Space Syntax, a UK-based planning firm specializing in “space-based” modeling, developed two pedestrian forecasting models for the Berkeley Pedestrian Plan. These models and their findings are summarized in Section 5.2 Pedestrian Demand Model, of the Berkeley Pedestrian Master Plan.

The complete summary of Space Syntax’s qualitative baseline analysis and the forecasting models are summarized in the Space Syntax report, “Walkability, Movement and Safety for the City of Berkeley” provided in this appendix.
Contents page

1. Introduction 3

2. Quantitative baseline analysis
   2.1 Study area 8
   2.2 Urban form 10
   2.3 Land use 16
   2.4 Pedestrian movement 27

3. Pedestrian volume model
   3.1 Forecasted mid-day peak movement levels 30

4. SWATRS Exposure analysis 36

5. Conclusions 46

© Space Syntax Limited, 2006
1 Introduction

Background & scope

This document has been produced to assist the Alta team during the creation of the Berkeley Pedestrian Master Plan. It uses a series of scientific analyses to provide a quantitative, predictive perspective for the City of Berkeley, combining Space Syntax's unique methodology with years of experience in complex pedestrian planning projects around the world.

For this project Space Syntax has been contracted to perform the following elements of work:

Task 3: Creation of a basic pedestrian movement model and SWITRS safety analysis
Task 7: Using the above model produce a list and map of key parcels and intersections of strategic interest and opportunity
Task 8: Assist in evaluating, ranking, and prioritizing baseline pedestrian activity

The current report presents preliminary results from Task 3, model creation, with implications for Task 8.

General approach

In working alongside the Alta team in the development of the pedestrian master plan for Berkley, we have taken an “evidence-based” approach to the measurement of factors which influence walking and walkability in the City of Berkeley.

The term “evidence-based” denotes the use of a peer reviewed scientific methodology. This means that it has been tested and verified through an extensive review process, giving added confidence to the accuracy of its results. In the case of Space Syntax’s consulting work, our methods have also been tested in the laboratory of the “real world”, having been applied to hundreds of successful projects around the world.

Because each place is different and is the result of its own unique conditions and histories, an evidence-based approach can also provide quantitative backup for what planners already know “in their gut”. This means that long held “rules of thumb” or “truisms” about a place can be tested and verified, using the hard evidence produced by scientific analysis.

But this approach can also produce surprises and unexpected results, especially for complex or uncertain problems. This has been the case in Berkeley, where quantitative modelling of pedestrian volumes has produced a surprising figure of pedestrian risk which looks different than the picture of collisions alone.

This combination of affirmation and surprise is what gives Space Syntax’s approach its merit.

Key questions

The key questions which this piece of work aims to answer are:

1) Where are pedestrians currently located in the City of Berkeley?
2) What are the major factors that influence people’s decision to walk?
3) Can these factors be combined to create a predictive model of movement in locations where pedestrian counts do not exist?
4) What is the relationship between pedestrian volume (exposure) and pedestrian risk (collisions)?

Each of these questions will be addressed in detail in the following report, drawing upon a scientific analysis of the walkable factors in the City of Berkeley.
1 Introduction Understanding pedestrian behavior in the public domain

The spatial logic of pedestrian experience

The life on an urban dweller is made up of series upon series of everyday pedestrian journeys.

The public realm is the setting in which these journeys unfold and, occasionally, in which they pause. People use the public domain to move between private origins and destinations (from a house to an office, for example), between public origins and destinations (from the train station to the shopping mall), or between a mixture of the two. And sometimes people stop – perhaps to rest, ask directions, browse in a market or take refreshment.

The purposes people have for moving and stopping may be necessary or practical (to buy food or re-energise themselves), or they may be optional or recreational (walking for exercise or people-watching). In fact, the presence of the latter – leisure activities – is often taken as a sign of a successful urban area.

The public domain offers opportunities for socialising with others, and high rates of socialising are another traditional sign of success. But of course, the city can also be a place for solitude.

In the end, the true success for a city or town lies in the creation and maintenance of a network of spaces that support a variety of uses and users. Knowing about the relative levels of usage for streets, squares, walkways, bridges, and other spaces helps agencies responsible for creating and maintaining the public domain to better target limited resources.

Pedestrian behaviour baseline assessments can assist in this process. These studies are concerned with the routes and public spaces individuals choose to use – either while going about their necessary daily tasks, or while spending their leisure time – and, in the patterns such decisions form, in aggregate.

Methods for understanding pedestrian movement

In undertaking pedestrian baseline assessments, it is crucial to employ methods for capturing individual pedestrian choices, and aggregate patterns, in an efficient, yet accurate manner. This section reviews what is known on the topic.

There are two methods for gathering information about the choices pedestrians make in moving about an area. On the one hand, individuals can be questioned and their answers recorded in ‘stated preference’ surveys. This type of observation is typically undertaken as part of the UK planning consultation requirements for development plan production processes.

On the other hand, individuals’ actual movements can be observed, and then mapped. This often takes the form of cordon counts. People are counted as they pass through a series of virtual ‘screen lines’, located throughout a study area.

Although this sort of data is frequently used as an indicator of activity, it can also be viewed as a consultation which presents the ‘revealed preferences’ of an area’s users – the manner in which they are consulted is by a ‘vote with their feet’.

Perhaps surprisingly, the results of these data collection activities often differ. This is because it is rarely possible to achieve a sample for stated preference surveys of the same size, or geographic density, as with observations of actual movements. The two methods are complementary, with the former providing a useful qualitative understanding of the quantitative data generated by the latter.

In addition, these observation methods can only answer questions about how a specific change to the environment affects pedestrian behaviour after that change has been made. They do not offer any help to decision-makers evaluating change proposals.

Fortunately, the results of extensive observational research show that pedestrian movement patterns tend to follow certain rules. Individuals appear to use specific intentional, environmental and (most importantly of all) spatial criteria when they choose a route between an origin and destination.

These rules can be used to generate criteria for qualitatively evaluating the pedestrian infrastructure of an urban area.

Taken together, these methods can be very useful to those responsible for planning, designing, maintaining, and monitoring urban infrastructure.
1 Introduction Influences on pedestrian movement

Influences on pedestrian movement

People construct mental maps of an area by using both perceptual information (what they can see, hear, etc.), and inferences about things they cannot directly perceive. These mental maps then inform route choice plans across an area. They also change in response to new information, and are thus part of a ‘way-constructing’ and ‘way-finding’ process.

Beyond mental maps, research has shown that the influences on pedestrian route choice preferences include income level, gender, age, perception of one’s own strength and stamina, familiarity with an area, and the time and place of their journey’s origin.

Pedestrians also tend to exhibit a number of spatially-related tendencies that affect route choice decisions. Most of the time most people will:

- use spaces that lie on the shortest path towards their seen or unseen destination
- select the longest direct leg earlier in a journey, when faced with alternatives
- minimize directional changes along a journey and avoiding back-tracking
- select spaces that offering natural surveillance/deterrence, such as those with active frontages, and clear indications of use and ownership
- select routes which allow them to link into ‘chain’ destinations, and so facilitate multi-purpose journeys

Proceeding from and ‘multiplying’ all these other factors, the presence or absence of other people along routes or in spaces will also affect on individuals’ route choice preferences.

Influences on public space use

Extensive research has found that there are six main influences on pedestrian stopping and public space use:

1 Proximity to high levels of pedestrian movement – good public spaces are located close to the routes with high levels of pedestrian movement

2 Good accessibility from the surrounding area – successful squares are located at strategic points in the pedestrian movement network (such as at the intersections of important pedestrian movement routes)

3 Movement routes pass through the body of the space – to achieve good levels of use, it is important that the routes bring movement from several directions through the heart of the space, and do not just ‘skirt’ around the edges

4 Multi-directional views into the surrounding urban area – people are more likely to use squares where they can see where they are going, and feel safe. Similarly, people prefer to stay where they have good visibility from within a space into the surrounding areas

5 Proximity of ‘live-uses’ – land uses such as retail and catering attract activity over and above the effects of spatial layout, and contribute to the natural surveillance of the space by providing presence in the space

6 Adequate seating and street furniture – good seating, lighting, and high-quality landscaping all encourage informal / stationary activity within public spaces.

Influences on visitors’ spending in downtowns

The result of these factors is pedestrian movement and public space activity. This can have profound impact on the economic and social success of cities.

New research from the United Kingdom has found that the mode of transportation used to get to urban areas has a strong relationship to the average spend of visitors.

It found that those who walk to the downtown areas of cities spend more than those who use any other mode of transportation. This is followed by people who travel by car or bus.

Although the demographic profile of transit ridership is different in America, the same pattern is likely to apply for pedestrians. The more people walk in the downtown area, the more money they are likely to spend. The more money pedestrians spend, the greater the demand for retail and commercial space. The greater this demand, the higher the capital investment in a city becomes. The more capital, the more jobs and, finally, the more jobs, the more residents. Taken as a whole, increased pedestrian activity can be vital for the success or failure of America’s downtowns.
Space Syntax analysis methods

A wide variety of factors have been found to influence pedestrian movement in modern cities. These include important attraction factors such as land uses, transit stops, and proximity to major trip generators such as universities and downtown areas.

They also include urban form factors such as block size and grain, permeability, street connectivity, route directness, and spatial accessibility. Sidewalk conditions and pedestrian amenities play a lesser but still important role.

Personal preference and demographic considerations have also been found to contribute to levels of walking. These include age, income, race, knowledge of an area, physical fitness and feelings of safety.

The combination of these three factors determines the level of walking in an urban environment. Space Syntax modeling begins by diagnosing the existing conditions of many of these factors, then analyzing their statistical relationships to determine which are the most important factors on walking in a given area. Once these factors have been mathematically defined, walking rates can be extrapolated into the future or over larger areas.

Three general types of analysis were used for this report. These include:

- Quantitative baseline analysis
  - Urban structure
  - Land use
  - Pedestrian movement
- Pedestrian volume forecasting
- SWITRS collision data for exposure and risk measurement.

This chapter presents the results from the quantitative baseline analysis, beginning with a brief discussion about the methodology used in this section.

Urban structure analysis

We see “urban structure” as the framework of routes and public open spaces that connect locally and to their wider context. This structure (often called “public space”, “urban realm”, or the “space between buildings”) provides the basic plan from which all other aspects of form and use arise.

Different kinds of urban structure can result in different kinds of “character”, the distinctive culture of place and its activities. Slight changes in the physical structure can also introduce differentiation, distinction and interest which define this character.

In order to assess this differentiation and to analyze the influence urban structure has on urban activity it is necessary to use a representation that allows comparison of different factors.

Space Syntax does this by representing all publicly accessible open space as a map, formed by the fewest set of longest, straight lines that cover all streets and spaces within a city. This map is known as an “axial map”.

This map can be understood in two ways; first, as a representation of the longest lines of direct sight, and second, as a map of possible lines of movement that can be quantitatively analyzed. Both interpretations are useful for analysis, and represent all possible ways of perception and movement in the city.

Measuring urban structure

The axial map was used to analyze urban structure in five primary ways:

1. Block size
2. Directionality
3. Connectivity
4. Local accessibility
5. Legibility and citywide accessibility

1. Block size

Urban blocks are defined by their surrounding street configuration. Their size and shape can have an influence on pedestrian activity around them, above and beyond the land uses which they contain. Large, long blocks create blockages in the urban environment that are hard to navigate around. Smaller, more compact blocks create a variety of route choice options and can foster more pedestrian friendly land uses. A measurement of block sizes provides the foundation for quantifying the factors which influence walkability, upon which other factors rest.

2. Directionality

Next, measuring the geometry of the urban layouts helps to establish the “character” of a place in terms of its directional characteristics, distribution, and trends. Long, straight streets that occur in regular repetition create a certain kind of character, while short streets of varying directions create a very different one. Also, people prefer to take the most direct routes to and from their destination, so a measure of directionality can help identify these streets and routes through different neighborhoods.
Aside for the feel of a place, street geometry also has other far reaching consequences. Not only on movement activity, but also on the orientation and solar access of dwelling. This can in turn affect energy use for climate regulation purposes and natural lighting.

3. Connectivity
An analysis of how streets come together and form junctions can provide information about the interface between different areas and neighborhoods. This is expressed through the measure of connectivity, which depends on the number of streets intersecting each other. In general, more connected streets result from smaller block sizes, resulting in a compound influence on walkability.

4. Local accessibility
The result of block sizes, directness and connectivity is a measure of “nearness”, or “local accessibility”. The layout of a city’s streets and blocks has a fundamental influence on the nearness of different destinations which is often different from the obvious “as the crow flies” distance.

Measuring the amount of street available within a given walking distances from every street provides a measure of the movement potential of the street network itself, before even considering the actual location of different origins and destinations. Well placed destinations will take advantage of the natural nearness potentials of a street, providing more access to a greater numbers of origins then those which are placed in more difficult to get to neighborhoods.

5. Legibility and citywide accessibility
The cumulative effect of all of these factors is “accessibility”, which can be defined as the ability and degree of ease that people have when moving around in their environment. Research has found that neighborhoods with shorter blocks and more direct, connected streets produce more accessible streets at both the local and citywide scales, facilitating easier and more direct movement of all modes. In pedestrian terms, streets with higher accessibility provide more direct access to a greater number of destinations and are thus more likely to be used when taking short trips. A similar logic applies to cyclist and vehicles, although a variety of other concerns affect these modes such as one-way streets, congestion, and the presence of safe bicycle routes.

Taken together, these five measures produce a baseline picture of spatial accessibility. This framework can be thought of as the “skeleton” of a city, upon which all land uses and activity hang.

Land use
The location and distributions of land uses is what adds the “muscle” to the skeleton of urban space. It is the lifeblood of the city, providing the key origins and destinations to which people must move.

Well structured cities often have the right kind of land uses in the right place, taking advantage of the natural benefit which urban accessibility provides. Movement sensitive uses such as retail and commercial centers, for example, are best suited to an environment which is easy to get to and high pedestrian and vehicular movement potential. Residential and other more private land uses require additional seclusion and often seek more isolated parts of the city.

To account for the effect of land use distribution in the City of Berkeley, Space Syntax mapped the location and distribution of key land uses, including:

- Parks
- Schools
- Healthcare centers
- Libraries
- Community centers
- Major retail locations
- Neighborhood retail
- Office buildings
- High density residential
- University buildings
- Transit stops
- BART stations

The location of each of these facilities was analyzed using a real-world measurement of walking distances from them to surrounding areas. This measurement takes into account the specific street layout in the City of Berkeley and avoids the oversimplification that can result from simple “as the crow flies” walking buffers.

Pedestrian movement
The last step in the quantitative baseline analysis for the City of Berkeley was a mapping exercise of existing pedestrian volume counts. This was done using a random sample of locations within the city, based upon mid-day peak movement rates. The location and volume of flows within the city was then analyzed and assessed against the urban structure factors outline above, providing the baseline for further analysis in the following chapters.
2.1 Study area City of Berkley

The City of Berkeley is located in the San Francisco Bay Area, between the cities of Oakland and Albany and El Cerrito.

The city has a total area of 10.5 square miles of land, with an additional 7.2 square miles of area encompassing the water of the San Francisco Bay.

Berkeley had approximately 102,000 residents at the time of the 2000 Census, with a population density of nearly 9,800 people per square mile. With a total of over 46,000 housing units, a highly diverse, mixed race population, and a median income of $44,485 per household, the City of Berkeley is among the more liveable, mixed communities in the Bay Area.

The campus of UC Berkeley at the eastern edge of the city comprises the densest areas of population and activity, with medium rise commercial buildings fronting the major north–south commercial corridor of Shattuck Avenue. This area is well served by AC Transit bus service and is provided with three major regional commuter rail stations (Downtown Berkeley, North Berkeley, and Ashby BART stations). The city is also connected to the regional highway network by a two mile segment of I-80 / I 580 which runs along the coast to the west.

Berkeley is also reported to have one of the highest rates of bicycle and pedestrian commuting in the nation.
2.1 Study area Regional transportation context

The diagram to the left reveals the major transportation connections and routes in the City of Berkeley and its region.

Interstate 80 bounds the city to the west, providing access to the entire San Francisco Bay area. Highway 24 skirts just outside the city limits to the south.

These two regional highways support an older, more intra-city system of avenues and boulevards. These include San Pablo Avenue, University Avenue, Shattuck Avenue, Adeline Street, Telegraph Avenue and Claremont Avenue. Together these form the major circulatory system in the city for through traffic.

Finally, the presence of three major BART stations plays a profound influence in the City of Berkeley’s life. These include the Downtown Berkeley stop, the North Berkeley stop, and the Ashby stop.
2.2 Urban structure Block size

The map to the left illustrates a block size analysis of the City and its surroundings. Smaller block sizes facilitate easier walking trips and produce more compact, functional neighborhoods. In retail terms, they also maximize display frontage and reduce trip length between attractors, resulting in more valuable retail environments when clustered appropriately.

The City of Berkeley was found to have a mixture of block sizes in the different areas regardless of their function.

The CBD and the roads where ‘live center’ functions (such as retail and catering) are predominant, University Avenue and Shattuck Avenue, comprise a mix of relatively fine (red and orange) and medium (green and light blue) blocks.

However, the area immediately around the CBD on three directions (north, south and west) has a predominance of medium (light green blocks) while further west and south the grain becomes finer. The University Campus on the east side has a coarse grain next to the CBD.
2.2 Urban structure Street directionality

The diagrams to the left show the extent of directionality in the study area.

The City of Berkeley’s dominant street directions are north-south and east-west.

There is discontinuity between the CBD and its surroundings in both north-south and east-west directions. To the west, lines are interrupted by big school and green area blocks; to the east, by the University. The latter, however, behaves as a strong attractor, generating its own levels of activity irrespective of grid conditions.

The area to the north-west of Hopkins Street appears defined by an offset grid, mainly in north-east and south-west direction.

The north-east area shows a different and fragmented grid with lines going in all four directions.
The diagram to the left shows a combined picture of four line directions. It confirms the observations in the previous page.

The dominant directions for Berkeley are clearly north-south and east-west. The CBD is to an extent enclosed, with discontinuities in the grid around it, forming a kind of ‘pocket’ or ‘island’. There is a small offset area north-west Hopkins Street. Finally, the area to the north-east of Berkeley shows its own grid with a different character made of shorter, broken lines in all directions.
The map to the left shows the connectivity of the grid. This is the number of streets that each street intersects.

In grid-like cities such as Berkeley, these values tend to be relatively high. Streets tend to be longer and straighter, which connects to a greater number of other streets.

In practice, however, most grid-like cities are not so uniform. The map to the left reveals that this is the case for Berkeley. Excluding the low connectivity regions of the hills, the city itself displays a range of connectivity resulting from variations in how local streets connect. Patches of higher connectivity can be seen in green and orange, separate by other pockets of less connected blue streets. These different areas are connected by the city’s major circulator streets, which have the highest connectivity and are shown in red.

In particular, the areas west of downtown, north of University Avenue and south of Ashby exhibit lower connectivity values. This often translates to more localized neighborhoods with less through-movement.
This map illustrates areas of increased walkability, as measured by the proximity of street surface within a 10 minute walk.

Clusters of red, yellow, and green illustrate areas that offer more surface area within a shorter walk due to the arrangement of streets and blocks in this area. If the surrounding land uses support walking trips, these areas are likely to generate more pedestrian activity than those with similar land uses but less conducive urban layouts.

Despite the fairly regular grid of Berkeley’s urban morphology, the city displays a strong variation in local walking catchments. Of note, the downtown and UCB campus areas are highlighted as part of a close knit walkable system. The downtown is also surrounded by areas of lower walkability (seen in blue), indicating that there is less street area available within a walkable distance once one is outside of the CBD. This does not mean that there are less destinations in this area per se, but rather that the layout of streets creates longer walking trips and can therefore act as an inhibitor to walking as a mode choice. The presence of many destinations in this area can overcome this to some degree and is explored further in subsequent analysis.
2.2 Urban structure Legibility and citywide accessibility

The map to the left displays the “movement potential” of streets in Berkeley when viewed at the city-wide scale. Streets in red are those which are more directly connect to and from different parts of the city and, all other factors being equal, are those which are most likely to carry longer distance movement through the study area.

This type of model considers Berkeley at the strategic level and therefore does not include details about individual sidewalks, crossing locations, street directions, etc. Studies have shown that this level of analysis corresponds well to people’s mental understanding or “cognitive map” of a city. This in turn reflects on how they navigate and wayfind in the area, preferring the shortest, most direct routes whenever possible.

It can be seen that San Pablo, Sacramento, Martin Luther King Jr. Way and Shattuck are the main north – south routes in Berkeley. Other important east – west roads are Hopkins Street to the north, Cedar Street, Bancroft Way and Ashby Avenue.
2.3 Land use Zoning

The map to the left includes a general graphic of land use throughout the City of Berkeley.

It can be seen that the majority of the City is comprised of low and medium density residential uses, with strips of retail and commercial activity along major corridors. A moderate amount of high rise commercial office buildings can be found downtown, just to the west of the University campus. Some mixed use and light industrial buildings can be found west of San Pablo, creating a distinctly different character for this area.

This kind of land use distribution, clusters of pedestrian friendly land uses interspersed in a backdrop of lower density residential neighborhoods, often results in pockets of intense activity separated by much lower levels of activity in between.
2.3 Land use Location of key facilities

Special land use categories are picked out in the map to the left. These include:

- Parks
- University
- Health Care Centers
- Libraries
- Schools
- Community Centers

The accessibility to each of these special uses was analyzed using an adaptation of the traditional 5 minute walking buffer technique.

This technique, known as “Manhattan Distance” measurement, traces out the actual distance from each destination to its surrounding area. This takes into account the variations in trip length caused by different urban design factors and can be more accurate than simply drawing circles around key facilities based on “as the crow flies” distance.

The following pages present the result of this analysis for each key land use type.
2.3 Land use Walking distance to school facilities

Distance to attraction

- < 5 minute walk
- ~ 15 minute walk
- > 30 minute walk

Schools
2.3 Land use Walking distance to libraries

Distance to attraction
- < 5 minute walk
- ~ 15 minute walk
- > 30 minute walk

Libraries
2.3 Land use **Walking distance to healthcare facilities**

Distance to attraction:
- < 5 minute walk
- ~ 15 minute walk
- > 30 minute walk
- Healthcare
2.3 Land use Walking distance to parks and open spaces

![Map showing walking distance to parks and open spaces in Berkeley, with different color codes indicating distance in minutes.](image)
2.3 Land use Walking distance to transit services
2.3 Land use Walking distance to the Central Business District
2.3 Land use Walking distance to the University
2.3 Land use Walking distance to major retail areas

Distance to attraction
- < 5 minute walk
- ~ 15 minute walk
- > 30 minute walk

Commercial zoning
2.3 Land use **Walking distance to neighborhood retail**

![Map showing walking distance to neighborhood retail](Image)

**Distance to attraction**
- < 5 minute walk
- ~ 15 minute walk
- > 30 minute walk

**Neighborhood retail zoning**

---

*Space Syntax*
*Pedestrian Master Plan City of Berkeley*
2.4 Pedestrian movement Count locations

The map to the left displays the sample locations of the pedestrian movement observations that were analyzed in this study.

This data set was selected from a larger data set of pedestrian movement counts provided by the City of Berkeley. Because these counts were in paper form, from different suppliers and in different formats, only a limited number of counts were able to be included for this study.

A random sampling technique was used to ensure accuracy and eliminate bias in selecting a sub-set of count locations. After initial analysis it was found that additional counts were necessary, resulting in a supplementary round of sampling to improve the geographic coverage of the data set. A third set of supplementary counts were then added to address specific questions relating to the area south of the University campus.

The final sample included average hourly movement rates during the weekday lunchtime peak hour (11:30 to 13:30) and estimated mid-day peak counts for the area south of UCB where only afternoon peak counts were available. A total of 64 counts were used for the model, covering a number of different months and collected over a nine year period between 1997 and 2005.
2.4 Pedestrian movement **Observed volumes**

The map to the left displays the intensity of pedestrian flows at the observed locations in the City of Berkeley. Circles are sized according to the number of pedestrians per hour passing through that junction. Larger circles indicate locations with higher hourly average movement rates.

A total of 64 locations were used, spread through-out the city. The minimum hourly average was 8 people per hour whereas the maximum was 2628 people per hour appeared around the BART Downtown Berkeley.

It can be seen that there is a marked concentration of higher pedestrian movement activities in the areas around the downtown. There is also heavy pedestrian activity around the UCB campus, particularly to the south along Telegraph Avenue.

Movement then falls off sharply to the west and in the remaining areas of the city, indicating that the UCB campus and the downtown activity zone exerts a powerful, but geographically constrained influence on pedestrian movement. It is suggested that the combination of the Downtown Berkeley BART station, the high level of offices and ground floor commercial activity, and the proximity to the UCB campus account for these peaks in movement.

NOTE: The other two BART stations in Berkeley did not exhibit similar levels of pedestrian movement levels in their vicinity as did the Downtown Berkeley stop. Statistics provided by the 1999 BART Station Profile Study reveal that the total daily number of commuters walking to Downtown Berkeley BART Station was almost three times higher than that of Ashby Bart Station and almost six times higher than North Berkeley Station. Although it is likely that the station areas experience higher movement in the morning and evening rush hour peaks, the BART study suggests that pedestrian activity around the other two stations is more localized and / or that a greater number of people drive or are picked up from these stations.
2.4 Pedestrian movement Distribution analysis

The graph to the left displays the distribution of pedestrian movement values from the sample data set.

The shape of the graph indicates that the vast majority of areas in Berkeley have very low pedestrian movement rates. Only a few locations exhibit higher rates, a trend which is common in many world cities.

The average mid-day peak pedestrian flow was 325 people per hour. There is a high degree of variance in this data, however, resulting from the presence of a very small number of high volume locations located in the CBD and on Telegraph Avenue.

If these busy locations are removed from the sample, the average movement rate for the rest of the City of Berkeley is approximately 100 pedestrians per hour, with a much lower variance. This indicates that outside of the CBD / UCB area there is a low level but consistent rate of mid-day peak movement which hovers around the 100 pedestrian per hour rate.

Although data for variation in time was not available from the sample data, it is likely that the city displays a typical "W-shaped" pattern of pedestrian movement. The second graph to the left displays an example of this W-shaped pattern. Pedestrian movement peaks in morning as people go to work, in the lunchtime as they leave their place of work for lunch and evening as they go home. Data was not available on the demographic characteristics of different pedestrian types in the City of Berkeley.
3 Pedestrian volume model Methodology

Introduction

Although it is often easy to determine accessibility from a single given location to any other (we often do this in our head when giving directions), it becomes extremely difficult to determine accessibility from tens of thousands of different origins and destinations, as is the case in real urban environments.

Past research has found that despite the wide range of origins and destinations within a city, there is often a relatively stable movement pattern in time and space. This suggests that the pattern of journeys used by most people, most of the time, is relatively tractable and predictable. When viewed from this perspective, it becomes clear that what is most important is not the specific origins and destinations pairs, but the character and pattern of the journey flows themselves. This distribution is exactly what spatial accessibility analysis measures.

Space Syntax journey simulation

Space Syntax performs “journey simulation” and route choice analysis which takes into account the route choice strategy and preference of most pedestrians and cyclists.

These analytical techniques are a proven, robust way of assessing the spatial accessibility of the urban structure and grain and, in so doing, indexing the ease of movement for most people in an area most of the time. This index is often referred to as “spatial accessibility”.

An understanding of spatial accessibility can then be used to establish a robust hierarchy of routes, within the public domain movement network.

The balance between spatial accessibility and other factors is critical to the success of well functioning urban spaces. Where the coupling between urban form, accessibility, land use, and transport is out of balance, the fit between accessibility and movement levels can be out of balance. This often results in the potential for socio-economic disorder. When this is the case, space syntax analysis incorporates multiple variables such as frontage quality, land use, ownership status, exposure, and social data such as crime rates and aesthetic preference.

Spatial accessibility analysis in Berkeley was performed using the public open space line map (axial map) as its base.

The “integration” measure was used to establish a hierarchy of routes. This was then colored using a scheme to represent most likely used routes within this hierarchy. Streets which comprised the most direct journeys were colored in red, orange, and yellow. Streets which carried less journeys were colored greenish-blue and blue.

Where observations of existing movement levels are available, the relationship between simulated and observed movement levels can be statistically compared to determine the exact degree of “fit” between them. Empirical studies have shown that these simulations conform to real movement, with up to 80% accuracy in many cases – especially in well structured urban environments where accessibility, land use, and transportation nodes are in synergy with ease of movement.

In cases where movement data is not available simulated journeys alone can be used to identify approximate movement levels and route hierarchies based on their robust history of use and comparative cases.

All of the urban form, land use, and pedestrian observations were then processed in a customized statistical model. This model, using standard multi-variate regression techniques, was then used to explore the influence of various urban design and land use factors on observed movement.

Where a statistically significant connection was found, these relationships were used to extrapolate values with a reasonable degree of confidence across the geographic area of Berkeley.
The graph to the left illustrates the significance and validity of the model that was used for the Berkeley area. It can be seen that forecasts around this area approach 70% accuracy, when compared to existing observations.

As distance from the downtown area increases (falling inversely with the distance, i.e., decaying rapidly), two other secondary factors were found to come into play. The first was the average daily traffic at each junction (ADT). A negative correlation was found with increase ADT, suggesting that pedestrian actually avoid junctions with high vehicular volumes if possible. This factor, combined with the distance from the CBD and the relative accessibility of a junction (Radius 6 spatial integration), were found to account for the majority of movement in the City of Berkeley.

Analysis of the movement model revealed two distinct movement systems in Berkeley. The first was clustered around UCB and the downtown CBD. This system is powerfully influenced by a simple inverse gravity relationship from the major attractors in the area, most notably the Downtown Berkeley BART station and the two north and south entrances to the UCB campus.

As distance increased even farther from downtown, however, these effects reduced significantly. A “second movement system” was found to extend throughout the remaining areas of town outside of the sphere of influence of the downtown. Average movement rates in these areas were less than 100 people per hour, which past studies have shown to be nearly insignificant in statistical terms at the citywide level. Because of this fact, a logarithmic decay model was used from observed data points to extrapolate values for these areas.

Of note, the proximity to parks, libraries, schools, and transit stops were found to be insignificant factors on mid-day pedestrian movement in these areas. This suggests that movement in the more residential areas of Berkeley is more vehicle based and that, even where local retail or community facilities are present, they are accessed by other modes of transit which were not recorded in the data set provided. Crosswalks, signalization, and other more detailed urban amenities were also found to exert no influence on pedestrian movement rates in the City of Berkeley.

Analysis of the movement model revealed two distinct movement systems in Berkeley. The first was clustered around UCB and the downtown CBD. This system is powerfully influenced by a simple inverse gravity relationship from the major attractors in the area, most notably the Downtown Berkeley BART station and the two north and south entrances to the UCB campus.

As distance increased even farther from downtown, however, these effects reduced significantly. A “second movement system” was found to extend throughout the remaining areas of town outside of the sphere of influence of the downtown. Average movement rates in these areas were less than 100 people per hour, which past studies have shown to be nearly insignificant in statistical terms at the citywide level. Because of this fact, a logarithmic decay model was used from observed data points to extrapolate values for these areas.

Of note, the proximity to parks, libraries, schools, and transit stops were found to be insignificant factors on mid-day pedestrian movement in these areas. This suggests that movement in the more residential areas of Berkeley is more vehicle based and that, even where local retail or community facilities are present, they are accessed by other modes of transit which were not recorded in the data set provided. Crosswalks, signalization, and other more detailed urban amenities were also found to exert no influence on pedestrian movement rates in the City of Berkeley.
This statistical model was then used to extrapolate pedestrian volumes for all of the remaining junctions in the City of Berkeley. The map to the left demonstrates the output of this model, with the color representing the average mid-day peak movement rates for each junction.

NOTE: Movement rates were not forecasted inside the UCB campus and the colors shown to the left are representative only. Pedestrian movement patterns in a complex environment such as a university campus requires more detailed analysis in a separate study. Student movement rates are subject to a variety of other more complex factors than a traditional city street and campuses are more complex spatial entities. Class times, open space layout and provision, dormitory locations and other factors have all been shown to play a large role in the nature and pattern of campus life. Such variables were beyond the remit of this study but have been dealt with comprehensively in other university master planning scenarios.
Estimates for junctions were then assigned to individual street segments at the request of the client. It can be seen that the vast majority of pedestrian movement is highly clustered around the Downtown Berkeley BART station, as well as the southern and northern entrances of the UC Berkeley campus. Movement rates are shown to fall off sharply from the downtown CBD area. The statistical model highlights the importance of the Downtown Berkeley BART station, although clearly the University plays a major role in generating movement around its entrances. This effect can be seen particularly to the south, where many retail and pedestrian oriented business support and take advantage of this movement.

As in the observed counts, variations throughout the rest of the city are relatively minor, with slightly increased movement rates (between 200 – 500 people per hour) between San Pablo Avenue and I-80, north of University Avenue. Although the presence of local neighborhood retail is found to exert an important influence, it was not found to be statistically significant when compared to the influence of the CBD and University campus.

### Forecasted mid-day peak movement levels

<table>
<thead>
<tr>
<th>Location</th>
<th>Forecasted Pedestrian Volumes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downtown Berkeley</td>
<td>&gt; 2000 people per hour</td>
</tr>
<tr>
<td>CBD</td>
<td>~ 1000 people per hour</td>
</tr>
<tr>
<td>UCB</td>
<td>~ 500 people per hour</td>
</tr>
<tr>
<td>BART North Berkeley</td>
<td>~ 250 people per hour</td>
</tr>
<tr>
<td>BART Downtown Berkeley</td>
<td>&lt; 50 people per hour</td>
</tr>
</tbody>
</table>

**Symbols:**
- Larger dots represent higher movement volumes.
- Smaller dots represent lower movement volumes.
3 Pedestrian volume model Corridor analysis

The graphics to the left display forecasted pedestrian movement along key corridors in the City of Berkeley.

These visuals, which are rotated for comparability, provide graphic examples of the variation in pedestrian movement along some of the most important streets in Berkeley. The same color scale is also used for all examples, such that the same color represents the same value in forecasted pedestrian movement.

Key areas of activity are circled with black dotted lines and the maximum movement on this street annotated.

This can be used to help prioritize improvement options to target opportunities where streets are being used the most.

University Avenue

San Pablo Avenue

Shattuck Avenue

Forecasted pedestrian volumes
- > 2000 people per hour
- ~ 250 people per hour
- < 50 people per hour
3 Pedestrian volume model Corridor analysis

Forecasted pedestrian volumes
- > 2000 people per hour
- ~ 250 people per hour
- < 50 people per hour

Telegraph Avenue

~ 2,500 people per hour

College Avenue

~ 350 people per hour

~ 150 people per hour

Martin Luther King Jr. Way

~ 750 people per hour
The Federal Highway Administration (FHWA) and the National Highway Traffic Safety Administration (NHTSA) recently identified four major areas of need in pedestrian planning. Among these, accurate pedestrian exposure data was identified as the least understood and most important area of research for pedestrian planners and decision-makers.

The term “exposure” originates from the field of epidemiology and is defined as the rate of contact with a potentially harmful agent or event. Applied to the world of transportation planning, pedestrian exposure is defined as a pedestrian’s rate of contact with potentially harmful vehicular traffic. Pedestrian exposure is therefore measured by pedestrian volume, as expressed in units of pedestrians per hour.

Many US cities have access to pedestrian crash data through police reports, which give planners a detailed picture of the amount and location of pedestrian—vehicle collisions occurring each year. But without pedestrian volume counts to determine walking rates, this information paints an incomplete picture of actual pedestrian risk.

High volume intersections may experience a large number of collisions per year, but they may be relatively safer than intersections that experience less annual collisions but also less usage. This mismatch often results in funding pedestrian planning projects based on the “squeaky wheel” principle instead of on objective data analysis (i.e., intersections with the highest rates of collision are given attention instead of those that experience the greatest risk).

This would be accurate, based on the absolute number of collisions alone. But dividing the annual number of collisions by the pedestrian volume rate (exposure) gives a measurement of relative risk and reveals that Intersection A experiences 0.001 annual collisions per pedestrian, while Intersection B experiences 0.0002 annual collisions per pedestrian. This approach reveals that Intersection A is actually the more dangerous intersection by volume, experiencing five times the likelihood of collision than Intersection B.

It can be seen that absolute collision data alone can provide an inaccurate or misleading picture of pedestrian risk when considered in isolation.

This technique was pioneered for the City of Oakland, CA during the preparation of their first pedestrian master plan in 2003 and has been extensively peer reviewed since then. The City of Berkeley is the second city in the country to apply this advanced technique, placing them among the vanguard in pedestrian safety planning in the nation and in the world.

An example can help illustrate this point. The figure to the right demonstrates the concept of exposure as it relates to pedestrian risk. Intersection A experiences 10 collisions per year, with an average annual pedestrian volume of 10,000 pedestrians per year. Intersection B experiences 20 collisions per year, but has an average annual pedestrian volume of 100,000 pedestrians per year.

Which intersection is the most dangerous? At first glance, it would appear that Intersection B is the most dangerous, with 20 collisions per year. Intersection B is more dangerous than Intersection A because even though it has twice the number of annual collisions, it carries 10 times the number of pedestrians (Source: Raford and Ragland, 2003)
After forecasting the pedestrian volumes at all intersections in the City of Berkeley, a detailed pedestrian risk analysis was conducted using SWITRS vehicle–pedestrian crash data provided by the California Highway Patrol. A total of 965 pedestrian collisions were recorded in Berkeley between the years of 1997 and 2004. For analytical purposes the exact locations of these collisions were aggregated to the intersection level, as this was the level of output provided by the pedestrian movement model.

The map to the left displays the locations of with associated collision data that were available for this study. It can be seen that pedestrian collisions extend throughout the City of Berkeley, with the majority occurring along the lengths of the major streets such as San Pablo, Telegraph, and Shattuck Avenues. Other concentrations include a higher number of collisions in the downtown area, as well as to the south of the UCB campus.
The charts to the left illustrate some statistical trends in the collision data.

The bar chart shows the number of collisions per year from 1997 to 2004. The average across this years is 120 collisions. The years of 2001 and 2004 have the lowest number of incidents with 95 and 98 respectively, while 1997 appears to have the highest rate with 142.

The line chart at the bottom of the page highlights the pattern of collisions throughout different hours of the day. The highest counts of collisions are during peak hours. The period between 5pm and 7pm has a maximum number of incidents per hour slot of 97. There is also a high rate of 76 from 8am to 9am. The average number of collisions across different times is 42.

As it is expected, the period with the least absolute number of collisions is late night/early morning, from 11pm to 6am with an average of only 5 collisions per year during this time period.
After aggregation to the intersection level, more sophisticated analysis could be conducted.

The map to the left shows the average number of annual collisions per street junction. This number was calculated as the average of collisions of all street segments that connect at each junction.

It is noticeable that there are clusters of high collision rates around the CBD-University Campus and on main road junctions, in particular San Pablo Avenue with both, University Avenue and Ashby Avenue, as well as Martin Luther King Way and College Avenue with Ashby Avenue.

A pattern can also be found primarily along main roads: University Avenue, Ashby Avenue, San Pablo Avenue, Martin Luther King Way, Telegraph Avenue.

These and several major junctions are highlighted in pink.
Past studies have found that a better measure of actual pedestrian risk is the average number of collisions per pedestrian using that intersection.

The map shows this figure, with larger circles indicating the annual number of collisions per street junction by pedestrian movement model forecast. It can be seen that this reveals a different picture than simply mapping annual or total collisions alone – one which more accurately displays pedestrian risk in the City of Berkeley as a function of the use each intersection actually receives.

It can be seen that is a higher incidence of risk at the crossing of major streets, with a marked decrease at intersections within the residential portions of the city.

All major concentrations of risk are found at major junctions outside of the city center. The areas around the CBD and to the south of the University, although bearing a significant number of accidents, were actually found to be less risky due to the large volumes of pedestrian traffic these areas receive.

Key areas of pedestrian risk, as measured by collisions per person, are highlighted in pink.

Annual collisions per pedestrian

- **0.43**
- **0.215**
- **0.043**
Another way of estimating risk is by dividing the number of annual collisions by average daily traffic (ADT). The map to the left illustrates this figure, with larger circles representing the annual number of collisions per junction by average daily traffic.

Again, a very different picture emerges. One key finding is that the highest values of collisions by traffic are, either near but not on points of high collisions per junction (except for the area south the UCB) or completely away from these areas and in the outer suburban edge.

It can be seen that San Pablo Avenue exhibits a very high collisions per vehicle ratio, as does several markedly residential areas of the city (such as those in the hills to the north and south).

A high ratio of collisions per car can indicate two things, either increased risk due to a disproportion ally high number of collisions per vehicle in areas of low pedestrian traffic (as can be seen in the examples in the hills) or an increased risk due to excessively high collisions even in areas of both high pedestrian and vehicle traffic.
The tables to the left summarize the top 12 most dangerous intersections by the following categories:

- Total annual collisions
- Collisions per pedestrian
- Collisions per vehicle

It can be seen that these lists vary significantly. Past studies have indicated that collisions per pedestrian is often the most important indicator of risk, and it is suggested that the City of Berkeley begin to use this index for its prioritization of pedestrian safety improvements.

The most dangerous intersections per pedestrian are generally split between two areas – the San Pablo corridor and the area south of UCB’s campus. These areas should be given greater attention in the following phases of this study.

Areas which have high numbers of total collisions but are relatively safer per pedestrian include most of the intersections in downtown Berkeley. This finding suggests that despite their high number of collisions, the amount of people using these intersections is so great that the relative risk per person is actually quite safe.

The following graphics display pedestrian risk as a function of pedestrian volume and collisions along key corridors as presented previously.
The tables to the left summarize the top 12 most dangerous intersections by the following categories:

- Total annual collisions
- Collisions per pedestrian
- Collisions per vehicle

It can be seen that these lists vary significantly. Past studies have indicated that collisions per pedestrian is often the most important indicator of risk, and it is suggested that the City of Berkeley begin to use this index for its prioritization of pedestrian safety improvements.

The most dangerous intersections per pedestrian are generally split between two areas – the San Pablo corridor and the area south of UCB’s campus. These areas should be given greater attention in the following phases of this study.

Areas which have high numbers of total collisions but are relatively safer per pedestrian include most of the intersections in downtown Berkeley. This finding suggests that despite their high number of collisions, the amount of people using these intersections is so great that the relative risk per person is actually quite safe.

The following graphics display pedestrian risk as a function of pedestrian volume and collisions along key corridors as presented previously.
4 SWITRS exposure analysis Corridor analysis

University Avenue

The graphics to the left compare the collisions rate per pedestrians with the pedestrian volumes presented previously for key corridors in Berkeley.

It can be seen that there is a general relationship between higher pedestrian volumes and lower risk, with several notable exceptions. These exceptions should be examined in more detail because the represent areas of elevated risk relative to the use they receive.

Conversely several areas of low volume and high risk are picked out. These two should be addressed because they have a disproportionate number of collisions per year relative to the use they receive. This means that they are more dangerous for those who use them and therefore require further attention and investigation.

As in the previous graphics, the pedestrian risk bubbles are drawn to the same scale for accurate comparison between corridors.

San Pablo Avenue

Shattuck Avenue

Annual collisions per pedestrian

High volume, low risk

Medium volume, high risk

Low volume, high risk

Annual collisions per pedestrian

- 0.43
- 0.215
- 0.043

Forecasted pedestrian volumes

- > 2000 people per hour
- ~ 250 people per hour
- < 50 people per hour
4 SWITRS exposure analysis Corridor analysis

Telegraph Avenue

College Avenue

Martin Luther King Jr. Way

Space Syntax
Pedestrian Master Plan  City of Berkeley
5 Conclusions

Safer streets for the City of Berkeley

The report analyzed many of the important factors which influence pedestrian movement in the City of Berkeley.

It found that the majority of pedestrian activity occurs within a small radius of the Downtown Berkeley BART station. Several smaller pockets of activity exist, notably at the main southern and northern gates of the University of California Berkeley campus. Outside of these areas, very little mid-day pedestrian activity was measured.

A statistically significant mathematical model was then created which analyzed the relationship between observed movement and key urban design and land use patterns. This model found that approximately 70% of pedestrian activity could be accurately described based on distance from the downtown, avoidance of heavy car traffic, and the straightness and connectedness of the street. These factors were then combined to estimate pedestrian volumes for the remaining streets in the city.

Once citywide pedestrian volume estimates had been forecasted, these could be compared to annual vehicle-pedestrian collision rates to determine the pedestrian exposure of every street and intersection in Berkeley.

It was found that many of the intersections which experienced the most number of collisions also carried a very high proportion of the city’s pedestrian traffic. Conversely, several lower volume intersections experienced many times more collisions than they should. This analysis revealed a new, more accurate picture of pedestrian safety in the City of Berkeley which can now be used to help prioritize and improve upon these dangerous intersections.

This has been used as evidence by some that increased provision of pedestrian priority facilities should not be pursued.

This report builds upon a growing body of research that provides evidence counter to this claim. While increased walking rates can result in an increased total number of collisions (also called “absolute collisions”) the rate of this increase is much smaller when compared to the rate of decreasing risk per pedestrian when more people are walking in the streets.

Indeed, the more pedestrians are on the street, the safer the street becomes – with sharply increasing benefit. The number of total collisions does rise, but only slowly and in a way which gradually plateaus at a certain point.

This suggests that by addressing the areas identified in this report will serve to increase the amount of walking in the City of Berkeley and by doing so, create a safer, healthier, more active public realm.

A general note on risk versus collision

It has been debated amongst traffic engineers and pedestrian planners that providing additional facilities to increase the walking rates of pedestrians in busy urban environments will necessarily result in increased collisions, injuries, and even deaths.

Safer streets for the City of Berkeley

Generic Risk vs. Collision Rates as a Function of Ped Volume