorized transportation, thus it is essential to consider other factors such as transit oriented design, dedicated bike lanes, and quality sidewalks.

Environmental Stewardship

Street connectivity has major impacts on the environment. Shifts towards transit and active transportation modes in a connected network reduce VMT, delays, and usage of automobiles which reduces air pollution, noise, and energy consumption.

GOALS WITH INHERENT IMPLIED BENEFITS

Some of the identified community goals have not been explored in the literature to a large extent, but street connectivity offers inherent benefits related to them.

Interlocal and Regional Compatibility

Past research efforts used the term "internal connectivity" and "external connectivity" for measuring the connectivity of specific region within itself, and "inter-local connectivity" of that region respectively (Dill 2004, Taylor and Van Nostrand, 2008, VTPI 2015). Studies on inter-local connectivity are rare, but measures can be developed based on regional connections to arterials and other neighborhoods. Areas of interest are in connections between state and local jurisdictions for issues such as transit access and freight.

Overcoming Geographical Barriers

Natural features such as rivers and man-made features, like highways and freeways, often serve as or create barriers to direct local travel, particularly for bicycle and pedestrian travel (VTPI 2015). This is a so-called “barrier effect” (Litman 2016), which reduces accessibility for active transportation modes and forces a shift to motorized travel. In order to help alleviate the barrier effect, street connectivity strategies need to be combined with other design strategies. Albeit expensive, these strategies can help improve connectivity across such barriers, including special bridges or sometimes under crossings (freeways).

STREET CONNECTIVITY DRAWBACKS

As with any public policy decision, tradeoffs exist regarding decisions to make street networks more connected. An important part of this study is identifying those tradeoffs, so we must understand the drawbacks, both real and perceived, of increased connections.

Some literature, most notably Portland Metro, 2004, and the 2011 Lehigh Valley Planning Commission study, discusses these drawbacks. They include:

Cost: Providing increased connections costs money, whether implemented by cities or developers. However, studies do not provide details on these potential increased costs. On the other side, there are strategies that communities implement to avoid increase in costs, such as narrower street standards, avoiding long streets, limiting maximum block length, landscaping, different treatments of cul-de-sacs etc (Handy 2002, OKI 2007, WSDOT 2006). When it comes to utilities and their maintenance, it was observed that better connectivity actually can decrease these costs, since the utility connections are improved, easier to access and maintain (OKI 2007). Developers may also argue that improved street connectivity decreases the amount of salable lend they will have for development, since potential building lots may be used for transportation connections (Handy 2002, OKI 2007). Again the practice does not provide any actual measurements to support this. However, incorporating appropriate traffic control and security features into connected streets, as well as the opportunity to have more diversity of uses, can offset the potential decrease in property values (VTPI 2015).

Residential traffic: Residents’ concerns about increased street connectivity are often related to increased traffic on residential streets (LVPC 2011, WSDOT 2006, Handy 2002). While increased traffic on residential streets has been observed in some studies (Zhou 2013, Charlotte 1), there are strategies that are implemented in the field to keep the traffic increase and traffic speeds at tolerant levels. It is also important to provide good arterial and collector streets on the network borderlines that will provide more capacity and higher speeds for non-residential traffic, therefore minimizing the possibility that this traffic will use residential streets.

Crime: The increase in crime rates in relation to street connectivity has not been quantified in practice. A study performed in Western Australia (Foster et al. 2014) did not find that better street connectivity alone is not related to the increase in crime rate, although it correlated more walking and activity with increase in crime. Rather, the study found that the presence in local destinations, especially those that serve alcohol, is related to the increase in crime rate. Another London study (Hillier and Sahbaz, 2005) found that the risk of crime is less in well-connected network with more activity, following the “safety in numbers” principle. That study also found that the high-tax properties on cul-de-sacs are more vulnerable to crime in small cul-de-sacs, and that dwellings on cul-de-sacs have twice as many burglaries as dwellings on connected streets.

Impact of new intersections: Connectivity could lead to diminished vehicle capacity on major streets due to new intersections.

More impervious street surface: Connectivity can create more stormwater runoff.

Political costs: Connectivity often comes with high political costs if the proposed changes are unfamiliar or unpopular.

Market forces: Connectivity is not always aligned with current market forces in housing market.

HOW CAN WE ACHIEVE STREET CONNECTIVITY? EXPLORING THE MOST APPROPRIATE STRATEGIES

Review of the literature points to several types of strategies to improve the different measures of connectivity and hence achieve the benefits described above. A lot of research efforts discussed earlier were implemented into city guidelines, ordinances, and practices. Policies should be adopted to require a local street circulation pattern that provides access to property and connections to collector and arterial streets, neighborhood activity centers, and emergency access.

Plans and policies

A jurisdiction’s planning documents often create the foundations for good connectivity. While often not explicitly requiring types of street connections, plans can create the justification for street connectivity within a community’s overall vision, and set forth the template for the large-scale connections that are important within a community.

Explicit general plan policies supporting street connectivity

Including street connectivity in a community’s general plan or other primary vision document creates the directive for connectivity in the foundation of policy.

Policies to design for all users

Directing city staff to design places and networks with all users in mind inherently points these efforts toward better street connectivity. Addressing the needs of different modes leads to a finer network of connections. For example, Fort Collins, CO, requires that all local interconnected systems be designed with all users in mind (automobile, transit, bicycle, and pedestrian).

Policies encouraging redundant and direct connections to destinations

Transportation master plans, area plans, and other planning documents can encourage and support the creation of multiple connections among destinations and neighborhoods. They can outline the street pattern and connectivity standards and emphasize that the local street system provides multiple direct connections between local destinations.

Portland, Oregon’s right-of-way requirements and standards include pedestrian connectivity. Their code requires direct routes for bicycles and pedestrians in residential areas and between neighborhood facilities. It also has specific standards and requirements for through streets and pedestrian connections which allow the most direct route.

Connections to outside jurisdictions

Planning documents, especially large-scale plans such as transportation master plans, can identify preferred connections among jurisdictions. These inter-jurisdictional connections can also be coordinated by larger agencies such as state departments of transportation and metropolitan planning organizations.

Types of street networks

Planning documents can identify preferred patterns of streets that generally create good connectivity, such as grids of small blocks. This practice is long-established in the United States, with the well-connected networks of cities such as Washington, D.C., New York City, and Sanavvah, Georgia, establishing effective street network planning.

Street and development standards

Standards are the complementary piece to plans and policies – they are concrete rules that implement the directives of the high-level policy. In some cases, standards apply to public infrastructure such as streets designed and built by jurisdictions. In other cases, standards apply more to private developers who build streets and other connections as part of their projects.

Minimum connectivity standards

Codes can require that developments achieve a minimum connectivity index (see metrics section), or reward developments that have a high connectivity index with various incentives. Lehi, UT is developing draft code language that requires new developments to meet s minimum connectivity index.

Maximum block lengths / local intersection spacing

Codes can also require maximum block lengths, which is essentially the spacing of local street intersections. Best practices are generally average intersection spacing for local-streets of 300-400 feet, and maximum intersection spacing for local streets of about 600 feet. Lehi, Utah, includes maximum block lengths in its draft code language; the exact maximum depends on the zone the street is located in.

Maximum block size

Another tool to create dense networks is to limit the size of whole blocks. Best practice is generally a maximum block size of 5-12 acres.

Cul-de-sac management

Eliminating, limiting, or otherwise managing cul-de-sacs is a major direct way to increase street connectivity in new development. Development standards can:

- *Prohibit cul-de-sacs*: PennDOT’s guidelines for improving connectivity (PennDOT 2012) note that Cranberry Township in Pennsylvania does not recommend approval of cul-de-sacs, while Peters Township, PA, prohibits dead-end streets.

- *Limit cul-de-sacs to a certain percentage of total streets*: for example, to 20% of streets.
- *Limit the maximum length of cul-de-sacs*: for example, to 200 feet.
- *Provide specific exceptions*: such as only when they can access land not otherwise accessible through a connected street pattern due to topography or other constraints.

Pedestrian circulation plans
Pedestrian circulation plans provide a concept of how pedestrians will move around and through a development.

Redundant access to destinations
Jurisdictions can require developments to provide multiple routes to key destinations for most, if not, all places in the community. The Kentucky Transportation Cabinet encourages proposed developments to provide multiple direct connections in its local street system to and between local destinations, such as parks, schools, and shopping.

Access to arterials
In the same vein as providing multiple routes between a community and local destinations, city codes can require multiple access connections between a development and arterial streets.

Non-arterial access to destinations
Jurisdictions can require that new developments provide access from the community to destinations within it without the use of arterial streets, thereby preserving capacity on arterial streets for non-local traffic. The Kentucky Transportation Cabinet encourages jurisdictions to require that a proposed development shall provide multiple direct connections in its local street system to and between local destinations without requiring the use of arterial streets.

Maximum arterial intersection spacing
For large developments including several arterial streets, standards can create maximum amounts of space between arterial street intersections. Best practices limit maximum intersection spacing for arterial streets to about 1,000 feet. The Kentucky Transportation Cabinet recommends jurisdictions require a proposed development shall provide a potentially signalized, full-movement intersection of a collector or a local street with Arterial Street at an interval of at least every 1,320 feet or one-quarter mile along arterial streets. A proposed development shall provide an additional non-signalized, potentially limited movement, intersection of a collector or local street with an arterial street at an interval not to exceed 660 feet between the full movement collector and the local street intersection.

Maximum spacing between bike and pedestrian connections
Standards can require a maximum spacing between pedestrian and bicycle connections through a development and across major barriers such as arterial streets. Best practices place this maximum at about 350 feet.

Emphasis on bike and pedestrian connections
Connected streets don’t necessarily include accommodations for pedestrians and cyclists – and this creates defacto disconnection for those users. Standards can ensure that pedestrians and

cyclists can use all streets, primarily by requiring sidewalks or other paths. In some cases, connections can be made for cyclists and pedestrians only, such as in connecting cul-de-sacs.

Limits on width of streets

Limiting the width of new streets achieves connectivity (and mitigates its negative effects) in a number of ways, including facilitating pedestrian crossing, discouraging through traffic, reducing speeds, and helping to offset increased costs to developers of building more streets required to achieve better connectivity. Best practices limit local street pavement widths to 24-32 feet (varies with on-street parking restrictions).

Restrict private and gated streets

Jurisdictions can improve connectivity by limiting or discouraging gated communities and other restricted access roads.

Street stub requirements

Jurisdictions can require developments to create street “stubs,” that is, streets that are initially dead ends but can be connected when adjacent parcels are developed in the future. The Kentucky Transportation Cabinet’s guidelines recommend that each development “shall incorporate and continue all collector or local streets stubbed to the boundary of the development plan by previously approved but unbuilt development or existing development.”

Retrofit tools

Many Utah communities are built-out and many lack good street connectivity. Yet, as with newly-built communities, improved street connectivity can help achieve many community goals in built-out communities as well. However, a different set of strategies is needed for this street connectivity retro-fitting.

- Planning document guidance on key connections
- Complete streets
- Pedestrian crossing improvements
- Cul-de-sac connections – full street
- Cul-de-sac connections – bike – pedestrian
- Pedestrian pass-throughs to arterial streets and commercial areas
- Large land use pass-throughs and entries
- Transit stop and destination walk-sheds
- Leverage easements for active transportation
- Grade separation

Managing Street Connectivity

An additional set of strategies help maintain and implement the benefits of street connectivity and mitigate its drawbacks.

Traffic Calming Measures

Traffic calming measures (TCM) are means to force speed reduction. As mentioned before, enhanced connectivity increases the accessibility and path alternatives for each trip. Many of these paths may be located in residential areas. If not managed, multiple path alternatives could lead to increased congestion and decreased safety in these locations. TCMs can help preventing this situation, thus they are an important part of street connectivity.

TCMs originally were developed for safety purposes by lowering vehicular speeds. In recent years, TCMs are known as ways to manage traffic volumes on network links. In this context, for motorists, TCMs will reduce the utility (increase the cost) of using a specific link (usually in a residential area) by reducing speed and increasing travel time.

According to FHWA, general objectives of TCMs are:

- To encourage citizen involvement in the traffic calming process by incorporating preferences and requirements of the citizens
- To reduce vehicular speeds
- To promote safe and pleasant conditions for motorists, bicyclists, pedestrians, and residents
- To improve the environment and livability of neighborhood streets
- To improve real and perceived safety for non-motorized street users
- To discourage use of residential streets by non-citizens cut through vehicular traffic

The Institute of Traffic Engineers defines four categories of TCM techniques including: vertical deflections, horizontal deflections, road narrowing, and closures. Different TCMs and their impact on traffic are well described in past literature (MUTCD, DOTs policies, Ewing 1999, Ewing 2006, Zhou et al. 2013, Lee et al. 2013).

Transit-Friendly Design

Enhanced connectivity by itself may not be able to provide the desired impact on mode choice, and consequently on health, environment, and active transportation. Several other improvements must be made simultaneously to reach the expected results. One of these measures is transit-friendly design (TFD). TFD is set of design guidelines that ease the integration of transit facilities into residential and non-residential areas (Calgary Transit Division, Transportation Department of the City of Calgary 2006, Ewing 1999). TFD will improve the attractiveness of transit modes by increasing its utility. Consequently, TFDs will decrease traffic congestion and improve air quality (TransIT Services of Frederick County 2009, TSRP Report 33 1998).

As mentioned above, TFDs increase the utility of transit modes. TFD guidelines focus on the following eight principles (Calgary Transit Division, Transportation Department of the City of Calgary 2006):

1) Provide appropriate community densities
2) Minimize walking distance (Figure 3)

3) Provide a mix of land uses
4) Organize density, land use, and buildings to benefit from transit
5) Create a pedestrian-friendly environment
6) Route transit into the community
7) Reduce transit travel time
8) Build quality, user-friendly transit facilities

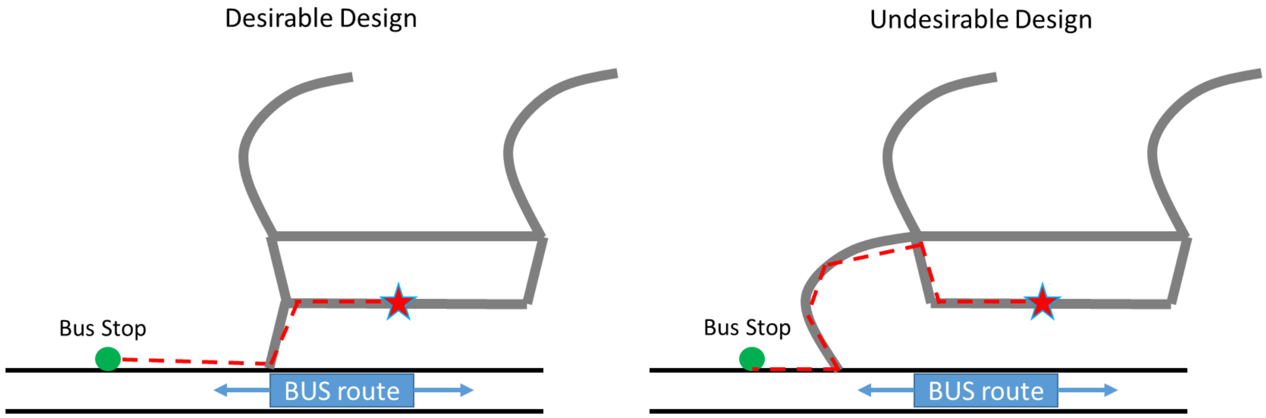


FIGURE 3 Undesirable and Desirable Designs for Walking Access

Complete Streets & Connected Streets

Complete street policies emphasize a high degree of street connectivity. While complete street policies are not directly related to street connectivity, these policies can support connectivity by ensuring that the links in the network cater to all types of users.

The following is adopted from Smart Growth America and National Complete Streets Coalition report on "Implementing Complete Street" (*factsheet 1*).

> "In a complete network, short, local trips can be taken without burdening the arterial systems with more cars. Roads in sprawling communities see up to 75 percent more travel demand on those arterials than similar arterials in connected networks (Proft and Condon 2001). People with a complete, connected network of options may opt to reach their destination entirely without driving on arterials, or will instead walk, bike, or take public transportation. One study found that single-family households located in a network of Complete Streets made a similar number of total trips as those in an incomplete network, but made significantly fewer by car, instead opting to walk (Khattak and Rodriguez 2005). Complete streets with enhanced connectivity reduce the fatal and severe crashes (Marshall and Garrick 2010). In addition, they provide a better platform to for emergency vehicles to reach their destination safer.
>
> Some places with Complete Streets policies have included provisions specifically to increase connectivity. For example, Virginia's Complete Streets policy was augmented by a new policy to end maintenance support for new streets that end in cul-de-sacs. Other communities have required new developments to connect into

the existing grid in multiple locations. Some built-out communities with a sprawling road system have looked for opportunities to create more non-motorized connections by installing paths that connect cul-de-sacs and other disconnected streets to nearby roads. Even when roads are connected, there may still be a need for connected grids of walking and bicycling networks. The incorporation of Complete Streets into all of Seattle, Washington's plans helps to identify gaps in the network for different modes and prioritizes investment to create complete networks for all modes."

Market strategies for Implementing Connectivity

A key strategy for implementing connectivity is to ensure that incentives and rewards accrue to the level of government or the private developer making the initial investment. These tools include private market incentives such as higher rents and property values through higher densities and public tools such as value capture, tax increment support, and special assessment districts.

State-of-Practice Street Connectivity Standards and Requirements

Tables 2 and 3 summarize street connectivity standards and requirements in various U.S. cities (Handy 2003, VTPI 2015).

TABLE 2 Street Connectivity Standards

Location	Max. Local Street Intersection Spacing (feet)	Max. Arterial Intersection Spacing (feet)	Street Stubs Required?	Cul-De-Sacs Allowed	Max. Cul-De-Sac Length (feet)
Portland Metro	530	530	No	No (With Exceptions)	200
Portland, OR	530	530	Yes	No (With Exceptions)	200
Beaverton, OR	530	1000	Yes	No (With Exceptions)	200
Eugene, OR	600	None	Yes	No (With Exceptions)	400
Fort Collins, CO	Max. Block size 7-12 acres	660 - 1320	Yes	Limited	660
Boulder, CO	300 - 350	none	Yes	No (With Exceptions)	350
Huntersville, NC	250 – 500	No data	Yes	No (With Exceptions)	350
Cornelius, NC	200 – 1320		Yes	No (With Exceptions)	250
Conover, NC	400 – 1200	No data	Yes	Yes	500
Raleigh, NC	1500	No data	Yes	Yes	400 – 800

Cary, NC	Index = 1.2	1250 – 1500	Yes	Yes	900
Middletown, DE	Index = 1.7	None	Yes	Yes, discouraged	1000
Orlando, FL	Index = 1.7	None	Yes	Yes	700

TABLE 3 Street Connectivity Requirements

Location	Max. Spacing Between Bike/Ped Connections (feet)	Local Street Width (feet)	Private Street Allowed?	Gated Streets Allowed?
Portland Metro	330	<28	Not Regulated	Not Regulated
Portland, OR	330		Limited	No
Beaverton, OR	330	20-34	Limited	No
Eugene, OR	Connections required at cul-de-sacs	20-34	Limited	Limited
Fort Collins, CO	700	24-36	Limited	No
Boulder, Co	300-350 recommended	24-36	No	No
Huntersville, NC	None	18-26	No	No
Cornelius, NC	None	18-26	Yes	No
Conover, NC	None	22	No	No
Raleigh, NC	None	26	Discouraged	Discouraged
Cary, NC	If index waived	27	yes	No
Middletown, DE	No data	24-32	No	No
Orlando, FL	None	24 min.	Yes	No

STREET CONNECTIVITY CASE STUDIES

Street connectivity has been a subject of numerous research efforts. However, incorporating strategies into actual plans and designs in many cases is not straightforward. Agencies across the world and the U.S. have been working towards providing ordinances that would incorporate street connectivity strategies into requirements. Through the case studies presented here, it can be seen that there is no universal solution that fits all situations. Depending on the actual networks, goals, and requirements, different strategies lead to different benefits. The presented case studies show also the lessons learned from these efforts.

Charlotte: Retrofit Street Connectivity (*Charlotte 1*)

The street connectivity program of Charlotte Department of Transportation (CDOT) started in 2006 and monitors inventory and implementation of needed street connections within and between neighborhoods as well as the construction of new connectors and local streets to provide improved access and connectivity for future development. Potential street connections are analyzed through a GIS mapping tool for potential land use linkages, mode impact, road network impact, and route-directness impact. CDOT's Street Connectivity program, however, has encountered significant public resistance to new street links. Obstacles to public approval include perceptions that street connections will increase traffic speeds or volumes, affect neighborhood crime rates, or lower property values. Street-connection retrofit projects that win community support need to have political support, flexibility in the scope and timeline of the project to accommodate community concerns and requests, and clear, tangible benefits for neighborhoods both "upstream" and "downstream" of a proposed street link.

Cary: Subdivision Ordinances (*Cary 1*)

Through the process of creating its 2001 Land Use Plan, the town of Cary, NC, formulated goals for itself: retain a sense of place, have a more human-scale and pedestrian-oriented environment, avoid strip development along arterials, focus commercial activity into discrete nodes, and increase connectivity. They came up with several policies including:

1. Developments should be linked by roads and continuous sidewalks and have easy-to- use internal-circulation networks for all modes of travel.
2. For residential subdivisions, the design guidelines recommended reducing the use of cul-de-sacs or adapting them to include pedestrian or bicycle connections.
3. Blocks should be no more than 1,250′ in length to create minimum street-connectivity standards for new residential development.
4. Requiring vehicular and pedestrian access to at least two public streets for all developments with more than 100 residential units.
5. Creating a pedestrian connectivity index to supplement the existing vehicular-oriented street connectivity index.

Through these street connectivity measures, the city managed to improve a sense of community at these places.

Bremen: Traffic Cells (*Goltz-Richter 2003*)
In the early 1960s, the city of Bremen was divided into four sectors, or "traffic cells." Automobiles are allowed to travel within each cell, but to travel between these cells they must use a circumferential ring road. Pedestrian, bicycle and transit vehicles can travel directly between these cells. As a result, vehicle traffic volumes are significantly reduced and travel by other modes is significantly improved. The author made an interesting observation from this case study::

"To conclude, in order to make our city a good place for our inhabitants to live, and an attractive place for business, integration of our transportation systems is key. No single element plays the main role, rather the interaction between the various agents form an integrated transport policy and integrated urban development policy."

Gothenburg: Reduce Traffic & Increase Safety (*Vuchic 1999*)
The city of Gothenburg is Sweden's second largest city, with almost half a million residents. In the late 1960s, the city's historic center was divided into five traffic cells. Automobiles can travel within each cell but not directly between cells, they must use a ring road. Pedestrians, bicyclists, and transit vehicles can travel directly between cells. The result has been a 48% reduction in vehicle traffic despite increased vehicle ownership by residents, improved pedestrian and cycling conditions (and a 45% reduction in pedestrian accidents), and improved transit service. This is an example of a traffic management strategy combined with street connectivity strategies, which created better and safer conditions for transit and non-motorized transportation modes.

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APPENDIX

Case Study Benefit Modeling

UTAH STREET CONNECTIVITY STUDY BENEFITS MODELING OVERVIEW

Background

The Utah Street Connectivity Study seeks to assess the benefits of street connectivity; provide recommendations on how to implement elements of connectivity into Utah communities; and inform decision-makers and stakeholders how street connectivity can benefit their communities.

As a key part of the study, we used modeling techniques to investigate and quantify specific benefits we believe result from changes to the street network to increase connectivity. We were, in effect, identifying the community benefits that result from increases in street connectivity. In order to set the stage for this benefit modeling, we needed to 1) quantify the change in connectivity; 2) identify which benefits to model; and 3) identify in which geographic areas the modeling will take place.

Changes in connectivity

The consultant team has defined street connectivity as consisting of four aspects:

- Relative level of connection
- Network density
- Ability to connect to specific destinations
- Quality of network for all users (walkability)

These aspects mean different things at different scales. The consultant team has defined three scales of connectivity for this study. They are:

- Regional
- Community
- Neighborhood/District

Each aspect of connectivity is represented by a metric at each scale. They are shown in the following table:

	REGION-SCALE METRICS	COMMUNITY-SCALE METRICS	NEIGHBORHOOD-SCALE METRICS
Basic connectivity metrics			
the relative level of connection	Connectivity index of arterial-level streets	Connectivity index of collectors and above-level streets	Connectivity index of all streets
network density	Arterial intersections per square mile	Collector or above intersections per square mile	Intersections per square mile
Advanced connectivity metrics			
ability to connect to destinations	Average travel-shed percentage for key destinations	Percentage of community travel-shed for key destinations	Percentage of NH/district travel-shed for key destinations
quality of network for all users (walkability)	Percentage of potential half-mile walk shed from set of community destinations	Percentage of potential half-mile walk shed from set of community destinations	Average of highest 5 spaces between parallel pedestrian links

Consequently, for a given region, community, or neighborhood or district, we measured change in some or all of the four areas above. The measurement of change focused on the Basic connectivity metrics, with the Advanced connectivity metrics being used as we are able. Together these will quantify the change in connectivity resulting from a series of changes to the street network.

Identification of benefits

Benefits in this study are defined as changes resulting from increased street connectivity that achieve community goals. At the onset of the Utah Street Connectivity Study, the consultant team worked together with the project's Working Group to identify community benefits potentially affected by increased street connectivity.

The Working Group came up with the following community goals:

- Regional and community mobility
- Transportation choice
- Accessibility to destinations
- Safety and health
- Effective infrastructure
- Community livability
- Economic vitality
- Environmental stewardship
- Interlocal and regional compatibility
- Overcoming geographic barriers
- Growth management

Consequently, in completing the project literature review, the consultant team identified benefits closely associated with these goals. For example, under the goal "regional and community mobility," the team found benefits such as arterial traffic reduction, vehicle miles traveled (VMT) reduction, and trip length reduction.

The team emerged with the following list of benefits, which we categorized into direct benefits (resulting directly from an increase in street connectivity) and indirect benefits (resulting from a direct benefit of street connectivity):

Direct Benefits

Goal	Associated benefits
Regional and community mobility	• Shorter trips and fewer miles traveled • Reduction in arterial traffic volumes • Increased overall capacity • Improved mobility of transit vehicles
Transportation choice	• Improved performance of non-auto modes • Increased selection of non-auto modes
Accessibility of destinations	• Improved pedestrian and bike accessibility to community destinations
Effective infrastructure	• Faster service response times and larger service areas or emergency vehicles • Improved utility connections • Improved protection of public investment
Health & safety	• Increased traffic-related safety
Community livability	• Improved community access • Improved community comfort • Improved community life

Indirect Benefits

Goal	Associated benefits
Health & safety	• Obesity prevention ○ Connectivity is one of a few key ingredients of walkable nei produce positive BMI outcomes ○ More connected networks lead to more walking, and thus h ○ Connectivity limits time spent in the car ○ Benefits are focused in urbanized areas
Economic vitality	• Increased market accessibility • Increased sales • Lower materials costs • Lower household costs • Walkable communities command price premiums • Transit-related economic benefits • Bicycling-related economic benefits
Environmental stewardship	• Reduced air pollution • Reduced energy consumption • Reduced land consumption

Many of these can be quantified: not only in terms of traffic but also dollars or time saved, amounts of healthy behavior, number of people able to access a destination, or the values of property.

Our modeling sought to quantify these benefits based on changes to the street network and the resulting street connectivity. We looked at the relationships between changes to the four measures of street connectivity (resulting from street network alterations) and accrual of these benefits.

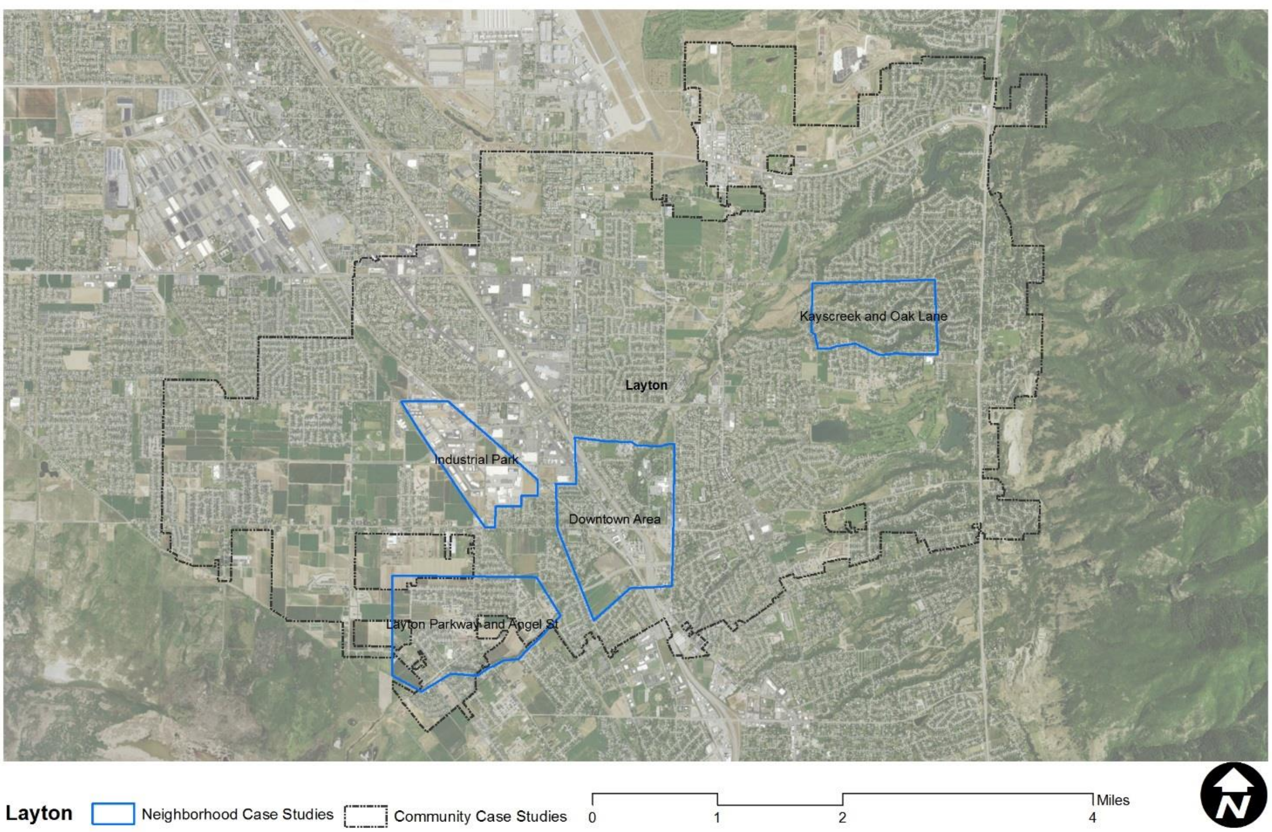
Case study areas

We explored the benefits of street connectivity increases in a set of case study areas. The Utah Street Connectivity Study designated three jurisdictions for these case studies: Lehi City, Layton City, and Tooele County.

The consultant team worked with each of the three case study communities to identify focus areas that both are of interest to the local jurisdictions and represent the range of typologies. Any small-area benefit modeling will take place in these areas:

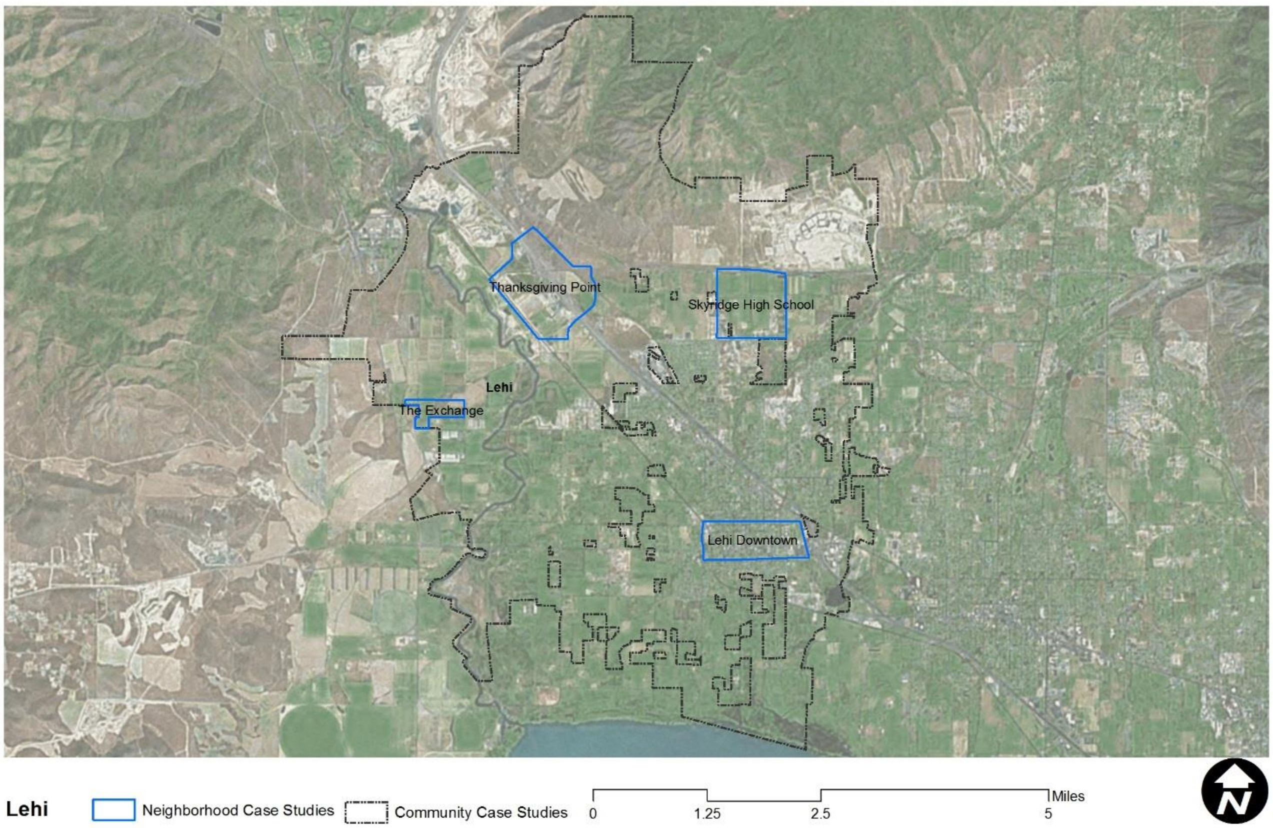
Layton

- Downtown Layton
- Hill Field Road Industrial District
- Kays Creek / Oak Lane neighborhood
- Angel / Layton Parkway neighborhood



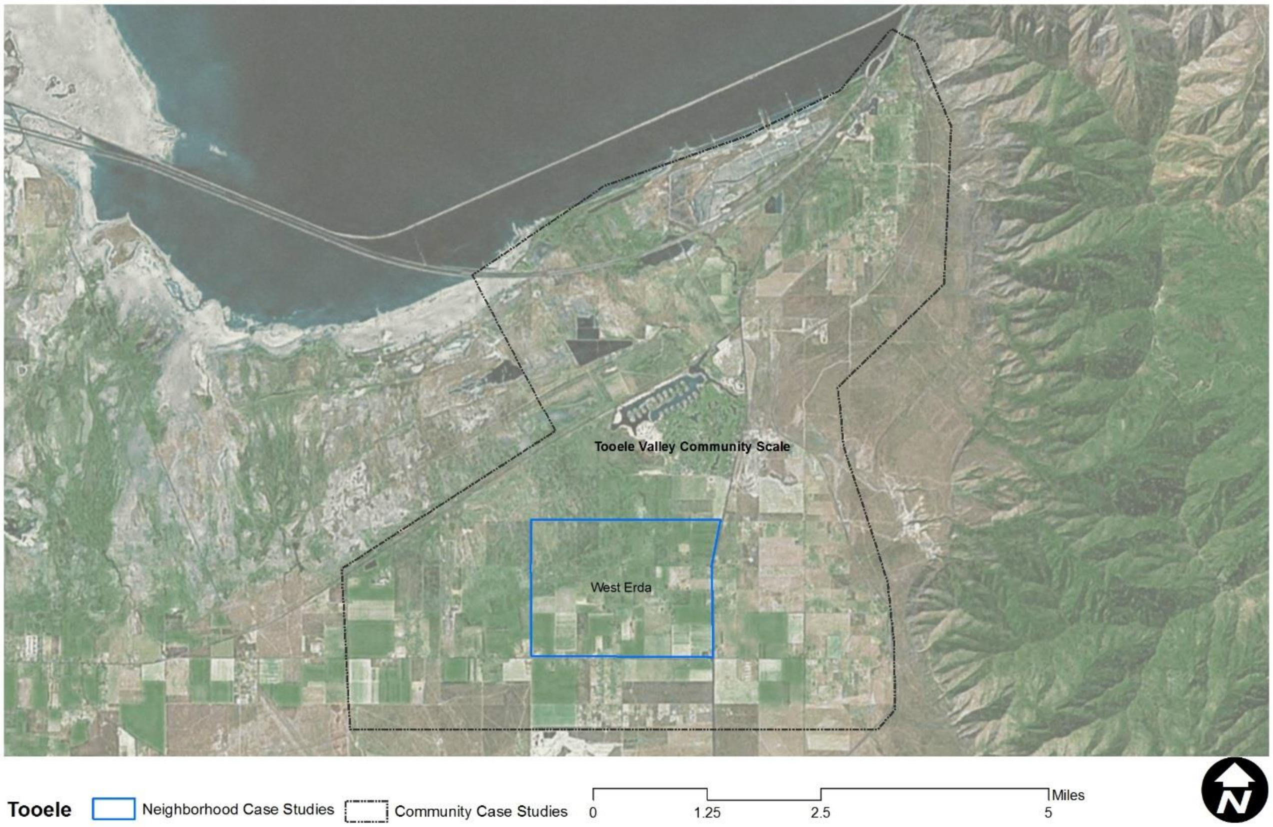
Lehi

- Thanksgiving Point
- Downtown Lehi
- Skyridge High School
- The Exchange



Tooele County

- West Erda



Within these areas, we will measure the existing connectivity for the four metrics, compare these scores against standards for the typologies, propose improvements to increase connectivity where needed, re-measure the connectivity metrics, and model the potential benefits resulting from the increases in connectivity.

Approach

The members of the consultant team who undertook the benefit modeling were: the University Traffic Lab, Alta Planning + Design, and GSBS. Parametrix, as the USCS lead consultant, coordinated the overall modeling effort. The following describes the approach of each firm.

Traffic modeling (Traffic Lab)

Overview

Traffic modeling consisted of two types of models:

- Mesoscopic dynamic traffic assignment (DTA) models or larger city-wide areas, and
- Microscopic models of selected parts of the networks.

The two types of models were integrated, meaning that the outputs of the mesoscopic DTA models (mainly traffic volumes) were used as inputs for microscopic models. Mesoscopic DTA models were developed in PTV VISUM software, using the existing Regional Travel Model developed by WFRC as the base. The three case studies (Lehi, Layton, and Tooele Valley) were created as subnetworks. However, the Tooele Valley model does not exist in the

Regional Travel Model, and it was manually created in VISUM. The subnetworks were recalibrated in VISUM using available traffic data obtained from UDOT and other sources, as described later in this section. Recalibrated demand matrices were used to perform network assignment for the case study networks, which represented the existing conditions.

Upon developing street connectivity strategies, the network changes were added into the VISUM models and the assignment was repeated to measure the changes caused by the changes in street connectivity on the city-wide level. Microsimulation models were developed in PTV VISSIM for defined areas, such as Thanksgiving Point in Lehi, Downtown area in Layton, and a selected residential neighborhood. VISSIM models were exported directly from VISUM to keep the current demand obtained through DTA. These models included more detailed network elements, such as local roads and intersections with the existing control type (signalized, stop-controlled, yield, or uncontrolled). The VISSIM models were developed for the existing conditions and street connectivity alternatives. The proposed hybrid approach captured different measures of effectiveness on several levels.

Benefits measured

The benefits were measured on several levels from both the meso and microscopic models. Mesoscopic models captured changes in volumes on the network wide and segment levels, vehicle-miles traveled (VMTs) and overall speeds. Microscopic models measured benefits on sub-network, corridor (link) and intersection (node) levels. These benefits, among others, included changes in volumes, speeds, delays, distances traveled, and travel times. Other indirect measures were calculated from these outputs.

The Traffic Lab's modeling output measures of the following benefits:

- Traffic volume changes per segment
- Vehicle miles traveled per segment
- Travel times
- Delay

Target areas

Mesoscopic models included city-wide networks. The Lehi network spans approximately between Redwood Road on the west to Canyon Road on the east, and SR-92 (Timpanogos Road) on the north to the intersection of Main and State Street on the south. The Layton network spans approximately between 2000 West on the west to US-89 on the east, and 700 South on the north to 200 North on the south.

Microsimulation models included Thanksgiving Point in Lehi, Downtown area in Layton, and a selected residential neighborhood to be determined.

Data needed and sources

The needed data for mesoscopic models included the existing Regional Travel Model with OD matrices, existing volumes on certain roads and existing speeds. The Regional Model was obtained from WFRC and customized for the three case-study networks (with the exception of West Erda, which was created manually). The existing OD matrices and roadway speeds were also contained in the models. The existing volumes on certain roads within the networks were obtained from UDOT sources, such as AADT maps, PeMS stations, and the Signal Performance Metrics (SPM) system. These volumes were used to recalibrate OD matrices for the subnetworks. The microscopic models also included volumes obtained from the DTA and measured in the field (turning movement counts are available for certain signalized intersections). They also included existing signal timing parameters for signalized intersections within the microscopic networks, which were obtained from the UDOT's MaxView system. Existing travel times were obtained from sources such as UDOT ATMS, INRIX data, Google Maps, and Waze.

Mode choice, health, environment, and infrastructure effectiveness modeling (Alta)

Overview

Alta quantified the health-, environmental-, and transportation-related benefits associated with the estimated number of motor vehicle trips replaced by active transportation trips (bicycling and walking) through a series of economic multipliers that derived from the National Household Travel Survey (2009), local household travel surveys, and peer-reviewed journal articles.

Benefits measured

Alta's modeling output measures of the following benefits:

- Travel Behavior
    - Estimated annual bicycle and pedestrian trips
    - Estimated annual motor vehicle trips reduced
    - Estimated annual vehicle miles traveled reduced
- Environmental Benefits
    - Estimated annual metric tons of particulate matter ($PM_{2.5}$ and PM_{10}) reduced
    - Estimated annual metric tons of nitrous oxides (NO_x) reduced
    - Estimated annual metric tons of sulfur oxides (SO_x) reduced
    - Estimated annual metric tons of volatile organic compounds (VOC) reduced
    - Estimated annual metric tons of carbon dioxide (CO_2) reduced
    - Estimated annual environmental benefits from reduced greenhouse gases and criteria pollutants ($USD)
- Health Benefits
    - Estimated average annual newly active persons (number of persons meeting the CDC's minimum level of physical activity per week from active transportation)
    - Estimated annual healthcare cost savings ($USD)
- Transportation Benefits
    - Estimated annual household transportation cost savings (individual motor vehicle maintenance, fuel, and ongoing operations costs avoided due to active transportation, $USD)
    - Estimated annual traffic congestion cost savings ($USD)
    - Estimated annual collision cost savings ($USD)
    - Estimated annual roadway maintenance cost savings ($USD)

Target areas

- Citywide for each case study jurisdiction
- Downtown Layton, if possible

Data needed and sources

- Project study area
- Count data (if available)
- Population, employment, and school enrollment forecasts (if available)
- Estimated trip distance (if available)
- Estimated all trip purpose mode spilts (if available)
- Collisions by injury type (if available)

Economics modeling (GSBS)

Overview

GSBS estimated the economic benefits of improved connectivity. To complete this they established an existing baseline and measured the benefits against it. They focused this analysis on the impact to the city overall.

Depending on the type of connection made, along with the type of uses that connection is bringing together, GSBS assigned an increased value ratio from the literature.

Benefits measured

GSBS's modeling output measures of the following benefits:

- Change in total taxable sales

Target areas

- Citywide for each case study jurisdiction

Data needed and sources

- Property value by parcel (Assessor's data)
- Existing sales per square foot by individual location (Layton City or request to state tax office)
- Total sales by industry for each city (Online)

UTAH STREET CONNECTIVITY STUDY:

TRAFFIC MODELING

Technical Report

Principal Author:
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(Previous affiliation: Traffic Lab, University of Utah)

Date of Research: July – November 2016

Report date: November 07, 2016

OVERVIEW

Traffic modeling of street connectivity benefits consists of two types of models, mesoscopic VISUM models of community-scale networks, and micsroscopic VISSIM models of selected neighborhood networks. The two types of models are integrated, where the outputs of the mesoscopic models (mainly traffic volumes) are used as inputs for microscopic models. Mesoscopic traffic equilibrium assignment models are developed in PTV VISUM software, using the existing Regional Travel Model developed by WFRC as the base. The three case studies (Lehi, Layton and Tooele) were created as subnetworks. However, the Tooele model does not exist in the Regional Travel Model, and it was manually created in VISUM. The subnetworks are recalibrated in VISUM using available traffic data obtained from UDOT and other sources, as described later in this section. Recalibrated demand matrices were used to perform network assignment for the case study networks, which represents the existing conditions. The developed street connectivity alternatives were added into the VISUM models and the assignment was repeated to measure the changes in traffic patterns caused by the changes in street connectivity. Microsimulation models are developed in PTV VISSIM for defined neighborhood areas, such as Thanksgiving Point in Lehi, Downtown area in Layton, and West Erda in Tooele. VISSIM models were exported directly from VISUM to keep the current demand obtained through the traffic equilibrium assignment. These models include more detailed network elements, such as local roads and intersections with the existing control type (signalized, stop-controlled, yield, or uncontrolled). The VISSIM models were developed for the existing conditions and street connectivity alternatives. This hybrid approach captured different measures of effectiveness on several levels.

Benefits Measured

The benefits will be measured on several levels from both the meso and microscopic models. Mesoscopic models captured changes in volumes on the network wide and segment levels, vehicle-miles traveled (VMTs) and overall travel times. Microscopic models measured benefits on sub-network, corridor (link) and intersection (node) levels. These benefits included changes in volumes, speeds, delays, distances traveled, travel times and number of stops. Other indirect measures can be calculated from these outputs.

Target areas

Mesoscopic models will include city-wide networks. The Lehi network spans approximately between Redwood Road on the West to Canyon road on the East, and SR 92 (Timpanogos road) on the North to the intersection of Main and State street on the South. The Layton network spans approximately between 2000 W on the west to US 89 on the East, and 700 S on the North to 200 N on the South side. The Tooele network includes areas between I-80 ramp on the North to 1000 North street on the south, and the intersection of UT 138 and Erda Way on the West to Droubay Road on the East.

Data needed and sources

The needed data for mesoscopic models include the existing Regional Travel Model with OD matrices, existing volumes on certain roads and existing speeds. The Regional Model was obtained from WFRC and customized for the three case-study networks (with the exception of Tooele, which was created manually). The existing OD matrices and roadway speeds are also contained in the models. The existing volumes on certain roads within the networks were obtained from UDOT sources, such as AADT maps, PeMS stations and the Signal Performance Metrics (SPM) system. These volumes were used to recalibrate OD matrices for the subnetworks. The microscopic networks also include existing signal timing parameters for signalized intersections within the neighborhood networks, which were obtained from the UDOT's MaxView system.

COMMUNITY-SCALE VISUM NETWORKS OF EXISTING CONDITIONS

The community scale networks for Lehi, Layton and Tooele were developed and simulated in VISUM, mesoscopic transportation planning software which is used to analyze and plan transportation systems. VISUM was used to perform traffic assignment, the 4^{th} step in the planning process, based on existing and calibrated Origin-Demand (OD) matrices and field traffic volume data.

The Lehi network was simulated for a typical weekday PM peak period (3 - 6 pm). The network configuration was exported from the Regional Travel Model with sub-network adjustments for the study area. The VISUM network shows highways that have a functional class of collectors and higher (major/minor collectors, principal/minor arterials and freeways). The existing OD matrices were used for the sub-network Equilibrium Traffic Assignment, where the sub-network contains 60 TAZs.

Volume data were obtained from three different sources. UDOT's PeMS data were used to calculate typical PM peak period volumes and directional distribution for freeways, with April 28, 2016 as the typical day. PeMS data were available only for one measurement location along I-15 at Timpanogos Highway (SR 92). Volume data for other locations were obtained from UDOT's AADT maps and adjusted for the PM volume and directional split using PeMS data analysis. Volumes for certain links in the vicinity of signalized intersections were obtained from UDOT's Signal Performance Metrics system, either through the "Approach Volume" or "Turning Movement Count" features (depending on the dataset that was available for the particular location). April 28, 2016 in the PM peak was again used as a representative day. In the end, there was a total of 37 links with available traffic volumes for the three hour PM peak period.

The available link volume data were entered into the corresponding VISUM links for OD estimation purposes and sub-network calibration. The OD matrix was corrected using VISUM's T-Flow Fuzzy function, which adjusts zone productions, attractions and zone-to-zone distribution to closely match field link volumes. The corrected OD matrix was used to perform Equilibrium Traffic Assignment for the study network.

Figure 1 shows calibrated VISUM network after the T-Flow Fuzzy matrix correction. The network with link volumes is shown in Figure 2.

The same approach was applied to the Layton network. In this case, the PeMS data were available for one measurement station at I-15 and Layton Parkway. The remaining data were obtained from UDOT AADT maps and Signal Performance Metrics system. A total of 46 links with available traffic volumes was used to calibrate the model. Figure 3 shows the calibration of the Layton network, while Figure 4 shows link volumes after T-Flow Fuzzy matrix calibration. The Layton subnetwork consists of 51 TAZs.

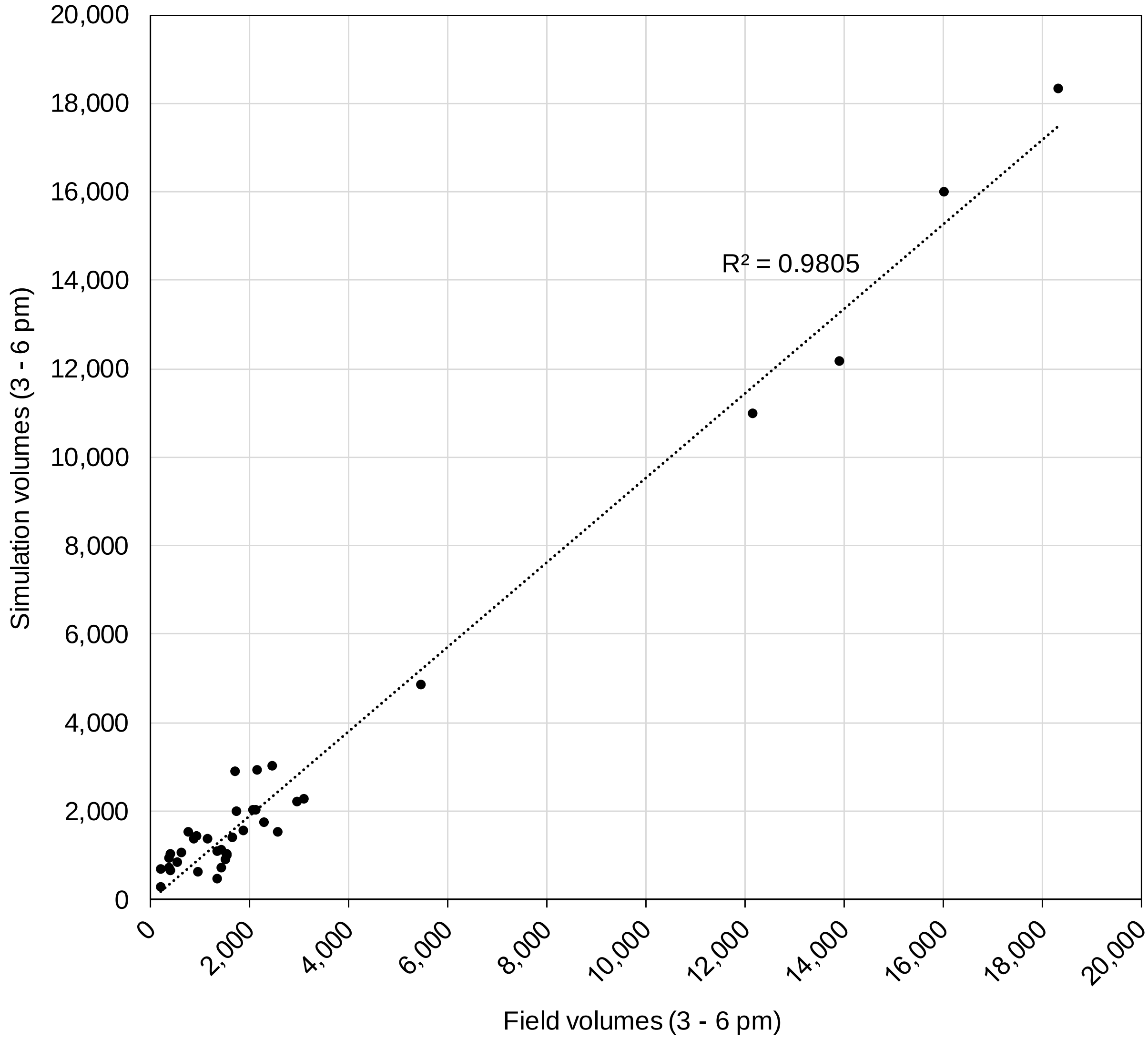

Figure 1: Lehi VISUM Network Calibration

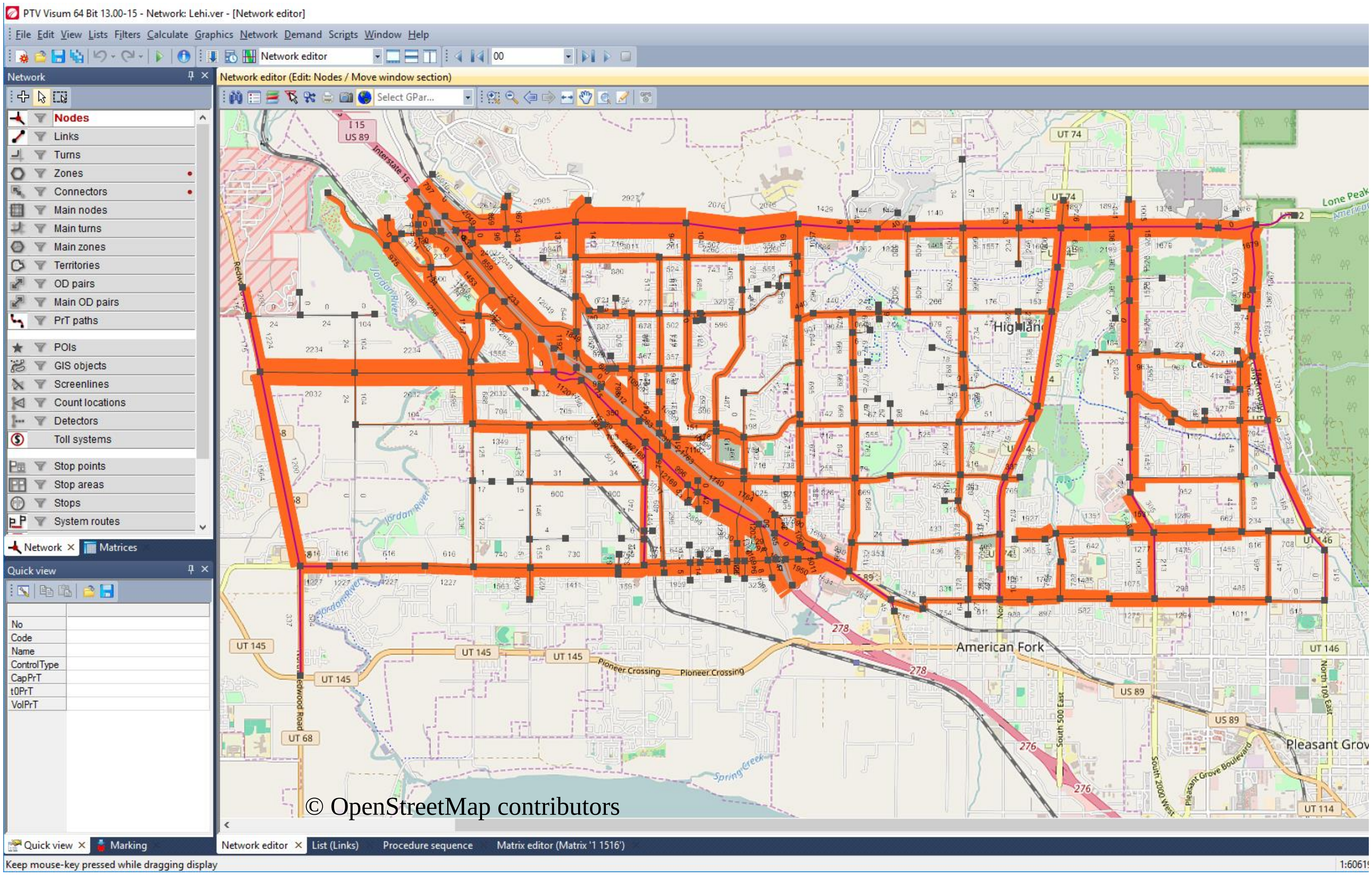

Figure 2: Lehi VISUM Network with PM Peak Link Volumes

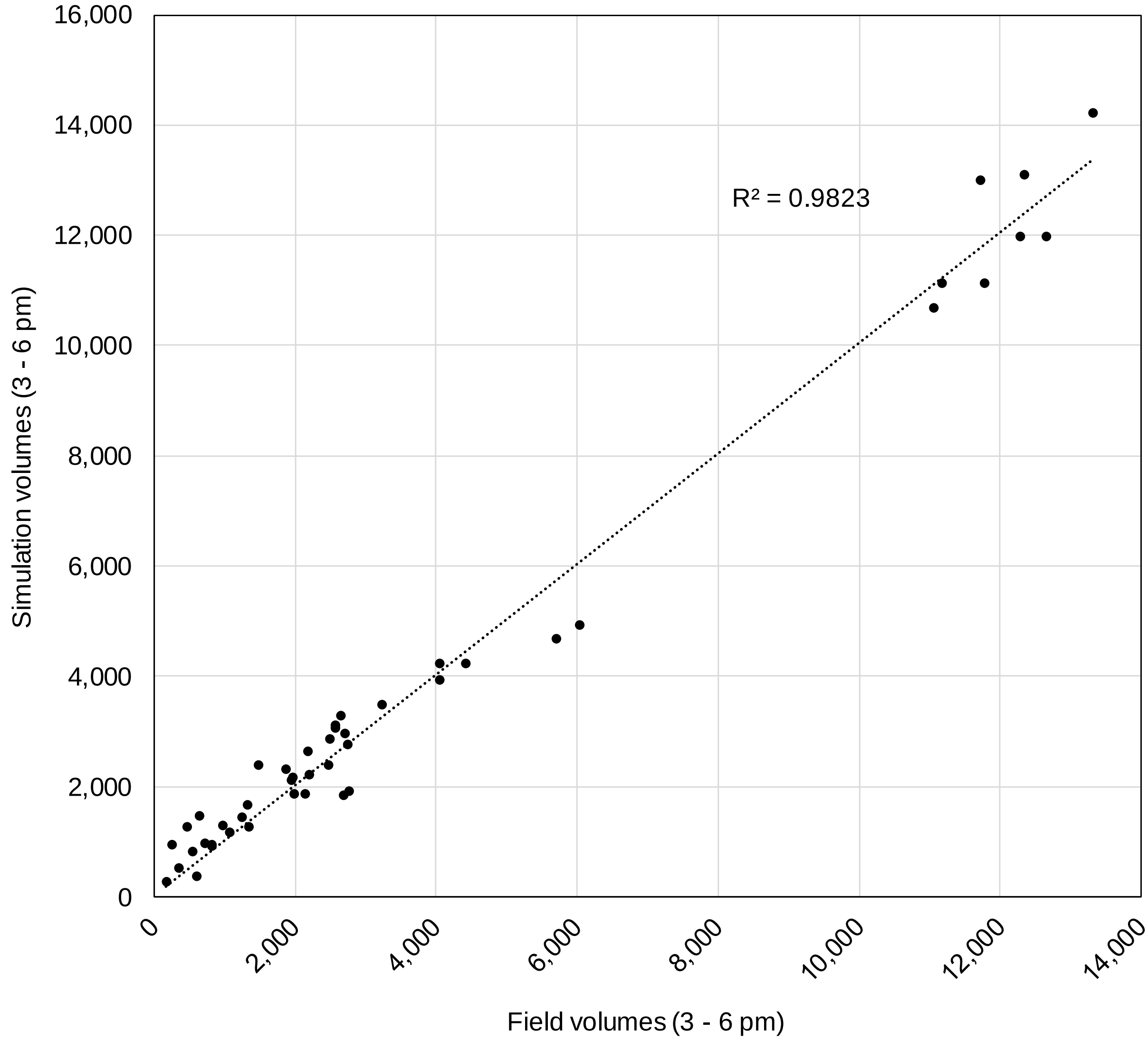

Figure 3: Layton VISUM Network Calibration

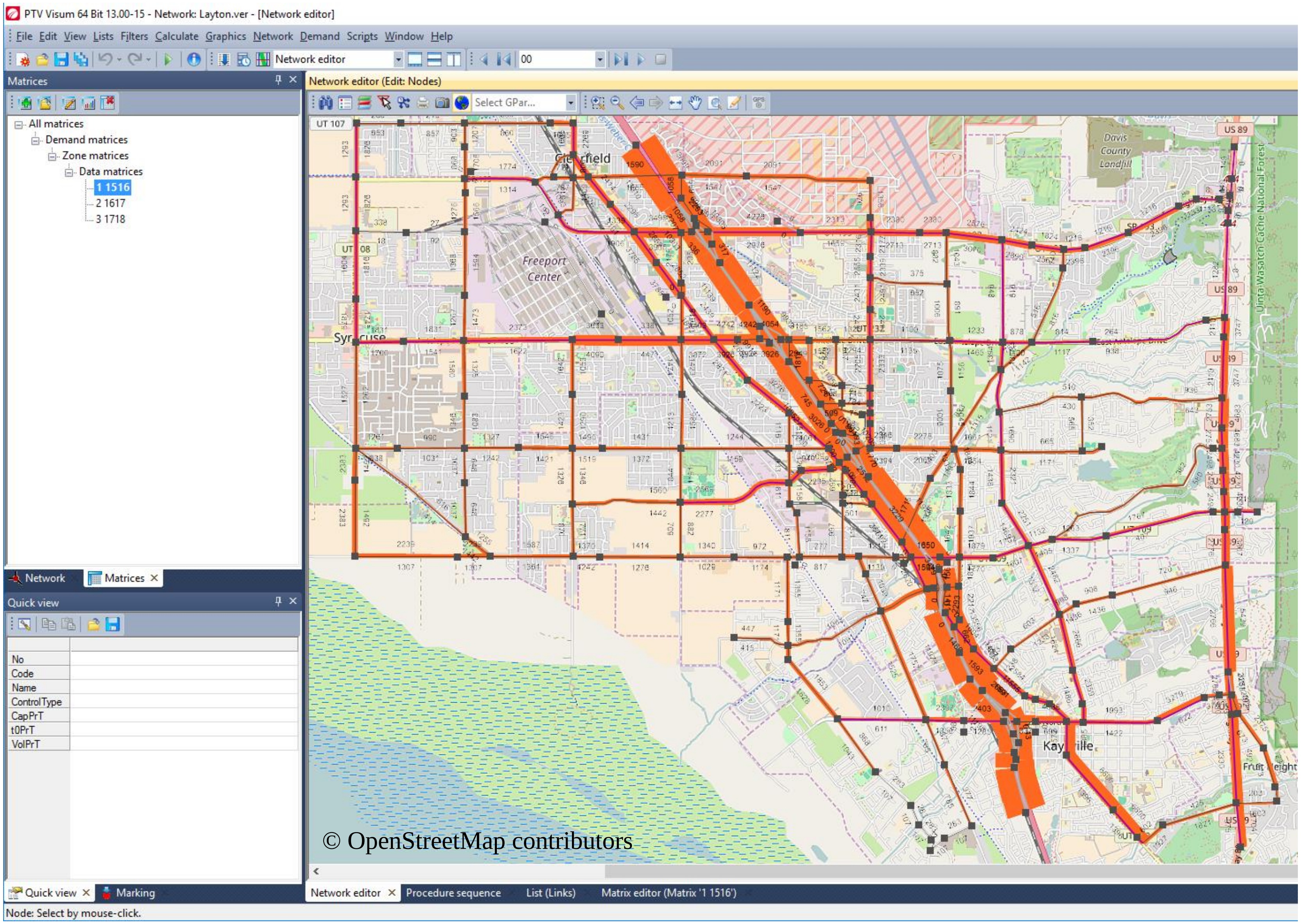

Figure 4: Layton VISUM Network with PM Peak Link Volumes

The Tooele network was created "from scratch", since this network was not available in the Regional Travel Model. The network layout was based on background maps, and functional classification of the roadways was assigned according to the UDOT's functional class map and OpenStreetMap© export. The Tooele network includes 17 TAZs. The same data sources for traffic volumes are used as in previous two cases (UDOT's AADT map and the SPM system). A total of 27 links with available volumes was used for network calibration.

Figure 5 shows calibrated VISUM network after the T-Flow Fuzzy matrix correction. The network with link volumes is shown in Figure 6.

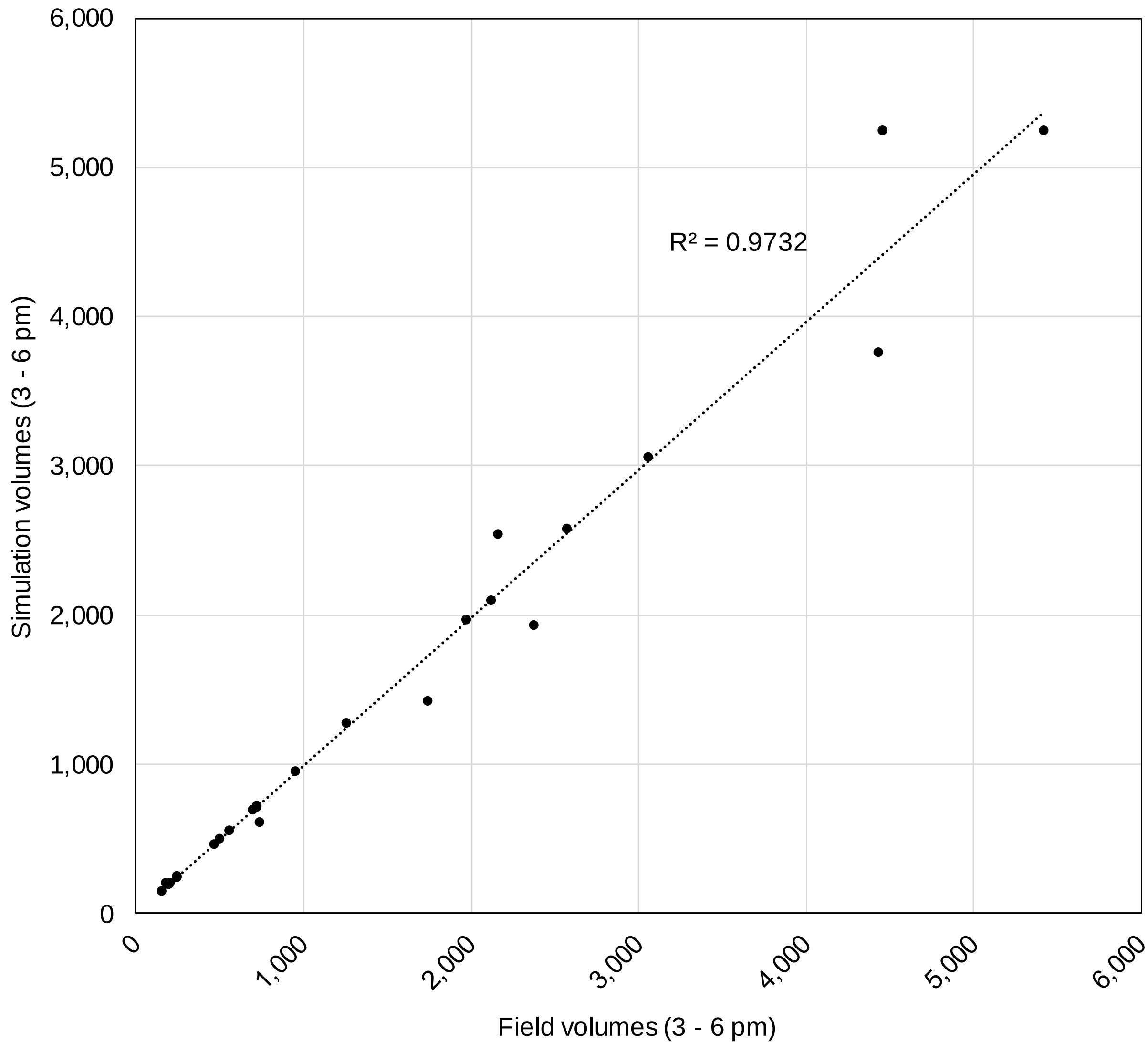

Figure 5: Tooele VISUM Network Calibration

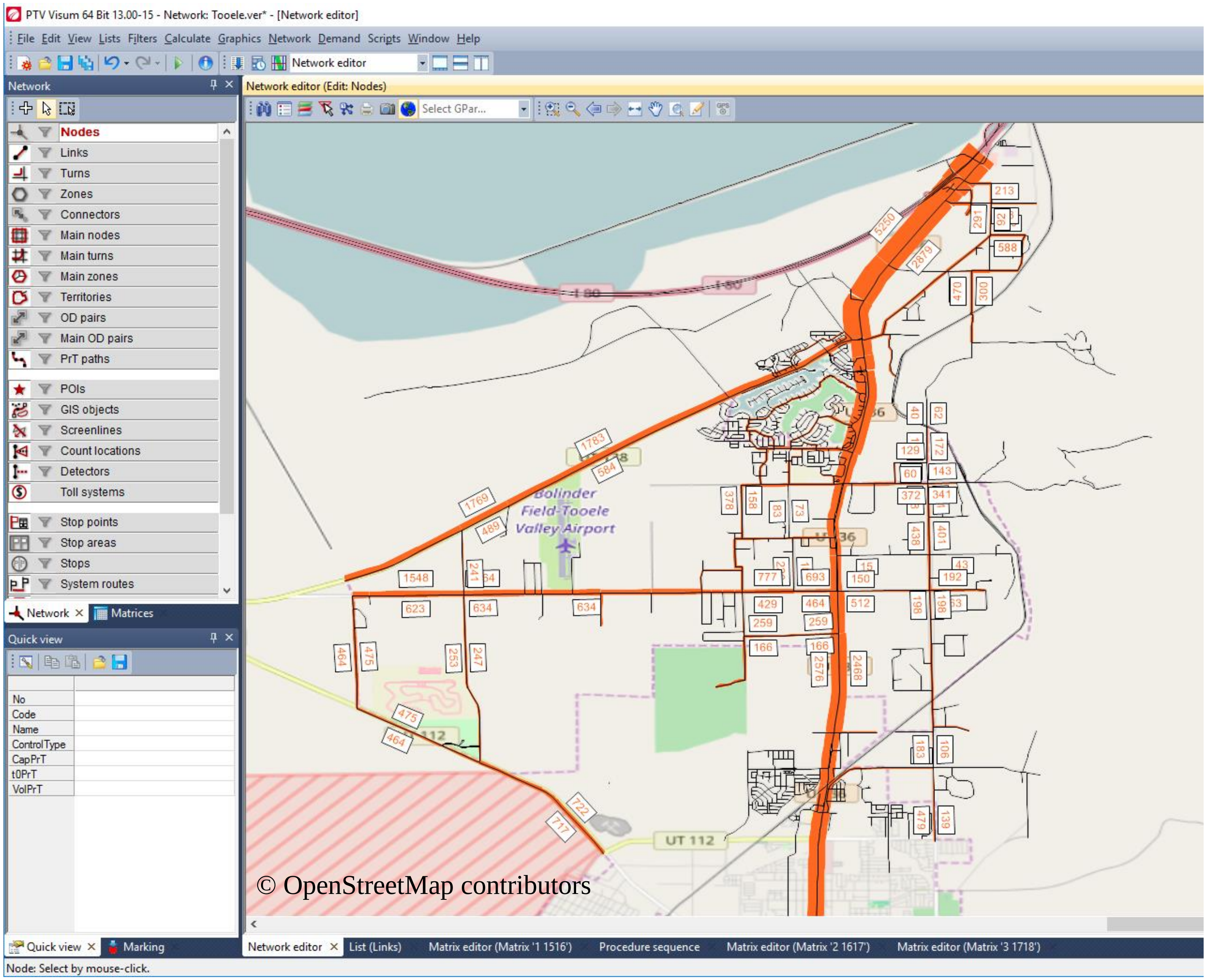

Figure 6: Tooele VISUM Network with PM Peak Link Volumes

COMMUNITY-SCALE NETWORK WITH CONNECTIVITY IMPROVEMENTS

According to the recommendations for community improvements, the existing networks were modified with added connections, which were defined as collector streets. To make a comparison to the existing condition, the same OD matrices were used to perform traffic assignment in the new networks. Using outputs from VISUM, the networks were compared for the total length (both directions), 3-hour traffic volumes, free-flow and actual network travel times, as well as delays and vehicle-miles traveled (VMT). A comparison of traffic volumes and VMTs for some of the main arterials and collector streets is also performed. The results are given in the following tables.

Table 1: MOE Comparison for Lehi Community-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Length (mi)	254.815	332.051	30.31%
Volumes (vp3h)	910,023	901,750	-0.91%
TT_o (h)[1]	8.170	10.524	28.82%
TT_{act} (h)[2]	38.106	33.253	-12.74%
Delay (h)[3]	29.937	22.729	-24.08%
3 hr VMT (mi)	320,135	314,238	-1.84%

[1] Free flow travel time

[2] Actual travel time

[3] Delay = TT_o - TT_{act}

Table 2: Arterial Volumes and VMTs for Lehi Network

	Avg. 3 hour volumes			Total 3 hour VMT		
Arterial / Collector	Base	Improvements	Difference (%)	Base	Improvements	Difference (%)
SR 92	2,256	1,754	-22.28%	30,499	25,599	-16.06%
MVC	1,964	916	-53.35%	6,408	3,065	-52.17%
State St	1,684	1,475	-12.38%	14,006	12,841	-8.32%
Lehi Main St	1,680	1,639	-2.43%	12,208	11,233	-7.99%
2300 W	639	211	-66.98%	2,855	984	-65.53%

Connectivity improvements increased the total length of the Lehi network for 30%, with a similar increase in the free-flow travel time. However, the actual travel time reduced in the improved network by 13%. This is attributed to more direct, faster connections between points in the network, and also by the introduction of new connections over the freeway. Total delay, computed as the difference between the free flow and actual travel times, reduced 24% in the better connected network. Total volumes traversing the network and VMTs are slightly reduced in the connectivity improvement scenario.

A significant decrease in volumes and VMTs is observed in the connected scenario. The volumes were distributed to other connections, relieving the arterials a giving a better distribution of traffic flows in the network.

Table 3: MOE Comparison for Layton Community-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Length (mi)	252.479	292.875	16.00%
Volumes (vp3h)	140,5481	144,6527	2.92%
TT_o (h)[1]	7.307	8.535	16.81%
TT_{act} (h)[2]	40.401	38.808	-3.94%
Delay (h)[3]	33.094	30.273	-8.53%
3 hr VMT (mi)	531,861	528,495	-0.63%

[1] Free flow travel time

[2] Actual travel time

[3] Delay = TT_o - TT_{act}

Table 4: Arterial Volumes and VMTs for Layton Network

	Avg. 3 hour volumes			Total 3 hour VMT		
Arterial / Collector	Base	Improvements	Difference (%)	Base	Improvements	Difference (%)
SR-193	1,938	1,618	-16.51%	16,471	13,396	-18.66%
700 South	2,548	2,588	1.57%	13,982	13,186	-5.69%
Syracuse	2,648	2,571	-2.92%	15,288	14,724	-3.69%
Antelope	2,387	2,252	-5.64%	16,542	13,678	-17.31%
Gentile	1,444	1,371	-5.04%	17,959	17,718	-1.34%
Hillfield	3,012	2,690	-10.69%	21,566	19,793	-8.22%
Layton Pkwy	1,265	1,334	5.49%	4,634	4,438	-4.23%
Gordon Ave	1,957	1,276	-34.79%	6,421	4,882	-23.97%

The length of the Layton community-scale network increased 16%, with a similar increase in free-flow travel times. The actual travel times, as well as the total delays were reduced 4% and 9% respectively, showing the benefits of better connectivity on network mobility. A small reduction in VMTs is also observed on the network level.

A reduction in volumes is also observed along most arterials, except 700 S and Layton Parkway. The VMTs along all arterial are reduced, ranging from very small reductions of 1% to significant ones of more than 20%.

Table 5: MOE Comparison for Tooele Community-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Length (mi)	129.172	200.904	55.53%
Volumes (vp3h)	266,637	292,444	9.68%
TT_o (h)[1]	2.749	4.927	79.21%
TT_{act} (h)[2]	3.866	5.846	51.19%
Delay (h)[3]	1.117	0.918	-17.78%
3 hr VMT (mi)	105,653	107,069	1.34%

[1] Free flow travel time

[2] Actual travel time

[3] Delay = TT_o - TT_{act}

Table 6: Arterial Volumes and VMTs for Tooele Network

	Avg. 3 hour volumes			Total 3 hour VMT		
Arterial / Collector	Base	Improvements	Difference (%)	Base	Improvements	Difference (%)
State Route 36	3,194	3,049	-4.53%	55,427	53,767	-2.99%
State Route 138	1,112	1,000	-10.05%	14,776	13,007	-11.98%
West Erda Way	935	655	-30.03%	9,024	6,551	-27.40%
East Erda Way	416	269	-35.40%	1,647	1,021	-37.98%
Bates Canyon Rd	351	325	-7.40%	1,752	1,651	-5.76%
UT 112	532	524	-1.48%	4,159	4,126	-0.77%
Village Blvd	313	333	6.25%	894	1,031	15.23%
Center Street	510	507	-0.69%	2,108	2,133	1.22%
Droubay Road	252	235	-6.76%	3,229	3,014	-6.64%

The total length of the Tooele network increased about 55%, with an 80% increase in free-flow travel times. In this case, the actual travel time in the new network also increased, but the total delay (computed as the difference between the free-flow and actual travel time) reduced about 18%. About 10% more volumes, with a slight increase in VMTs, are also observed in this network. This is due to the major changes in the network layout, much more than in the previous two networks, since the total network length increased more than 50%. This caused major changes in traffic flow patterns. That can be seen from Table 6, with some significant reductions in traffic volumes and VMTs for almost all arterials and major collectors. The only collector for which an increase in volumes and VMTs is observed is Village Blvd, which in the new connected scenario took over traffic volumes from Bates Canyon Road. The reductions in volumes and VMTs range from insignificant (less than 1%) to very significant (close to 40%).

Comparison with Street Widening Scenarios

Capacity increase and operational improvements in a network can be achieved by street widening, i.e. adding travel lanes to existing roadways. The result would be a redistribution of traffic flows within the network, with the roads with increased capacity attracting more traffic. Street widening scenarios were tested on the three community-scale networks for the purpose of comparing street connectivity with street widening.

In the Lehi network, the following arterials and collectors were widened, by adding a lane in each direction: SR 92, Lehi Main Street, State Street and Alpine Highway. In the Layton network, a lane was added to the Main Street south of Antelope drive, Fairfield, and Antelope Drive east of Hillfield. The street widening scenario for these two networks was designed in such a way to achieve similar actual travel times with the street connectivity scenario, for easier comparison. In the Tooele network, an extra lane in each direction was added to West Erda Way and Bates Canyon Road. Since in the street connectivity scenario the actual travel time increased, the method behind street widening was to achieve similar delays with the street connectivity scenario. The results are given in the following tables.

Table 7: MOE Comparison for Lehi Network with Street Widening Scenario

	Base	Connectivity improvements	Street widening	Street con./Base	Street wid./Base
Length (mi)	254.82	332.05	254.82	30.31%	0.00%
Length (lane-mi)	313.64	391.78	349.53	24.91%	11.44%
Volumes (vp3h)	910,023	901,750	918,807	-0.91%	0.97%
Average street capacity (veh/h)	932	878	1,051	-5.86%	12.73%
Total network capacity (veh/h)	739,312	875,028	833,402	18.36%	12.73%
TTo (h)	8.17	10.52	8.17	28.82%	0.00%
TTact (h)	38.11	33.25	33.07	-12.74%	-13.23%
Delay (h)	29.94	22.73	24.90	-24.08%	-16.84%
3 hr VMT (mi)	320,135	314,238	319,486	-1.84%	-0.20%

Table 8: Arterial Volumes and VMTs for Lehi Network with Street Widening Scenario

	Avg. 3 hour volumes				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
SR 92	2,256	1,754	2,644	-22.28%	17.19%
MVC	1,964	916	1,750	-53.35%	-10.90%
State St	1,684	1,475	2,201	-12.38%	30.72%
Lehi Main	1,680	1,639	1,807	-2.43%	7.59%
2300 W	639	211	538	-66.98%	-15.75%
			Avg.	**-31.48%**	**5.77%**

	Total 3 hour VMTs				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
SR 92	30,499	25,599	35,251	-16.06%	15.58%
MVC	6,408	3,065	5,700	-52.17%	-11.05%
State St	14,006	12,841	18,423	-8.32%	31.54%
Lehi Main	12,208	11,233	13,584	-7.99%	11.27%
2300 W	2,855	984	2,489	-65.53%	-12.81%
			Avg.	**-30.01%**	**6.91%**

Although the total roadway length remained unchanged, the lane-miles increased in the street widening scenario by about 12%. The lane-miles increase in the street connectivity scenario is 25%, about twice as much as in the street widening scenario. Street widening resulted in about the same actual travel time as improved connectivity, but the delay reduction (computed as the difference between the free-flow and actual travel times) is still higher in the street connectivity scenario (24% vs. 17% reduction). Although the average street capacity reduced 6% in the street connectivity scenario, the total network capacity increased 18%. The increase in the average street and total network capacity in the street widening scenario was the same, about 13%. The widened streets attracted more traffic, between 8% and 31%, with a similar increase in VMTs. Total increase in volumes and VMTs along the analyzed alternatives was 6% and 7% respectively. Improved street connectivity reduced volumes and VMTs along these streets for about 30%.

Table 9: MOE Comparison for Layton Network with Street Widening Scenario

	Base	Connectivity improvements	Street widening	Street con./Base	Street wid./Base
Length (mi)	252.48	292.88	252.48	16.00%	0.00%
Length (lane-mi)	356.05	396.45	376.79	11.35%	5.82%
Volumes (vp3h)	1,405,481	1,446,527	1,389,940	2.92%	-1.11%
Average street capacity (veh/h)	1,303	1,212	1,357	-6.97%	4.13%
Total network capacity (veh/h)	905,662	1,000,130	943,052	10.43%	4.13%
TTo (h)	7.31	8.54	7.31	16.81%	0.00%
TTact (h)	40.40	38.81	37.55	-3.94%	-7.05%
Delay (h)	33.09	30.27	30.25	-8.53%	-8.61%
3 hr VMT (mi)	531,861	528,495	530,424	-0.63%	-0.27%

Table 10: Arterial Volumes and VMTs for Layton Network with Street Widening Scenario

	Avg. 3 hour volumes				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
SR-193	1,938	1,618	1,797	-16.51%	-7.27%
700 South	2,548	2,588	2,502	1.57%	-1.80%
Syracuse	2,648	2,571	2,629	-2.92%	-0.70%
Antelope	2,387	2,252	2,501	-5.64%	4.79%
Gentile	1,444	1,371	1,421	-5.04%	-1.58%
Hillfield	3,012	2,690	2,844	-10.69%	-5.56%
Layton Pkwy	1,265	1,334	1,216	5.49%	-3.87%
Gordon Ave	1,957	1,276	1,761	-34.79%	-9.98%
			Avg.	**-8.57%**	**-3.25%**

	Total 3 hour VMTs				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
SR-193	16,471	13,396	15,297	-18.66%	-7.12%
700 South	13,982	13,186	13,815	-5.69%	-1.19%
Syracuse	15,288	14,724	15,165	-3.69%	-0.81%
Antelope	16,542	13,678	18,828	-17.31%	13.82%
Gentile	17,959	17,718	17,882	-1.34%	-0.43%
Hillfield	21,566	19,793	20,597	-8.22%	-4.49%
Layton Pkwy	4,634	4,438	4,413	-4.23%	-4.76%
Gordon Ave	6,421	4,882	5,696	-23.97%	-11.29%
			Avg.	**-10.39%**	**-2.04%**

The lane-miles increased in the street widening scenario is about 6%, compared to the 11% increase in the street connectivity scenario. Street widening resulted in about the same actual travel time and delay reduction as improved connectivity. Although the average street capacity reduced 7% in the street connectivity scenario, the total network capacity increased more than 10%. The increase in the average street and total network capacity in the street widening scenario was the same, about 4%. The widened streets attracted more traffic, changing the traffic distribution in the network. Improved street connectivity reduced volumes and VMTs along analyzed streets for about 8-10%, more than the street widening scenario (2-3%).

Table 11: MOE Comparison for Tooele Network with Street Widening Scenario

	Base	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
Length (mi)	389.75	454.34	389.75	16.57%	0.00%
Length (lane-mi)	437.60	502.19	454.48	14.76%	3.86%
Volumes (vp3h)	360,539	376,206	368,055	4.35%	2.08%
Average street capacity (veh/h)	526	552	544	5.01%	3.35%
Total network capacity (veh/h)	1,267,400	1,399,900	1,309,800	10.45%	3.35%
TTo (h)	11.14	13.09	11.14	17.49%	0.00%
TTact (h)	13.24	14.88	12.82	12.41%	-3.15%
Delay (h)	2.10	1.80	1.68	-14.55%	-19.83%
3 hr VMT (mi)	120,625	120,302	121,499	-0.27%	0.72%

Table 10: Arterial Volumes and VMTs for Layton Network with Street Widening Scenario

	Avg. 3 hour volumes				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
State Route 36	3,194	3,049	3,262	-4.53%	2.13%
State Route 138	1,112	1,000	907	-10.05%	-18.48%
West Erda Way	935	655	1,210	-30.03%	29.35%
East Erda Way	416	269	406	-35.40%	-2.40%
Bates Canyon Road	351	325	406	-7.40%	15.74%
UT 112	532	524	525	-1.48%	-1.41%
Village Boulevard	313	333	300	6.25%	-4.17%
Center Street	510	507	507	-0.69%	-0.54%
Droubay Road	252	235	252	-6.76%	0.00%
			Avg.	**-10.01%**	**2.25%**

	Total 3 hour VMTs				
Street	**Base**	**Connectivity improvements**	**Street widening**	**Street con./Base**	**Street wid./Base**
State Route 36	55,427	53,767	56,621	-2.99%	2.15%
State Route 138	14,776	13,007	11,685	-11.98%	-20.92%
West Erda Way	9,024	6,551	11,523	-27.40%	27.70%
East Erda Way	1,647	1,021	1,593	-37.98%	-3.28%
Bates Canyon Road	1,752	1,651	2,046	-5.76%	16.83%
UT 112	4,159	4,126	4,127	-0.77%	-0.75%
Village Boulevard	894	1,031	876	15.23%	-2.05%
Center Street	2,108	2,133	2,096	1.22%	-0.56%
Droubay Road	3,229	3,014	3,232	-6.64%	0.09%
			Avg.	**-8.56%**	**2.13%**

Due to the network of the Tooele network, as discussed earlier, the actual travel times in the network increased in the street connectivity scenario, but the total delay (computed as the difference between the free-flow and actual travel times) reduced. The street widening scenario reduced the actual travel time in the network by about 3%, with a comparable reduction in delays with the street connectivity scenario. The total lane miles in the street connectivity scenario increased about 15%, compared to 4% in the street widening scenario. In this case, the average and street and the total network capacity increased 5% and 11% respectively in the street connectivity scenario, compared to a 3% increase in both cases in the street widening scenario. The distribution of traffic volumes was quite different in the two scenarios, with improved street connectivity reducing total volumes and VMTs along analyzed streets 9-10%, compared to a 2% increase in volumes in the street connectivity scenario. This again shows a much better distribution of traffic flows in a better connected network.

NEIGHBORHOOD-SCALE NETWORKS WITH CONNECTIVITY IMPROVEMENTS

One neighborhood-scale network from each community networks was selected for further analysis of connectivity improvements. In this case, the networks were analyzed in VISSIM microsimulation environment for a more detailed insight into their operations. Thanksgiving Point was chosen from the Lehi network as a representative of a campus district neighborhood, Downtown Layton from the Layton network as a representative of an urban neighborhood, and West Erda from the Tooele network as a representative of a rural neighborhood. These networks were cut from the VISUM models using previously loaded traffic assignment and exported into VISSIM for further analysis. Traffic signals were also included in VISSIM, with the signal timing data obtained from UDOT's MaxView system. Freeway were not included in the analysis, but the freeway ramps were, where applicable. The VISSIM neighborhood networks are given in Figures 7 to 9.

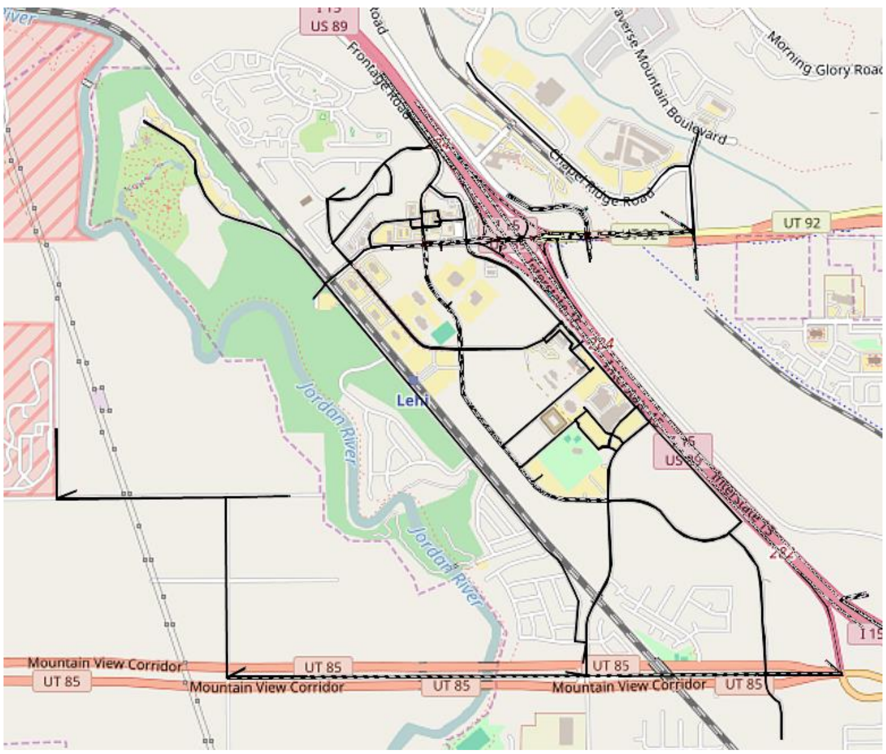

Figure 7: Layout of Thanksgiving Point Neighborhood-Scale VISSIM Network

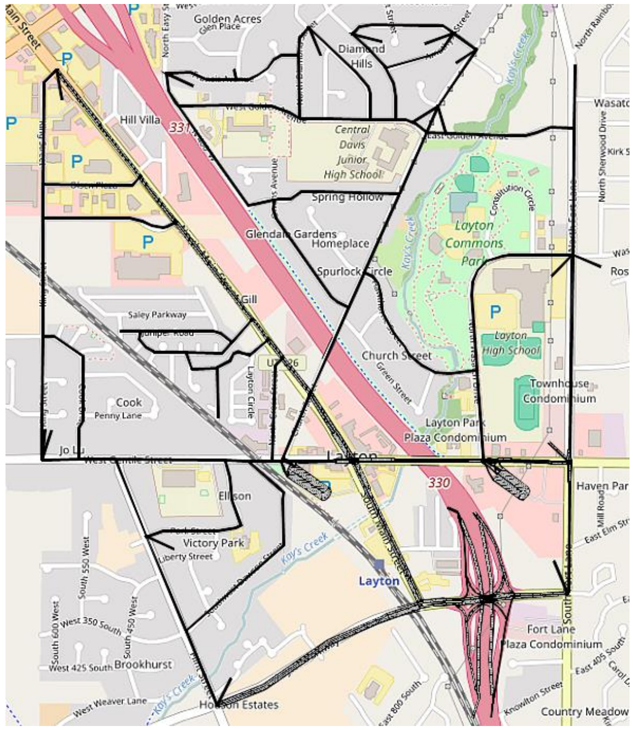

Figure 8: Layout of Downtown Layton Neighborhood-Scale VISSIM Network

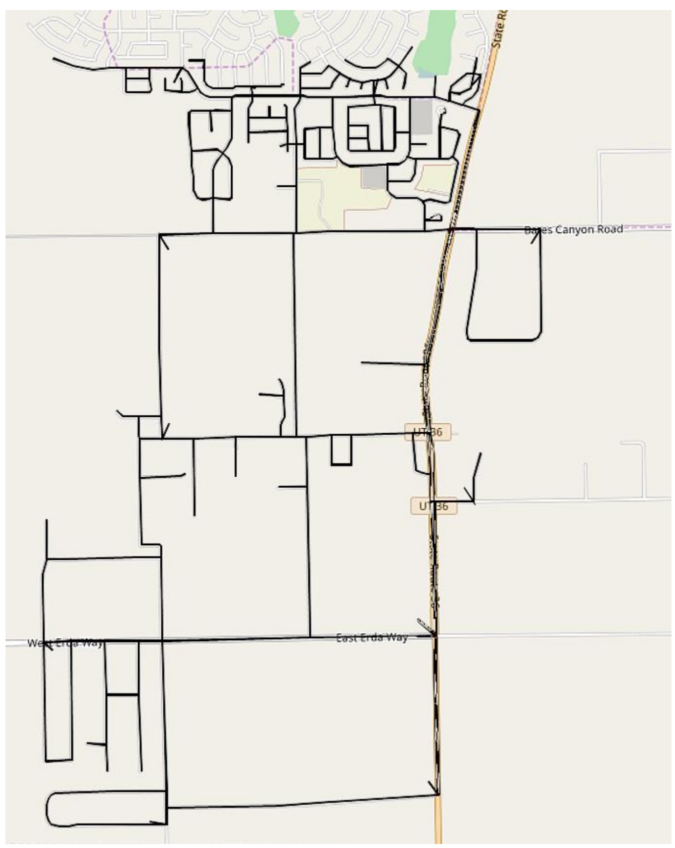

Figure 9: Layout of West Erda Neighborhood-Scale VISSIM Network

According to the recommendations for neighborhood connectivity improvements, the existing networks were modified with added connections, which were defined as local streets. To make a comparison to the existing condition, the same vehicle inputs were used in base and improved networks, and VISUM vas used to determine the new traffic assignment/routing for the connected scenario, which was replicated in VISSIM microsimulation. The obtained results on the neighborhood-scale are given in the following tables.

Table 7: MOE Comparison for Thanksgiving Point Neighborhood-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Total vehicles (veh/3h)	15,846	18,753	18.35%
Distance traveled (mi)	30,010.94	33,563.51	11.84%
Average speed (mph)	26.09	24.90	-4.56%
Total travel time (h)	1,150.19	1,348.16	17.21%
Average delay (s/veh)	35.13	42.31	20.44%
Average stops per vehicle	1.31	1.68	28.24%

In the connected scenario of the Thanksgiving Point network the total volumes increased close to 20%, followed by the similar increase in travel times and average vehicular delays, with about 5% reduction in average speeds. Total traveled distances, and therefore VMTs, increased about 19%. The increase in volumes and VMTs is attributed to the traversing traffic which is using new network connections throughout the neighborhood. Part of the increase in travel times and stops per vehicle is also attributed to new intersections in the network. However, the reduction in speeds and increase in stops is beneficial for non-motorized modes, since it can lead to improved safety along local streets and at intersections. If the traffic volumes in the neighborhood increase beyond the set threshold, they can be controlled by other measures, such as traffic calming and speed limit reduction. The overall layout of the connected scenario is beneficial to non-motorized mode from operational perspective too, since it provides better accessibility and shorter travel distances within the network. Furthermore, as the travel demand increases in the future, the benefits of better neighborhood connectivity will become more significant.

Table 8: MOE Comparison for Downtown Layton Neighborhood-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Total vehicles (veh/3h)	17,056	17,087	0.18%
Distance traveled (mi)	23,003.72	23,612.77	2.65%
Average speed (mph)	24.58	23.25	-5.41%
Total travel time (h)	935.96	1,015.69	8.52%
Average delay (s/veh)	41.71	49.39	18.41%
Average stops per vehicle	1.42	2.50	76.06%

No changes in traffic volumes were recorded in the connected scenario of the Downtown Layton network, meaning that the traversing traffic was mostly avoiding the downtown area, even with the added connections. The distance traveled and VMT slightly increased, with about 5% reduction in average speeds and increase in delays, travel times and stops. This can be attributed to the increased number of intersections, as well as the low-speed connections introduced to the network. Similarly as in the previous case, this can benefit non-motorized traffic from the safety and operational standpoints. Since no additional traffic was recorded in this network, there would be no need for other strategies to control volumes.

Table 9: MOE Comparison for West Erda Neighborhood-Scale Network

MOE	Base scenario	Connectivity improvements	Difference (%)
Total vehicles (veh/3h)	9,755	9,757	0.02%
Distance traveled (mi)	17,956.56	17,941.35	-0.08%
Average speed (mph)	40.15	39.29	-2.14%
Total travel time (h)	447.28	456.69	2.10%
Average delay (s/veh)	18.28	20.44	11.82%
Average stops per vehicle	0.29	0.46	58.62%

No changes were observed in traffic volumes and VMTs in the West Erda network, meaning that the traversing traffic did not use the new connections. A slight reduction in speeds with a similar increase in travel times, and a more significant increase in average delay and number of stops per vehicle were recorded. This can be attributed to the increased number of intersections, as well as the low-speed connections introduced to the network. Compared to the previous two networks, significantly higher speeds and lower delays and number of stops per vehicle were observed in West Erda. This is due to the fact that this is a rural neighborhood, with higher speed limits and lower traffic volumes. The extension of safety benefits for non-motorized traffic in this case would be lower than for the previous two networks, but the operational benefits would be significant due to better accessibility and shorter travel distances within the network.

CONCLUSIONS

The impacts and benefits of increased street connectivity tested on the case-study networks show similar results with other studies presented in the literature. In urban and suburban community-scale networks, a significant reduction in network travel times and delays was observed. VMTs on higher-rank streets was in most cases significantly reduced, attributed to a more balanced distribution of traffic flows within the network. Travel times and delays in the rural tested network were increased, but the traffic volumes and VMTs were also reduced along higher-rank roads. This is due to the fact that a rural network has different characteristics, with higher speed limits and less signalized and stop controlled intersections, so any introduction of a new intersection can increase delays. However, the benefits of a more balanced traffic distribution, as well as shorter travel distances are evident in all community-scale networks.

A campus-type neighborhood network with better street connectivity was shown to attract more traversing traffic. However, this does not have to be the rule, since in most cases this will depend on the location of the network and the proximity of high-capacity and high-speed highway facilities, as well as connections to those facilities. Improving connectivity in urban and rural neighborhoods does not seem to attract more traversing traffic, but at the same time provides a safer and better environment for non-motorized traffic modes. These benefits are much higher in an urban network, due to overall lower speeds and more intersection with traffic control devices.

It should be noted that these effects of improved street connectivity refer to the analyzed networks. However, similar effects may be assumed for other similar networks, since traffic flows and the distribution of traffic will follow the same general patterns.

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Utah Street Connectivity Study Active Transportation Benefits Modeling

Introduction

This memo contains an analysis of the quantified benefits that might occur as the result of implementing recommended urban level street and trail connectivity improvements in the Utah Street Connectivity Study Case Study communities of Lehi, Layton, and Tooele County. The analysis estimates the number of bicycle and walking trips that would result from an increase in bicycle and pedestrian mode share, approximates the corresponding reduction in vehicle trips and vehicle-miles traveled (VMT), and assesses the potential health, environmental, and transportation-related benefits.

Methodology

The impact analysis uses a standard methodology for calculating health, environmental, and transportation-related benefits. All projections are based on the most recent (2010-2014) five-year estimates from the American Community Survey (ACS), which are then extrapolated through the use of various multipliers derived from national studies. Then, the low, mid, and high estimates of improved walking and bicycling mode shares, or rates, which are based on peer cities that roughly meet the urban level street and trail connectivity that is recommended, are quantified in terms of monetary and other values, where appropriate.

LEHI

Selecting Peer Cities

In order to estimate future bicycling and walking mode split increases that may result from the implementation of the connectivity improvements in the Utah Street Connectivity Study's deliverables, the consultant team examined many different municipalities and areas with similar demographics, industries (technology, in these cases), proximity to a major urban center, and land uses, called peer cities. Selection factors in choosing the final "peer cities" included the existing street network and trail connectivity, geographic location, climate, typography, sociodemographic data, rates of walking and bicycling, and the completeness of the city or area's bicycle and pedestrian network. **Table 1** *shows general characteristics of Lehi and the selected peer cities.*

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Table 1: General Characteristics Comparison of Selected Peer Cities

	Lehi, UT	Beaverton, OR	Bellevue, WA	Menlo Park, CA	Palo Alto, CA	Redmond, WA	Salt Lake City, UT	West Sacramento, CA
Region	Mountain West	Pacific NW	Pacific NW	Northern California	Northern California	Pacific NW	Mountain West	Northern California
Climate	Hot-summer continental (Dfa)	Mediterranean (Csb)	Mediterranean (Csb)	Mediterranean (Csb)	Mediterranean (Csb)	Mediterranean (Csb)	Hot-summer continental (Dfa)	Mediterranean (Csa)
Elevation (ft)	4,564	189	85	72	30	43	4,226	30
Population[i]	51,982	92,593	132,268	32,792	65,998	56,704	189,267	49,946
Population Density per Square Mile[ii]	~2,000/sq mi	~4,900/sq mi	~4,100/sq mi	~3,300/sq mi	~2,800/sq mi	~3,500/sq mi	~1,700/sq mi	~2,300/sq mi
Bicycle Friendly Community Award Level[iii]	n/a	Silver	Bronze	Silver	Gold	Silver	Silver	Bronze
Walk Friendly Community Award Level[iv]	n/a	n/a	Silver	n/a	n/a	n/a	n/a	n/a

[i] *American Community Survey (2010-2014).*
[ii] *Ibid.*
[iii] *"Current Bicycle Friendly Communities." (2016). The League of American Bicyclists. http://bikeleague.org/sites/default/files/BFC_Master_Spring%202016_1.pdf*
[iv] *"Full List of Walk Friendly Communities." (2016). Walk Friendly Communities. http://www.walkfriendly.org/communities/list.cfm*

Table 2: Existing and Estimated Bicycle and Walk Commute Mode Share

	Bicycle Commute Mode Share	Walk Commute Mode Share
Baseline[v]	0.25%	0.85%
Low Estimate	1.10%	3.22%
Mid Estimate	1.75%	4.46%
High Estimate	5.24%	5.25%

[v] *American Community Survey (2010-2014)*

Multipliers

Multipliers were developed through an analysis of the relationship between two or more model inputs, such as the number of vehicle-miles traveled and the cost of road maintenance. The model used for this study includes over 50 multipliers in order to extrapolate annual trip rates, trip distance, vehicle trips replaced, emission rates, physical activity rates, and other externalities linked to an increase in bicycling and walking trips and to a decrease in motor vehicle trips.

Limitations

The primary purpose of the analysis is to enable a more informed policy discussion on whether and how best to invest in an active transportation network in the study area. Even with extensive primary and secondary research incorporated into the impact analysis model, it is impossible to accurately predict the exact impacts of various factors. Accordingly, all estimated benefit values are rounded and should be considered order of magnitude estimates, rather than exact amounts.

Health Benefits

The implementation of a well-designed, connected bicycle and pedestrian network across the study area will encourage a shift from energy-intensive modes of transportation, such as cars and trucks, to active and less energy-intensive modes of

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transportation, such as bicycling and walking. The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips, the estimated increase in hours of physical activity, and the annual savings resulting from reduced healthcare costs. The primary inputs into the health component of the Benefit Impact Model derived from 2010-2014 ACS Journey to Work data, 2009 National Household Travel Survey, and historic Safe Routes to School data. Existing bicycling and walking commute data was multiplied by national trip purpose ratios to generate mode share data that includes all trip purposes. This balanced mode share data was indexed against the mode share data of Lehi's peer cities, and multiplied by various health factors.

If the recommended connectivity improvements are implemented, the study area could experience between about **5,000,000 and 12,500,000** *more bicycle and pedestrian trips per year and between about* **1,600,000 and 6,500,000** *more miles bicycled and walked per year, resulting in an annual reduction of about* **1,700,000 to 5,900,000** *vehicle-miles traveled (VMT) over the baseline.*

These annual distance estimates and VMT reduction estimates were used to estimate changes in physical activity rates among study area residents. Implementation could result in between about **330,000 and 970,000** *more hours of physical activity per year among study area residents over current activity rates. This increase in physical activity means that up to about* **7,500** *more residents will be meeting the Centers for Disease Control and Prevention's guidelines for the minimum recommended number of hours of physical activity per day, which is equal to a jump from approximately* **4.73** *percent of the local physical activity need being met through bicycling and walking to between* **9.62 and 19.10** *percent of the regional physical activity need being met. This growth in the percent of people within the study area exercising equates to an additional* **$176,000 to $500,000** *reduction in healthcare expenses per year.* **Table 3** *shows the estimated annual health benefits for the study area.*

Table 3: Estimated Annual Health Benefits

		Future Estimates					
	Baseline	Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Bike and Walk Trips	1,698,000	6,624,000	4,926,000	9,389,000	7,691,000	14,213,000	12,515,000
Miles Biked and Walked	1,301,000	2,923,000	1,622,000	3,981,000	2,680,000	7,886,000	6,585,000
Hours of Physical Activity	319,000	650,000	331,000	844,000	525,000	1,291,000	972,000
Recommended Physical Activity Min. Met	2,500	5,000	2,500	6,500	4,000	10,000	7,500
Physical Activity Need Met	4.72%	9.62%	4.90%	12.49%	7.77%	19.10%	14.38%
Healthcare Cost Savings	$60,000	$236,000	$176,000	$338,000	$278,000	$560,000	$500,000

Environmental Benefits

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The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips and the annual savings from reduced vehicle emissions. In order to evaluate these environmental factors, a number of readily-available data inputs were analyzed. Using the estimates of VMT reductions calculated in the health benefits analysis, changes in hydrocarbon, particulate matter, nitrous oxides, carbon monoxide, and carbon dioxide were analyzed.

In total, the replacement of motor vehicle trips with active transportation trips in the study area may result in an estimated range of approximately **2,900,000 to 11,900,000** *fewer pounds of CO_2 emissions per year and between* **57,000 and 190,000** *fewer pounds of other vehicle emissions above the baseline benefits. Based on a review of air emissions studies, each pound of emissions was assigned an equivalent dollar amount based on how much it would cost to clean up the pollutant or the cost equivalent of how much damage the pollutant causes to the environment. The total reduction in vehicle emissions is equal to a savings between* **$58,000 and $197,000** *in related environmental damage or clean-up per year in addition to the baseline benefits. Other potential ecological services associated with improved active transportation connectivity projects include water regulation, carbon sequestration, carbon storage, and waste treatment exist, but the quantifiable value of these services are negligible on the overall impact of the recommended improvements.* **Table 4** *summarizes the estimated environmental benefits in the study area.*

Table 4: Estimated Annual Environmental Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
CO_2 Emissions Reduced (lbs)	934,000	3,869,000	2.935.000	5,786,000	4,852,000	12,857,000	11,923,000
Other Vehicle Emissions Reduced (lbs)	18,000	75,000	57,000	110,000	92,000	208,000	190,000
Total Vehicle Emission Costs Reduced	$19,000	$77,000	$58,000	$113,000	$94,000	$216,000	$197,000

Transportation Benefits

The most readily-identifiable benefits of the recommended connectivity improvements are evident in their ability to increase transportation options and access to activity centers for residents in and visitors to the study area. While money rarely changes hands, real savings can be estimated from the reduced costs associated with congestion, vehicle crashes, road maintenance, and household vehicle operations. Using the same annual VMT reduction estimates highlighted in the health and environmental sections, transportation-related cost savings were calculated.

By multiplying the amount of VMT reduced by established multipliers for traffic congestion, vehicle collisions, road maintenance, and vehicle operating costs, monetary values were assigned to the transportation-related benefits. In total, an additional annual transportation-related cost savings between **$2,243,000 and $7,557,000** *is estimated for the study area after completion of recommended connectivity improvements.* **Table5** *summarizes the estimated transportation benefits in the study area.*

Table 5: Estimated Annual Transportation Benefits

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	Baseline	Future Estimates: Low		Future Estimates: Mid		Future Estimates: High	
	Total	Total	Difference	Total	Difference	Total	Difference
Annual VMT Reduced	574,000	2,312,000	1,738,000	3,375,000	2,801,000	6,431,000	5,857,000
Reduced Traffic Congestion Costs	$40,000	$162,000	$122,000	$237,000	$197,000	$451,000	$411,000
Reduced Vehicle Crash Costs	$287,000	$1,156,000	$869,000	$1,688,000	$1,401,000	$3,215,000	$2,928,000
Reduced Road Maintenance Costs	$86,000	$347,000	$261,000	$506,000	$420,000	$965,000	$879,000
Household Vehicle Operation Cost Savings	$327,000	$1,318,000	$991,000	$1,923,000	$1,596,000	$3,666,000	$3,339,000
Total Transportation Benefits	**$740,000**	**$2,983,000**	**$2,243,000**	**$4,354,000**	**$3,614,000**	**$8,297,000**	**$7,557,000**

Total Benefits

If levels of connectivity similar to the peer cities are reached and the active commute mode shares increase to low, mid, or high estimates based on peer cities' mode shares, the study area could experience between **$2,477,000 and $8,254,000** *in additional health, environmental, and transportation-related benefits every year.* **Table 6** *summarizes the estimated benefits of existing active transportation in the study area, as well as the estimated benefits that may result from completion of recommended improvements.*

Table 6: Total Estimated Annual Benefits

	Baseline	Future Estimates: Low		Future Estimates: Mid		Future Estimates: High	
	Total	Total	Difference	Total	Difference	Total	Difference
Health Benefits	$60,000	$236,000	$176,000	$338,000	$278,000	$560,000	$560,000
Environmental Benefits	$19,000	$77,000	$58,000	$113,000	$94,000	$216,000	$197,000
Transportation Benefits	$740,000	$2,983,000	$2,243,000	$4,354,000	$3,614,000	$8,297,000	$7,557,000
Total Benefits	**$819,000**	**$3,296,000**	**$2,477,000**	**$4,805,000**	**$3,986,000**	**$9,073,000**	**$8,254,000**

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Note: Please ignore the footnotes below.

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[i] American Community Survey (2010-2014)
[ii] *Ibid.*
[iii] "Current Bicycle Friendly Communities." (2016). *The League of American Bicyclists.* http://bikeleague.org/sites/default/files/BFC_Master_Spring%202016_1.pdf
[iv] "Full List of Walk Friendly Communities." (2016). *Walk Friendly Communities.* http://www.walkfriendly.org/communities/list.cfm
[v] American Community Survey (2010-2014)

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LAYTON

Selecting Peer Cities

In order to estimate future bicycling and walking mode split increases that may result from the implementation of the connectivity improvements in the Utah Street Connectivity Study's deliverables, the consultant team examined many different municipalities and areas with similar demographics, industries, proximity to a major urban center, and land uses, called peer cities. Selection factors in choosing the final "peer cities" included the existing street network and trail connectivity, geographic location, climate, typography, sociodemographic data, rates of walking and bicycling, and the completeness of the city or area's bicycle and pedestrian network. **Table 7** *shows general characteristics of Layton and the selected peer cities.*

Table 7: General Characteristics Comparison of Selected Peer Cities

	Layton, UT	Albany, OR	Claremont, CA	Edina, MN	Goshen, IN	Portage, MI	Redmond, WA	West Sacramento, CA
Region	Mountain West	Pacific NW	Southern California	Midwest	Midwest	Midwest	Pacific NW	Northern California
Climate	Hot-summer continental (Dfa)	Mediterranean (Csb)	Mediterranean (Csa)	Hot-summer continental (Dfa)	Hot-summer continental (Dfa)	Hot-summer continental (Dfa)	Mediterranean (Csb)	Mediterranean (Csa)
Elevation (ft)	4,350	210	1,168	922	801	879	43	30'
Population[v]	69,508	51,210	35,569	48,940	32,297	47,137	56,704	49,946
Population Density per Square Mile[v]	3,159	2,919	2,664	3,167	1,989	1,462	~3,500/sq mi	~2,300/sq mi
Bicycle Friendly Community Award Level[v]	n/a	Bronze	Silver	Bronze	Bronze	Bronze	Silver	Bronze
Walk Friendly Community Award Level[v]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[i] *American Community Survey (2010-2014).*
[ii] *Ibid.*
[iii] *"Current Bicycle Friendly Communities." (2016). The League of American Bicyclists. http://bikeleague.org/sites/default/files/BFC_Master_Spring%202016_1.pdf*
[iv] *"Full List of Walk Friendly Communities." (2016). Walk Friendly Communities. http://www.walkfriendly.org/communities/list.cfm*

Table 8: Existing and Estimated Bicycle and Walk Commute Mode Share

	Bicycle Commute Mode Share	Walk Commute Mode Share
Baseline[v]	0.17%	1.26%
Low Estimate	0.75%	0.28%
Mid Estimate	1.51%	0.75%
High Estimate	1.66%	2.95%

[v] *American Community Survey (2010-2014)*

Multipliers

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Multipliers were developed through an analysis of the relationship between two or more model inputs, such as the number of vehicle-miles traveled and the cost of road maintenance. The model used for this study includes over 50 multipliers in order to extrapolate annual trip rates, trip distance, vehicle trips replaced, emission rates, physical activity rates, and other externalities linked to an increase in bicycling and walking trips and to a decrease in motor vehicle trips.

Limitations

The primary purpose of the analysis is to enable a more informed policy discussion on whether and how best to invest in an active transportation network in the study area. Even with extensive primary and secondary research incorporated into the impact analysis model, it is impossible to accurately predict the exact impacts of various factors. Accordingly, all estimated benefit values are rounded and should be considered order of magnitude estimates, rather than exact amounts.

Health Benefits

The implementation of a well-designed, connected bicycle and pedestrian network across the study area will encourage a shift from energy-intensive modes of transportation, such as cars and trucks, to active and less energy-intensive modes of transportation, such as bicycling and walking. The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips, the estimated increase in hours of physical activity, and the annual savings resulting from reduced healthcare costs. The primary inputs into the health component of the Benefit Impact Model derived from 2010-2014 ACS Journey to Work data, 2009 National Household Travel Survey, and historic Safe Routes to School data. Existing bicycling and walking commute data was multiplied by national trip purpose ratios to generate mode share data that includes all trip purposes. This balanced mode share data was indexed against the mode share data of Layton's peer cities, and multiplied by various health factors.

If the recommended connectivity improvements are implemented, the study area could experience between about **1,807,000 and 8,850,000** *more bicycle and pedestrian trips per year and between about* **1,406,000 and 4,273,000** *more miles bicycled and walked per year, resulting in an annual reduction of about* **1,141,000 to 3,992,000** *vehicle-miles traveled (VMT) over the baseline.*

These annual distance estimates and VMT reduction estimates were used to estimate changes in physical activity rates among study area residents. Implementation could result in between about **172,000 and 766,000** *more hours of physical activity per year among study area residents over current activity rates. This increase in physical activity means that up to about* **5,900** *more residents will be meeting the Centers for Disease Control and Prevention's guidelines for the minimum recommended number of hours of physical activity per day, which is equal to a jump from approximately* **6.62** *percent of the local physical activity need being met through bicycling and walking to between* **8.52 and 15.10** *percent of the regional physical activity need being met. This growth in the percent of people within the study area exercising equates to an additional* **$97,000 to $386,000** *reduction in healthcare expenses per year.* **Table 9** *shows the estimated annual health benefits for the study area.*

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Table 9: Estimated Annual Health Benefits

		Future Estimates					
	Baseline	Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Bike and Walk Trips	2,891,000	4,698,000	1,807,000	6,916,000	4,025,000	11,742,000	8,851,000
Miles Biked and Walked	2,183,000	3,589,000	1,406,000	5,113,000	2,930,000	6,456,000	4,273,000
Hours of Physical Activity	598,000	770,000	172,000	977,000	379,000	1,364,000	766,000
Recommended Physical Activity Min. Met	4,600	5,900	1,300	7,500	2,900	10,500	5,900
Physical Activity Need Met	6.62%	8.52%	1.90%	10.81%	4.19%	15.10%	8.48%
Healthcare Cost Savings	$110,000	$207,000	$97,000	$320,000	$210,000	$496,000	$386,000

Environmental Benefits

The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips and the annual savings from reduced vehicle emissions. In order to evaluate these environmental factors, a number of readily-available data inputs were analyzed. Using the estimates of VMT reductions calculated in the health benefits analysis, changes in hydrocarbon, particulate matter, nitrous oxides, carbon monoxide, and carbon dioxide were analyzed.

In total, the replacement of motor vehicle trips with active transportation trips in the study area may result in an estimated range of approximately **3,825,000 to 10,000,000** *fewer pounds of* CO_2 *emissions per year and between* **36,000 and 129,000** *fewer pounds of other vehicle emissions above the baseline benefits. Based on a review of air emissions studies, each pound of emissions was assigned an equivalent dollar amount based on how much it would cost to clean up the pollutant or the cost equivalent of how much damage the pollutant causes to the environment. The total reduction in vehicle emissions is equal to a savings between* **$39,000 and $134,000** *in related environmental damage or clean-up per year in addition to the baseline benefits. Other potential ecological services associated with improved active transportation connectivity projects include water regulation, carbon sequestration, carbon storage, and waste treatment exist, but the quantifiable value of these services are negligible on the overall impact of the recommended improvements.* **Table 10** *summarizes the estimated environmental benefits in the study area.*

Table 10: Estimated Annual Environmental Benefits

		Future Estimates					
	Baseline	Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
CO_2 Emissions Reduced (lbs)	1,632,000	5,457,000	3,825,000	9,473,000	7,841,000	11,639,000	10,007,000
Other Vehicle Emissions Reduced (lbs)	33,000	69,000	36,000	111,000	78,000	162,000	129,000
Total Vehicle Emission Costs Reduced	$33,000	$72,000	$39,000	$115,000	$82,000	$167,000	$134,000

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Transportation Benefits

The most readily-identifiable benefits of the recommended connectivity improvements are evident in their ability to increase transportation options and access to activity centers for residents in and visitors to the study area. While money rarely changes hands, real savings can be estimated from the reduced costs associated with congestion, vehicle crashes, road maintenance, and household vehicle operations. Using the same annual VMT reduction estimates highlighted in the health and environmental sections, transportation-related cost savings were calculated.

By multiplying the amount of VMT reduced by established multipliers for traffic congestion, vehicle collisions, road maintenance, and vehicle operating costs, monetary values were assigned to the transportation-related benefits. In total, an additional annual transportation-related cost savings between **$1,474,000 and $5,151,000** *is estimated for the study area after completion of recommended connectivity improvements.* **Table11** *summarizes the estimated transportation benefits in the study area.*

Table 11: Estimated Annual Transportation Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Annual VMT Reduced	1,004,000	2,145,000	1,141,000	3,423,000	2,419,000	4,996,000	3,992,000
Reduced Traffic Congestion Costs	$70,000	$150,000	$80,000	$240,000	$170,000	$350,000	$280,000
Reduced Vehicle Crash Costs	$501,000	$1,073,000	$572,000	$1,712,000	$1,211,000	$2,498,000	$1,997,000
Reduced Road Maintenance Costs	$151,000	$322,000	$171,000	$513,000	$362,000	$750,000	$599,000
Household Vehicle Operation Cost Savings	$573,000	$1,224,000	$651,000	$1,952,000	$1,379,000	$2,848,000	$2,275,000
Total Transportation Benefits	**$1,295,000**	**$2,769,000**	**$1,474,000**	**$4,417,000**	**$3,122,000**	**$6,446,000**	**$5,151,000**

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Total Benefits

If levels of connectivity similar to the peer cities are reached and the active commute mode shares increase to low, mid, or high estimates based on peer cities' mode shares, the study area could experience between **$1,610,000 and $5,671,000** *in additional health, environmental, and transportation-related benefits every year.* **Table 12** *summarizes the estimated benefits of existing active transportation in the study area, as well as the estimated benefits that may result from completion of recommended improvements.*

Table 12: Total Estimated Annual Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Health Benefits	$110,000	$207,000	$97,000	$320,000	$210,000	$496,000	$386,000
Environmental Benefits	$33,000	$72,000	$39,000	$115,000	$82,000	$167,000	$134,000
Transportation Benefits	$1,295,000	$2,769,000	$1,474,000	$4,417,000	$3,122,000	$6,446,000	$5,151,000
Total Benefits	**$1,438,000**	**$3,048,000**	**$1,610,000**	**$4,852,000**	**$3,414,000**	**$7,109,000**	**$5,671,000**

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TOOELE VALLEY

Selecting Peer Cities and Counties

In order to estimate future bicycling and walking mode split increases that may result from the implementation of the connectivity improvements in the Utah Street Connectivity Study's deliverables, the consultant team examined many different municipalities and areas with similar demographics, industries, proximity to a major urban center, and land uses, called peer cities and counties. Selection factors in choosing the final "peer cities and counties" included the existing street network and trail connectivity, geographic location, climate, typography, sociodemographic data, rates of walking and bicycling, and the completeness of the city or area's bicycle and pedestrian network. **Tables 13a and 13b** *show general characteristics of Tooele County and the selected peer cities and counties.*

Table 13a: General Characteristics Comparison of Selected Peer Cities and Counties

	Tooele Co., UT	Summit Co., UT	Garfield Co., CO	Grand Co., UT	Driggs, ID	Teton Co., ID
Region	Mountain West	Mountain West	Mountain West	Mountain West	Mountain West	Mountain West
Climate	Hot-summer continental (Dfa)	Warm-summer continental (Dfb)	Cold steppe climate (BSk)	Cold steppe climate (BSk)	Warm-summer continental (Dfb)	Warm-summer continental (Dfb)
Elevation (ft)	~5,000	~7,000	~5,700	~4,000	6,109	~6,000
Population[v]	59,973	37,877	56,684	9,348	2,141	10,212
Population Density per Square Mile[v]	8.6	20.2	19.2	2.5	775	22.7
Bicycle Friendly Community Award Level[v]	n/a	Silver (Park City, Snyderville Basin)	n/a	Silver	n/a	n/a
Walk Friendly Community Award Level[v]	n/a	n/a	n/a	n/a	n/a	n/a

[i] *American Community Survey (2010-2014).*
[ii] *Ibid.*
[iii] *"Current Bicycle Friendly Communities." (2016). The League of American Bicyclists. http://bikeleague.org/sites/default/files/BFC_Master_Spring%202016_1.pdf*
[iv] *"Full List of Walk Friendly Communities." (2016). Walk Friendly Communities. http://www.walkfriendly.org/communities/list.cfm*

Table ***Error! Main Document Only.****3b: General Characteristics Comparison of Selected Peer Cities and Counties*

	Crete, NE	Rushford, MN	Sheboygan Co., WI	Ridgecrest, CA	Aurora, MN
Region	Midwest	Midwest	Midwest	Central California	Midwest
Climate	Mediterranean (Csa)	Warm-summer continental (Dfb)	Warm-summer continental (Dfb)	Desert arid (BWh)	Warm-summer continental (Dfb)
Elevation (ft)	1,352	728	~600	2,290	1,470
Population	7,055	2,102	115,168	28,282	1,587
Population Density per Square Mile	2,416	1,229	225	1,361	424
Bicycle Friendly Community Award Level	n/a	n/a	Bronze	n/a	n/a
Walk Friendly Community Award Level	n/a	n/a	n/a	n/a	n/a

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Table 14: Existing and Estimated Bicycle and Walk Commute Mode Share

	Bicycle Commute Mode Share	Walk Commute Mode Share
Baseline[v]	0.33%	2.53%
Low Estimate	1.35%	2.53%
Mid Estimate	1.79%	3.44%
High Estimate	2.44%	5.33%

[v] *American Community Survey (2010-2014)*

Multipliers

Multipliers were developed through an analysis of the relationship between two or more model inputs, such as the number of vehicle-miles traveled and the cost of road maintenance. The model used for this study includes over 50 multipliers in order to extrapolate annual trip rates, trip distance, vehicle trips replaced, emission rates, physical activity rates, and other externalities linked to an increase in bicycling and walking trips and to a decrease in motor vehicle trips.

Limitations

The primary purpose of the analysis is to enable a more informed policy discussion on whether and how best to invest in an active transportation network in the study area. Even with extensive primary and secondary research incorporated into the impact analysis model, it is impossible to accurately predict the exact impacts of various factors. Accordingly, all estimated benefit values are rounded and should be considered order of magnitude estimates, rather than exact amounts.

Health Benefits

The implementation of a well-designed, connected bicycle and pedestrian network across the study area will encourage a shift from energy-intensive modes of transportation, such as cars and trucks, to active and less energy-intensive modes of transportation, such as bicycling and walking. The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips, the estimated increase in hours of physical activity, and the annual savings resulting from reduced healthcare costs. The primary inputs into the health component of the Benefit Impact Model derived from 2010-2014 ACS Journey to Work data, 2009 National Household Travel Survey, and historic Safe Routes to School data. Existing bicycling and walking commute data was multiplied by national trip purpose ratios to generate mode share data that includes all trip purposes. This balanced mode share data was indexed against the mode share data of Tooele County's peer cities and counties, and multiplied by various health factors.

If the recommended connectivity improvements are implemented, the study area could experience between about **1,166,000 and 6,466,000** *more bicycle and pedestrian trips per year and between about* **1,377,000 and 3,929,000** *more miles bicycled and walked per year, resulting in an annual reduction of about* **959,000 to 3,174,000** *vehicle-miles traveled (VMT) over the baseline.*

These annual distance estimates and VMT reduction estimates were used to estimate changes in physical activity rates among study area residents. Implementation could result in between about **138,000 and 647,000** *more hours of physical*

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activity per year among study area residents over current activity rates. This increase in physical activity means that up to about **5,000** *more county residents will be meeting the Centers for Disease Control and Prevention's guidelines for the minimum recommended number of hours of physical activity per day, which is equal to a jump from approximately* **11.21** *percent of the local physical activity need being met through bicycling and walking to between* **12.98 and 19.51** *percent of the regional physical activity need being met. This growth in the percent of people within the study area exercising equates to an additional* **$52,000 to $223,000** *reduction in healthcare expenses per year.* **Table 15** *shows the estimated annual health benefits for the study area.*

Table 15: Estimated Annual Health Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Bike and Walk Trips	4,033,000	5,199,000	1,166,000	7,019,000	2,986,000	10,499,000	6,466,000
Miles Biked and Walked	3,170,000	4,547,000	1,377,000	5,491,000	2,321,000	7,099,000	3,929,000
Hours of Physical Activity	874,000	1,012,000	138,000	1,189,000	315,000	1,521,000	647,000
Recommended Physical Activity Min. Met	6,723	7,785	1,062	9,146	2,423	11,700	4,977
Physical Activity Need Met	11.21%	12.98%	1.77%	15.25%	4.04%	19.51%	8.30%
Healthcare Cost Savings	$121,000	$173,000	$52,000	$233,000	$112,000	$344,000	$223,000

Environmental Benefits

The Benefit Impact Model evaluated and quantified the estimated increase in bicycling and walking trips and the annual savings from reduced vehicle emissions. In order to evaluate these environmental factors, a number of readily-available data inputs were analyzed. Using the estimates of VMT reductions calculated in the health benefits analysis, changes in hydrocarbon, particulate matter, nitrous oxides, carbon monoxide, and carbon dioxide were analyzed.

In total, the replacement of motor vehicle trips with active transportation trips in the study area may result in an estimated range of approximately **3,548,000 to 8,560,000** *fewer pounds of* CO_2 *emissions per year and between* **31,000 and 103,000** *fewer pounds of other vehicle emissions above the baseline benefits. Based on a review of air emissions studies, each pound of emissions was assigned an equivalent dollar amount based on how much it would cost to clean up the pollutant or the cost equivalent of how much damage the pollutant causes to the environment. The total reduction in vehicle emissions is equal to a savings between* **$32,000 and $106,000** *in related environmental damage or clean-up per year in addition to the baseline benefits. Other potential ecological services associated with improved active transportation connectivity projects include water regulation, carbon sequestration, carbon storage, and waste treatment exist, but the quantifiable value of these services are negligible on the overall impact of the recommended improvements.* **Table 16** *summarizes the estimated environmental benefits in the study area.*

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Table 16: Estimated Annual Environmental Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
CO_2 Emissions Reduced (lbs)	2,250,000	5,798,000	3,548,000	7,722,000	5,472,000	10,810,000	8,560,000
Other Vehicle Emissions Reduced (lbs)	45,000	76,000	31,000	102,000	57,000	148,000	103,000
Total Vehicle Emission Costs Reduced	$46,000	$78,000	$32,000	$105,000	$59,000	$152,000	$106,000

Transportation Benefits

The most readily-identifiable benefits of the recommended connectivity improvements are evident in their ability to increase transportation options and access to activity centers for residents in and visitors to the study area. While money rarely changes hands, real savings can be estimated from the reduced costs associated with congestion, vehicle crashes, road maintenance, and household vehicle operations. Using the same annual VMT reduction estimates highlighted in the health and environmental sections, transportation-related cost savings were calculated.

By multiplying the amount of VMT reduced by established multipliers for traffic congestion, vehicle collisions, road maintenance, and vehicle operating costs, monetary values were assigned to the transportation-related benefits. In total, an additional annual transportation-related cost savings between **$1,237,000 and $4,092,000** *is estimated for the study area after completion of recommended connectivity improvements.* **Table17** *summarizes the estimated transportation benefits in the study area.*

Table 17: Estimated Annual Transportation Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Annual VMT Reduced	1,383,000	2,342,000	959,000	3,142,000	1,759,000	4,557,000	3,174,000
Reduced Traffic Congestion Costs	$97,000	$164,000	$67,000	$220,000	$123,000	$319,000	$222,000
Reduced Vehicle Crash Costs	$692,000	$1,172,000	$480,000	$1,571,000	$879,000	$2,278,000	$1,586,000
Reduced Road Maintenance Costs	$208,000	$351,000	$143,000	$471,000	$263,000	$683,000	$475,000
Household Vehicle Operation Cost Savings	$788,000	$1,335,000	$547,000	$1,791,000	$1,003,000	$2,597,000	$1,809,000
Total Transportation Benefits	**$1,785,000**	**$3,022,000**	**$1,237,000**	**$4,053,000**	**$2,268,000**	**$5,877,000**	**$4,092,000**

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Total Benefits

If levels of connectivity similar to the peer cities and counties are reached and the active commute mode shares increase to low, mid, or high estimates based on peer cities and counties' mode shares, the study area could experience between **$1,321,000 and $4,421,000** *in additional health, environmental, and transportation-related benefits every year.* **Table 18** *summarizes the estimated benefits of existing active transportation in the study area, as well as the estimated benefits that may result from completion of recommended improvements.*

Table 18: Total Estimated Annual Benefits

	Baseline	Future Estimates					
		Low		Mid		High	
	Total	Total	Difference	Total	Difference	Total	Difference
Health Benefits	$121,000	$173,000	$52,000	$233,000	$112,000	$344,000	$223,000
Environmental Benefits	$46,000	$78,000	$32,000	$105,000	$59,000	$152,000	$106,000
Transportation Benefits	$1,785,000	$3,022,000	$1,237,000	$4,053,000	$2,268,000	$5,877,000	$4,092,000
Total Benefits	**$1,952,000**	**$3,273,000**	**$1,321,000**	**$4,391,000**	**$2,439,000**	**$6,373,000**	**$4,421,000**

Indirect Economic Benefits

Introduction & Methodology

Economic impacts of connectivity result from improved intermodal accessibility. Improved accessibility is measured through connectivity of customer base and economic generators such as employment and retail centers. The effectiveness of improved accessibility is measured using financial metrics such as sales per square foot for retail and real property values for all development types. Benefits from improved connectivity vary based on scale, geography, and land use type. Many of the benefits are measurable in the economy or in the fiscal well-being of households and governments. Some of the benefits are intangible such as increased personal time to spend with family and friends, improved overall health, and well-being and improved area air quality.

The economic benefits analysis undertaken in the Utah Street Connectivity Study focused on city-wide indirect impacts on retail sales[1]. We used two measures. First, we estimated a rate of retail business impact based on the change in store front traffic volumes. Second, we identified the revised 7-minute drive market-area accessibility. Both of these analyses were completed via network analyst. Traffic volume measures were completed by the University of Utah traffic lab, using their analysis we measured the change in store front traffic before and after connectivity improvements were made by each retail location. Additionally, we used the same data to measure the difference in market capture before and after network improvements.

Our approach focused on the context of the connections made. In order to estimate impacts, we needed to identify what was being connected. If two residential neighborhoods are connected, there might not be a benefit to retail sales, but there could be a benefit to property values. One study showed that a 10 percent increase in walkability resulted in a 1 to 9 percent growth in property value and made the point that walkable property types generated higher income and therefore have the potential to generate returns as good as or better than less walkable properties, assuming an efficient and well-functioning real estate market (Pivo 2010). Bicycle networks can have a positive impact on home values as well. The median home values in Minneapolis-St. Paul increased by $510 for every quarter of mile near an off-street bicycle trail, while homes within a half-mile of Indiana's Monon Trail had an average of 11 percent increase in sale price when compared to similar homes further away (Alliance for Biking & Walking 2013). For a local or neighborhood retailer, improved connectivity to residential uses results in improved access to an area's customer base, generally resulting in higher sales per square foot.

In order to estimate rates of impact on retail sales we focused on specific sectors that have multiple locations and tend to be visited more often. We avoided regional retail magnets such as malls, car dealerships, and specialty retail. Instead we wanted to estimate impacts on retail types most likely to attract neighborhood-based customers. These retail types were: supermarkets and grocery stores, full and limited service restaurants, gas stations, and warehouse supercenters such as Wal-Mart/Target. Table 1 shows the number of businesses by retail sector in each study area.

Table 1: Number of Businesses by Retail Sectors

	Layton	Lehi	Tooele
Full-service restaurants	49	16	13
Limited-service restaurants	92	62	20
Warehouse clubs and supercenters	3	3	1
Gasoline stations	26	16	8
Supermarkets and other grocery stores	9	4	3

Source: opendata.utah.gov, Firmfind County Businesses 2014

[1] Due to data limitations, we were not able to obtain property values and actual retail sales by individual business. This limited our ability to analyze connectivity impacts on property value and actual retail sales.

The study area boundary for the indirect economic impact assessment was determined by the original boundary of the existing network. Only those businesses that were located inside the road network were analyzed.

Layton Case Study

Figure 1 illustrates the existing major road network, in gray, and the connectivity improvements, in yellow. There were major improvements throughout Layton, especially on the east side of the city. Major connections were made inside residential neighborhoods. Additionally, some of these connections directly improved access to retail nodes.

The connection improvements in Layton increased the length of the road network by 16 percent, adding an additional 40 lane miles. In addition, 3-hour traffic volumes increased by 2.92 percent across the city. As a result of these improvements, study retail sectors saw major increase in market accessibility within the 7-minute drive time.

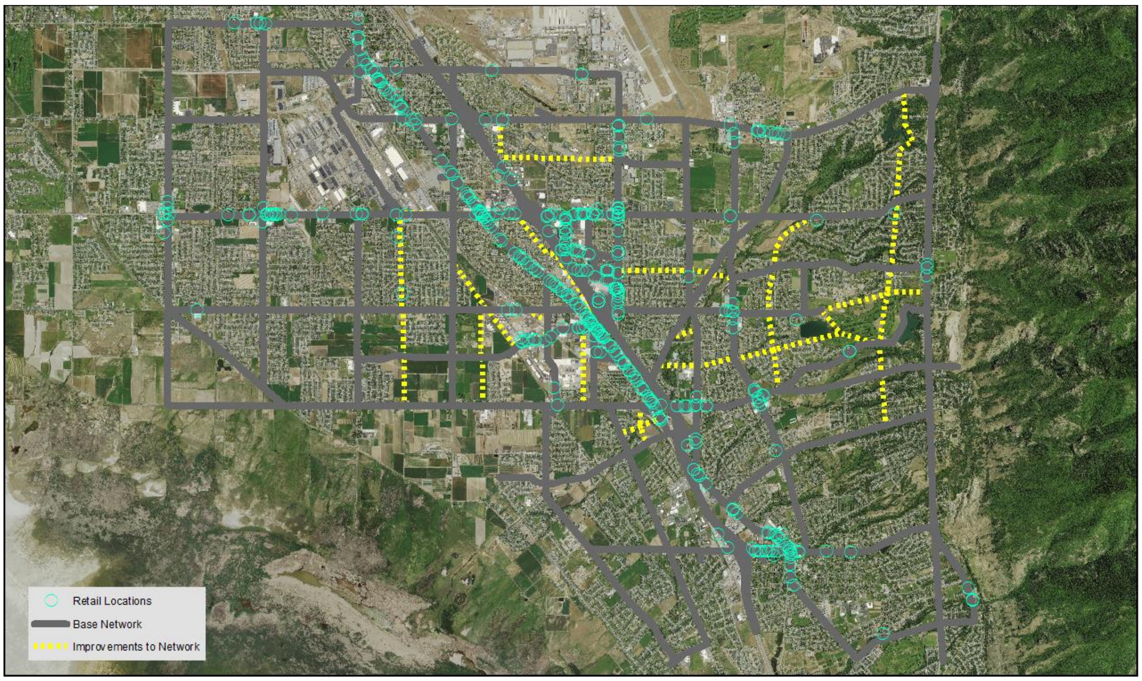


Figure 1: Layton City-wide Connectivity Improvements

From the connectivity improvements, potential impacts to retail sectors were calculated and are presented in Figure 2. Warehouse clubs and supercenters have the potential to increase their sales by 1.4 percent. Supermarkets and grocery stores could see an increase of 0.9 percent, gas stations could see similar impacts with the opportunity to increase sales by 0.8 percent. Limited and Full service restaurants saw almost no change.

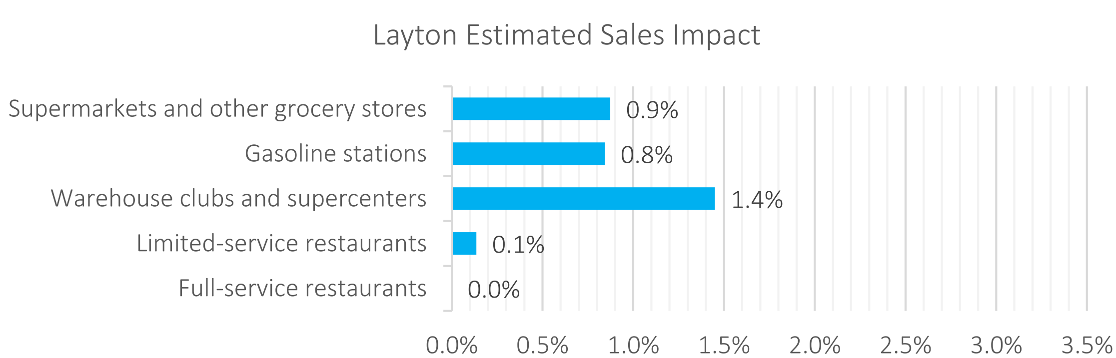


Figure 2: Layton City-wide Connectivity Impacts

For context, if we were to apply the percentages Figure 2 to actual sales for Layton in 2015, an additional $4.9 million in sales could have occurred as seen in Table 2. The largest impact was seen in Warehouse clubs and Supercenter retailers such as Wal-Mart/Target. These types of retailers could have seen an additional $3.7 million in sales across the city. Grocery store could see an additional $800,000 while restaurants could experience an additional $200,000 in sales and gas stations an additional $163,000.

Table 2: Layton Potential Sales Increase from Connectivity Improvements

	2015 Taxable Sales	Increased Sales from Connectivity
Food Services & Drinking Places(722000-722999) (Full/Limited Restaurants)	$144,183,674	$195,336
General Merchandise Stores(452000-452999) (Warehouse/Supercenters)	$258,035,098	$3,740,962
Gasoline Stations(447000-447999)	$19,378,449	$163,406
Food & Beverage Stores(445000-445999) (Grocery Stores)	$91,335,306	$797,631
Total	$512,932,527	$4,897,335

Source: State of Utah Tax Commission, GSBS Consulting

Lehi Case Study

Figure 3 illustrates the existing major road network, in gray, and the connectivity improvements, in yellow. There were major improvements throughout Lehi. The west side of the city saw major connectivity updates. There is very little development currently and limited retail on the west side of the city. However, this area is poised for new development and these connections will be vital to the economic success and quality of life of the area. Additional connections were made in the center of the city, providing quicker access to retail establishments. Improvements were also made in the northern part of the study area, while there isn't much retail here, quicker access to existing nodes was improved.

The connection improvements in Lehi increased the length of the road network by 30 percent, adding an additional 77 lane miles. In addition, 3-hour traffic volumes had a slight decrease of 0.91 percent across the city.

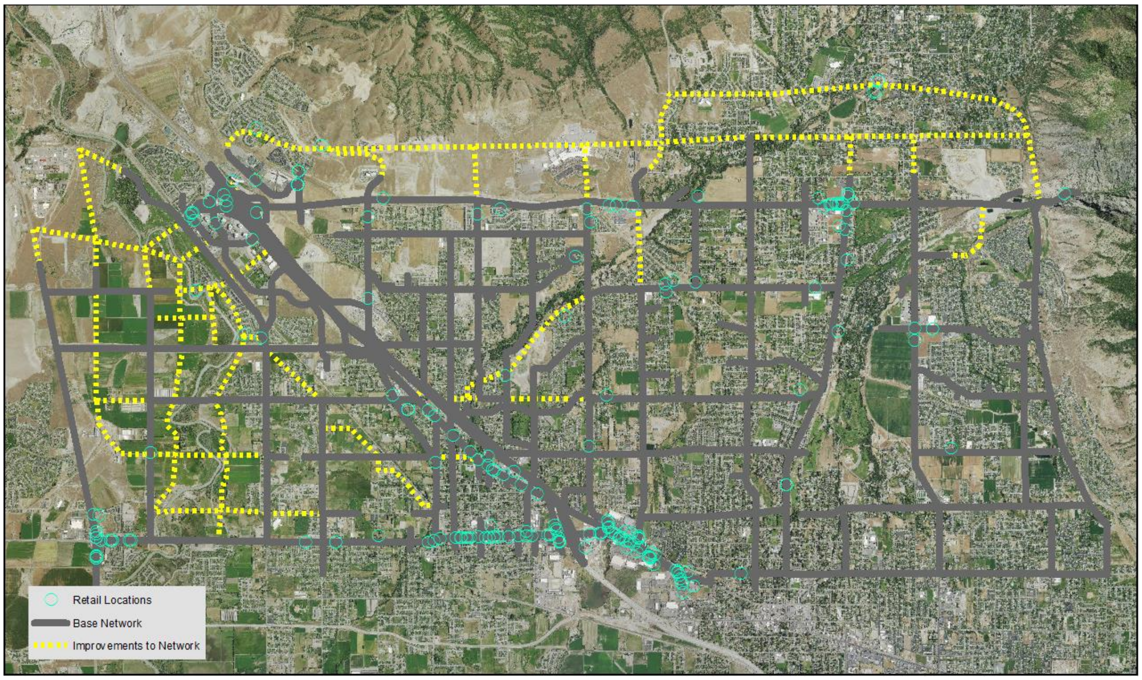


Figure 3: Lehi City-wide Connectivity Improvements

From the connectivity improvements, potential impacts to retail sectors were calculated and are presented in Figure 4. Grocery stores have the potential to increase sales by 0.8 percent, while warehouse clubs and supercenters could see a similar impact of 0.7 percent. Gas stations could experience an increase of 0.5 percent in sales. Limited service restaurants could see an additional 0.8 percent increase while full-service restaurants could see a slight increase of 0.1 percent.

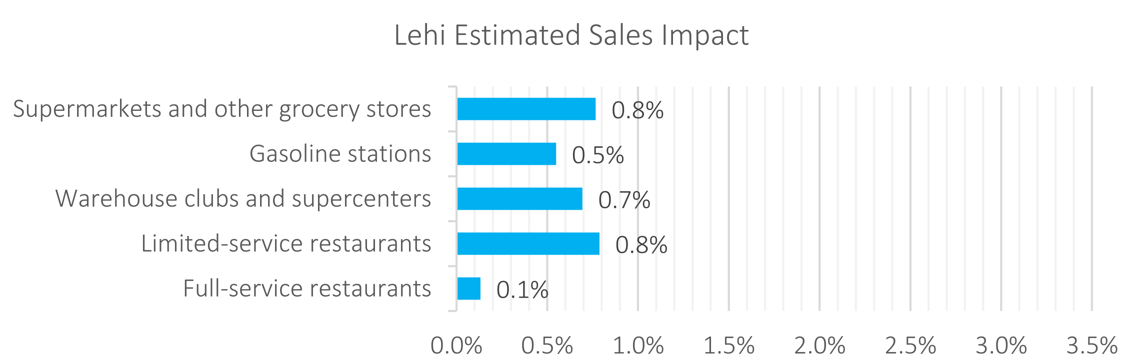


Figure 4: Lehi City-wide Connectivity Impacts

For context, if we were to apply the percentages from Figure 4 to actual sales for Lehi in 2015, an additional $2.6 million in sales could have occurred as seen in Table 3. Warehouse clubs and supercenters could experience and additional $1.2 million in sales, while grocery stores and restaurants could both experience close to $650,000 in additional sales. Gas stations could experience and additional $98,000 in annual sales.

Table 3: Lehi Potential Sales Increase from Connectivity Improvements

	2015 Taxable Sales	Increased Sales from Connectivity
Food Services & Drinking Places(722000-722999) (Full/Limited Restaurants)	$70,766,007	$650,897
General Merchandise Stores(452000-452999) (Warehouse/Supercenters)	$170,769,453	$1,183,998
Gasoline Stations(447000-447999)	$17,776,176	$97,502
Food & Beverage Stores(445000-445999) (Grocery Stores)	$86,164,276	$660,825
Total	$345,475,912	$2,593,221

Source: State of Utah Tax Commission, GSBS Consulting

Tooele Valley Case Study

The majority of unincorporated Tooele Valley's retail businesses are located near Tooele City limits to the south and near I-80 to the north. As seen in Figure 5, the majority of the connections were made in the middle of the study area with little to no retail. However, this increased the market accessibility of existing retail located along SR-36 to those living further away from exiting major arterials. The connection improvements in Tooele/Erda increased the length of the road network by 55 percent, adding an additional 72 lane miles. In addition, 3-hour traffic volumes increased by 9.68 percent across the area.

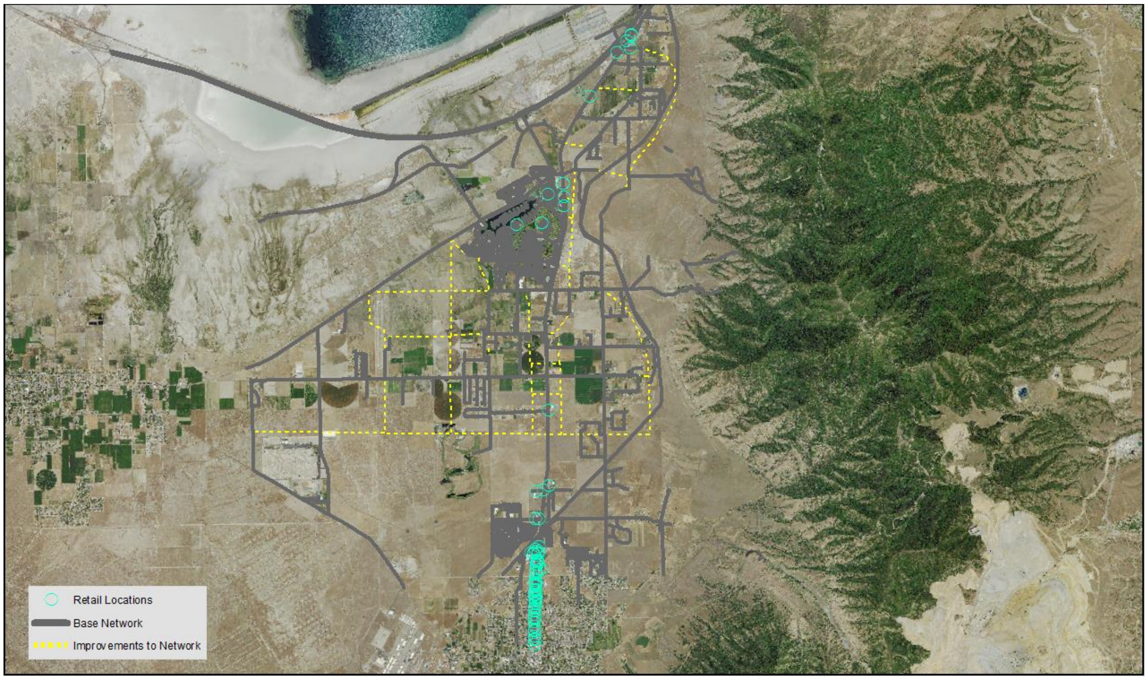


Figure 5: Tooele Valley-wide Connectivity Improvements

Figure 6 illustrates the percentage increase in sales from connectivity improvements. Combined, full and limited service restaurants could see an increase of 4 percent in annual sales. While this may seem drastic, it is important to understand that the majority of these establishments are located along a single corridor. Additionally, there are only 33 establishments in the City. With such a small market, any improvements to traffic flow and market accessibility have significant impacts. Warehouse Clubs and supercenters saw no change because there is only one of these in our study area. Grocery stores could see an increase of 0.9 percent, while gas stations could experience a minimal impact of 0.2 percent.

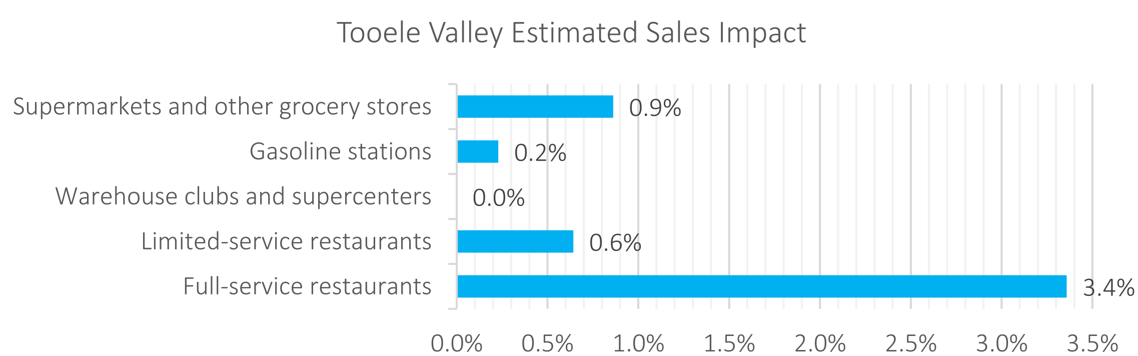


Figure 6: Tooele Valley-wide Connectivity Impacts

For context, if we were to apply the percentages from Figure 6 to actual sales for Tooele Valley in 2015, an additional $1.9 million in sales could have occurred as seen in Table 4. Full and limited service restaurants have to potential to add an additional $1.5 million in annual sales, while grocery stores have the potential to add over $300,000 annually. Gas stations could see minimal increase in sales, adding just over $20,000, and because there is only one warehouse club/supercenter establishment, there are no impacts.

Table 4: Tooele Valley Potential Sales Increase from Connectivity Improvements

	2015 Taxable Sales	Increased Sales from Connectivity
Food Services & Drinking Places(722000-722999) (Full/Limited Restaurants)	$38,939,342	$1,557,703
General Merchandise Stores(452000-452999) (Warehouse/Supercenters)	$111,595,748	$0
Gasoline Stations(447000-447999)	$9,500,000	$21,792
Food & Beverage Stores(445000-445999) (Grocery Stores)	$36,478,976	$314,250
Total	$196,514,066	$1,893,746

Source: State of Utah Tax Commission, GSBS Consulting

Conclusion

One of our most important takeaways is that context of connectivity improvements matters greatly. When traffic is increased along a storefront, sales typically tend to increase. When travel time is decreased and the number of customers captured, sales increase. Decreasing traffic and decreasing the trade area, tends to lead to lower sales.

A key takeaway from our findings is that cities can do more with what they have. Improving the performance of existing retail is possible through connectivity improvements. Our findings are similar to those found in our literature review showing that connectivity results in improved access to an areas customer base leading to higher sales.

With better data, such as actual sales by location, we can further improve our findings. Additionally having property valuations can help us quantify the impacts property values will experience by improving connectivity.

APPENDIX

Public Outreach

UTAH STREET CONNECTIVITY PUBLIC OUTREACH SUMMARY

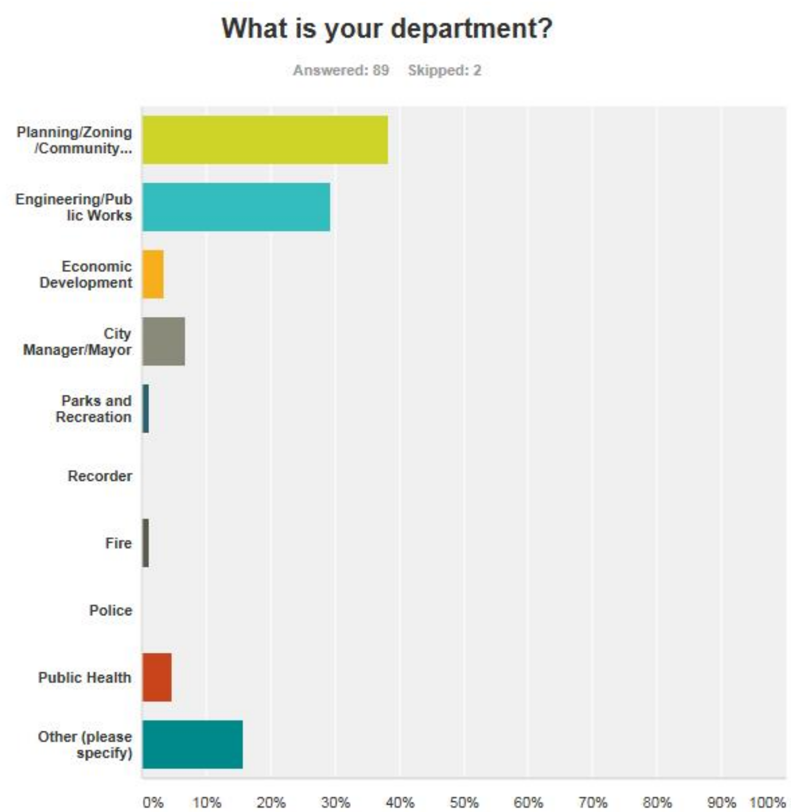
Community outreach was an important part of the Utah Street Connectivity Study. The community outreach goals for the study were to:

- learn about jurisdictions' existing attitudes, perceptions, and policy regarding street connectivity;
- query the public at large about their perceptions of the benefits and drawbacks of street connectivity;
- communicate the benefits of street connectivity to communities; and
- preview the project's recommendations with specific Case Study communities.

Consequently, community outreach for the Utah Street Connectivity Study was targeted in two areas: a set of surveys aimed at Utah communities and a series of community open houses in the selected Case Study communities.

Surveys

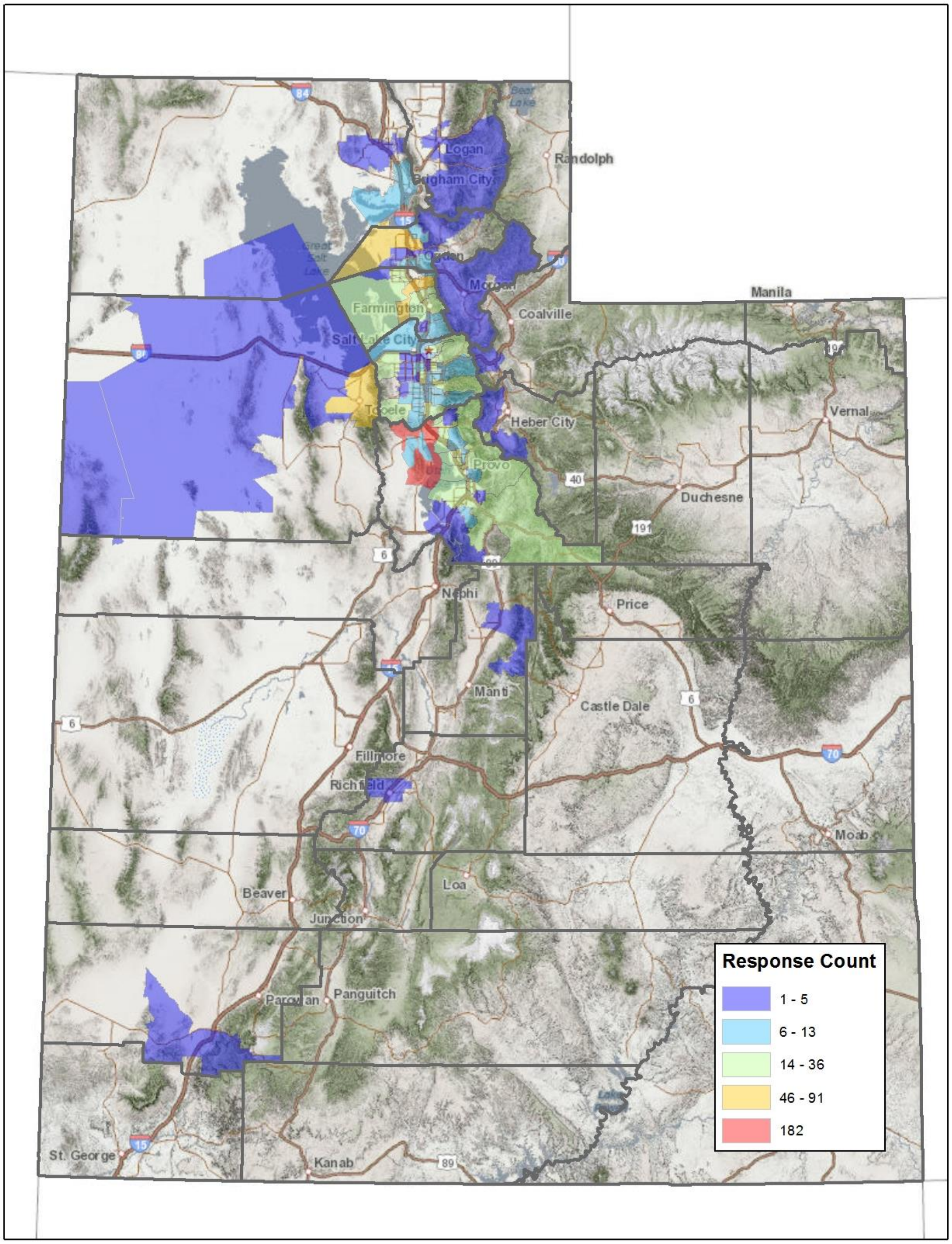
The project team conducted two separate surveys. These surveys aimed to achieve different study outreach goals. The first survey, targeted to city staff, helped the team understand jurisdictions' existing attitudes, perceptions, and policy regarding street connectivity. The second survey helped us query the public at large about their perceptions of the benefits and drawbacks of street connectivity. Both of these allowed us to understand the barriers and opportunities for implementing connectivity in communities, while also building awareness about the project.



Each survey was conducted using Survey Monkey, which allowed a link to the survey to be sent out by anyone. Our project partners as well as other jurisdictions and organizations were essential in disseminating these links.

Both surveys received a strong response. The staff survey received 91 responses. These responses represented 35 local jurisdictions and agencies. Most survey takers were from planning and engineering departments.

The community survey received 1,300 responses. While these responses were most numerous in the Case Study communities, they covered communities throughout the state; see map at right for community survey response distribution.



Staff survey

The staff survey is aimed at the professionals who are creating and implementing policy related to street connectivity. We aimed to get two things from this survey – 1) what the current state of policy and community preferences are, and 2) what the possibilities of and barriers to future change are. Following is the text of the survey:

Utah Street Connectivity Study Community Survey: City staff and leaders

Street connectivity is the degree to which streets in a community are connected to one another. The Utah Street Connectivity Study seeks to assess the benefits of street connectivity; provide recommendations on how to implement elements of connectivity into Utah communities; and inform decision-makers and stakeholders how street connectivity can benefit their communities.

Please take a moment to fill out this brief survey. It is important that we gain an understanding of jurisdictions' existing attitudes, perceptions, and policy regarding street connectivity. Thank you for your time.

1) What is your city/jurisdiction?
2) What is your department?
3) How would you describe the attitude towards increasing street connections in your community?
    a. Strongly support
    b. Somewhat support
    c. Neutral/unsure
    d. Somewhat oppose
    e. Strongly oppose
4) What is your jurisdiction's current policy approach to street connectivity? Choose all that apply.
    a. General Plan and other high level documents support high street connectivity.
    b. Zoning and development standards require or strongly incent high street connectivity.
    c. General Plan and other high level documents prevent street connectivity
    d. Zoning and development standards prevent street connectivity
    e. None applies
5) Describe how these policy documents support street connectivity if applicable.
6) Which of the following community goals are reasons your community might be interested in increased street connectivity? Choose up to **three**.
    a. Effective infrastructure
    b. Livable communities
    c. Accessibility of destinations
    d. Interlocal and regional compatibility
    e. Overcoming geographical barriers
    f. Safety and health
    g. Regional mobility
    h. Transportation choice
    i. Economic vitality
    j. Growth management
    k. Other

7) What are the biggest barriers to increased street connectivity in your community? Choose all that apply.
    a. Desire for individual privacy
    b. Concern over neighborhood traffic
    c. Perceptions of crime
    d. Property ownership patterns
    e. Availability of right-of-way
    f. Internal department coordination
    g. Funding for roadways and sidewalks
    h. Increased cost to developers
    i. Other
8) Assuming that your community values increased street connectivity, which of the following tools would be most useful? Choose all that apply.
    a. A manual containing specific policy recommendations
    b. Materials educating the public about the benefits of street connectivity
    c. Materials educating decision makers about the benefits of street connectivity and strategies for achieving it
    d. Assistance with developing interlocal agreements with other governmental entities
9) What other thoughts do you have about the subject of street connectivity in your community?

Public survey

The public survey presented a key challenge – "street connectivity" is not something most people think about. So, we need to get at this concept by asking members of the public about aspects of their travel habits and community preferences. We did this broadly, asking questions whose answers we can link to the implications for street connectivity (What is most important about your driving routes? What is your biggest concern about your neighborhood?), while also honing in on some issues we know are key to the street connectivity discussion (To what degree do you support connecting cul-de-sacs (dead end streets) in your community to other streets?). We also asked a few "identifier" questions so we can get a sense, within the context of an informal survey, which demographics have which preferences and perceptions.

This information was used, in conjunction with the staff survey described above, to assess the existing perceptions and opinions about street connectivity. In particular, this information was valuable for us to understand the barriers facing the implementation of connectivity strategies, and to develop strategies to mitigate those concerns. This information also helped us understand the relative importance survey respondents place on the community goals developed from the Working Group.

DRAFT Utah Street Connectivity Study Community Survey: General community

Street connectivity is the degree to which streets in a community are connected to one another. The Utah Street Connectivity Study seeks to assess the benefits of street connectivity; provide recommendations on how to implement elements of connectivity into Utah communities; and inform decision-makers and stakeholders how street connectivity can benefit their communities.

Please take a moment to fill out this brief survey. It is important that we gain an understanding of your opinion on the benefits and drawbacks of connecting streets to one another. Thank you for your time.

1) What is your zip code?
2) What is your age?
3) What is most important to you about your driving routes?
    a. They are short
    b. They are fast
    c. They are safe
    d. They are direct
    e. They are interesting or aesthetically pleasing
    f. Other
4) What is your biggest concern about driving?
    a. Trip will take too long
    b. Risks associated with turning
    c. Getting in an accident
    d. Waiting too long at traffic signals
    e. Impact on the environment
    f. Other
5) What is most important to you about your walking routes?
    a. They are short
    b. They are safe

c. They are direct
d. They are interesting or aesthetically pleasing
e. They provide good exercise
f. They connect to destinations I frequently visit
g. Other

6) What are the most significant obstacles preventing you from walking more?
   a. I do not enjoy or am unable to walk
   b. The lack of pedestrian infrastructure (such a sidewalks, crosswalks, or trails) near my home
   c. It takes too long to get where I want to go
   d. Potential destinations are either too far away or accessed by an indirect route
   e. There is nothing near my home that is worth walking to
   f. Personal safety
   g. Other
7) To what degree do you support or oppose the following statement: I would be willing to ride transit more if bus stops or train stations were more easily accessible by walking or biking from my home.
   a. Strongly support
   b. Moderately support
   c. Neutral
   d. Moderately oppose
   e. Strongly oppose
8) What is most important to you about your neighborhood?
   a. Good neighbors
   b. Amenities (stores, parks, freeways, public transit nearby
   c. Safety from traffic
   d. Safety from crime
   e. Ease of access
   f. Location
   g. Other
9) What is your biggest concern about your neighborhood?
   a. Lack of amenities
   b. Traffic
   c. Crime
   d. Growth
   e. Far away from places I go
   f. Other
10) To what degree do you support connecting cul-de-sacs (dead end streets) in your community to other streets?
    a. Strongly support
    b. Moderately support
    c. Neutral
    d. Moderately oppose
    e. Strongly oppose

11) To what degree do you support connecting cul-de-sacs (dead end streets) in your community to other streets ONLY WITH WALKING AND BICYCLING PATHS (no connections for motor vehicles)?
    a. Strongly support
    b. Moderately support
    c. Neutral
    d. Moderately oppose
    e. Strongly oppose
12) What is the most important reason or reasons for your answer in the previous question? Pick as many as three.
    a. Traffic-related safety
    b. Personal security from crime
    c. Privacy
    d. Desire for better access to amenities and destinations
    e. More effective emergency services
    f. Ability to walk or bike in my community
    g. Better access to public transit
    h. Other
13) Which of the following community goals are most important to you? Choose up to **three**.
    a. Effective infrastructure
    b. Livable communities
    c. Accessibility of destinations
    d. Interlocal and regional compatibility
    e. Overcoming geographical barriers
    f. Safety and health
    g. Regional mobility
    h. Transportation choice
    i. Economic vitality
    j. Growth management
    k. Other

Surveys takeaways

The surveys yielded a number of interesting conclusions. These are summarized below:

Safety is equated with disconnected streets.

- Traffic-related safety is important for all modes – no. 1 issue for driving, walking, and bicycling
- One of top reasons for not wanting to connect cul-de-sacs
- Traffic-related safety drives many neighborhood opinions
- Staff survey agreed that this is No. 1 barrier to increasing connectivity

Privacy is important to people.

- Does typology concept address this? i.e. cul-de-sacs appropriate in some contexts but need to be managed?

Retrofitting disconnected street networks

- For these reasons, about 40 percent of survey respondents oppose the general idea of connecting cul-de-sacs through to other streets
- However, 73 percent for connecting cul-de-sacs for pedestrians and cyclists only – only 11 percent against

Importance of access to destinations

- Both regional destinations and neighborhood destinations
- Interesting and connecting to destinations are also important
- Top barriers for walking is destinations are too far and it takes too long to get where I want to go

Growth management and quality of life are very important to people.

- Opportunity to show impact of connectivity on maintenance of quality of life

People want to use alternative transportation.

- 30 percent of people put “Good options for a wide range of transportation modes” as a top 3 issue
- Over half of respondents (53%) agreed with the statement that “I would be willing to ride transit more if bus stops or train stations were more easily accessible by walking or biking from my home.”
- For city staff, “Good options for a wide range of transportation modes” is top goal likely to lead to increased connectivity

4 of top 5 things people like about their neighborhoods are directly influenced by street connectivity:

- Safety from crime (67%)
- Safety from vehicular traffic (30%)
- Amenities (stores, schools, parks) are nearby (33%)
- It is close to my job, school or other regular destinations (26%)

Open House Summary

The Utah Street Connectivity Study project team held a series of three open houses to present the study's findings and preview the Utah Street Connectivity Guide. The open houses were held in the study's Case Study communities of Lehi, Layton, and Tooele Valley on December 6, 7, and 13 respectively.

The open houses included a series of presentation boards summarizing the key aspects of the study as well as the specific case studies in the host community. Copies of these displays are included in this appendix.

Attendance at the open houses was a mix of city staff (both from the host community and from other communities throughout the region) and the general public. Staff from 11 different local jurisdictions or agencies attended.

- 8 people attended the Tooele Valley Open House;
- 5 people attended the Lehi Open House;
- 22 people attended the Layton Open House.

Only one comment was received, related to a concern about the increase of traffic on Highway 138 in Tooele Valley and two new schools opening next fall.

PROJECT OVERVIEW

To help promote our shared regional and community goals, the Wasatch Front Regional Council, Utah Transit Authority, Mountainland Association of Governments, and Utah Department of Transportation are collaborating to create the **Utah Street Connectivity Study**.

Street connectivity occurs when streets in a community are connected to one another. Higher street connectivity yields numerous **mobility, livability, economic, and environmental benefits** for communities. The Utah Street Connectivity Study seeks to assess and **quantify these benefits**; provide recommendations on **how to implement** elements of connectivity into Utah communities; and **inform** decision-makers and stakeholders.

This project was undertaken throughout 2016 and included:

- A **Literature Review** of the metrics, benefits, and strategies for street connectivity.
- A set of **surveys** that asked both Utah local jurisdiction/agency staff and Utah communities about issues related to street connectivity.
- **Case studies** in three Utah communities- Lehi, Layton, and Tooele County.
- The development of **Street Connectivity Typologies** that give custom guidance for different types of communities.
- A **project document** that brings the above elements together into a guide and toolbox for street connectivity for Utah communities.

Users of this document will be able to:

- Understand the **aspects of street connectivity**
- Understand **why street connectivity matters** to our Utah communities
- See the **quantified benefits** of improving street connectivity
- Understand how street connectivity applies to **your specific community**
- Select **appropriate strategies** to improve the street connectivity in your community

In this **OPEN HOUSE**, we will show you **WHAT** street connectivity is, **WHY** is it important, and **HOW** you can increase it in your community.

Credit: Rick Willoughby

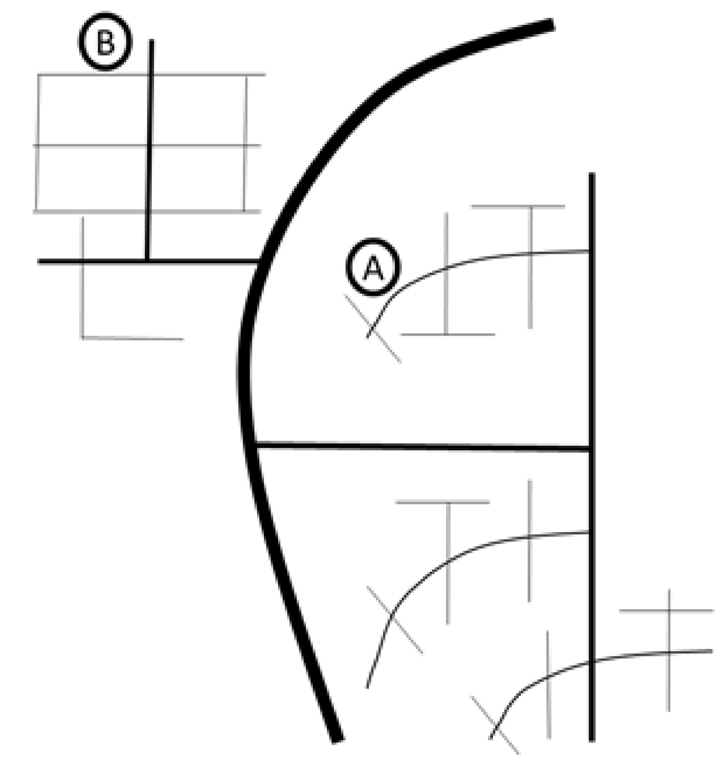
WHAT IS CONNECTIVITY?

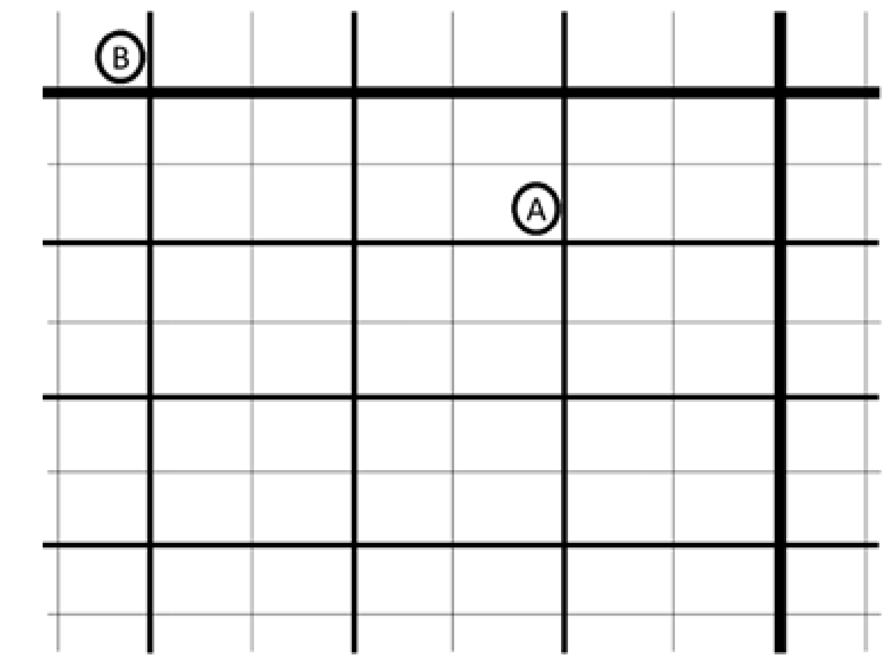
Street connectivity is a simple idea – providing a network of public streets whose intersections allow for easy movement around it.

Upon looking closer, however, we found that street connectivity is more elusive to define in detail.

Look at the two images to the right.

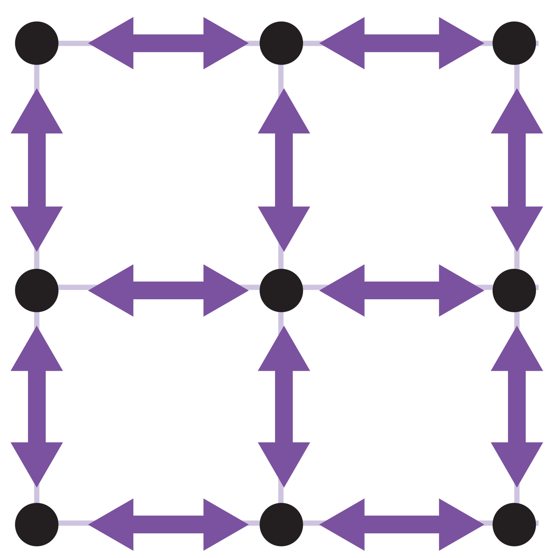
The images show two street networks, and they are clearly different. But why are they different?





Street connectivity has **four aspects**:

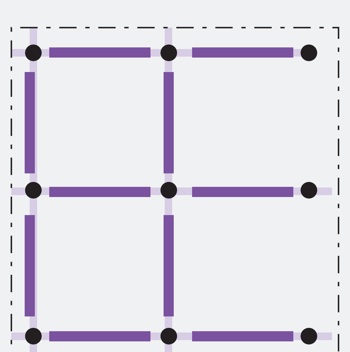
Street Connectivity



How many streets each intersection is connected to

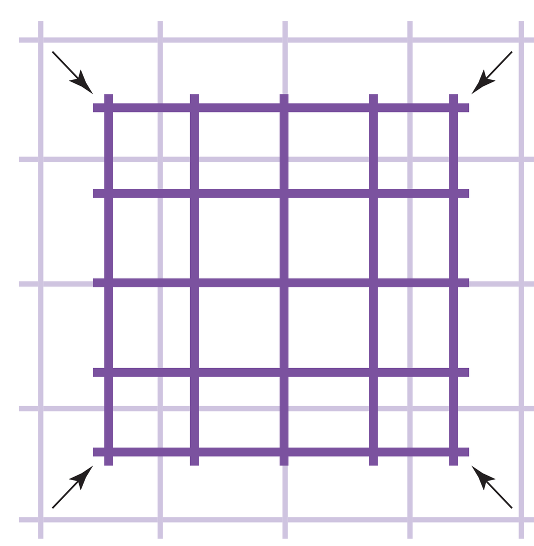
How we measure it:
Link-node ratio.

Link-node ratio =
the number of *links*, or street lengths, ( )
divided by
the number of *nodes* - intersections/dead ends (•)
within a given area ( )



Link-node ratio should be as high as possible.

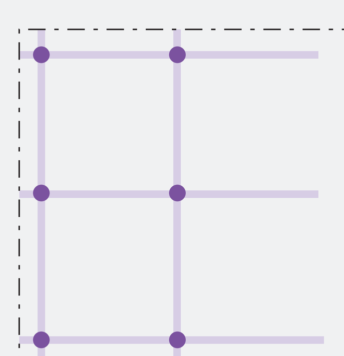
Network Density



How many streets and intersections are in a given area

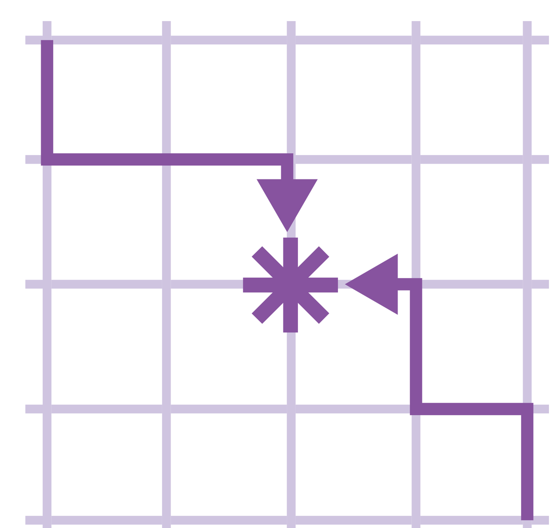
How we measure it:
Intersections per square mile.

Intersections per square mile =
the number of intersections (•)
in a given area ( )
divided by
the square mileage of that given area



Intersections per square mile should be as high as possible.

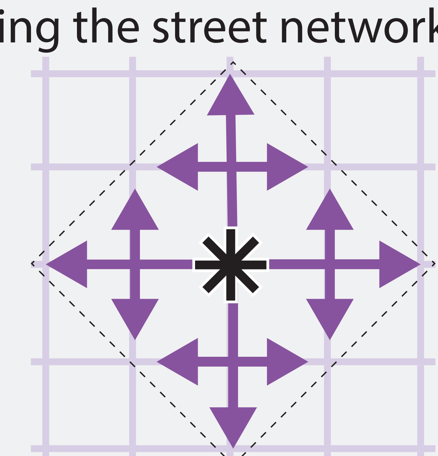
Destination Access



How well the street network connects to specific destinations

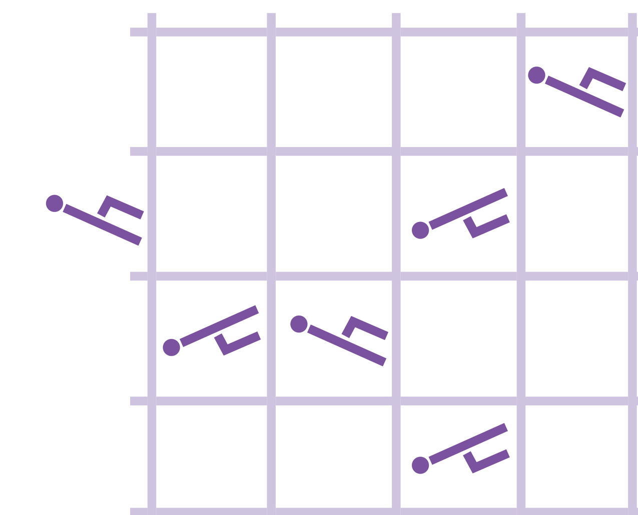
How we measure it:
The travel-shed.

Travel-shed =
the area reached ( )
within a given distance ( )
from a destination (✱)
using the street network ( )



The travel-shed should be as large as possible.

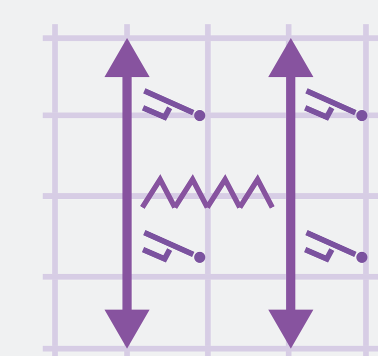
Accommodation of All Users



How well the network serves all users, especially pedestrians

How we measure it:
Pedestrian block length.

Pedestrian block length =
the distance, or gap ( ),
between walkable streets or paths
( )



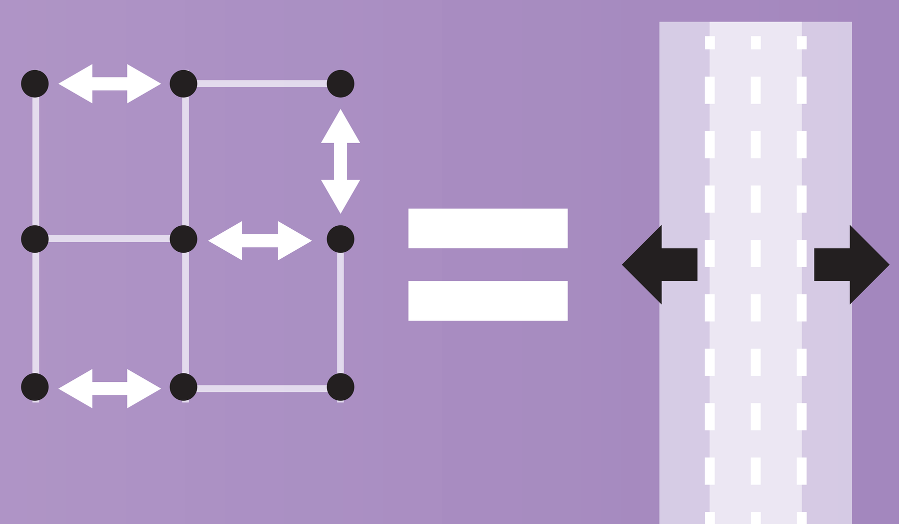
*The pedestrian block length should be as **small** as possible.*

WHY IS CONNECTIVITY IMPORTANT?

A highly connected street network – one where a dense set of intersections each connect to several streets, that connects a community to its key destinations and is walkable – provides a **multitude of benefits for Utah communities**.

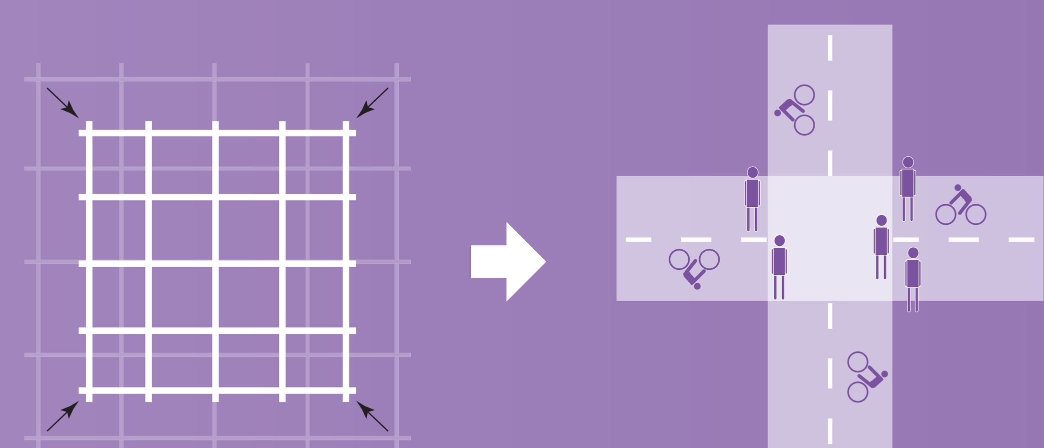
This guide has **quantified these benefits**. Using both a review of studies and literature available as well as modeling of potential benefits in case studies of three Utah communities, we show how an increase in connectivity causes the achievement of benefits associated with community goals commonly found in Utah communities. These include mobility, transportation choice, health and safety, infrastructure and growth management, economic vitality, and environmental conservation.

CONNECTIVITY IMPROVES
MOBILITY



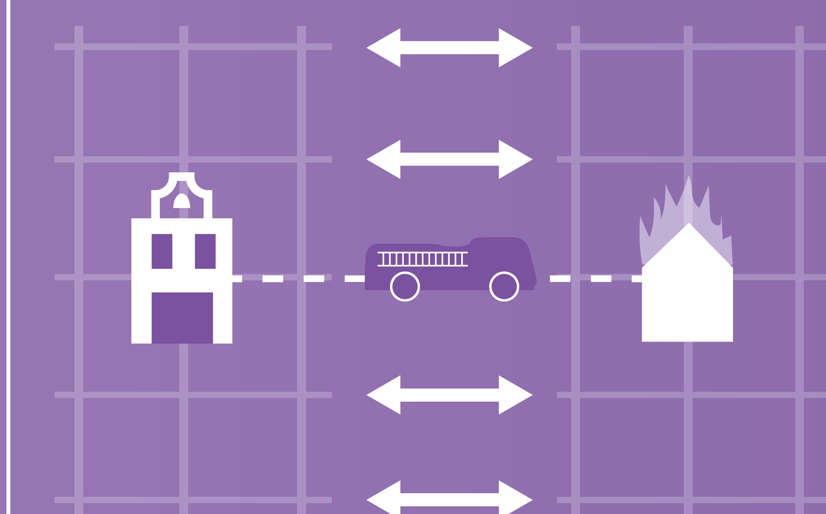
each **1%** increase of connectivity yields the same travel time benefits as **1 lane mile** of roadway

CONNECTIVITY CREATES
TRANSPORTATION CHOICE



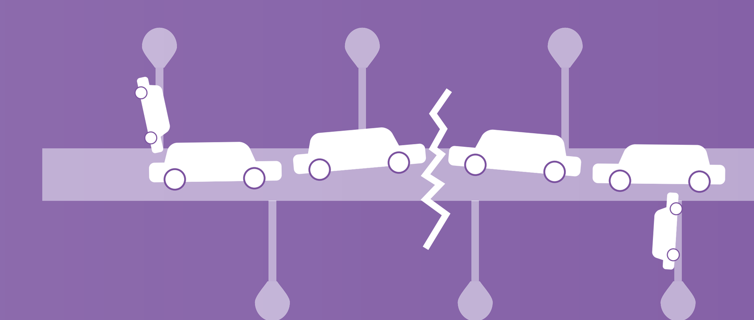
High intersection density is the **best predictor** for **use of active transportation**

CONNECTIVITY IMPROVES
EMERGENCY SERVICE



Adding **300 feet of roadway** between two subdivisions in Charlotte, N.C., **increased the fire station service area by 17 percent**

CONNECTIVITY IMPROVES
SAFETY



The **highest risks** of fatal or severe crashes tend to occur in areas with **low intersection densities**

CONNECTIVITY IMPROVES
THE ECONOMY

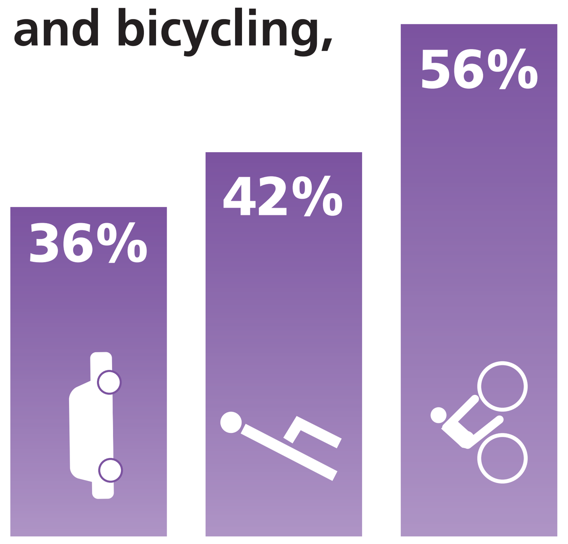
Compact, connected, walkable neighborhoods can command a **price premium** of **40 to 100 percent** compared to nearby less-connected neighborhoods

UTAH STREET CONNECTIVITY SURVEY

A set of **surveys asked** both Utah local jurisdiction and agency staff and Utah communities about opinions on street connectivity and existing connectivity-related policy but also opinions about broader topics such as neighborhoods and transportation. The community survey received 1,300 responses while the staff survey received nearly 100. Some key findings are summarized below.

Safety is the aspect of transportation most important to people.

For driving, walking and bicycling,

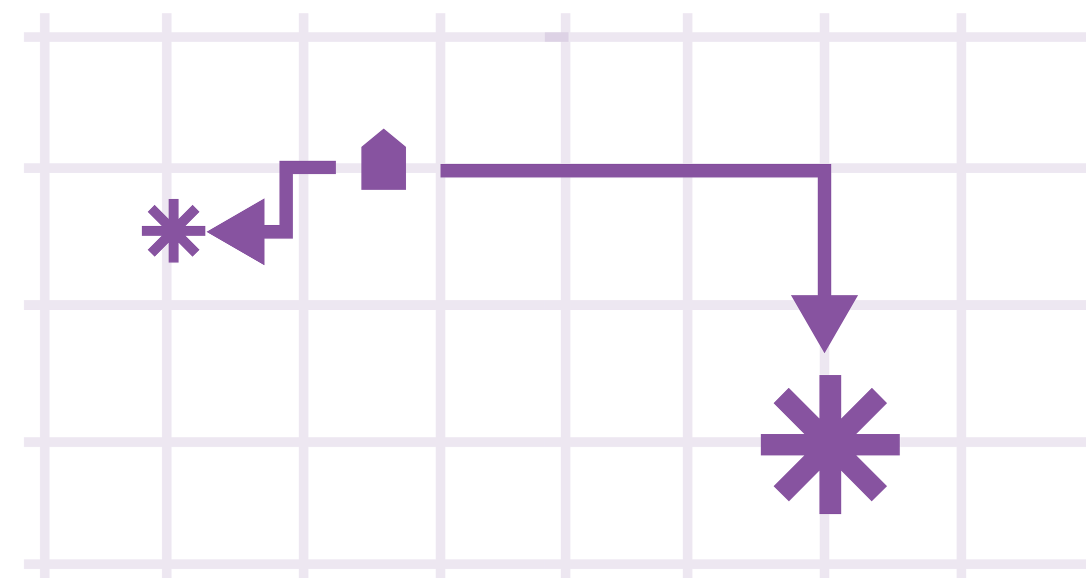


of survey respondents say safety is the most important issue - the top response for each mode.

Safety is often ***equated with disconnected streets*** (Our study has shown this not to be the case).

Yet the staff survey agreed that this perception is the No. 1 ***barrier to increasing connectivity.***

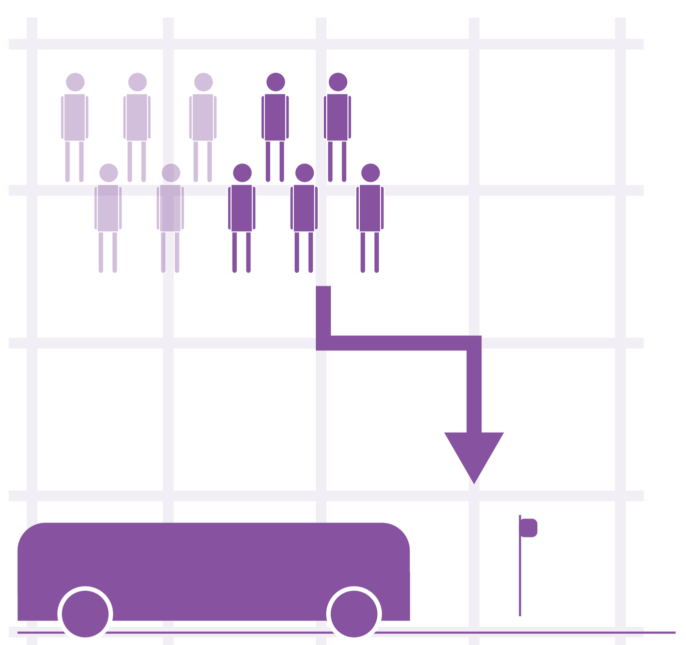
Access to destinations is very important to people.



One of the top barriers for walking is destinations are too far and ***"it takes too long to get where I want to go."***

Both ***neighborhood*** and ***regional*** destinations are important to access.

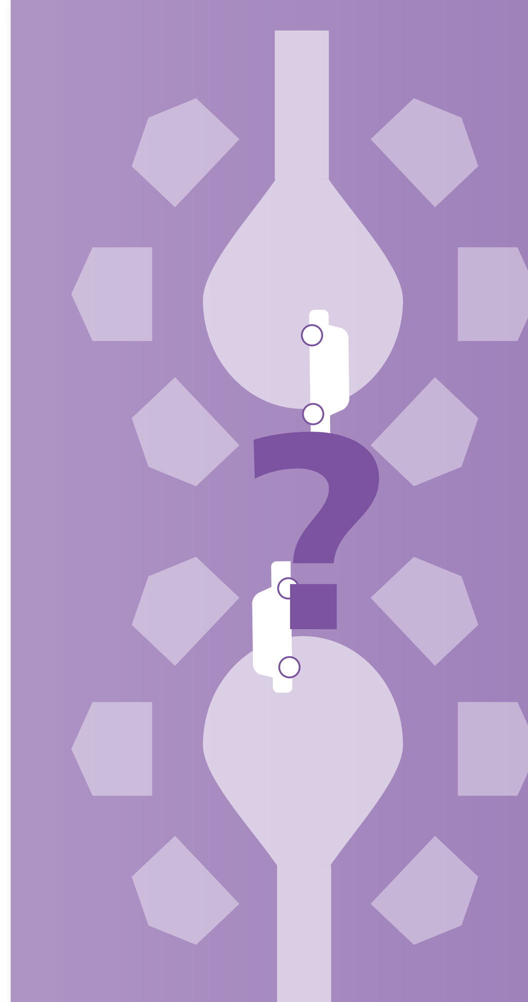
People want to use alternative transportation.



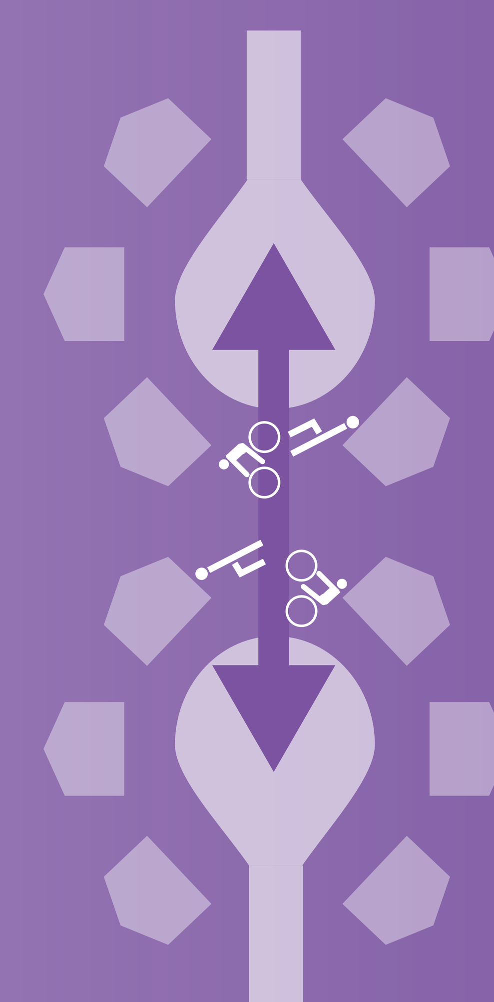
Over half of respondents agreed with the statement that *"I would be willing to ride transit more if bus stops or train stations were more easily accessible by walking or biking from my home."*

30% of community survey respondents identified "good options for a wide range of transportation modes" as one of the most important neighborhood issues.

Cul-de-sac connection is a flashpoint for the street connectivity discussion.



Survey respondents were split on generally connecting cul-de-sacs through to other streets, for all traffic.

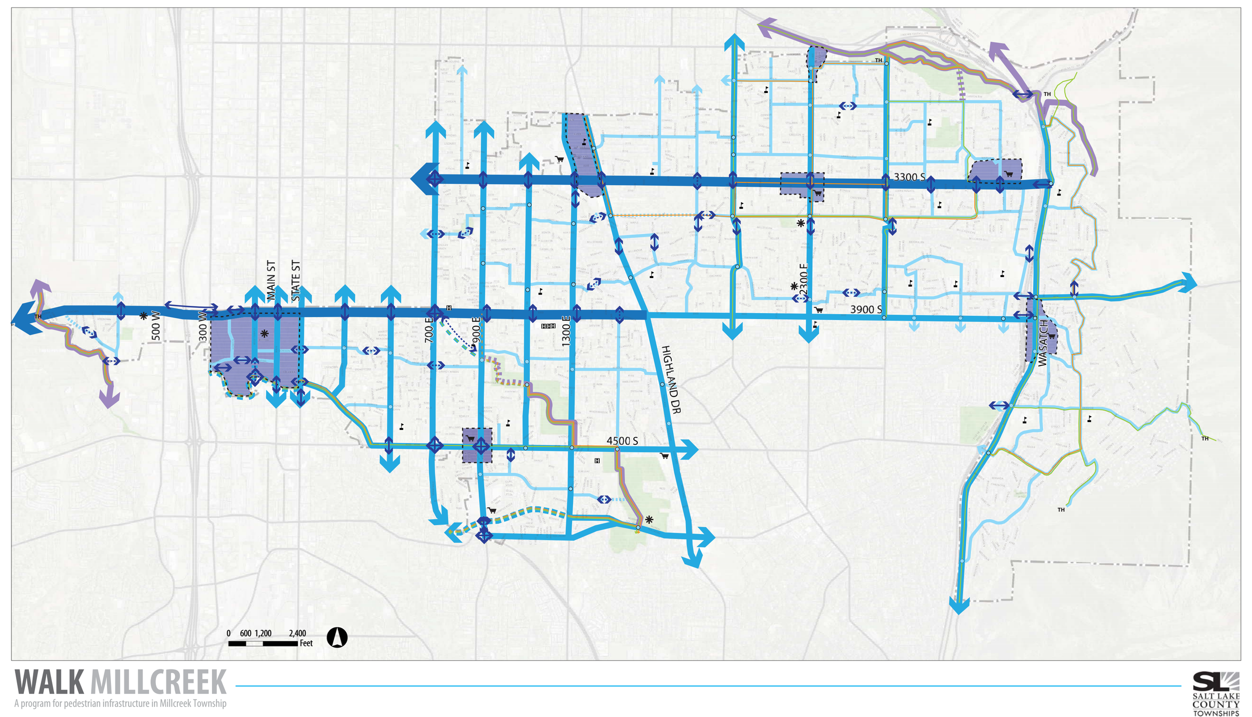


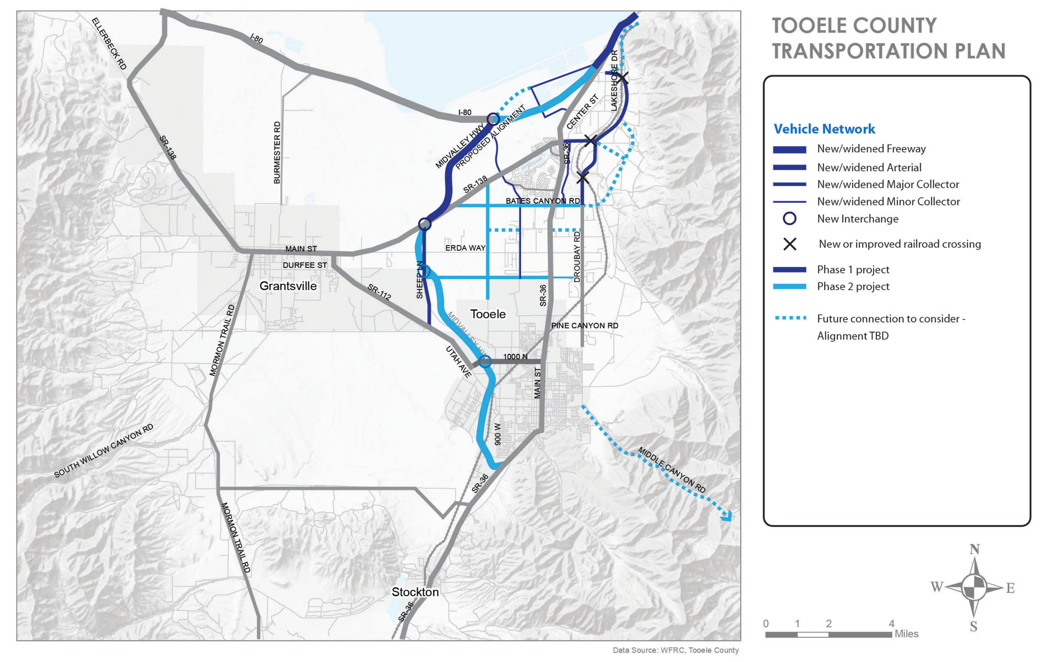
However

73% **supported connecting cul-de-sacs for pedestrians and cyclists only – only 11 % against**

HOW DO WE INCREASE CONNECTIVITY?

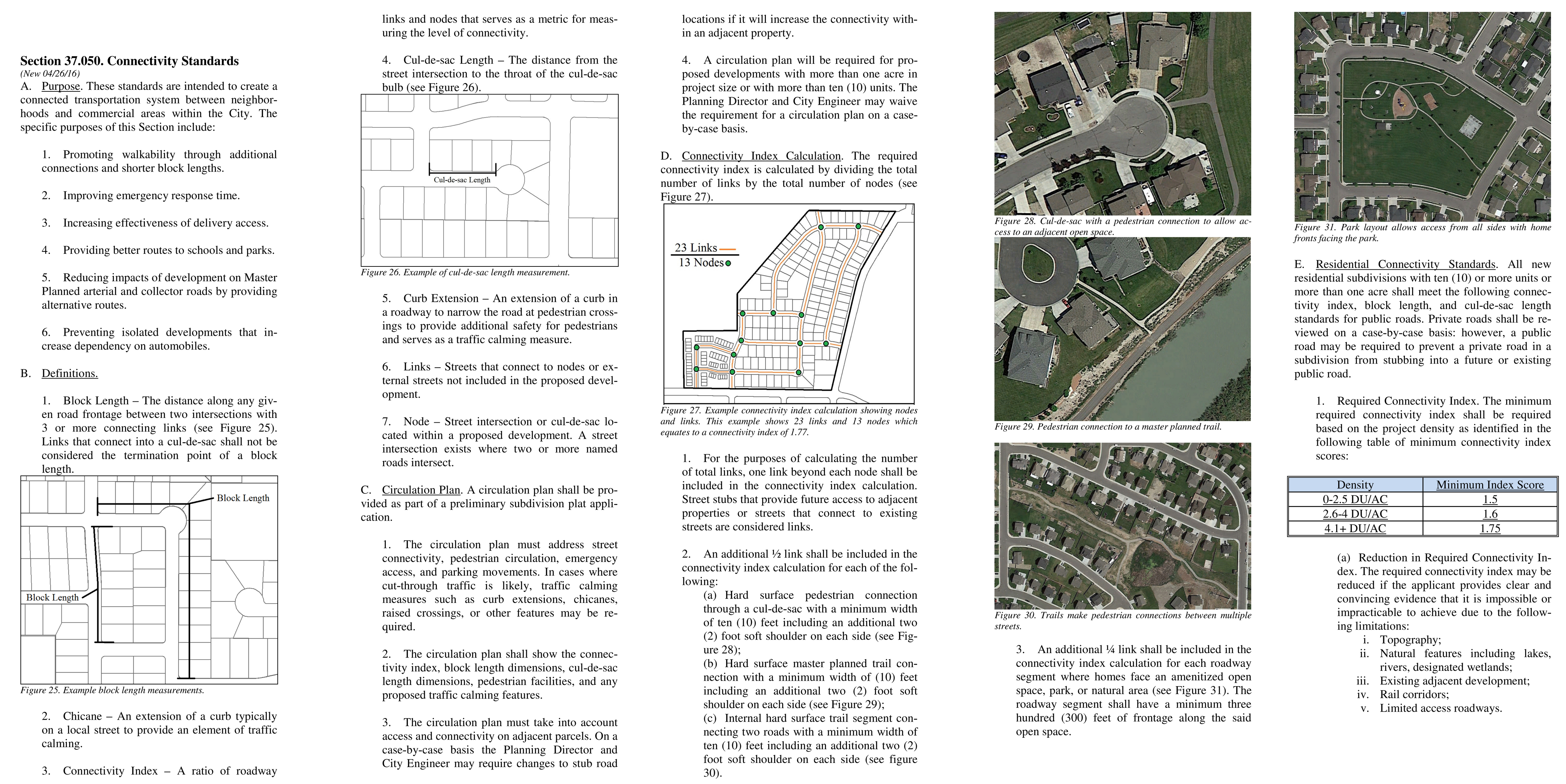
- **PLANS AND POLICIES** are higher-level policies that create the foundation for good street connectivity.





Examples of plans that seek to increase connectivity, whether focusing on roads (right) or pedestrian connections (left)

- **STREET AND DEVELOPMENT STANDARDS** are concrete rules that implement the directives of the high-level policy.



Section 37.050. Connectivity Standards
(New 04/26/16)

A. Purpose. These standards are intended to create a connected transportation system between neighborhoods and commercial areas within the City. The specific purposes of this Section include:

1. Promoting walkability through additional connections and shorter block lengths.
2. Improving emergency response time.
3. Increasing effectiveness of delivery access.
4. Providing better routes to schools and parks.
5. Reducing impacts of development on Master Planned arterial and collector roads by providing alternative routes.
6. Preventing isolated developments that increase dependency on automobiles.

B. Definitions.

1. Block Length – The distance along any given road frontage between two intersections with 3 or more connecting links (see Figure 25). Links that connect into a cul-de-sac shall not be considered the termination point of a block length.

Block Length
Block Length

Figure 25. Example block length measurements.

2. Chicane – An extension of a curb typically on a local street to provide an element of traffic calming.

3. Connectivity Index – A ratio of roadway links and nodes that serves as a metric for measuring the level of connectivity.

4. Cul-de-sac Length – The distance from the street intersection to the throat of the cul-de-sac bulb (see Figure 26).

Cul-de-sac Length

Figure 26. Example of cul-de-sac length measurement.

5. Curb Extension – An extension of a curb in a roadway to narrow the road at pedestrian crossings to provide additional safety for pedestrians and serves as a traffic calming measure.

6. Links – Streets that connect to nodes or external streets not included in the proposed development.

7. Node – Street intersection or cul-de-sac located within a proposed development. A street intersection exists where two or more named roads intersect.

C. Circulation Plan. A circulation plan shall be provided as part of a preliminary subdivision plat application.

1. The circulation plan must address street connectivity, pedestrian circulation, emergency access, and parking movements. In cases where cut-through traffic is likely, traffic calming measures such as curb extensions, chicanes, raised crossings, or other features may be required.

2. The circulation plan shall show the connectivity index, block length dimensions, cul-de-sac length dimensions, pedestrian facilities, and any proposed traffic calming features.

3. The circulation plan must take into account access and connectivity on adjacent parcels. On a case-by-case basis the Planning Director and City Engineer may require changes to stub road locations if it will increase the connectivity within an adjacent property.

4. A circulation plan will be required for proposed developments with more than one acre in project size or with more than ten (10) units. The Planning Director and City Engineer may waive the requirement for a circulation plan on a case-by-case basis.

D. Connectivity Index Calculation. The required connectivity index is calculated by dividing the total number of links by the total number of nodes (see Figure 27).

23 Links
13 Nodes

Figure 27. Example connectivity index calculation showing nodes and links. This example shows 23 links and 13 nodes which equates to a connectivity index of 1.77.

1. For the purposes of calculating the number of total links, one link beyond each node shall be included in the connectivity index calculation. Street stubs that provide future access to adjacent properties or streets that connect to existing streets are considered links.

2. An additional ½ link shall be included in the connectivity index calculation for each of the following:
   (a) Hard surface pedestrian connection through a cul-de-sac with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side (see Figure 28);
   (b) Hard surface master planned trail connection with a minimum width of (10) feet including an additional two (2) foot soft shoulder on each side (see Figure 29);
   (c) Internal hard surface trail segment connecting two roads with a minimum width of ten (10) feet including an additional two (2) foot soft shoulder on each side (see figure 30).

Figure 28. Cul-de-sac with a pedestrian connection to allow access to an adjacent open space.

Figure 29. Pedestrian connection to a master planned trail.

Figure 30. Trails make pedestrian connections between multiple streets.

3. An additional ¼ link shall be included in the connectivity index calculation for each roadway segment where homes face an amenitized open space, park, or natural area (see Figure 31). The roadway segment shall have a minimum three hundred (300) feet of frontage along the said open space.

Figure 31. Park layout allows access from all sides with home fronts facing the park.

E. Residential Connectivity Standards. All new residential subdivisions with ten (10) or more units or more than one acre shall meet the following connectivity index, block length, and cul-de-sac length standards for public roads. Private roads shall be reviewed on a case-by-case basis: however, a public road may be required to prevent a private road in a subdivision from stubbing into a future or existing public road.

1. Required Connectivity Index. The minimum required connectivity index shall be required based on the project density as identified in the following table of minimum connectivity index scores:

Density	Minimum Index Score
0-2.5 DU/AC	1.5
2.6-4 DU/AC	1.6
4.1+ DU/AC	1.75

(a) Reduction in Required Connectivity Index. The required connectivity index may be reduced if the applicant provides clear and convincing evidence that it is impossible or impracticable to achieve due to the following limitations:
   i. Topography;
   ii. Natural features including lakes, rivers, designated wetlands;
   iii. Existing adjacent development;
   iv. Rail corridors;
   v. Limited access roadways.

An example of street and development standards that increase connectivity is Lehi City's recently adopted Connectivity Standards.

- **RETROFIT TOOLS** are methods to improve the street connectivity of built-out areas.

Examples of retrofit improvements that increase street connectivity in built-out areas include street crossing improvements (left) and a pedestrian pass-through (right)

- **MANAGING STREET CONNECTIVITY** refers to tools that complement and maintain the functionality of connected streets and mitigate any negative side effects.

Examples of traffic calming treatments that can help manage street connectivity

UTAH STREET **CONNECTIVITY** STUDY

WASATCH FRONT REGIONAL COUNCIL | UTA | UDOT udot.utah.gov | MOUNTAINLAND ASSOCIATION OF GOVERNMENTS

CONTEXT-BASED GUIDANCE FOR STREET CONNECTIVITY

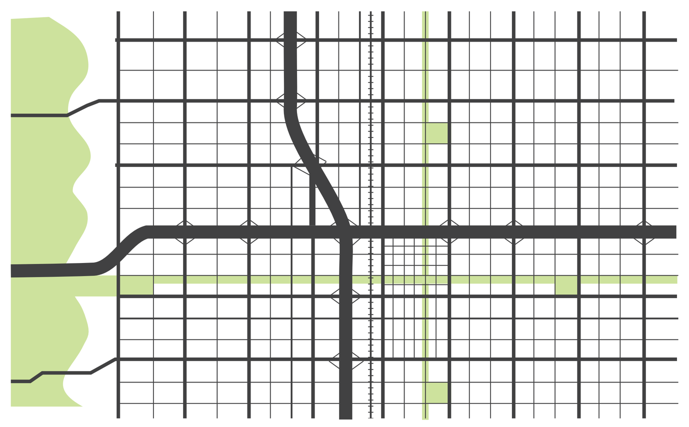
STREET CONNECTIVITY IS NOT ONE-SIZE-FITS-ALL. For example, the way we connect streets in Downtown Salt Lake City is different than how we connect streets in suburban communities like Layton, or rural communities like Tooele Valley. Yet street connectivity benefits all communities. So we have developed **Street Connectivity Typologies** that give custom guidance for different types of communities.

COMMUNITY-SCALE CONNECTIVITY

Community-scale connectivity is street connectivity within the borders of a local jurisdiction, most commonly a city. We define three types of communities:

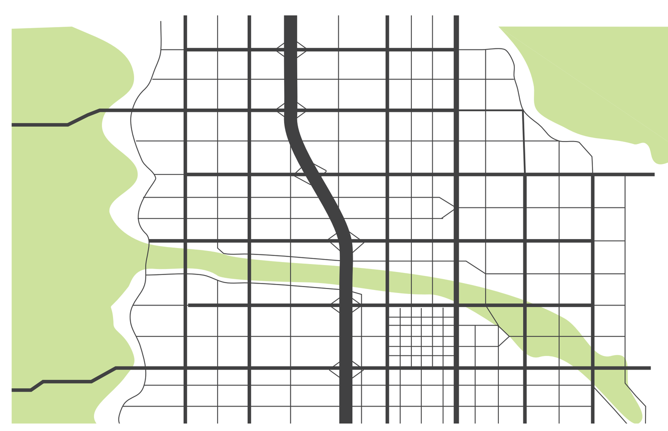
Urban: An urban community is a city or other local jurisdiction with:

- Higher overall density
- A high degree of intersecting regional transportation facilities and regional destinations
- A high degree of land use mix



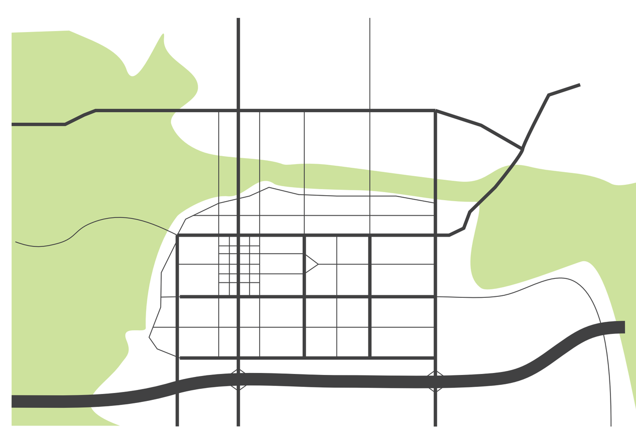
Suburban: A suburban community is a city or other local jurisdiction with:

- Medium overall density
- Fewer regional transportation facilities and regional destinations
- Lower degree of land use mix



Rural: A rural community is a city or other local jurisdiction with:

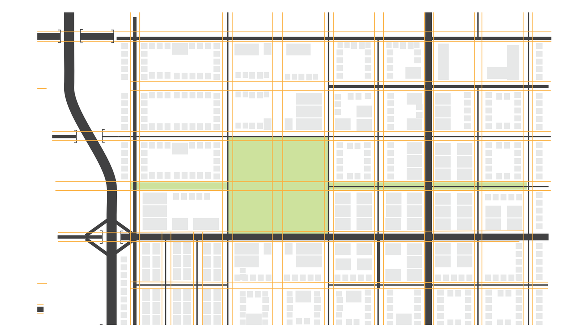
- Low density
- Relatively isolated from other communities
- High degree of agricultural, mountain land, or other natural open space within the community



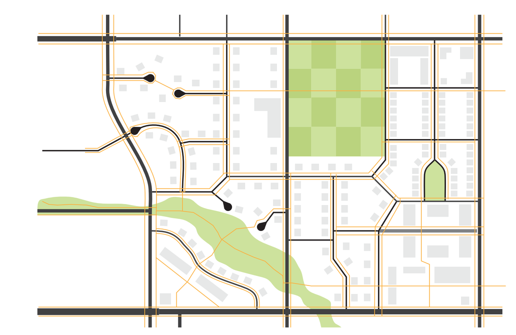
NEIGHBORHOOD AND DISTRICT-SCALE CONNECTIVITY

Neighborhood and district-scale connectivity is street connectivity within a neighborhood or district of common community character. These areas can range in size – as small as a single subdivision to as large as a several square mile subsection of a city. We define six types of neighborhoods/districts:

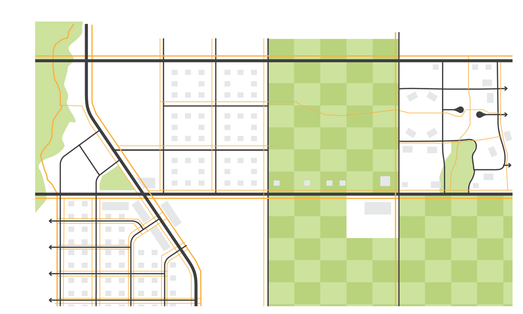
Urban residential neighborhood: An urban residential neighborhood is a higher-density residential area with civic, commercial, and office uses mixed in.



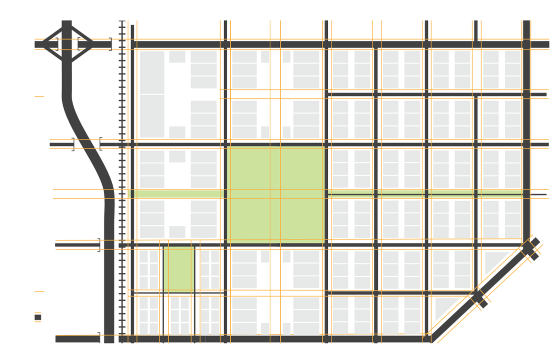
Suburban residential neighborhood: A lower-density residential area with other types of uses typically found on nearby arterial or collector corridors.



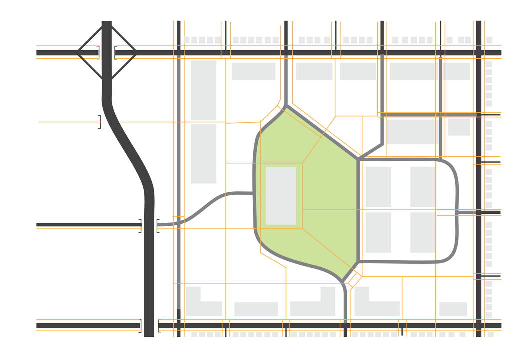
Rural residential neighborhood: A very low density residential area with agricultural or natural space mixed in and few other uses present.



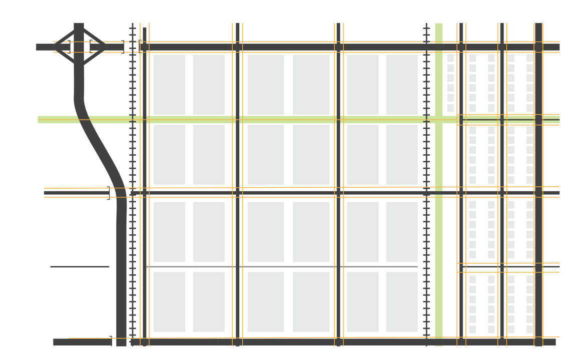
Downtown district: A mixed-use center of activity that attracts people from throughout the community and sometimes the region.



Campus district: A large land use such as an educational campus, shopping center, business park, or entertainment/lifestyle center.



Industrial district: An area focused on production or distribution activities.

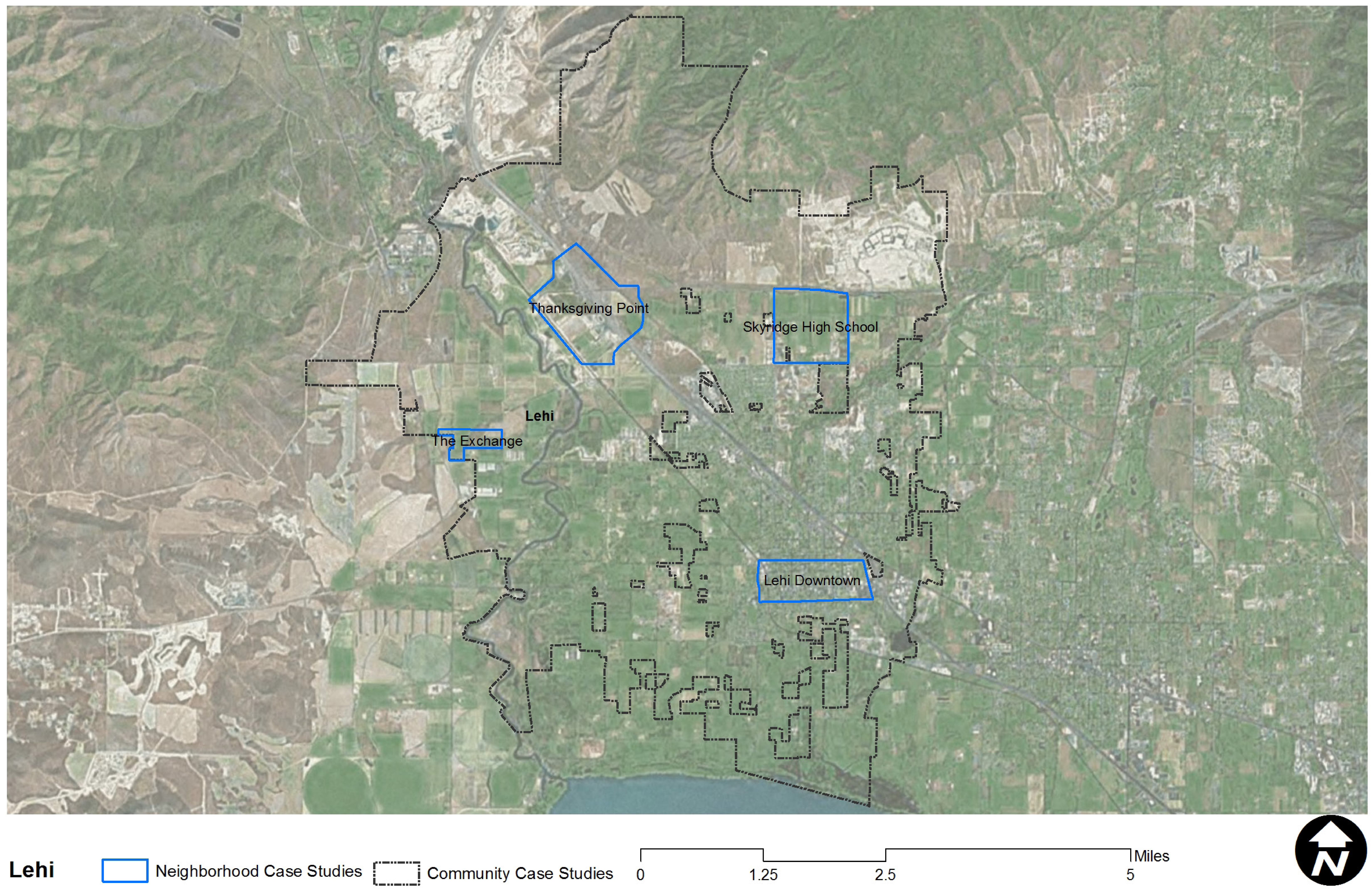


CASE STUDIES: OVERVIEW

The Utah Street Connectivity Study includes **case studies** in three Utah communities- Lehi, Layton, and Tooele County- that involved the evaluation of street connectivity in areas within each community, recommendations for strategies to improve the connectivity in these areas, and the modeling of various benefits based on the improvements.

DISCLAIMER: As you look at the case study street network connectivity recommendations, please note that **these are only ideas**- although some are based on adopted plans, the new connections shown are **not an active proposal** by the local jurisdictions or any other stakeholder.

LEHI CASE STUDY AREAS



CASE STUDIES: OVERVIEW

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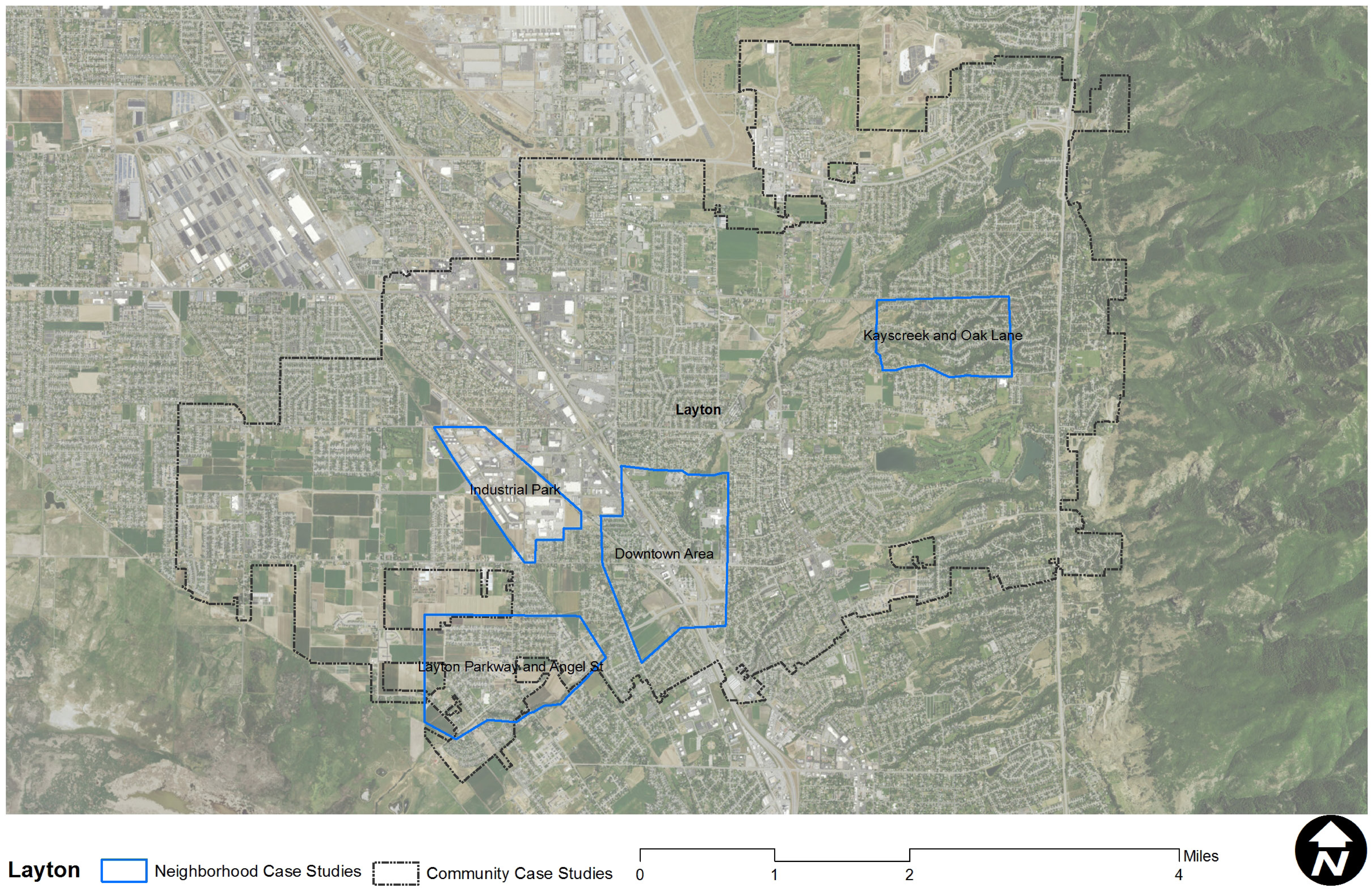
LAYTON CASE STUDY AREAS



CASE STUDIES: OVERVIEW

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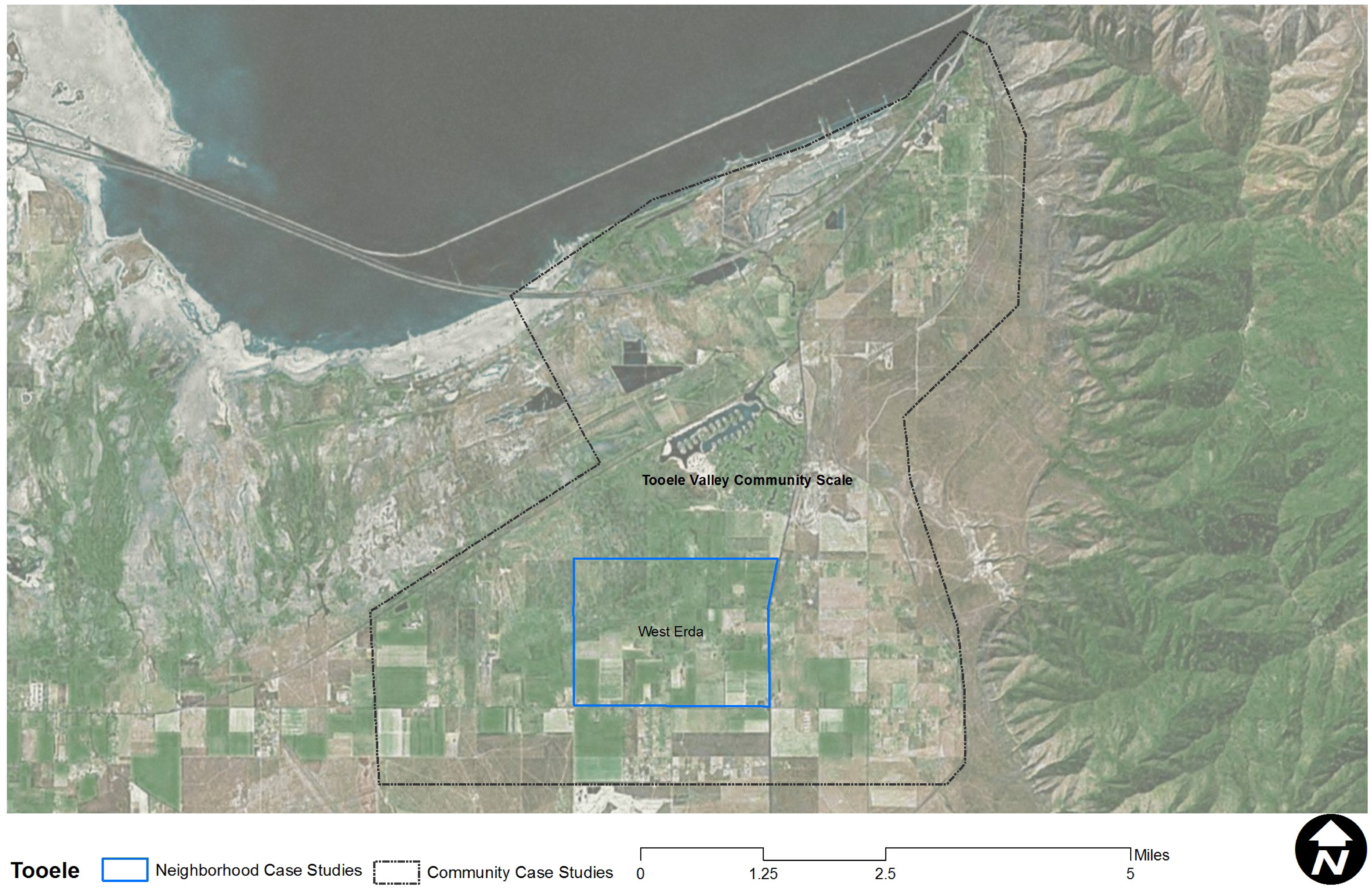
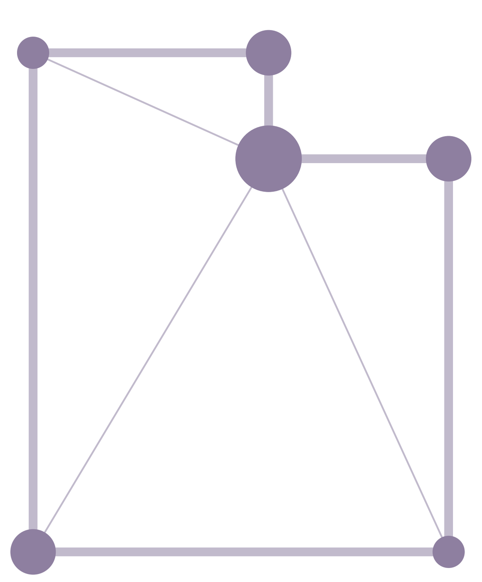
TOOELE COUNTY CASE STUDY AREAS





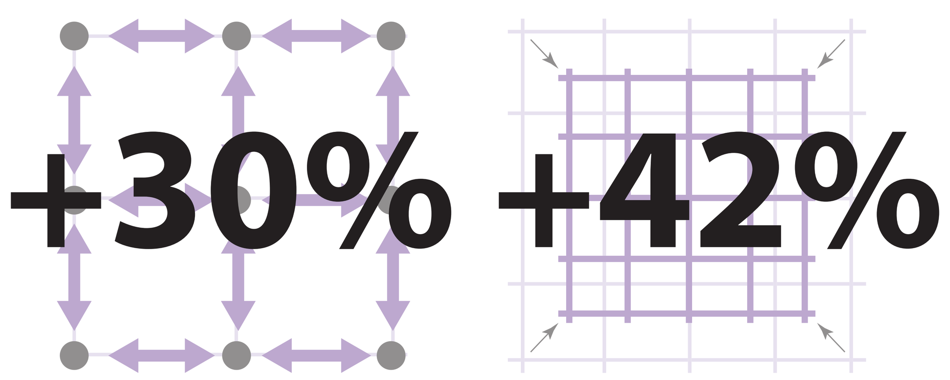
CASE STUDIES: LEHI

Urban Community case study: Lehi

Lehi is a fast-growing city in Utah County with several developing centers of activity - especially the Thanksgiving Point area. Lehi would currently be likely a suburban community under this guide's typology, but the community's potential growth, its activity hubs, and location could put it in the urban community category. The Wasatch Front's central transportation corridor, including I-15 and rail lines, splits the city. The east-west corridor of S.R. 92 is a growing transportation corridor.

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY | NETWORK DENSITY

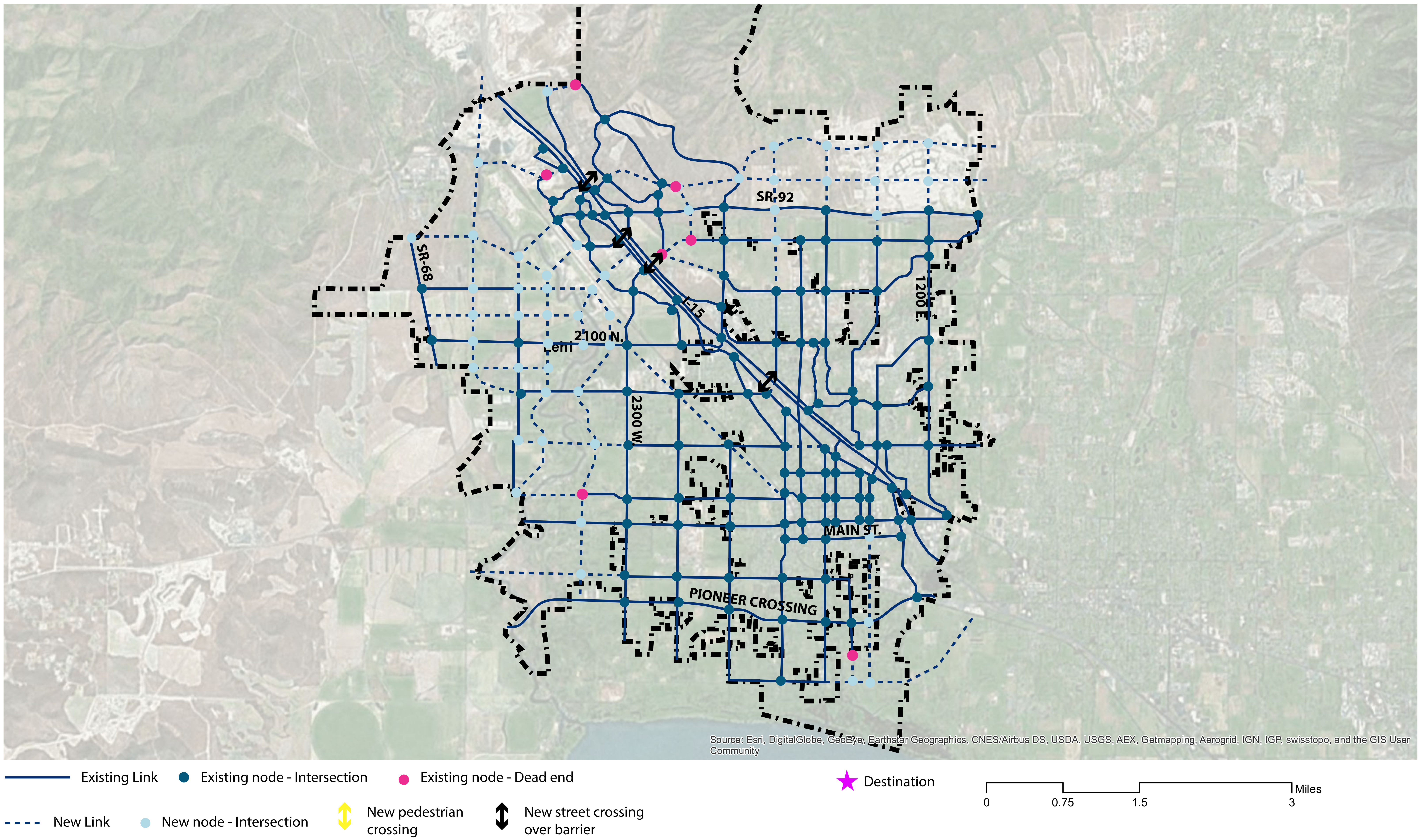


BENEFITS:

Our modeling showed that these improvements could:

- **Reduce traffic delay** by 24 percent
- **Increase the amount of walking** by up to 20 times
- **Increase restaurant and grocery store sales** by .8 percent
- Add up to **$7.4 million** of transportation, health, and environmental benefits

LEHI: POTENTIAL CONNECTIVITY IMPROVEMENTS



CASE STUDIES: LEHI

Downtown District case study: Downtown Lehi

Downtown Lehi is a classic Utah small town downtown, with a relatively consistent, dense grid of streets and blocks. While the connectivity in this area is better than most other case study areas this guide explores, there is plenty of room for improvement – and this area has a higher standard to achieve in the downtown context type.

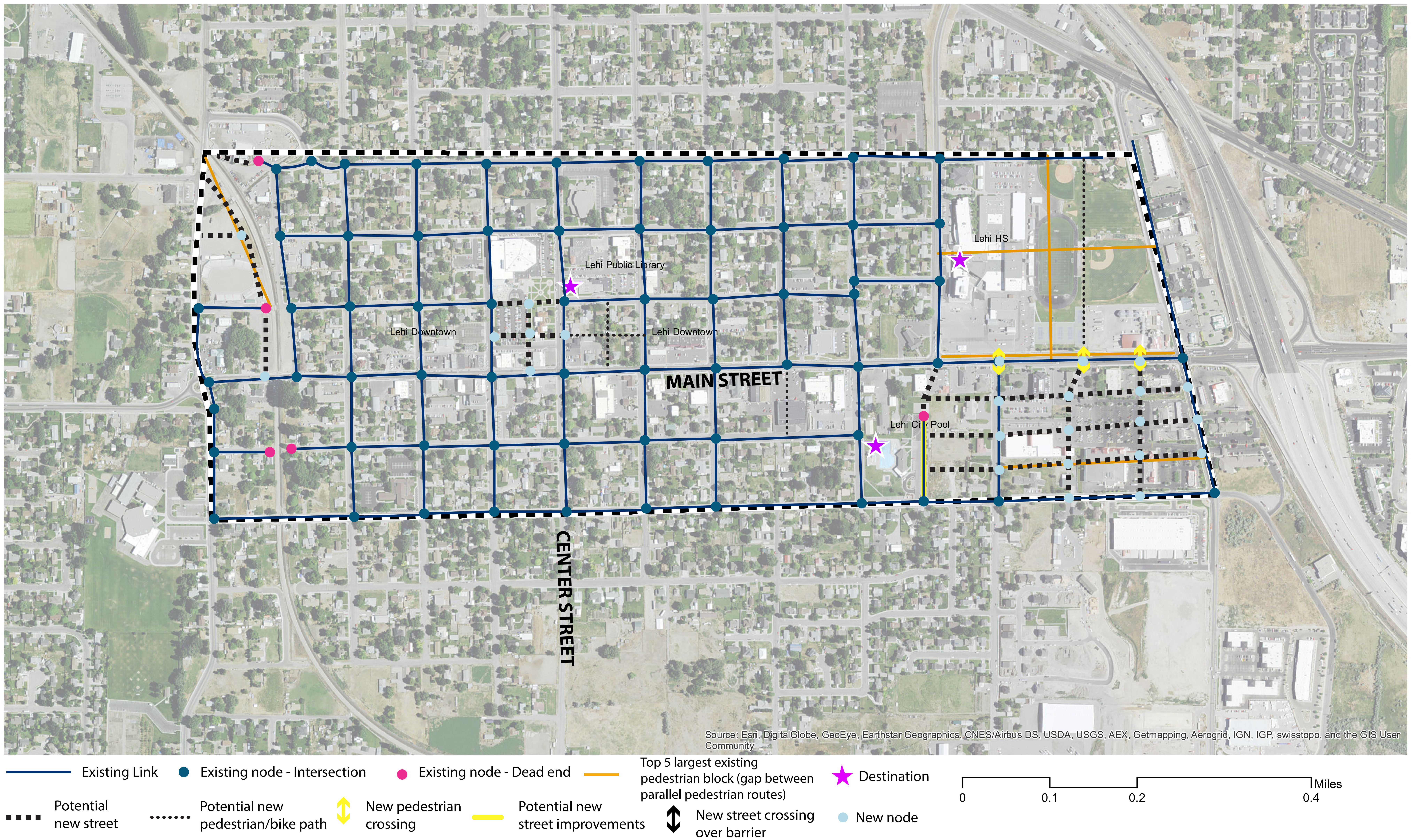
STRATEGIES:

- Fill out historic grid
- Improve pedestrian crossings across major streets
- Break up big blocks with redevelopment

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY	NETWORK DENSITY
+30%	+42%
DESTINATION ACCESS	**PEDESTRIAN FRIENDLINESS**
+0%	+19%

DOWNTOWN LEHI: POTENTIAL CONNECTIVITY IMPROVEMENTS



CASE STUDIES: LEHI

Campus District case study: Thanksgiving Point

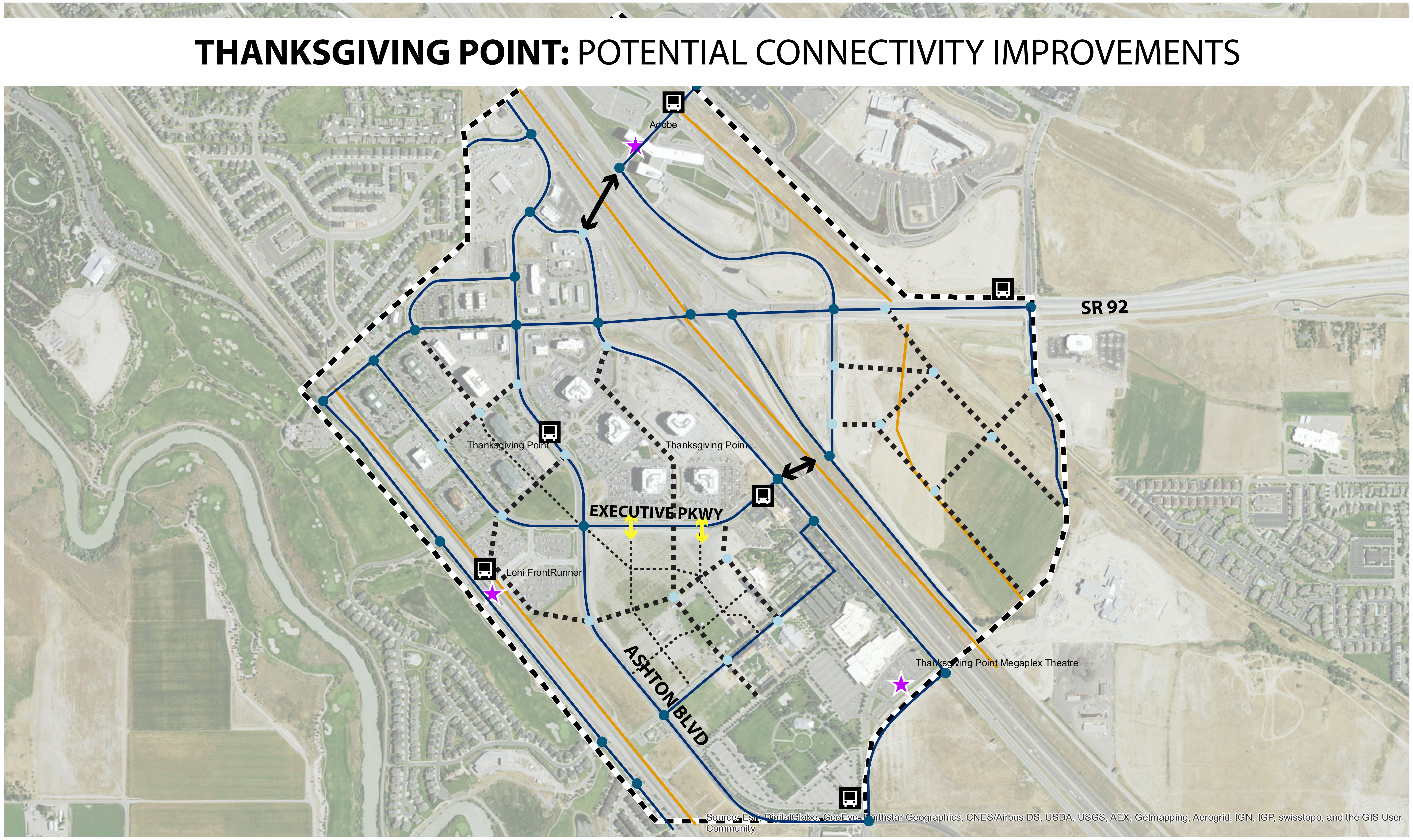
Thanksgiving Point is a fast-growing office park with some cultural and entertainment elements and presents a good opportunity to study a campus-type environment. The area is split by I-15, which creates a barrier for movement within it. It has the benefit of a UTA FrontRunner rail station but the rail tracks also present another barrier to the west of the area. Thanksgiving Point has few public streets connecting its large properties, creating a low-density network that also poses a challenge to connectivity.

STRATEGIES:

- Add connections over I-15
- Break up large blocks with new streets
- Improve multi-modal access to FrontRunner station

IMPROVED CONNECTIVITY RATINGS:

THANKSGIVING POINT: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link · Existing node - Intersection · Existing node - Dead end · Top 5 largest existing pedestrian block (gap between parallel pedestrian routes) · Destination

Potential new street · Potential new pedestrian/bike path · New pedestrian crossing · Potential new street improvements · New street crossing over barrier · New node · Existing transit stop/station

0 · 0.15 · 0.3 · 0.6 Miles

CASE STUDIES: LEHI

Suburban Neighborhood case study: Skyridge High School Area

Skyridge is a brand-new high school in the northeastern part of Lehi. Much of the neighborhood around it is also new and still being developed. This case study looks at how a suburban neighborhood can be built to connect to a major destination such as a school and how such a large land use can avoid being a barrier.

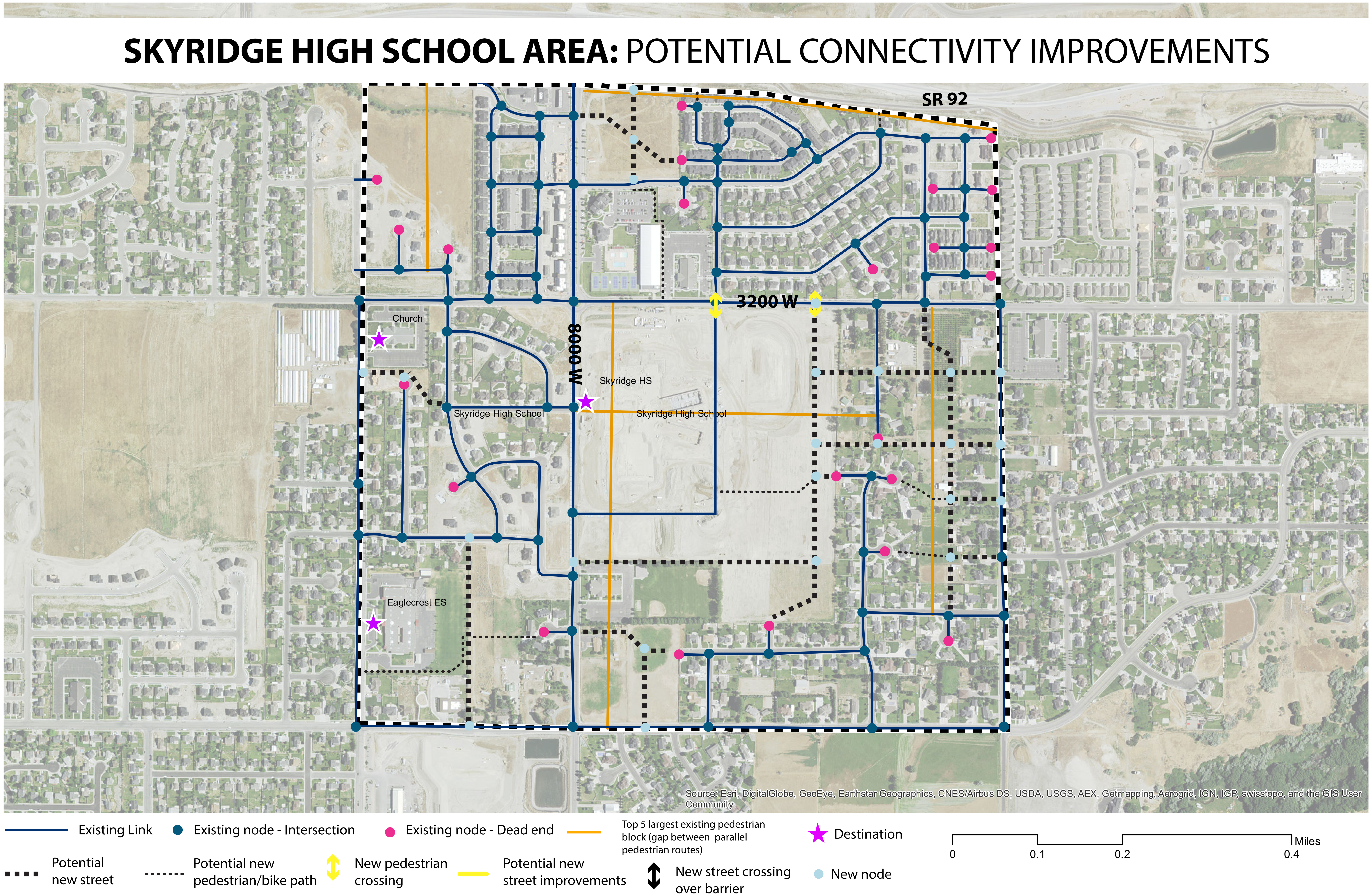
STRATEGIES:

- Create more connections betwen the neighborhood and high school
- Make strategic cul-de-sac connections
- Require new infill development to have high street connectivity and small block size

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY	NETWORK DENSITY
+44%	+32%
DESTINATION ACCESS	**PEDESTRIAN FRIENDLINESS**
+25%	+42%

SKYRIDGE HIGH SCHOOL AREA: POTENTIAL CONNECTIVITY IMPROVEMENTS



CASE STUDIES: LEHI

Suburban Neighborhood case study: The Exchange

The Exchange, a planned development on the growing west side of Lehi, presents a unique opportunity for a case study. The Exchange was entitled under Lehi's new street connectivity standards, which require a minimum street connectivity index and maximum block length. The development was tested against this guide's metrics and it scored very well. The Exchange provides a real-world example of how street connectivity standards can produce a much more connected street network and neighborhood. The Exchange has some cul-de-sacs but they are connected for pedestrians and cyclists; its other dead-end streets are planned to connect to adjacent developments.

The current connectivity ratings show how, largely due to Lehi's new standards for street connectivity, the Exchange scores very well on all aspects of connectivity.

EXISTING CONNECTIVITY RATINGS:

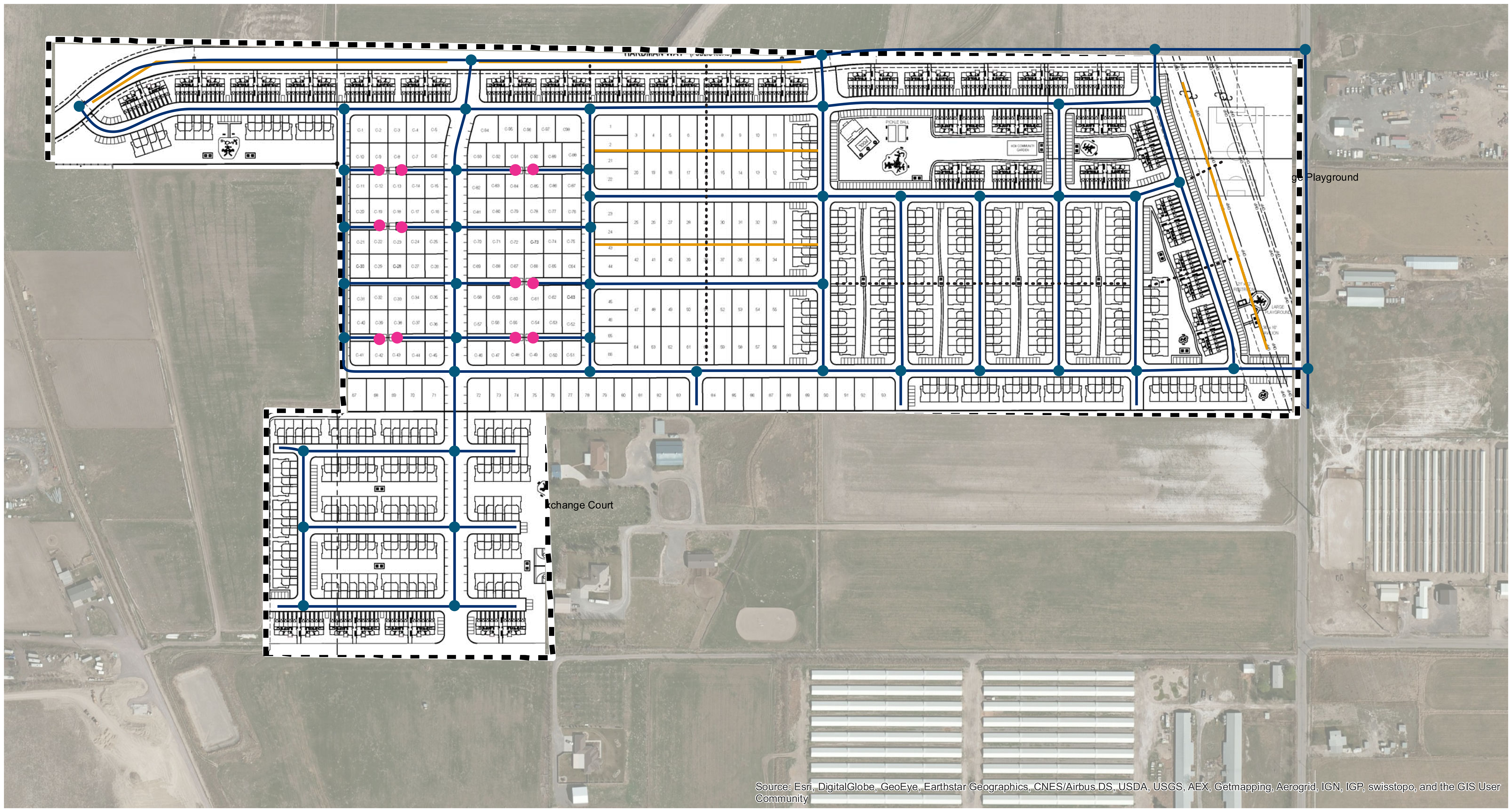
STREET CONNECTIVITY
98% of the standard

NETWORK DENSITY
223% of the standard

DESTINATION ACCESS
84% of the standard

PEDESTRIAN FRIENDLINESS
110% of the standard

THE EXCHANGE: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link · Existing node - Intersection · Existing node - Dead end · Top 5 largest existing pedestrian block (gap between parallel pedestrian routes) · Destination

Potential new street · Potential new pedestrian/bike path · New pedestrian crossing · Potential new street improvements · New street crossing over barrier · New node

0 · 0.05 · 0.1 · 0.2 Miles

UTAH STREET **CONNECTIVITY** STUDY

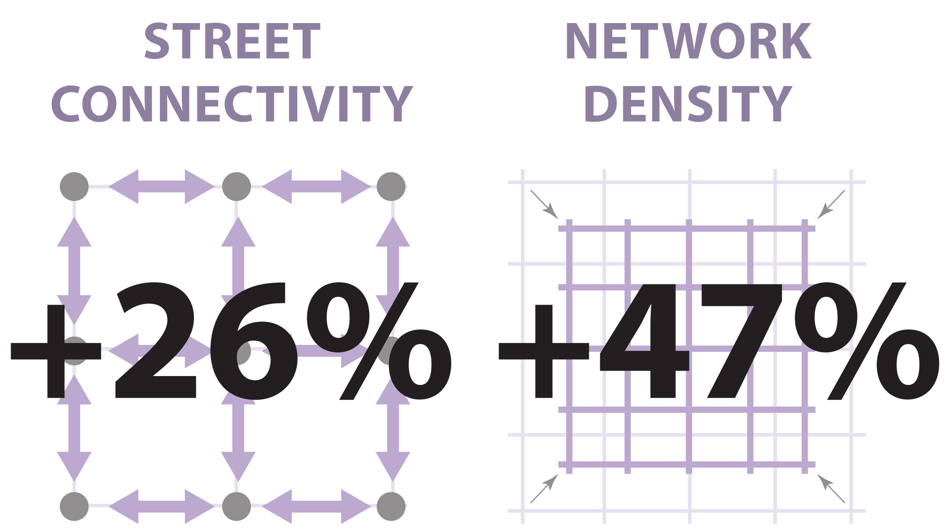
WASATCH FRONT REGIONAL COUNCIL · UTA · UDOT udot.utah.gov · MOUNTAINLAND ASSOCIATION OF GOVERNMENTS

CASE STUDIES: LAYTON

Suburban Community Case Study: Layton

Layton is a suburban city in Davis County. Layton has both established neighborhoods in the eastern, hilly areas against the Wasatch Mountains, and newer neighborhoods in growth areas near the Great Salt Lake shorelands to the west. The Wasatch Front's central transportation corridor, that includes I-15 and rail lines, splits the city.

IMPROVED CONNECTIVITY RATINGS:

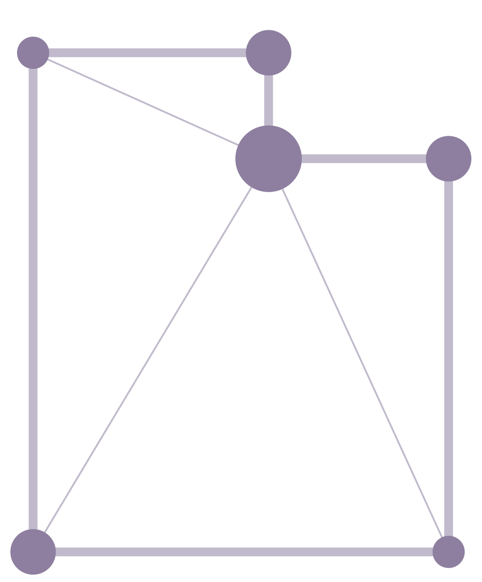


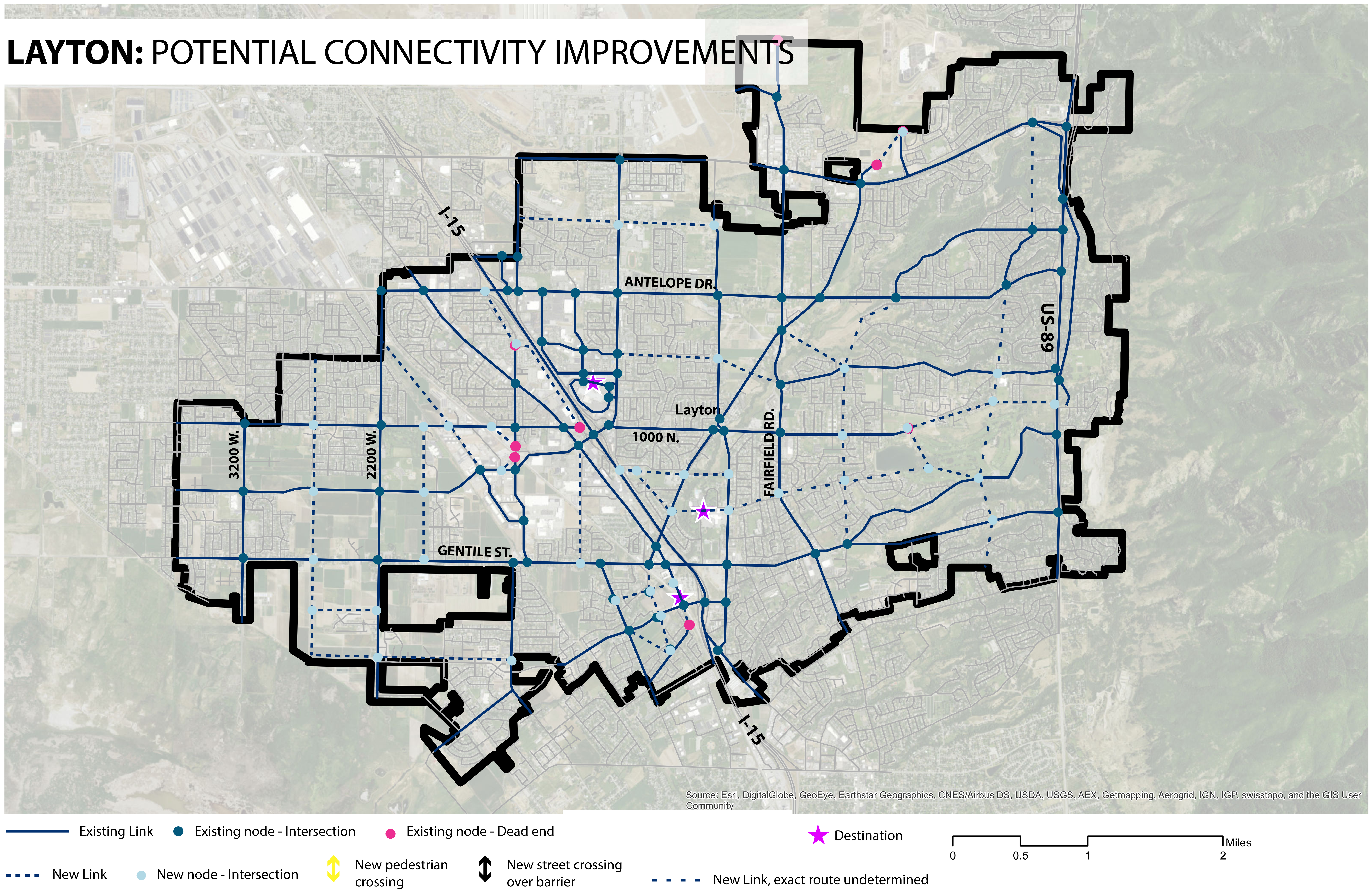
+26% **+47%**

BENEFITS:

Our modeling showed that these improvements could:

- **Reduce traffic delay by 8.5 percent**
- **Double the amount of walking**
- **Increase warehouse club and supercenter sales by 1.5 percent**
- **Add up to $4.2 million of transportation, health, and environmental benefits**





CASE STUDIES: LAYTON

Urban Neighborhood case study: Downtown Layton

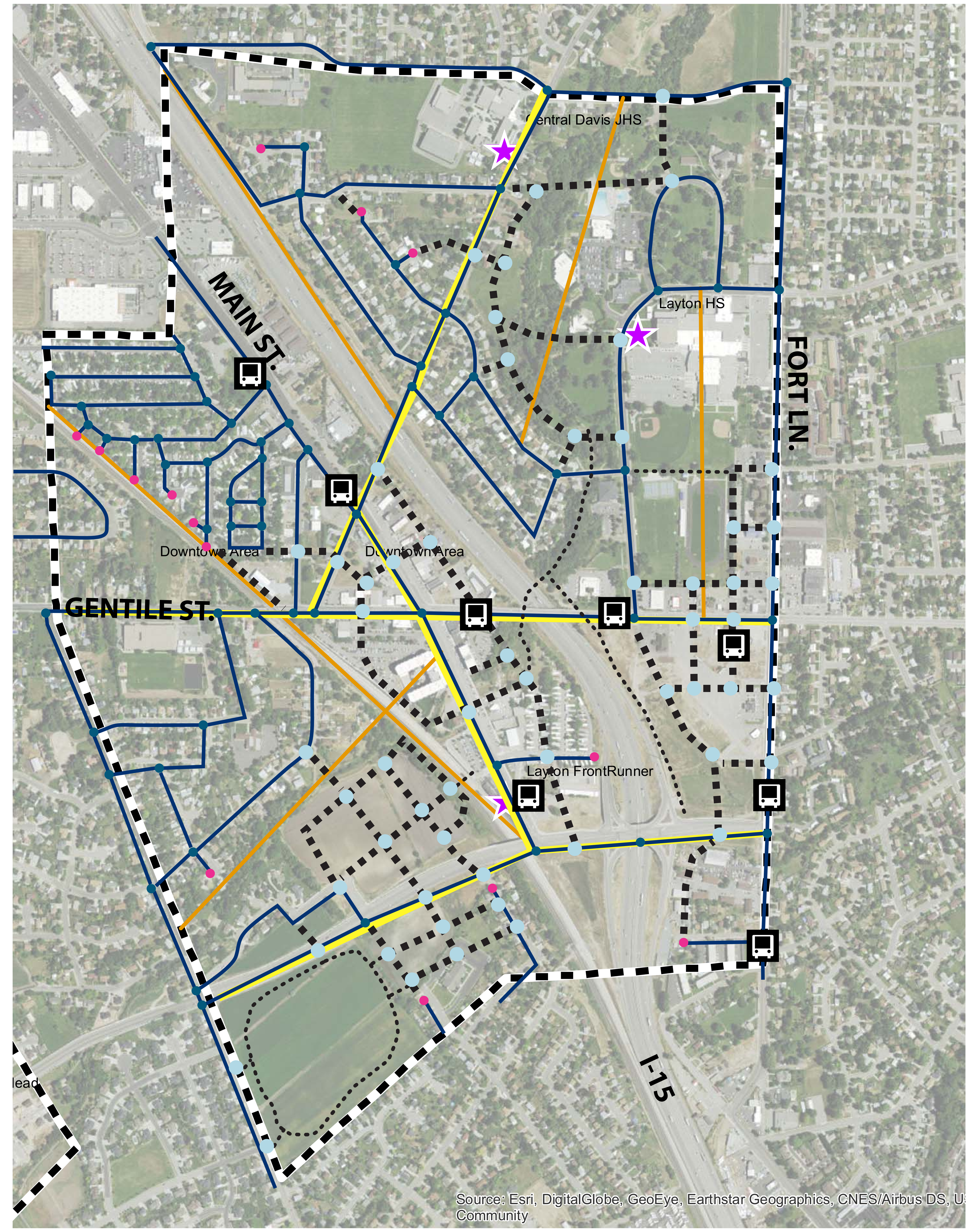
Layton's central district includes a mix of uses and popular destinations, such as Main Street, the civic campus, Layton High School, Layton Commons, a FrontRunner station, shopping areas, and residential neighborhoods. Street connectivity is challenged by I-15 running through the middle of the area, as well as the railroad tracks. The district's sub-areas also lack connections to one another yet the mix of uses, amenities and destinations here provide the foundation for a connected urban neighborhood.

STRATEGIES:

- Require new infill development to have small block size
- Connect Layton Commons area to surrounding neighborhood
- Improve I-15 crossings for walking/biking
- Build Kays Creek Trail to connect district

IMPROVED CONNECTIVITY RATINGS:

DOWNTOWN LAYTON: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link · Existing node - Intersection · Existing node - Dead end · Top 5 largest existing pedestrian block (gap between parallel pedestrian routes) · Destination

Potential new street · Potential new pedestrian/bike path · New pedestrian crossing · Potential new street improvements · New street crossing over barrier · New node · Existing transit stop/station

CASE STUDIES: LAYTON

Suburban Neighborhood case study: Angel Street and Layton Parkway

This area of Layton is located in the southwestern part of the city. It was traditionally an agricultural area, but recent growth has infilled residential subdivisions into the historic farm grid. Like in many suburban neighborhoods in Utah, cul-de-sacs are a common subdivision feature. However, this case study looks at how these popular cul-de-sacs can be limited and managed in the future with only very targeted changes to existing cul-de-sacs that increase active transportation access to destinations.

STRATEGIES:

- Require new infill development to have high street connectivity and small block size
- Create more pedestrian crossings of Layton Parkway
- Plan a community activity center in center of neighborhood

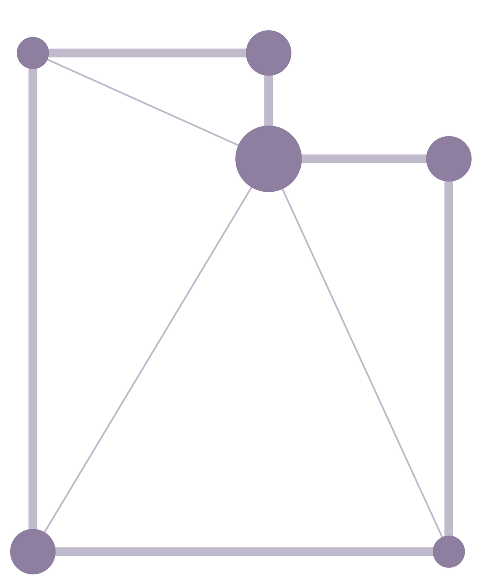
IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY
+121%

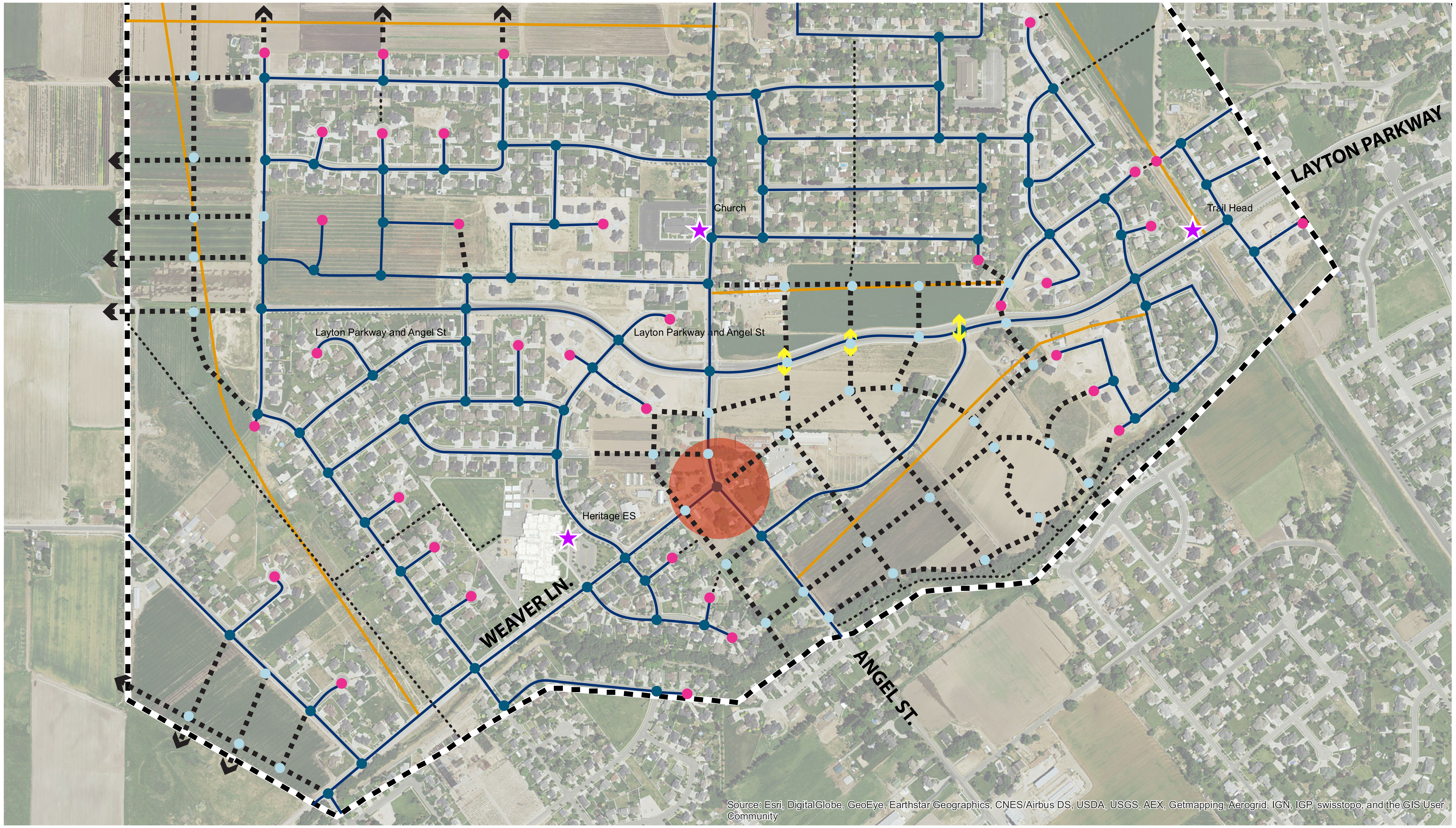
NETWORK DENSITY
+56%

DESTINATION ACCESS
+36%

PEDESTRIAN FRIENDLINESS
+194%



ANGEL ST. & LAYTON PARKWAY: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node
Potential future commercial center
0 0.1 0.2 0.4 Miles

CASE STUDIES: LAYTON

Suburban Neighborhood case study: Kays Creek and Oak Lane

This area is located in the foothills and ravines of the east side of Layton. The topography and the cul-de-sac-heavy street pattern currently restricts movement around the neighborhood; residents in different parts of this small area must travel in long circuitous paths to reach neighborhood schools and churches on the other side of the steep ravines. However, the potential exists for better pedestrian connections via an improved trail network.

STRATEGIES:

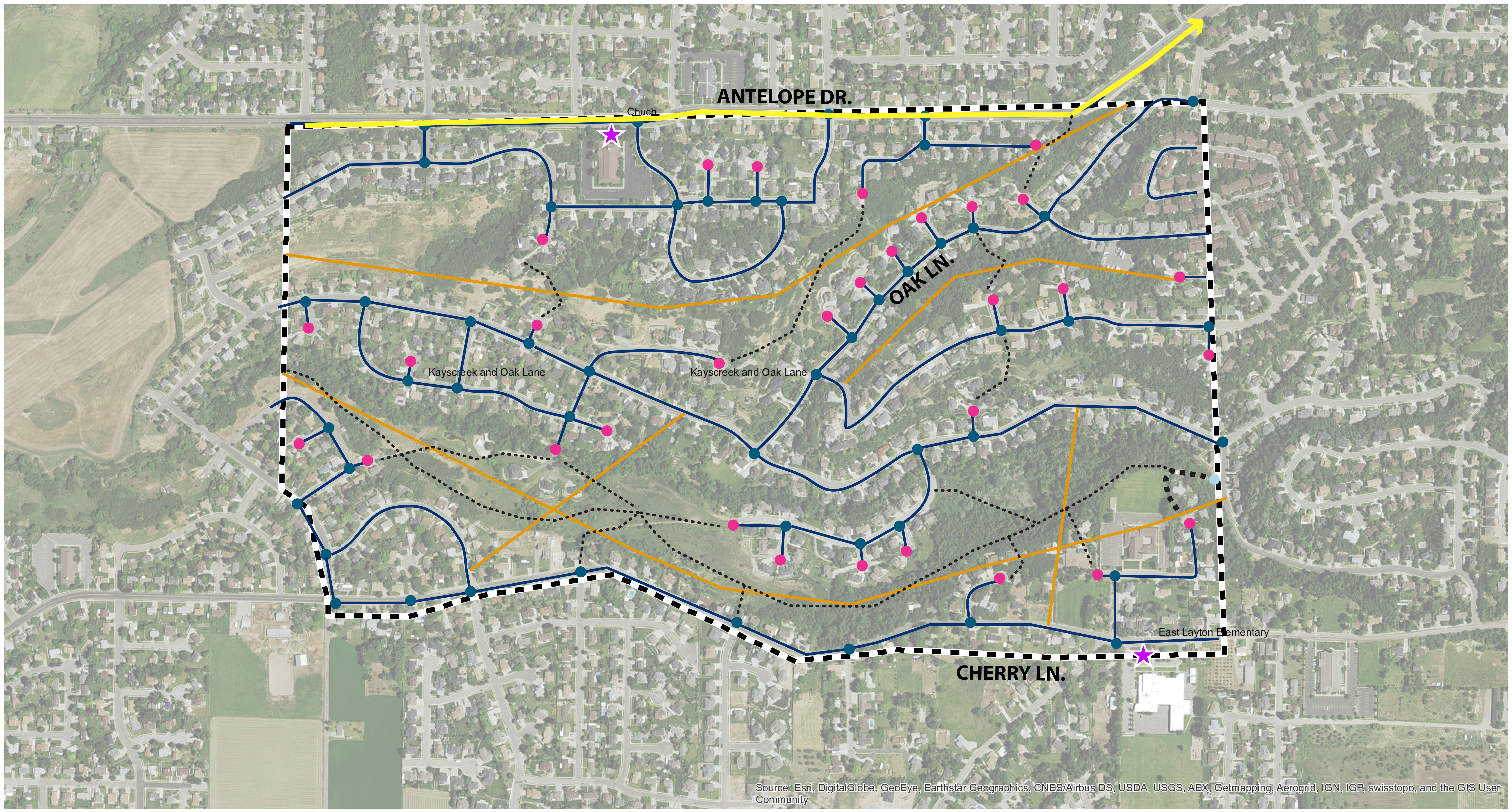
- Trails to connect across the creeks and hills for pedestrians and cyclists
- Pedestrian improvements on Antelope Drive

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY	NETWORK DENSITY
+9%	+2%

DESTINATION ACCESS	PEDESTRIAN FRIENDLINESS
+0%	+51%

KAYS CREEK & OAK LANE: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link · Existing node - Intersection · Existing node - Dead end · Top 5 largest existing pedestrian block (gap between parallel pedestrian routes) · Destination

Potential new street · Potential new pedestrian/bike path · New pedestrian crossing · Potential new street improvements · New street crossing over barrier · New node

0 · 0.1 · 0.2 · 0.4 Miles

CASE STUDIES: LAYTON

Industrial District case study: Layton industrial area

The industrial area in Layton oriented along Hill Field Road contains major distribution centers for companies such as the grocery chain Smith's. Issues raised in this case study include how well the area is connected for the freight trucks that must access it from I-15 and circulate within it, as well as the ability of the area to not be a barrier to citywide travelers moving through it.

STRATEGIES:

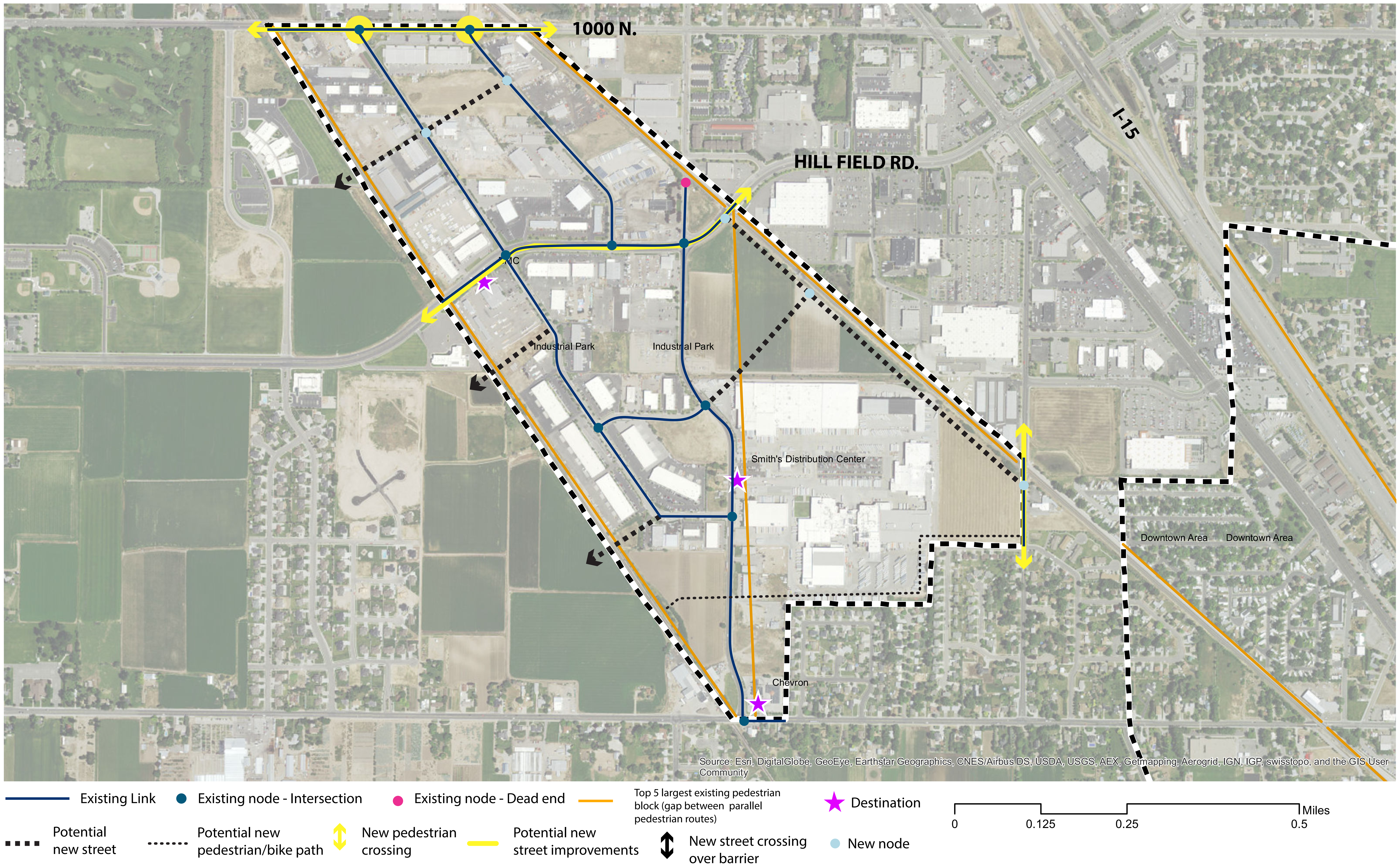
- Create stretgic new streets to break up biggest block
- Improve Hill Field Road for cyclists and pedestrians
- Plan future street connections to the west

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY	NETWORK DENSITY
+18%	+22%

DESTINATION ACCESS	PEDESTRIAN FRIENDLINESS
+33%	+21%

LAYTON INDUSTRIAL: POTENTIAL CONNECTIVITY IMPROVEMENTS



CASE STUDIES: TOOELE COUNTY

Rural Community Case Study: Tooele County

Tooele Valley is a broad Great Basin valley on the other side of the Oquirrh Mountains from Salt Lake Valley. The area of Tooele Valley being evaluated in this case study contains much of the valley's population outside the unincorporated communities of Tooele and Grantsville and covers the area roughly between Tooele City and I-80. These unincorporated communities include Erda, Stansbury Park, and Lake Point. The area is predominantly rural but is growing steadily with housing development.

IMPROVED CONNECTIVITY RATING:

NETWORK DENSITY

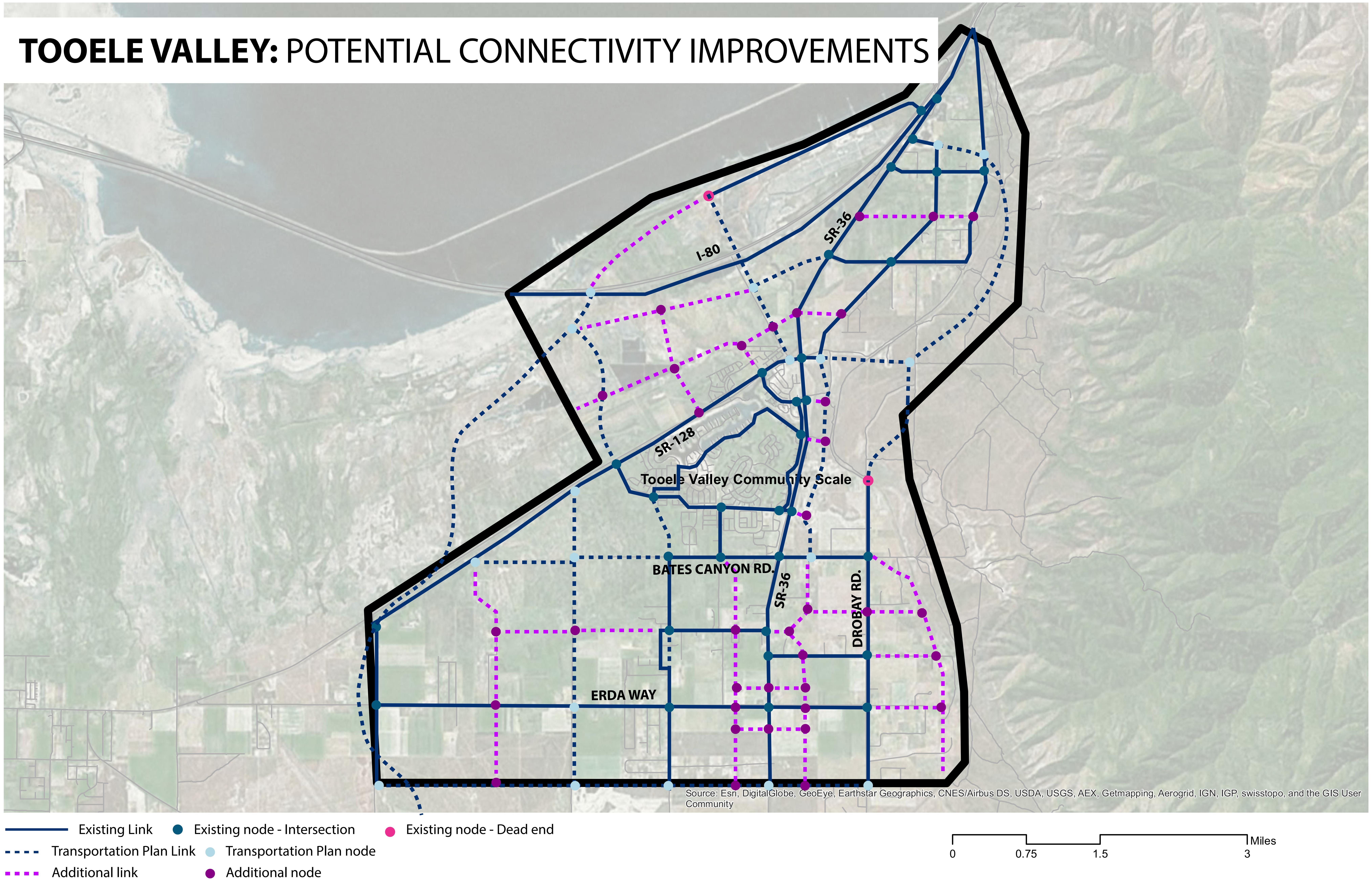
+62%

BENEFITS:

Our modeling showed that these improvements* could:

- **Reduce traffic delay** by 17 percent
- **Double the amount of walking**
- **Increase restaurant sales** by 3.4 percent
- **Add up to $2.5 million of transportation, health, and environmental benefits**

These reflect only the Transportation Plan improvements.



CASE STUDIES: TOOELE COUNTY

Rural neighborhood case study: West Erda

West Erda is one of Tooele Valley's fastest-growing areas. Over the past several years, it has seen new subdivisions that are not always well-connected to the existing rural street network or to one another. Yet an area that is largely not built-out presents a major opportunity to create a well-connected network of new neighborhoods while retaining the agricultural character of the area. This case study looks at the potential future of the West Erda street network in two phases – the near term adjustment and connections of projects currently in the planning stage; and the long-term build-out of the area.

STRATEGIES:

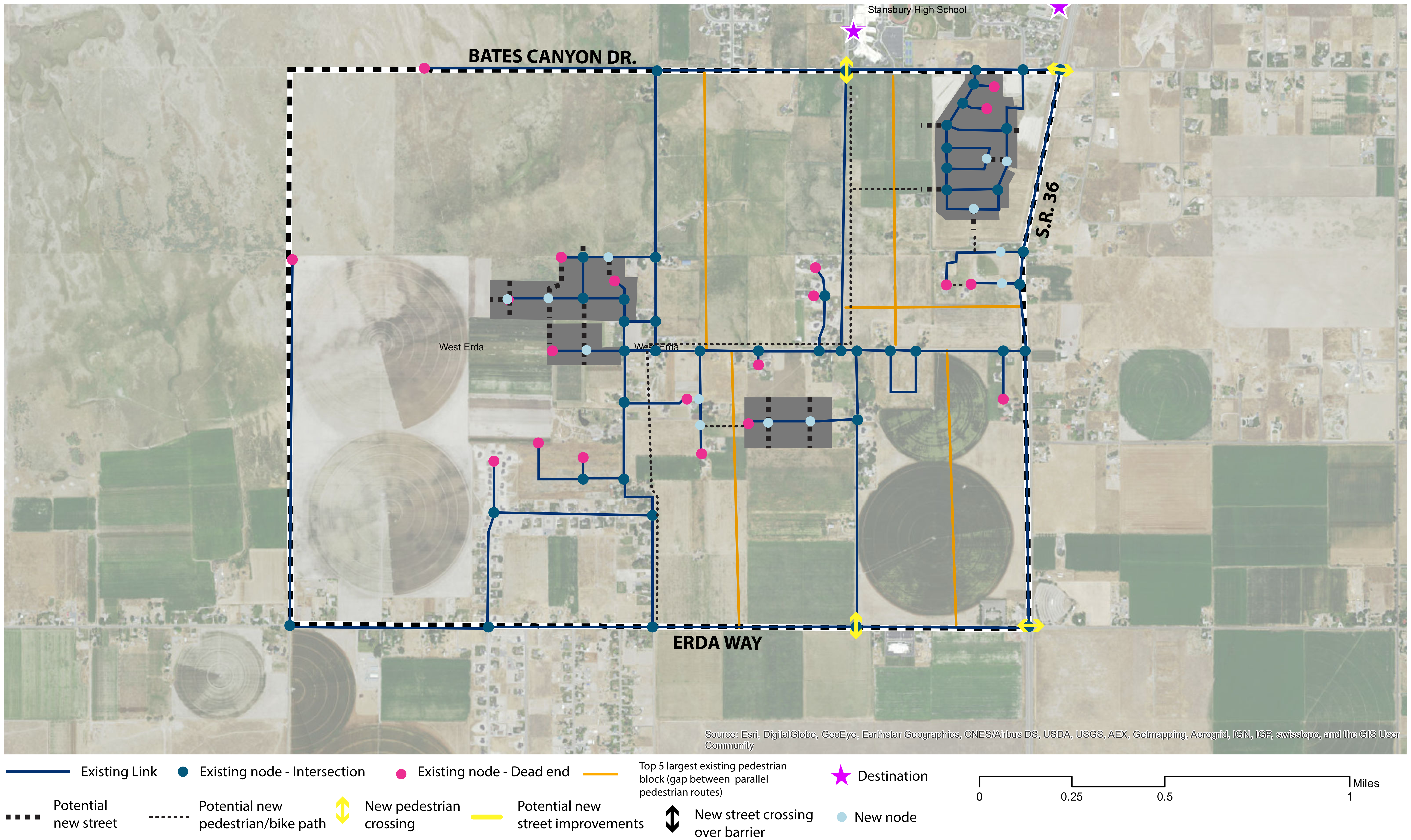
- Require more connections for new developments
- Require stub streets for new development
- Plan and build key pedestrian routes through the neighborhood

IMPROVED CONNECTIVITY RATINGS:

STREET CONNECTIVITY	NETWORK DENSITY
+94%	+23%

DESTINATION ACCESS	PEDESTRIAN FRIENDLINESS
+6%	+14%

WEST ERDA: POTENTIAL CONNECTIVITY IMPROVEMENTS (SHORT TERM)



CASE STUDIES: TOOELE COUNTY

Rural Neighborhood case study: West Erda

STRATEGIES:

- Plan a future connected and dense street grid
- Connect stub streets to new development
- Create smaller blocks near higher intensity development

IMPROVED CONNECTIVITY RATINGS:

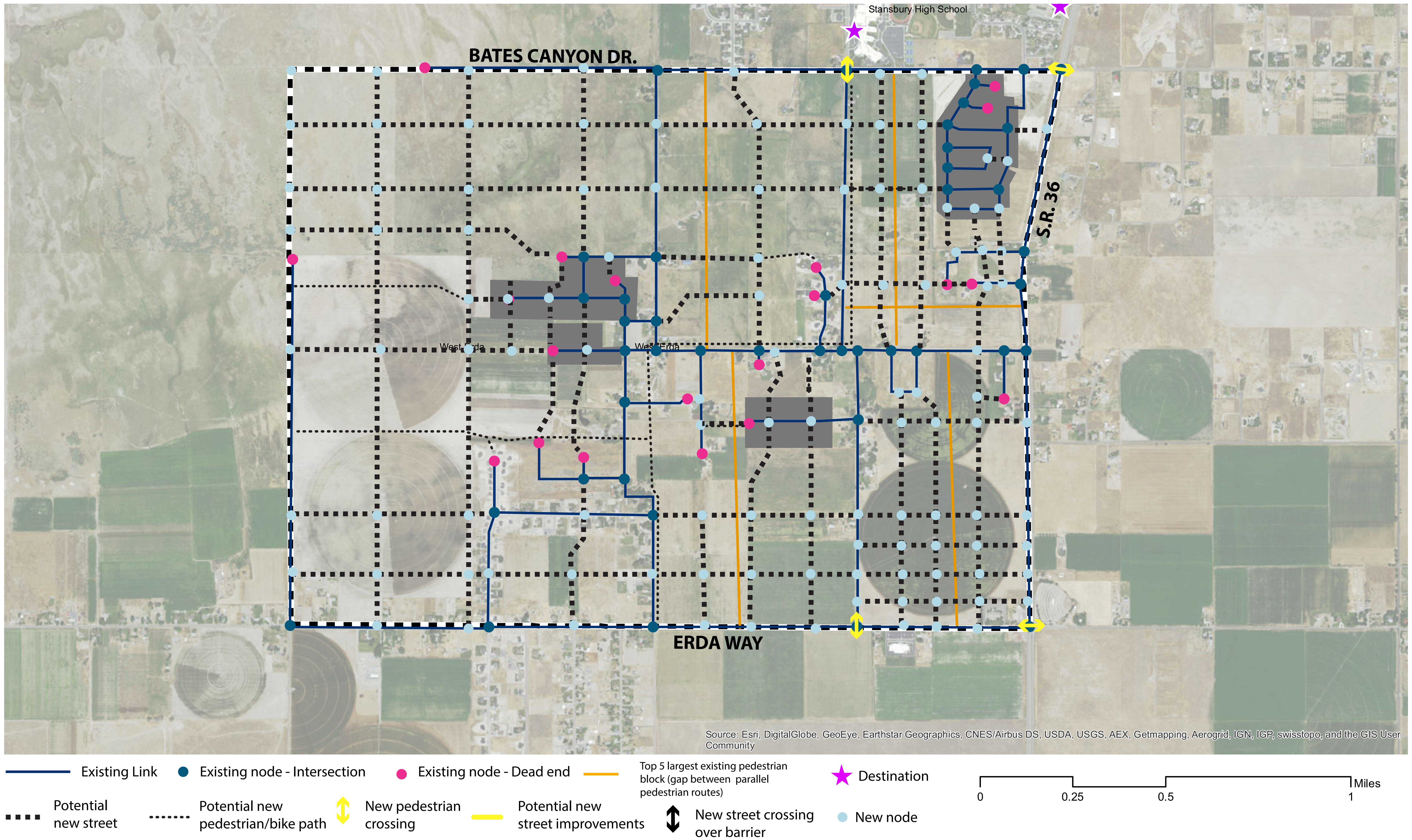
STREET CONNECTIVITY **+269%**

NETWORK DENSITY **+139%**

DESTINATION ACCESS **+61%**

PEDESTRIAN FRIENDLINESS **+59%**

WEST ERDA: POTENTIAL CONNECTIVITY IMPROVEMENTS (LONG TERM)

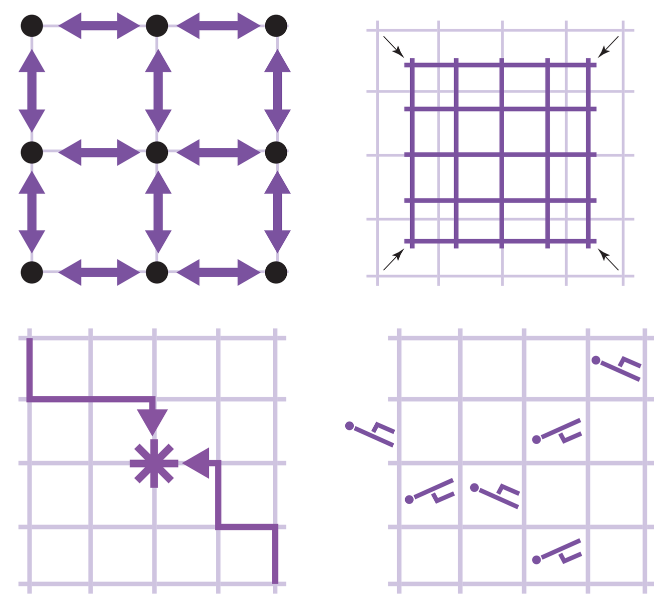


CONNECT **YOUR** COMMUNITY

3 ways to use this study for your community:

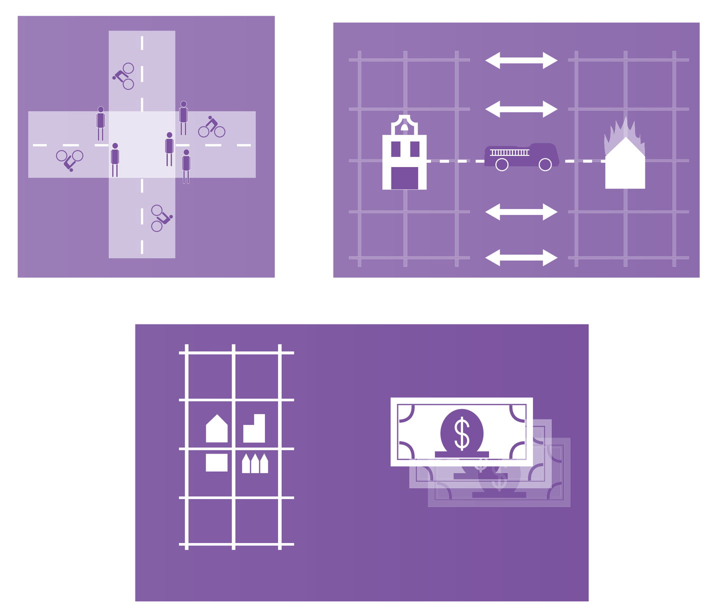
WHAT:

- **Use** the four aspects of street connectivity to assess how connected your Utah community's streets are, and how your projects improve them.



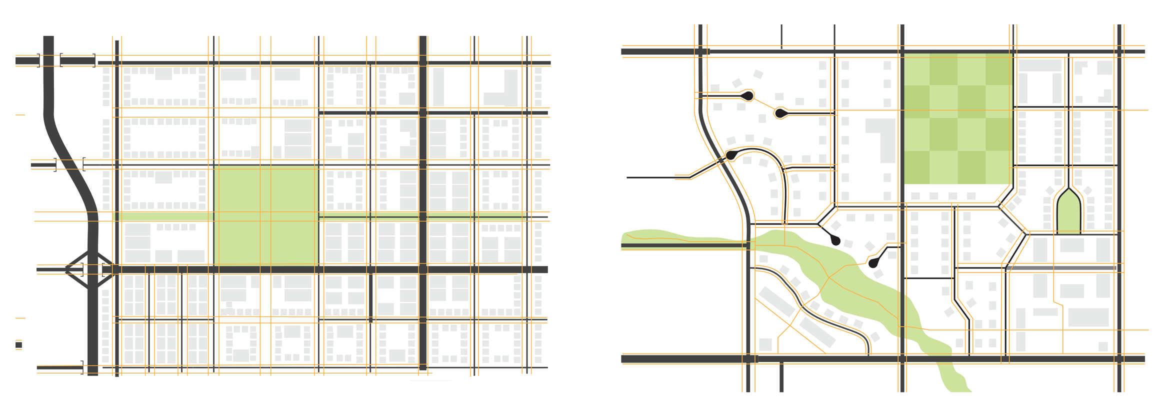
WHY:

- **Communicate** the mobility, transportation choice, safety, health, economic, environmental, and other benefits of street connectivity to others in your community.



HOW:

- Whether you are working in an urban, suburban, or rural community, in a neighborhood or other district, **apply the strategies** we have identified to increasing connectivity.



WHAT'S NEXT

- Watch for the *Utah Street Connectivity Guide* document early in 2017.

KEEP US POSTED!

- Let us know how you use this guide, how it is helpful, and how it could be improved.
- Tell us any benefits your community gains from street connectivity improvements.

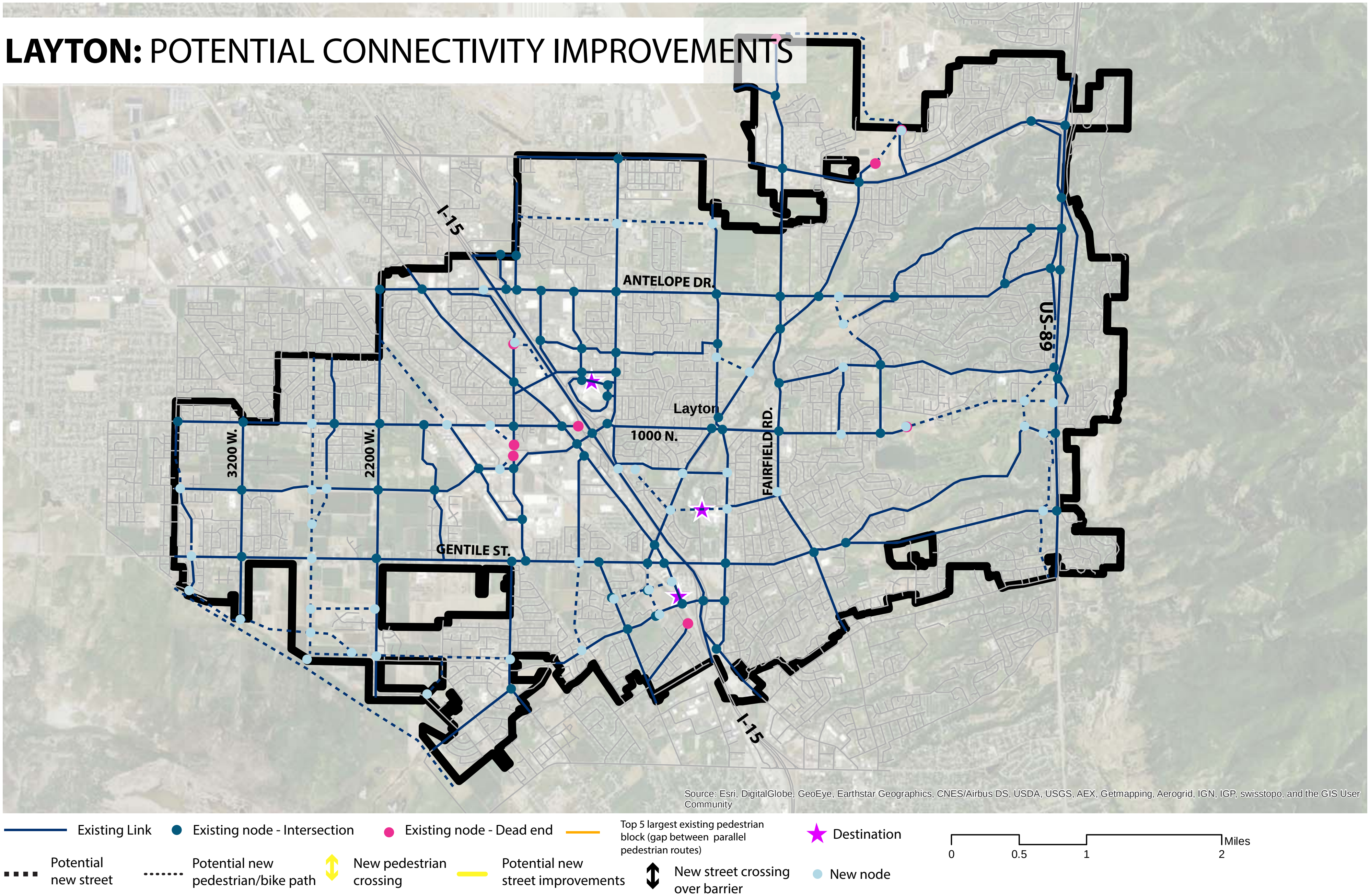
CONTACT INFORMATION

- Julie Bjornstad, Wasatch Front Regional Council, julieb@wfrc.org

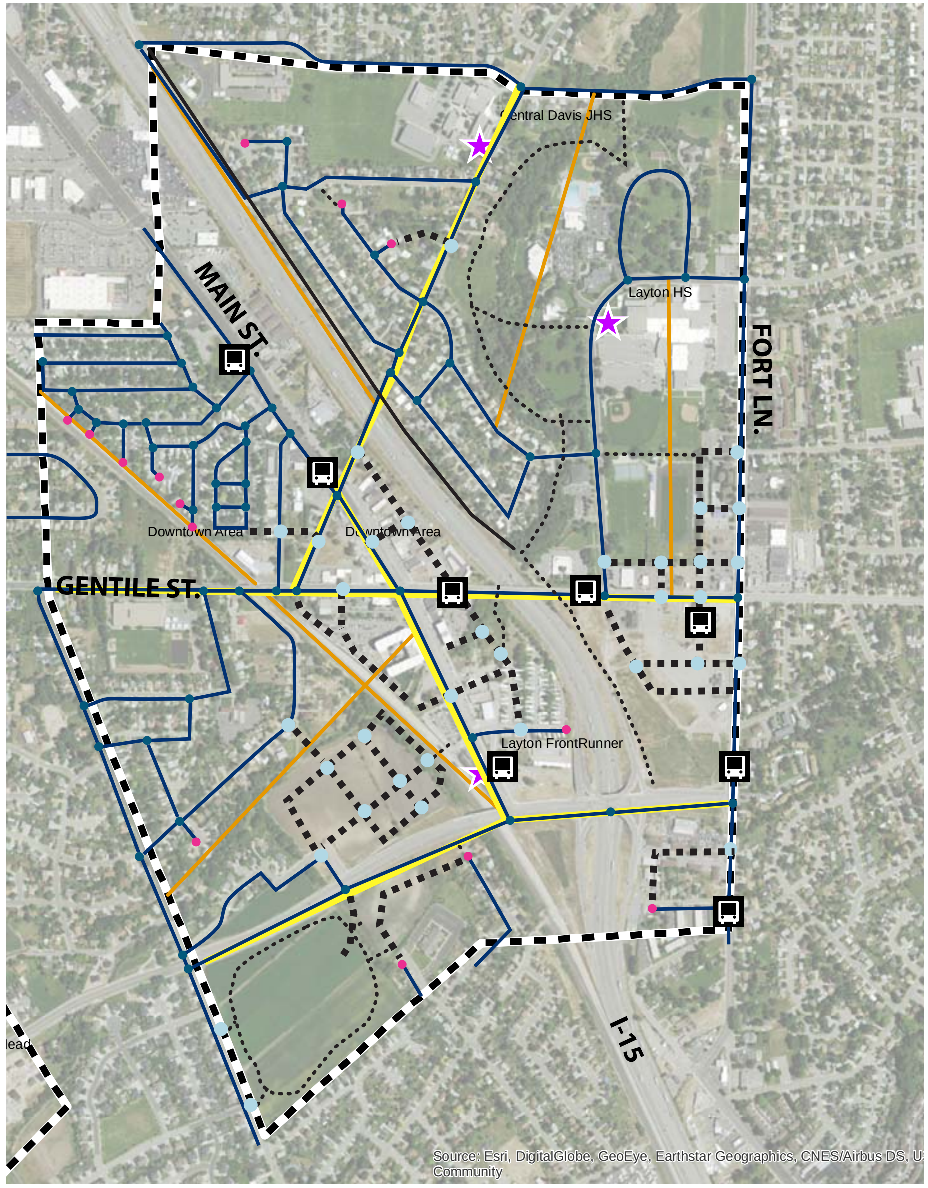
APPENDIX

Supplementary maps

Note: These case study maps more closely reflect Layton City's Master Transportation Plan that was completed in 2016.

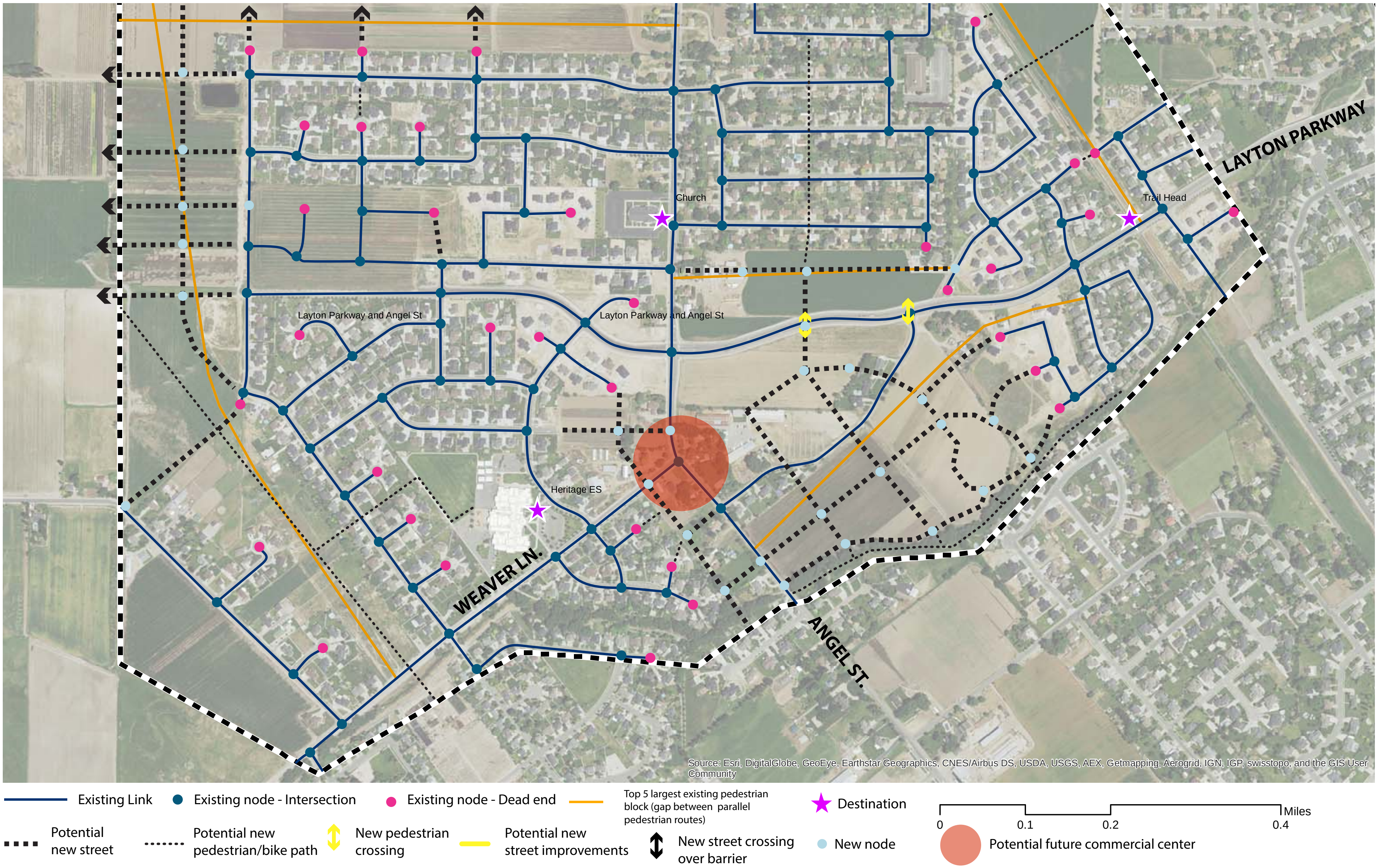


DOWNTOWN LAYTON:
POTENTIAL CONNECTIVITY IMPROVEMENTS

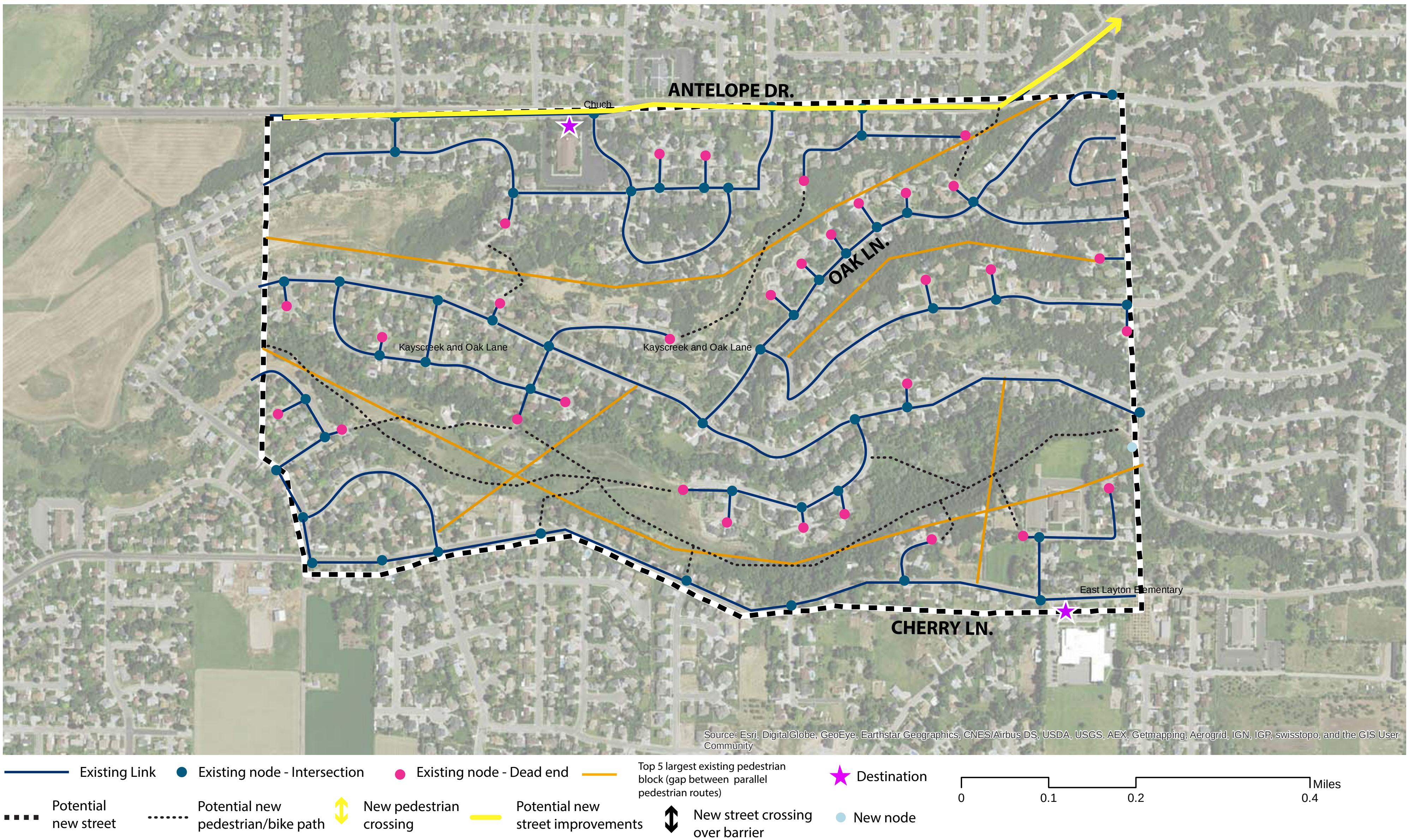


Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node
Existing transit stop/station

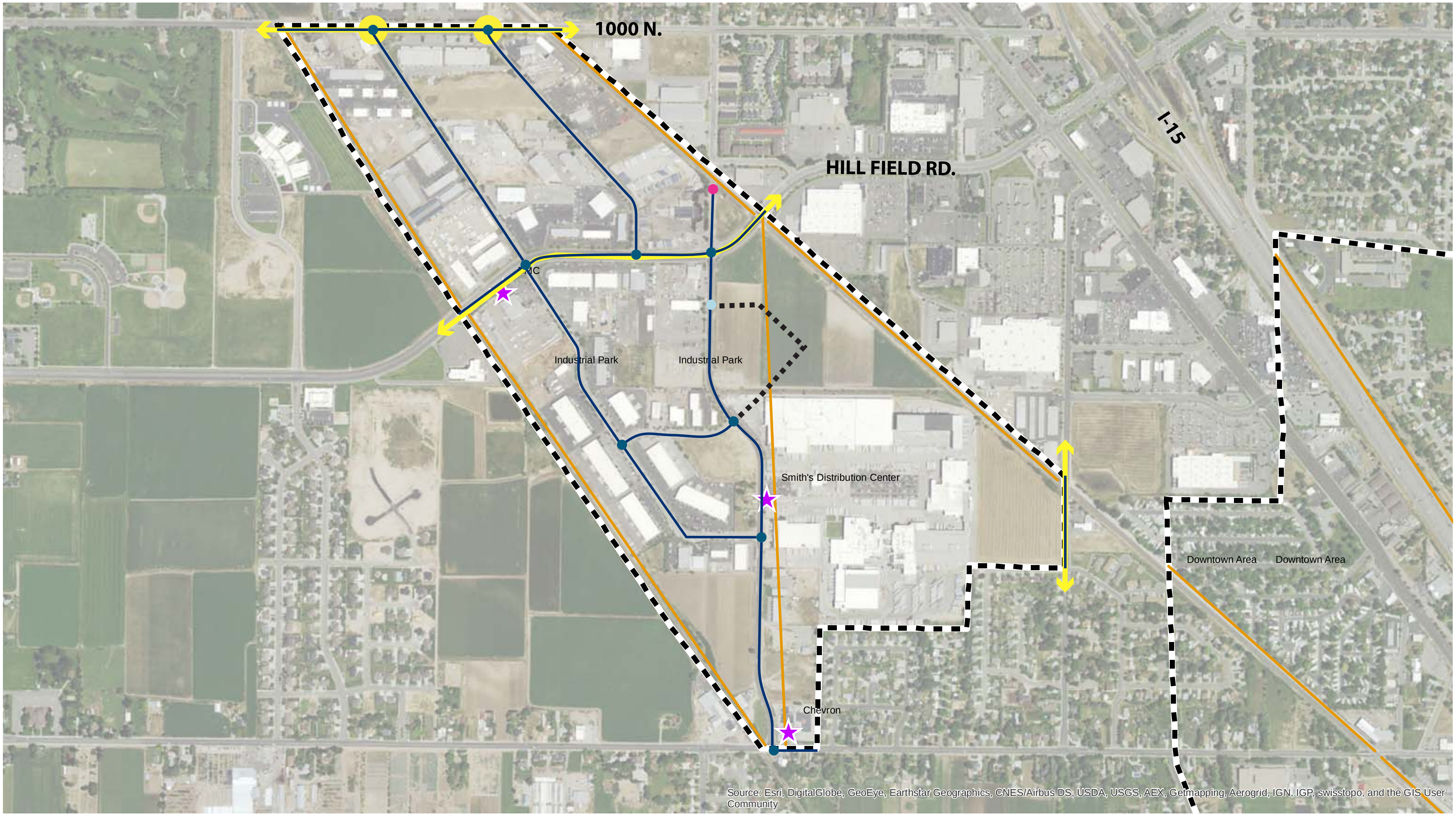
ANGEL ST. & LAYTON PARKWAY: POTENTIAL CONNECTIVITY IMPROVEMENTS



KAYS CREEK & OAK LANE: POTENTIAL CONNECTIVITY IMPROVEMENTS



LAYTON INDUSTRIAL: POTENTIAL CONNECTIVITY IMPROVEMENTS



Existing Link
Existing node - Intersection
Existing node - Dead end
Top 5 largest existing pedestrian block (gap between parallel pedestrian routes)
Destination
Potential new street
Potential new pedestrian/bike path
New pedestrian crossing
Potential new street improvements
New street crossing over barrier
New node

0 | 0.125 | 0.25 | 0.5 Miles