

NAVIGATING CAMPUS: A GEOSPATIAL APPROACH TO **3-D ROUTING**

by

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College of Architecture, Planning, and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2013

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2013

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Abstract

Evolving needs for universities, municipalities, and corporations demand more sustainable and efficient techniques for data management. Geographic Information Systems (GIS) enables decision makers to spatially analyze the built environment to better understand facility usage by running test scenarios to evaluate current efficiencies and identify opportunities for investment. This can only be conducted when data is organized and leveraged across many departments in a collaborative environment. Data organization through GIS encourages interdepartmental collaboration uniting all efforts on a common front. An organized system facilitates a working relationship between the university and the community of Manhattan increasing efficiency, developing sustainable practices, and enhancing the health and safety of Kansas State University and larger community. Efficiency is increased through automation of many current practices such as work requests and routine maintenance. Sustainable practices will be developed by generating self-guided campus tours and identifying area appropriate for bioswales. Lastly, safety will be enhanced throughout campus by increasing emergency response access, determining areas within buildings difficult to reach in emergency situations, and identifying unsafe areas on campus.

Optimizing data management for Kansas State University was conducted in three phases. First, a baseline assessment for facility management at Kansas State University was conducted through discussions with campus departments. Second, case study interviews and research was conducted with leaders in GIS management. Third, practices for geospatial data management were adapted and implemented for Kansas State University: the building of a centralized database, constructing a 3-dimensional routing network, and modeling a virtual campus in 3D.

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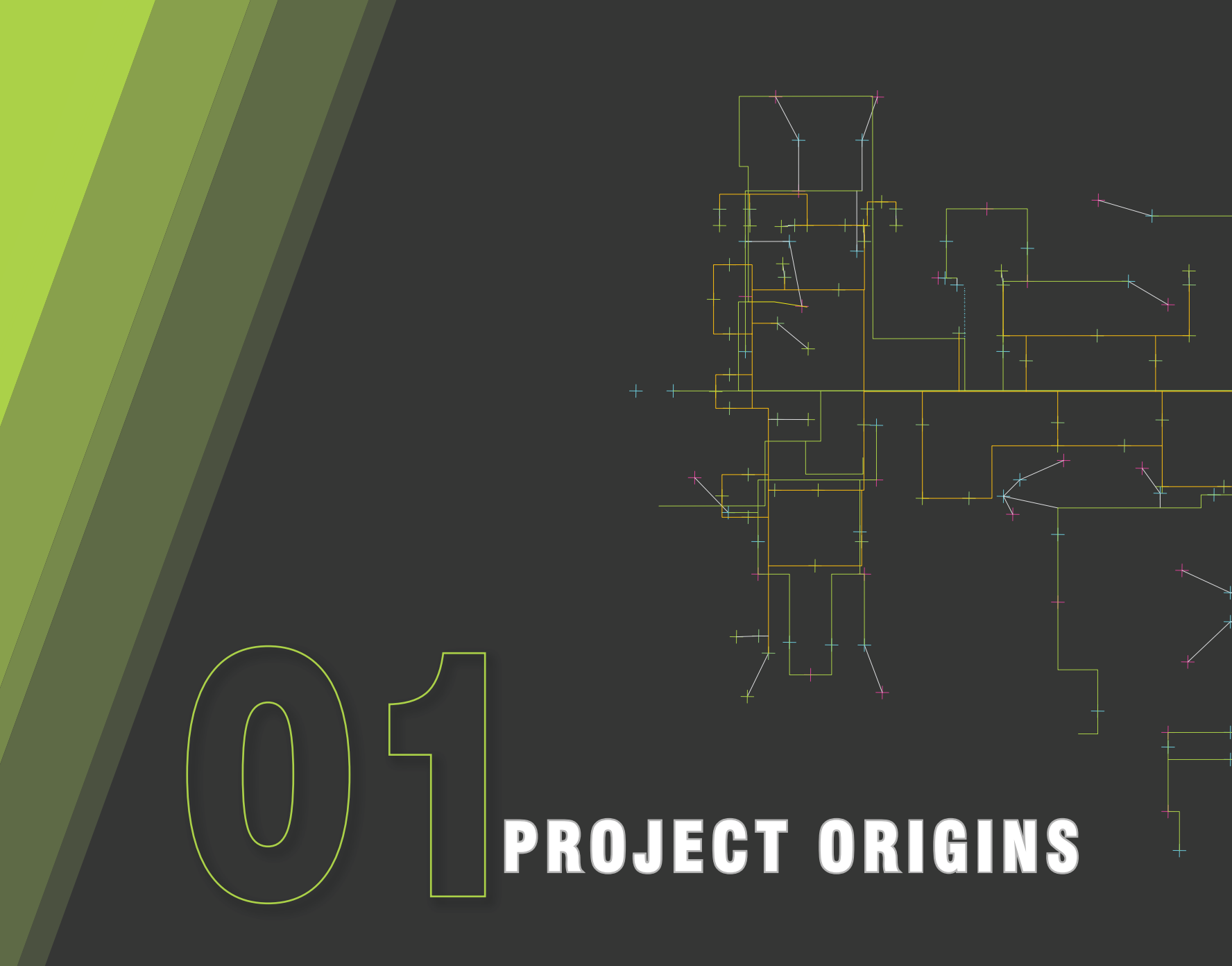
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Thank you to all faculty in the Landscape Architecture program at Kansas State and the community of Manhattan who provided encouragement, input, and direction on this project. Specifically thank you, Howard Hahn, for all the time, energy, and attention dedicated to this project. Thank you Eric Bernard who initiated this project long ago, it was a pleasure to develop it into what it has become. Thank you Dr. Hyung Jin Kim and Stephanie Rolley for all the excellent advice and feedback.

To my wife, Kaitlin, whose enduring support through this process meant the world to me. You always allowed me to dedicate unlimited amounts of time to my work and always provided a listening ear when I needed it. Thank you.

The background features a series of diagonal stripes in shades of lime green and olive green on the left side. On the right side, there is a faint, technical drawing of a building floor plan or circuit board layout, rendered in thin yellow lines with small colored markers (pink, blue, green) at various points.

01

PROJECT ORIGINS

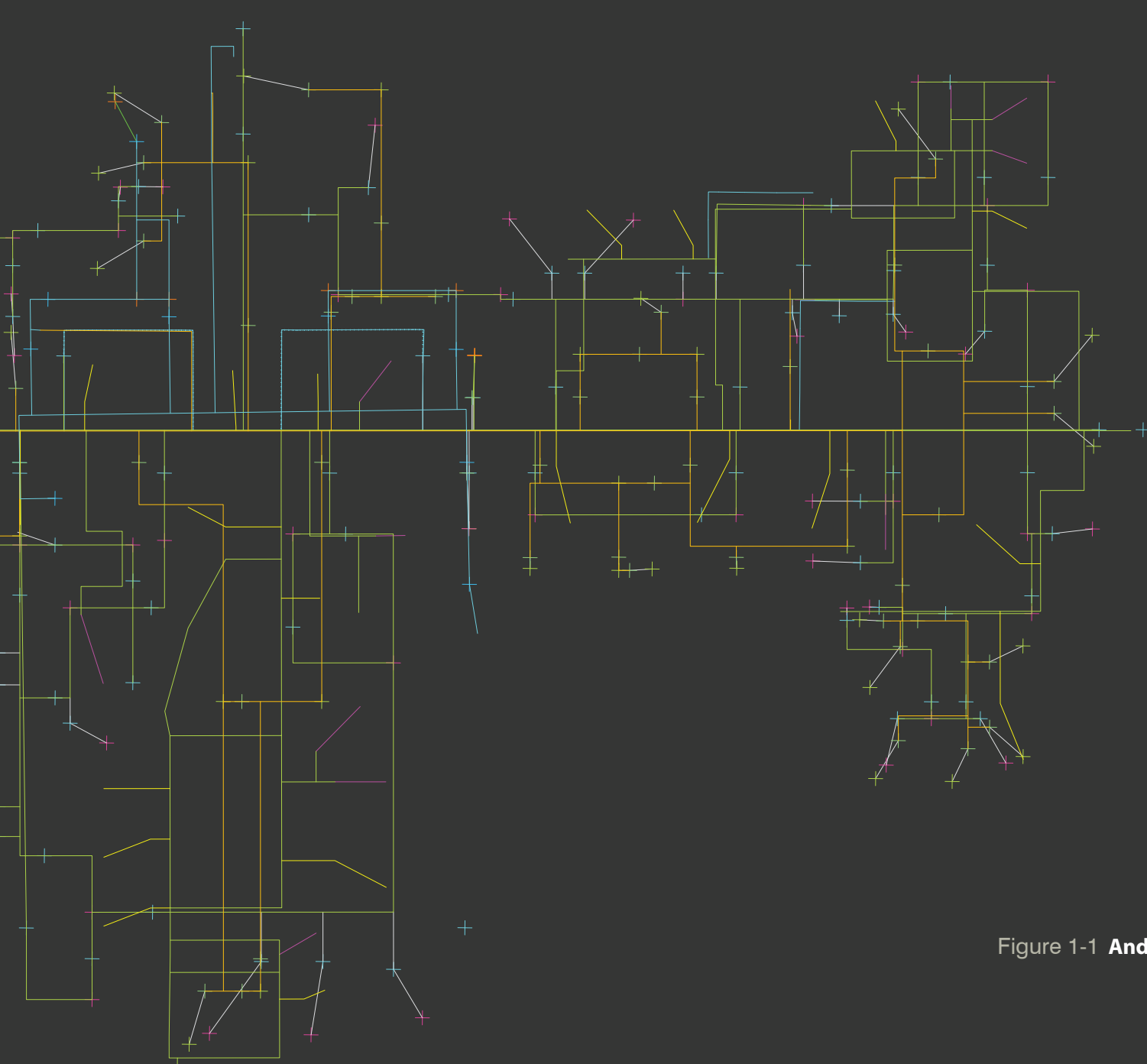


Figure 1-1 **Anderson Hall**





Figure 1-2 Goodnow 8th Floor

A sense of expansiveness can truly be experienced overlooking Kansas State from the highest point.

Project Origins

Kansas State University had very little spatial data for the campus a decade ago. Students and faculty often used campus for studio projects and research, and they needed a repository for data that was highly accurate and accessible. The College of Architecture, Planning, and Design saw an opportunity to build and develop campus datasets while providing an educational platform for students to develop skills in GIS and three-dimensional (3D) modeling. In 2004 a tree inventory was conducted by students in the Woody Plants course to document every tree species and their notable characteristics. In 2006 students in the Technical Module series of courses in Landscape Architecture developed SketchUp models of nearly every building

on campus. A LiDAR terrain was built during this time, and the base for a 3D campus was initiated. Aerial imagery could be draped on the surface for a realistic looking campus, but a basemap needed to be drawn and attributed containing landscape data for the campus including areas of turf, parking, and building footprints.

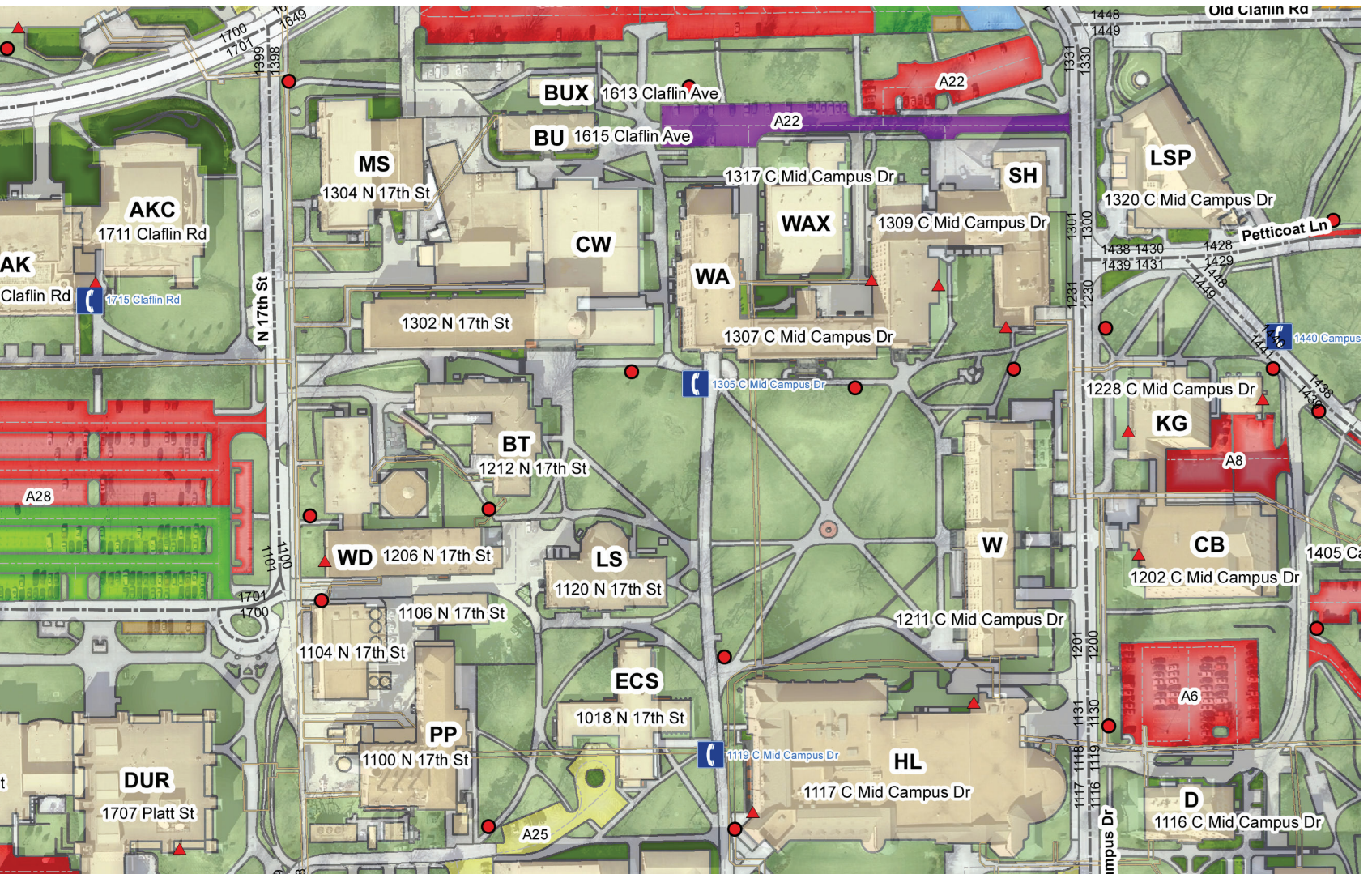
In the summer of 2012, I worked with Associate Professor Eric Bernard to develop a campus basemap as a visualization tool for the 150th Anniversary of Kansas State in combination with master planning efforts by private consultant Ayers Saint Gross. Over this time we worked closely with Riley County Police Department, the Manhattan Fire

Department, and Campus Facilities and Planning to focus our efforts in developing a campus basemap that could also be used for emergency dispatch, (Figure 1-3, Campus Basemap). After completing the basemap in August 2012, vested interests throughout the community expressed a desire in continuing to develop this spatial repository, specifically in areas of routing to aid in expedited emergency response. Using the basemap as a foundation, a 3D routing plan could be developed by aligning the existing building floor plans with the building footprints we had drawn. We saw routing as having enormous potential for everyone: the public, campus employees, and emergency responders. I saw this moment as an opportunity to work closely with the community and Kansas State University while developing skills in routing, campus planning, and geodesign.

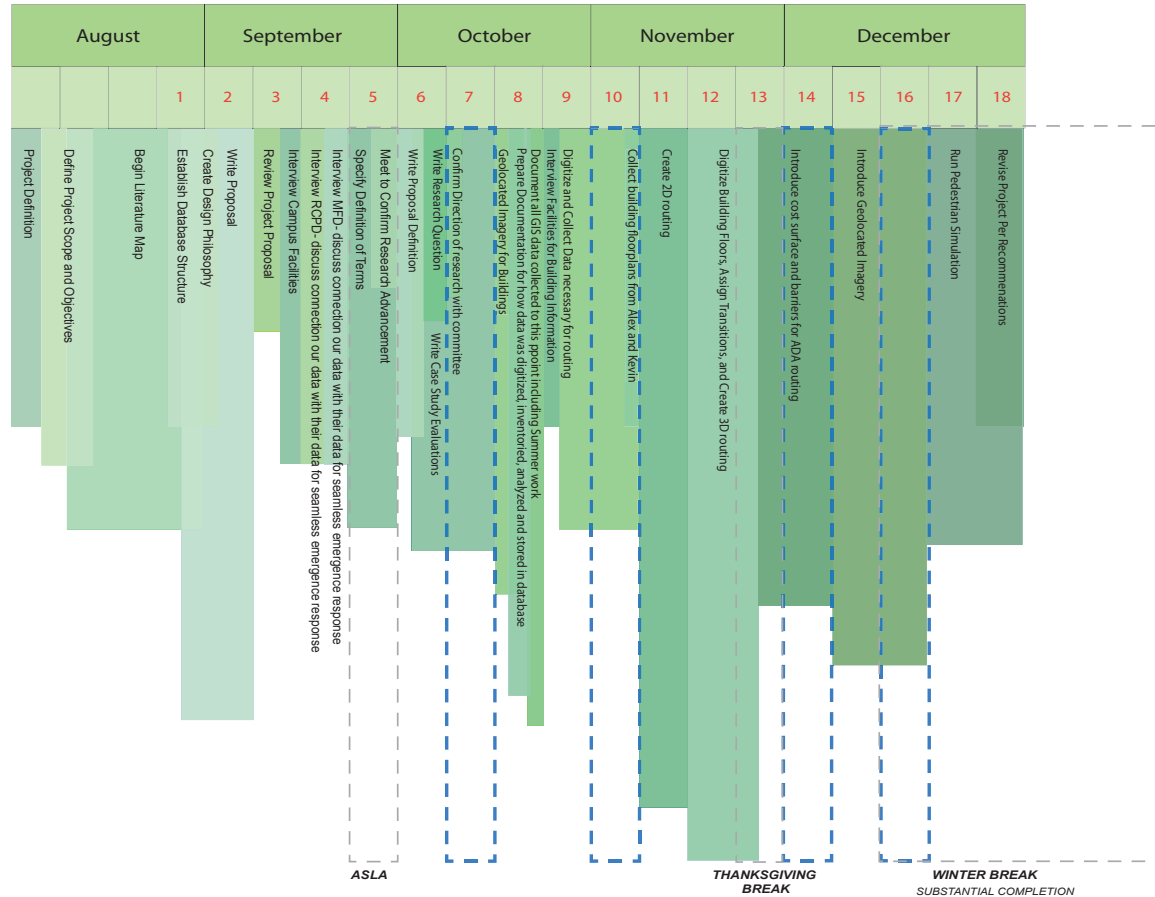
In August of 2012, Assistant Professor Howard Hahn's vision of the potential aligned with my own, and we continued to develop the project for another nine months (Figure 1-4, Time and Task Diagram). I connected every building with available floorplans of over 70 buildings and 8,200 classrooms, in the hope this data would help all who come to Kansas State in finding their way. Users of mobile devices will benefit by expending less time and stress through direct routing to a specific location. Similar to the datasets in 2003 when the repository was initially being built, this routing plan represents a foundation upon which to build. The capabilities are exponential as more data is created and brought together for all to access.

This project is about community. It's a community of social networks, infrastructure networks, and routing networks which tie us all together in space and time both figuratively and literally. It's about a community of learning, and growing, and developing together to achieve more than we can in isolation. Stephen Covey relates, "interdependent people combine their own efforts, with the efforts of others to achieve their greatest success." Our greatest successes are achieved through teamwork and expanding oneself beyond comfortable confines and building new networks. This project represents my greatest success.

Jake Jenkins
Master's Student
Department of Landscape Architecture
Kansas State University



2012



Collect Screen Captures to Document Process

Evaluate the Literature ••••• Advance Literature Map Advance Theoretical Foundation ••••• Advance Literature Map GIS for Facility Management ESRI Cloud

Focus on Case Studies

Refine Project Proposal and Methodology

2013

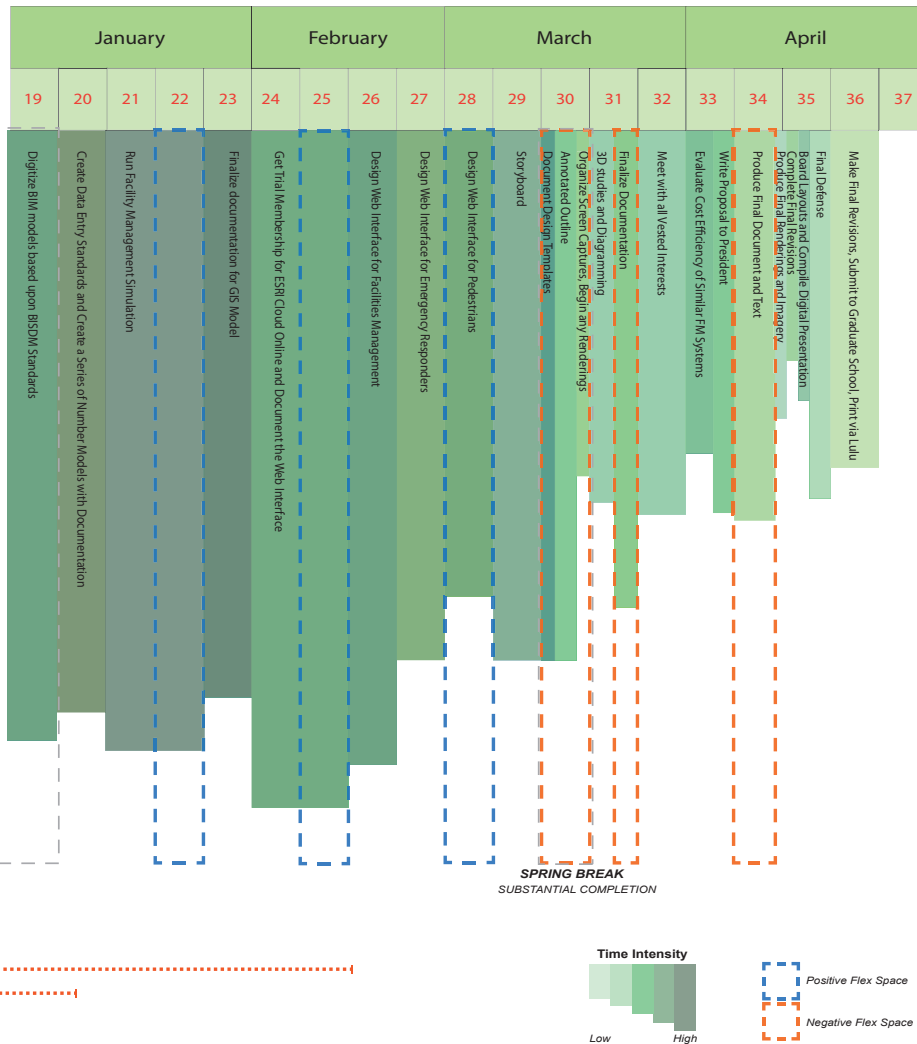


Figure 1-4 Time and Task Diagram
Fall 2012- Spring 2013. Jenkins

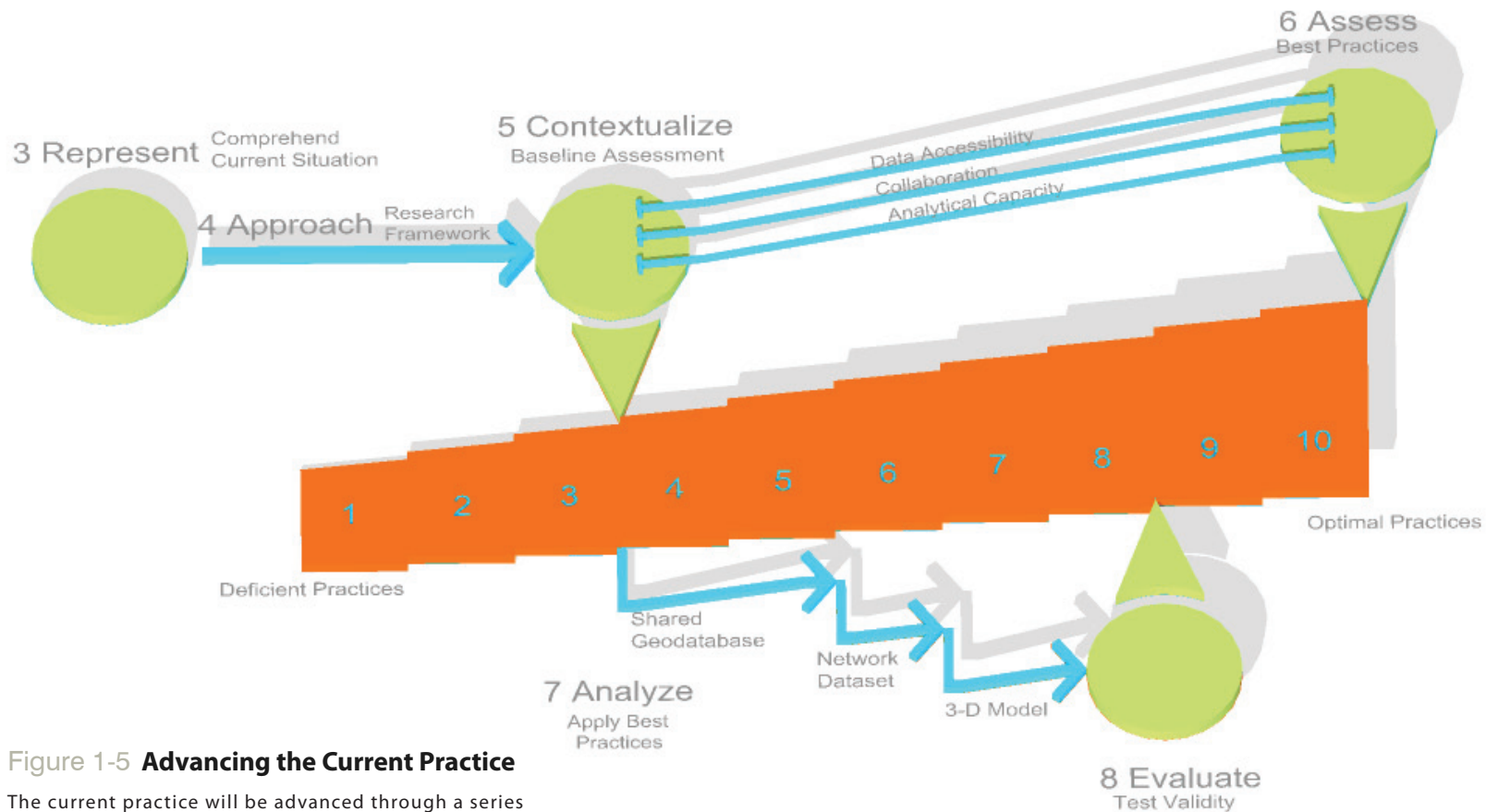


Figure 1-5 Advancing the Current Practice

The current practice will be advanced through a series of six steps constituting the research framework: represent, approach, contextualize, assess, analyze, and evaluate. This diagram is referenced in each step of the methodology.

Chapter

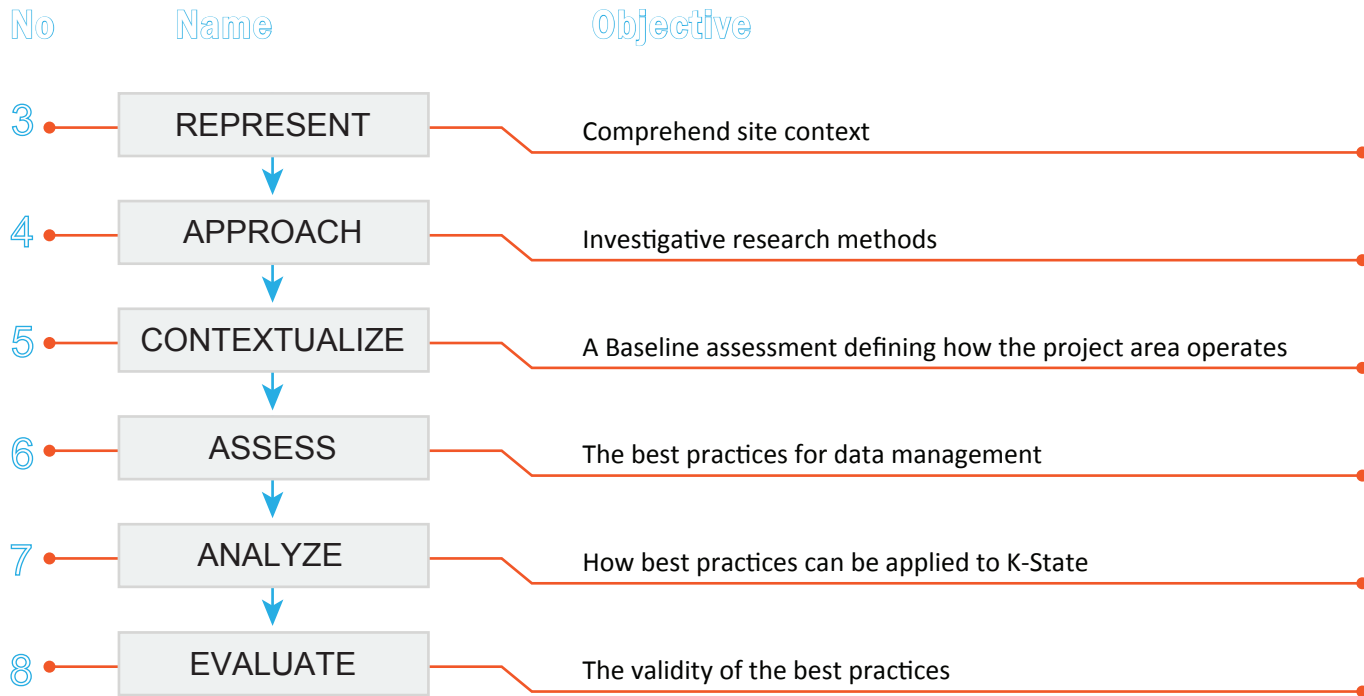
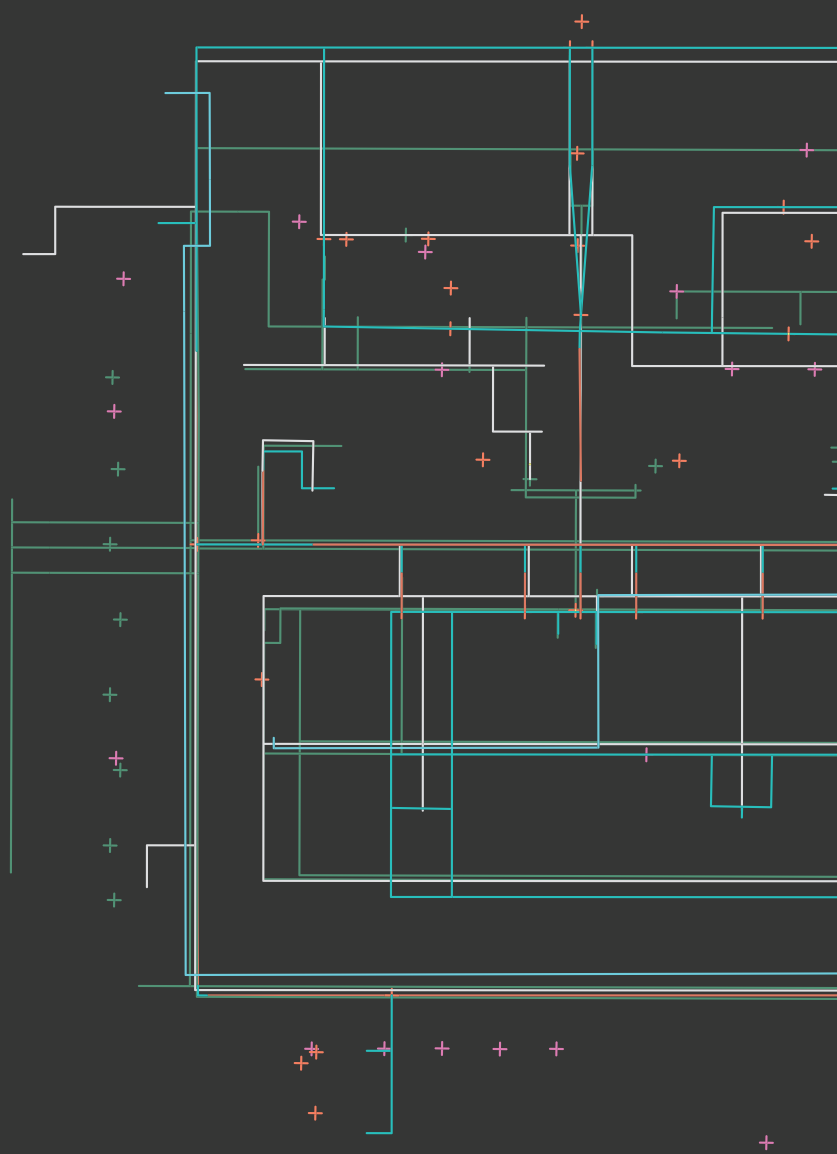


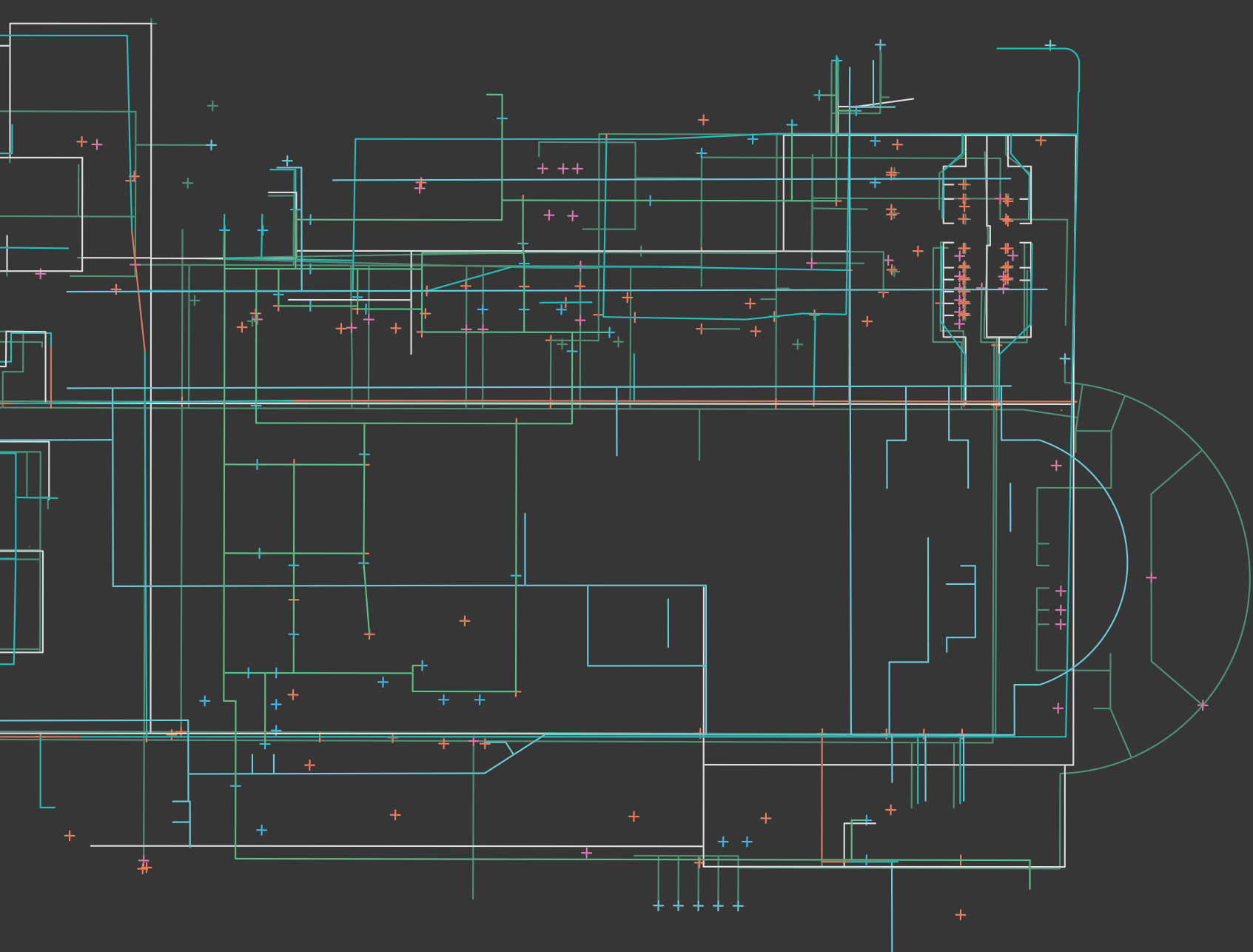
Figure 1-6 **Research Framework**

Research progresses in seven stages from understanding the site to evaluating the impacts of change.

02

INTRODUCE





Relevance to Landscape Architecture

The fundamental question posed by this research is, “How will this project advance landscape architecture research?” This project maps human movement through space, maps relevant exterior/ interior assets, generates optimized wayfinding routes, and displays all data using 3D modeling and visualization techniques. Landscape architects are concerned with how people move through space and transition from interior to exterior environments. Additionally, LA’s concentrate a bulk of their resources understanding the experience and wayfinding techniques of navigating space. Landscape Architecture is concerned with overcoming barriers of scale from site scale, to campus scale, to community scale. This project involves the spatial nesting of two communities; the campus community exists internally of the municipal

community of Manhattan, Kansas. A nested approach is dissimilar to traditional approaches used by landscape architects who often neglect what occurs outside of the site boundary (Stienitz, 2012). They are typically concerned with the exterior manifestation of geospatial design and management related to aesthetics and natural resources. This approach must be coordinated with architectural practices concerning interior building assets and infrastructure and utility assets typically governed by engineers. This project identifies the limitations associated with traditional approaches of landscape architects and seeks to remedy the gap between disciplines and scales. This project directly involves campus mapping, exterior asset, facility inventorying, wayfinding, route optimization, and 3D modeling/ visualization.



Landscape architects are attentive to how people move through or interact with both interior and exterior environments. GIS-based routing is an important development because it provides a quick and comprehensive way to analyze resources and user movements. Within a campus, the built environment is exceedingly complex to navigate. Spatial information is also essential for individuals trying to find a classroom, facility workers maintaining a piece of equipment, or emergency responders attempting to find a site and make timely decisions. Developing a network dataset is crucial for Kansas State because it provides a foundation for data integration. Common-use data can be captured, managed, integrated, manipulated, analyzed, and visualized across departments (Saleh and Sadoun, 2006). Possibly the greatest

contributions of this project is a template for planning and analysis at a university and community level. Routing is the initial step endorsing collaboration and accessibility across scales. Additionally the campus scale provides a testing-ground for future projects that may utilize routing analysis for small area site design or larger area community planning efforts. Furthermore, this project exemplifies data development with limited resources. Starting with only floor plans, we can develop an automated system of networks capable of unlimited routing options.

Additionally this project provides:

- Routing from a geodesign perspective
- Comprehensive 3D routing routines
- Compiled GIS routing information
- Best practices for data management
- Template for university and community analyses across scales



Current Situation and Needs

Current campus data management methods represent a snapshot in an ever unfolding timeline. The campus is transitioning away from isolated paper copies to a digitally connected network of data. Ever increasing demands strain finite resources of time, labor, and capital; campuses and communities are trying to do more with fewer resources. Campus facility managers and emergency responders, alike, are seeking ways to increase automation and efficiency to better manage facilities. Data sets used and maintained by various entities require more integration, coordination, and interchange. Shifting to digital data enables many opportunities for the community, campus, and individuals. As campuses expand, new students and visitors equipped with mobile devices can benefit from improved wayfinding using geospatial technology.

For more informed emergency response, Kansas State University (KSU) and Manhattan, KS would benefit from a single, integrated, and optimized routing system based on automated GIS technology. A 3D campus computer model can be used for academic projects while serving as a base for 3D visualization and analysis amongst all users. Overall, university efficiency and asset management could be greatly enhanced by structuring and maintaining common data that can be shared amongst interested entities. The Manhattan Fire Department, Riley County Police Department, and Campus Facilities and Planning worked in coordination to formulate the approach for establishing a data repository capable of building and analyzing routing patterns. Each participant took part in expressing their ideas for the framework through meetings

and interviews. These ideas were then aggregated into a single, unified routing design (Figure 2-2 Vested Interests Diagram) which focused on promoting campus efficiency, sustainability, and safety made possible through a centralized data repository equipped with routing capabilities.



Essential Research Questions

Routing will promote sustainability, efficiency, and safety for Kansas State University.

What are the needs of each user?

- What questions are facility managers and emergency responders trying to answer?
- How does the system empower individuals?
- Why hasn't an efficient, spatial management system been established at Kansas State?
- Is there resistance to change?

What information is needed for safer response, more sustainable and efficient facility management, and increased public wayfinding?

- What information is critical to make the system operable?
- What information will provide most value with the least investment?
- What information will transcend individual advancement and empower all users instead?
- How is the system managed and financed over time?

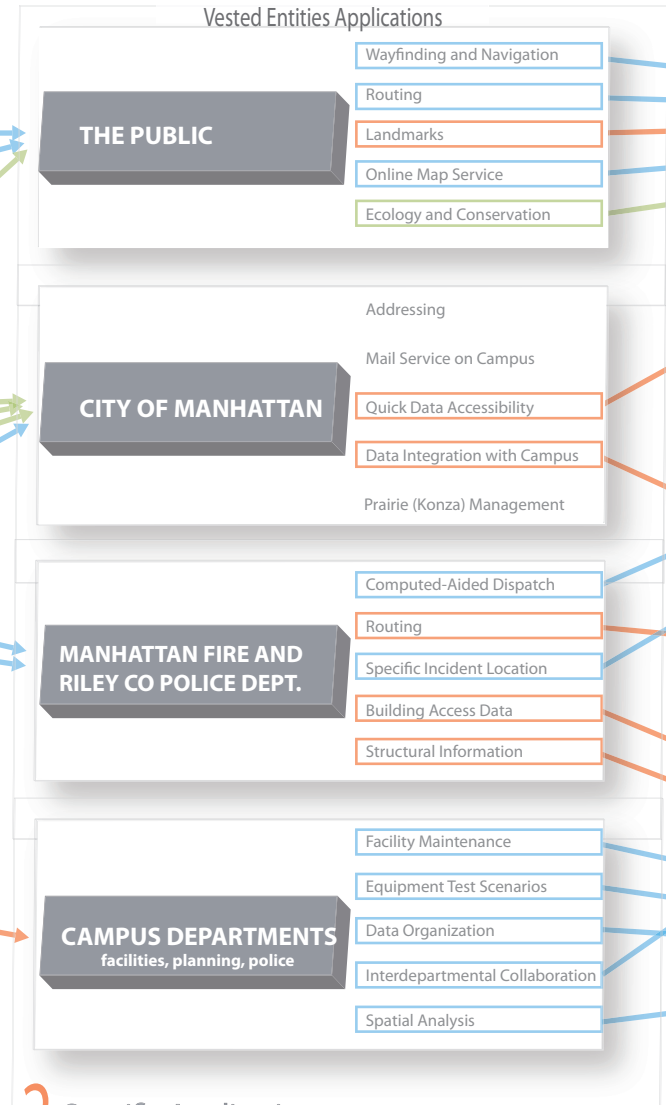
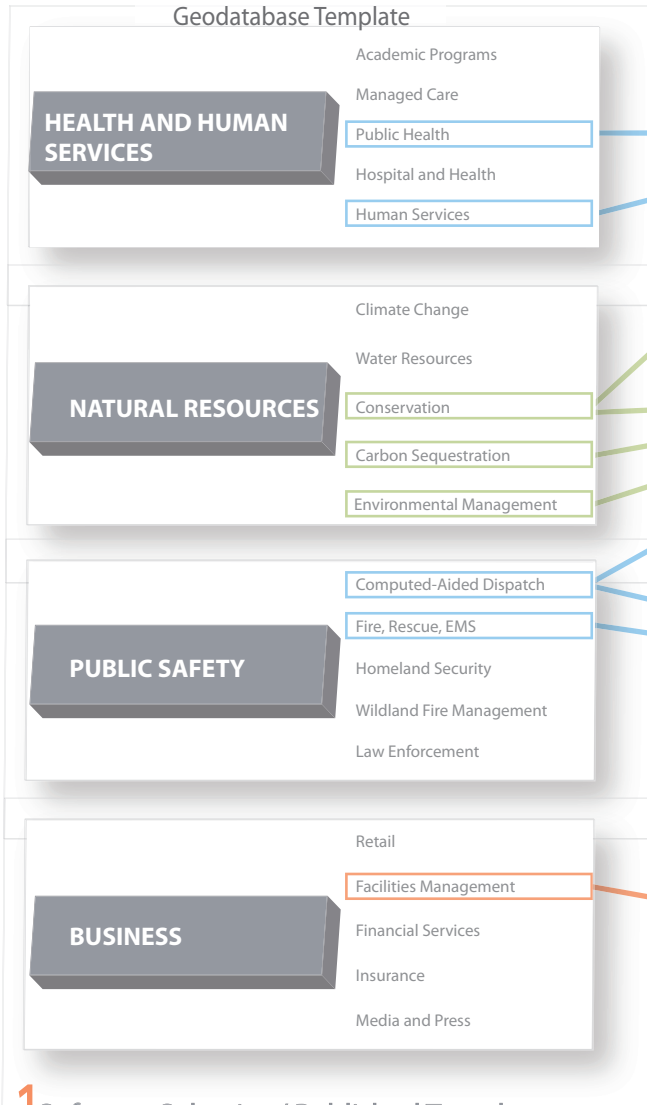
How can a geodatabase be structured to fulfill the needs of facility managers, emergency responders, and the public?

- How does the relationship between University, City, and Public function?
- What are the roles of each user- facility managers, emergency responder, and the public?
- How have other universities and cities made advances toward data integration?



ESRI GIS TOOLS

VESTED INTERESTS



1 Software Selection/ Published Templates

2 Specific Applications

2025 VISIONARY PLAN

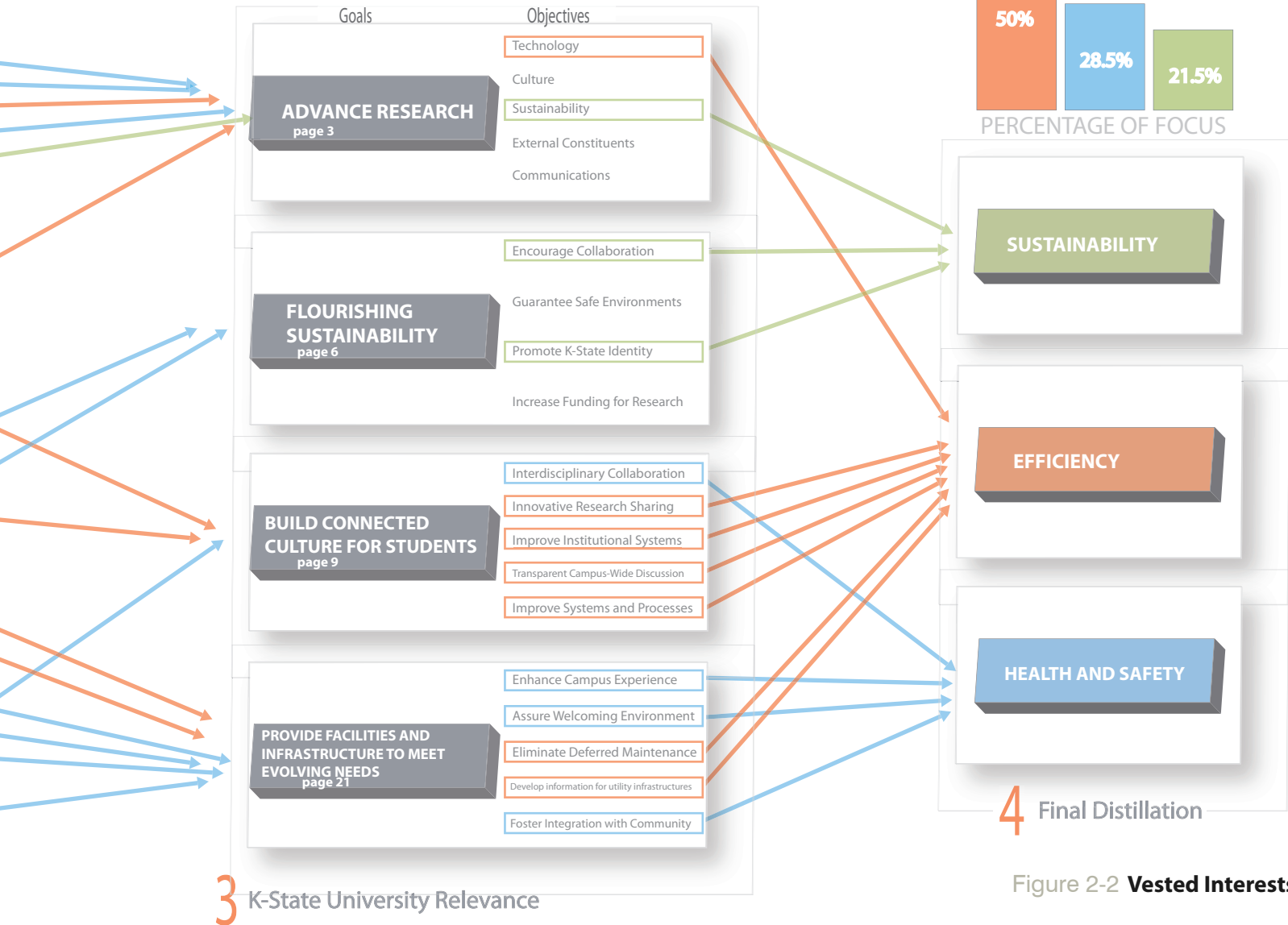


Figure 2-2 **Vested Interests**

Anticipated Results

A data framework will be created to structure digitization of routes, barriers, constraints, and assets. This structure serves as a prototype for data organization which can be replicated at other universities or communities. This structure also serves as a plan for how the digital campus plan and routing network can be completed and integrated with the new facilities management system being implemented at KSU, and the City of Manhattan Emergency Response.

A 3D campus computer model will be completed for visualization of routing and asset information. A virtual campus will demonstrate 3D campus fly through visuals promoting KSU's 150th Anniversary. Integrating routing into the 3D campus will show routing possibilities, constraints responses, and allow for more informed decision making on behalf of individuals,

the university, and community. Additional results from this project include:

- Organized data structure for integration
- Methods for creating a 3D network plan
- Visualizing routing options within a 3D virtual campus model
- Inventory and georeferenced many interior and exterior assets for facility manager and emergency response
- Analysis to reveal the capabilities of a newly integrated and automated system for data management



Hypothesis

Organization of spatial data will promote sustainability, efficiency, and safety for Kansas State University.

An organized data structure yields accessibility across campus departments and fosters a working relationship with emergency responders at the community level. Once data become accessible, spatial analysis can be conducted to optimize performance contributing to a more efficient workflow, sustainable practice, and a healthier environment.



Community of Users

An organized data structure unifies a community of users by:

- *Allowing each person to know their role-* A data structure identifying who maintains, accesses, integrates, verifies, and collects data will work to eliminate data duplication and break down isolated data silos.
 - *Achieving common or shared goals-* Wayfinding, access, and informed response are desired by all users from the individual level, to campus management, to community emergency response allowing for expedited data access and analysis.
 - *Enabling a comprehensive analysis-* Emergency responders and facility managers can access the repository
- to run analysis which can then be reintegrated into the system to perpetuate system growth exponentially.
 - *Equipping users with knowledge to respond intelligently to a variety of transportation questions-* Whether the question is, “How do I get to my classroom”, to “What is the most optimal way to access a fire due to structural conditions and availability of fire hydrants?” the questions are answerable due to a comprehensive routing scheme.

Spatially, these communities of users represent Kansas State University and the City of Manhattan.



Relevance to KSU

A repository for spatial data enables the university to transition from paper to digital data. This allows for a collaborative environment across departments and extends to the City of Manhattan enabling data accessibility and reducing the amount of redigitization and miscommunication. Additionally, a routing network will allow the public, university employees, and emergency responders with the tools required for informed emergency response.

Discussed in greater detail in Chapter 3
“Represent”

Relevance to Manhattan, KS

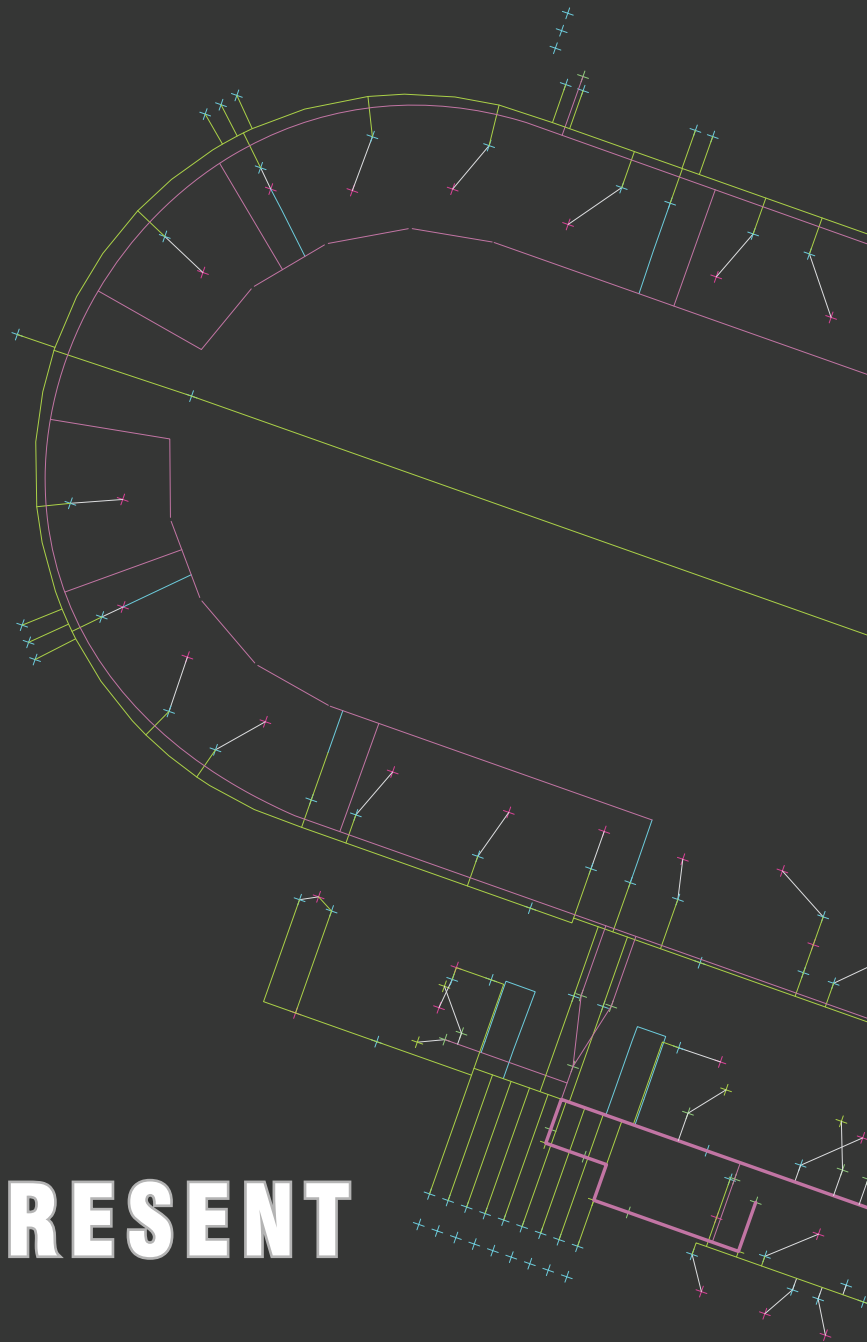
Fostering a working relationship between Manhattan and KSU enables more informed response for the most complex environment in Manhattan. This approach overcomes spatial barriers between campus and community. Furthermore this project serves as a template for future data input while showcasing the possibilities in transportation analysis once a routing network is built.

Discussed in greater detail in Chapter 3
“Represent”



03

REPRESENT



Working across scales

Working with vested entities across scales and overlapping service responsibilities is deceptively complex (Figures 3-2, 3-3, and 3-4). Certainly, the campus is the primary focus, but to effectively support emergency responders such as police and fire personnel, the context must be expanded to include the City of Manhattan. At this point, issues of scale start to arise. This project represents the interests of both campus and community, essentially targeting the middle ground between design professionals 'offensive' strategies and geographic sciences 'defensive' strategies described in the Introduce section. "Size matters," and a collaborative approach between entities with clear communication will work to overcome limitations from each approach. (Steinitz, 2008)

For small spatial areas, the Department of Facilities and Management is interested in routing to service individual pieces

of campus resources. Pedestrians are serviced through routing at a campus scale, and emergency responders will utilize routing and accompanying analysis at a community scale. Each of these entities are not independent, and often a shift in scales occurs depending upon circumstance. For example, the fire department will typically route at a community scale, but they are also interested in point assets within buildings such as the exact location of a fire hydrant, extinguisher, or area of rescue. Interests vary across scale and do not remain static through time. An understanding of the flexibility in the system must be carried through design of the network as well as implementation, sharing, and maintenance of the data.

Additionally, it is important to view this network as a structure for data integration across all scales. Network datasets allow for data to be integrated relative

to a common transportation network. As the system is built, analytical capabilities increase exponentially benefiting pedestrians, maintenance workers, and emergency responders. Since all users are verifying system accuracy and feeding information back into the system, the network datasets act as the common language for data to be integrated and organized. Ultimately, a repository of data will be built with privileges set allowing maintenance personnel to access pertinent information to find facility locations which fulfill specific maintenance requests.

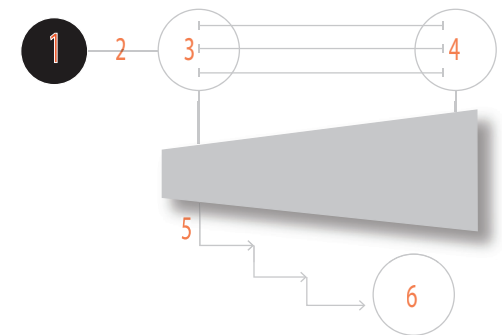


Figure 3-2 Research Framework

Represent is the first step of a six part research framework.

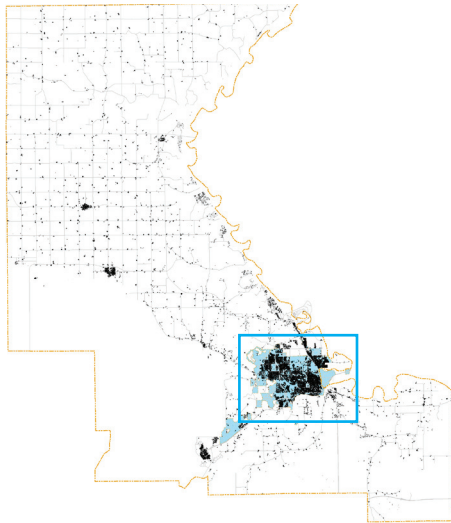


Figure 3-3 Riley County

2013 Riley County GIS Data

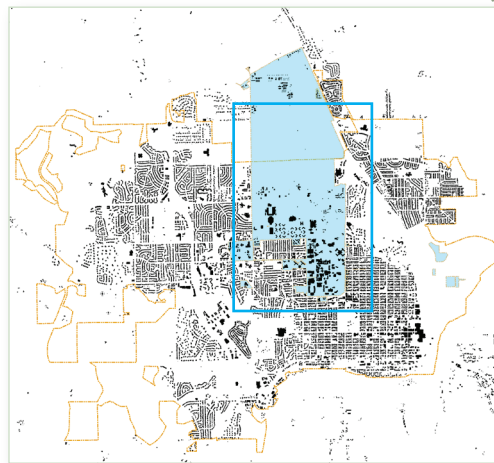


Figure 3-4 Manhattan, Kansas

2013 Riley County GIS Data

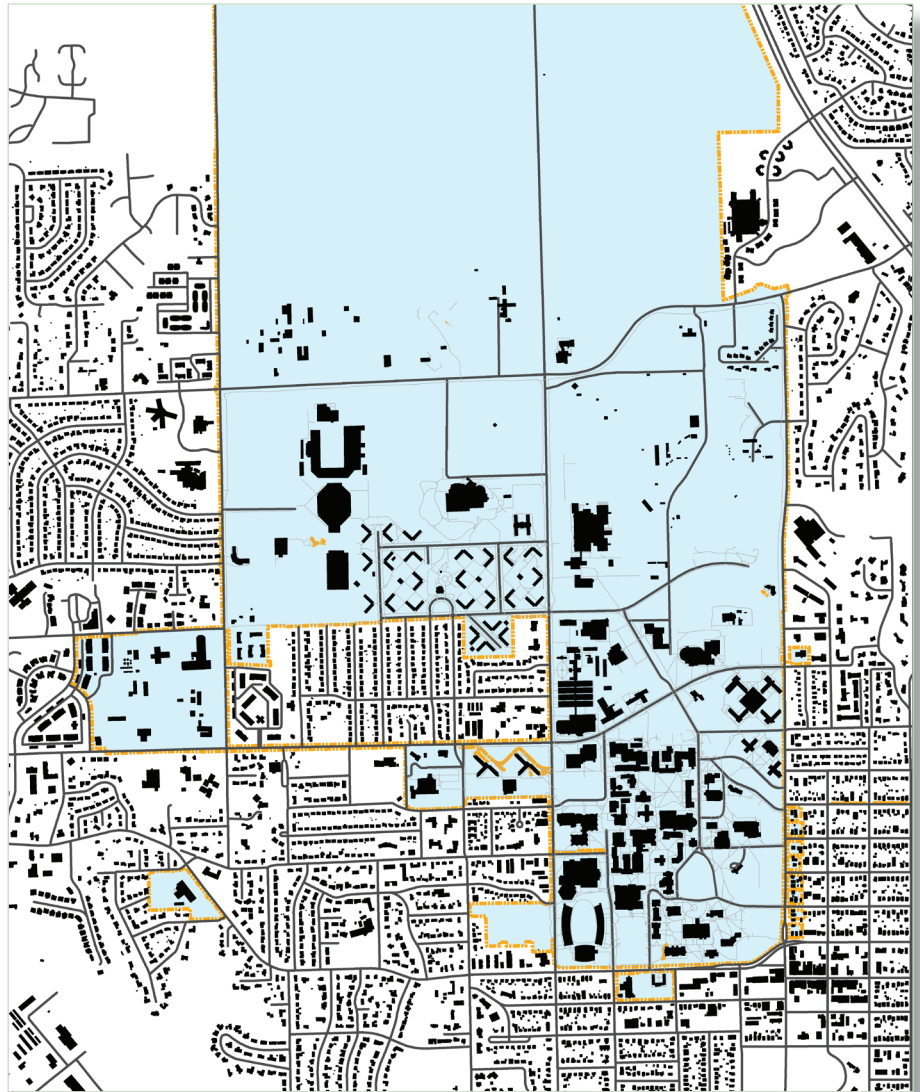


Figure 3-5 Kansas State Campus

2013 Riley County GIS Data

Community of Manhattan

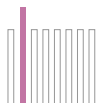
Manhattan is a community of 52,281 people which includes a transient student population (US Census Bureau, 2010). By 2020, the population is expected to grow by 11.1% (1.31% annually) to 58,105 (Figure 3-5). According to the Manhattan Comprehensive Plan adopted in April of 2003, most of the growth will take place in response to the National Bio and Agro-Defense Facility (NBAF), growth of Kansas State University, and expanded city boundaries annexing residents on the periphery. The growth is projected to be concentrated in northwest Manhattan which is considered unconstrained and serviceable according to the Manhattan Comprehensive Plan (Section 3-9). In turn, an increase in population will place more demand on major arterials, such as Seth Child Road, further promoting the need for pedestrian initiatives. The projected growth, both in terms of population and total number of drivers, urges future master planning efforts which favor pedestrian options.

Historic Population Trends from 1950- 2000				
Year	Population	Change	Total	Annualized
1950	19,056	--	--	--
1960	22,993	3,937	0.206	0.019
1970	26,897	3,904	0.169	0.0158
1980	32,644	5,747	0.214	0.0197
1990	37,712	5,068	0.155	0.0145
2000	44,831	7,119	0.189	0.0174
1950-2000	--	25,775	1.353	0.0173

Population Trends and Projections from 1990- 2020				
Year	Population	Change	Total	Annualized
1990	37,712	5,068	0.155	0.0145
2000	44,831	7,119	0.189	0.0174
2005	46,468	1,637	0.037	0.0072
2010	51,466	4,998	0.107	0.0103
2020	58,105	6,639	0.128	0.0122
2000-2020	--	13,274	0.296	0.0131

Figure 3-6 Manhattan Population Projections

Reconstructed from Table 2 In Manhattan Comprehensive Plan Background Section



The Manhattan Comprehensive Plan has outlined several strategies to promote more transit options. The number one identified goal is to “plan for a balanced, multi-modal transportation system of streets, sidewalks, bikeways, and future public transit to meet the current and future mobility needs of the community.” (Section 8-2). The “*Manhattan Area Transportation Strategy: Connecting to 2020*”, released in 2000, proposes to tie Manhattan together with a system of pedestrian and bike networks that connect town with the hinterland (Section 7-2). Emphasis has been placed on increasing levels of service, safety, and comfort when using sidewalks or bike lanes. Plans have been made and initiatives undertaken to foster greater pedestrian mobility. This further supports a routing system enabling wayfinding through newly created transit connections.

A growing population places added strain on police and fire coverage, as well. The primary responsibility of a fire department is delivering fire and rescue services within a typical five-minute time frame. The delivery of these services originates from a fire station located amongst the area to be protected. “In order to provide effective service, crews must respond in a minimum amount of time after the incident has been reported and with sufficient resources to initiate fire, rescue, or emergency medical activities,” (“GIS for Fire Station Locations and Response Protocols”, 4). The area that can effectively be serviced within the given response time defines a service area. GIS and routing enables responders to find the location of the incident, to respond intelligently to combat the emergency, and to administer assistance to those in need. Currently service coverage areas have not been calculated for the Manhattan Fire Department (MFD) or Riley County Police

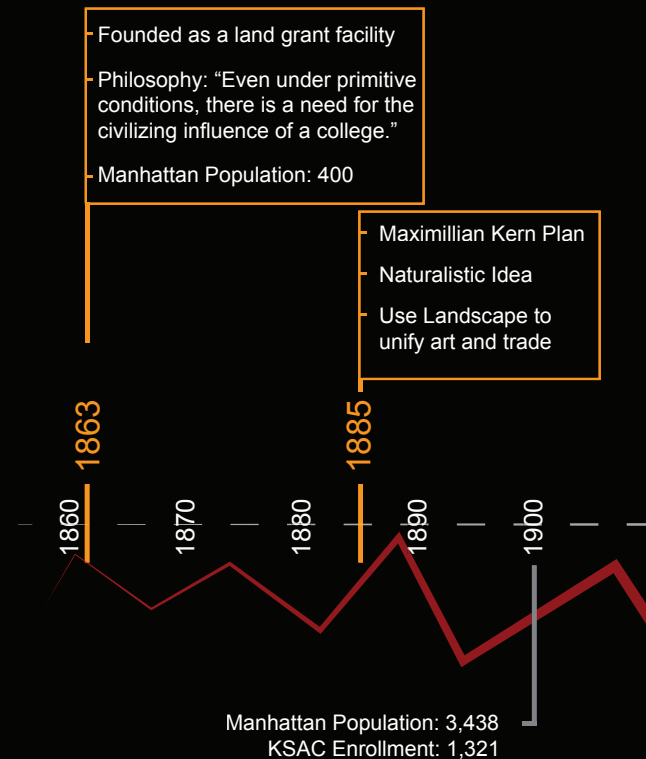
Department (RCPD) due to lack of routing plans and data. MFD service standards dictate a response time of five minutes (Martinson, 2012). Without routing plans, it is not possible to determine what areas can be reached within five minutes of dispatch. Furthermore, service area calculations accurately determine how projected growth will affect response times and if a new facility is required to support population growth. A routing analysis can be used to efficiently determine areas serviced by current facilities, and estimate service impacts posed by new development. By doing so, Manhattan’s 2020 strategy can be supported to enhance public health, welfare, and safety.



KSU Campus: Evolving through Time

Kansas State has never been negligent of pedestrian travel or the value of meaningful open space. Early on, in the Maximillian Kern Plan, the central motive was to preserve naturalistic areas. Early plans did not focus on pedestrians because there was little need. There were few conflicts between walkers and horse carriages since only 400 people lived in Manhattan in 1863. As the university and community grew, so did the conflict, represented by the blue and red lines in Figure 3-6. In the 1950s Manhattan was expanding and more reliance was placed on the automobile. Campus expanded north of Claflin Avenue. New roads through campus such as Petticoat Lane and Vattier Street encouraged cruising. Many new parking lots further promoted driving to campus. Campus continued to develop but in two; the original campus

maintained a core nucleus, and the area north of Claflin continued to sprawl. Master planning attempts since 1952 have attempted to balance parking with pedestrians. In 1973 with the Weisenburger Plan, a focus to facilitate pedestrian travel was developed like never before. Since then, attention has been paid to reinforce pedestrian circulation and limit vehicular access through campus by constructing parking structures and keeping parking lots on the periphery. Refer to Appendix 1 for a complete look at each campus plan individually.



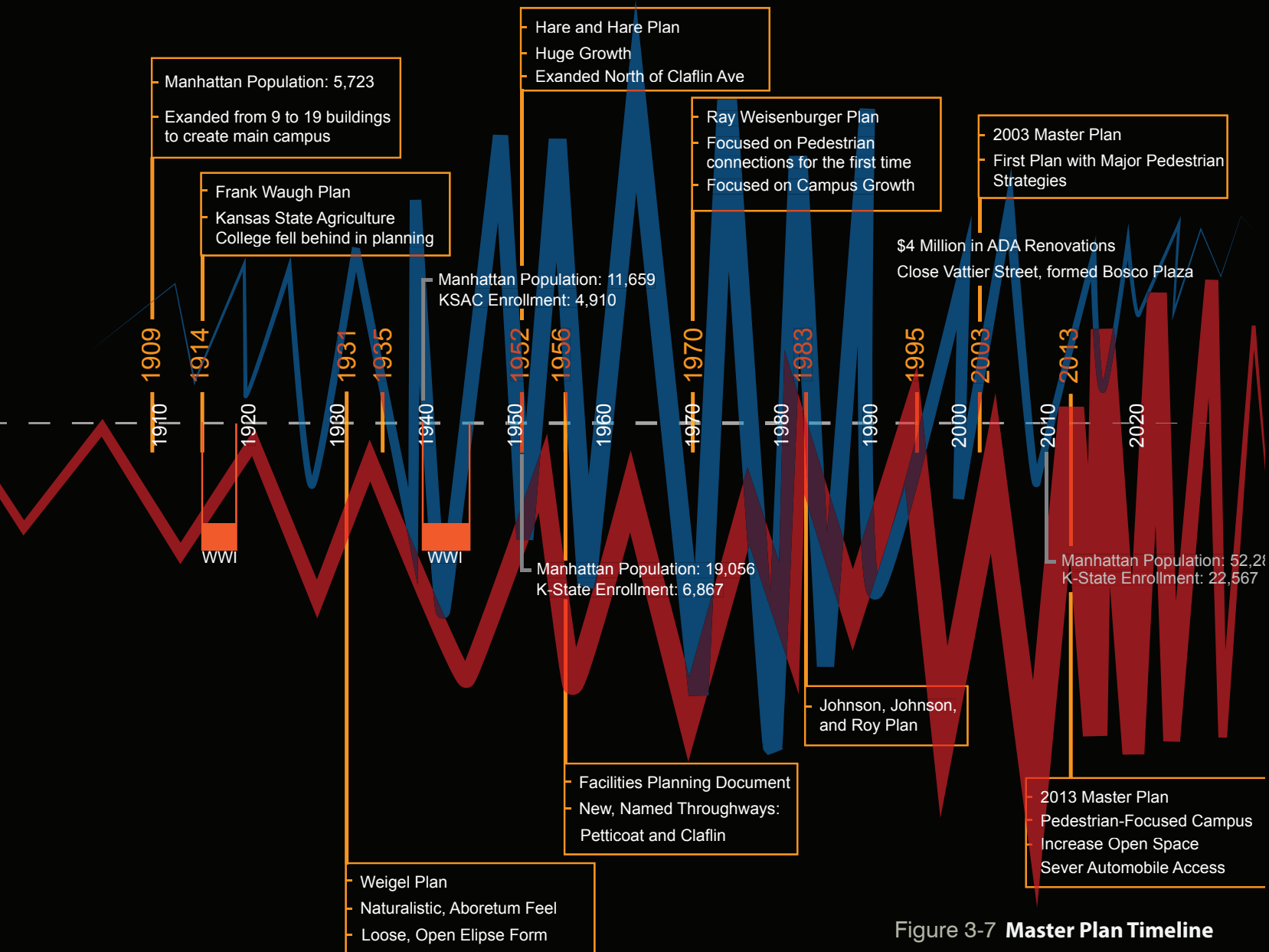


Figure 3-7 Master Plan Timeline

KSU Campus: Present Into the Future

Progressing into the future, the Kansas State University Campus Master Plan Update makes tremendous strides strengthening campus identity, promoting sustainability, clarifying circulation, and optimizing quality and accessibility to gathering spaces.

These efforts seek to promote a greater reliance on walking as a health benefit. This strategy is more aligned with European universities and municipal counterparts where increased walking, bicycling, and healthier lifestyles result in lower obesity rates as depicted in Figure 3-7 (Bassett, 2008).

The major influences fostering pedestrian movement are compact, dense environments, prohibiting vehicular circulation, and establishing lush, open space as an amenity which have all been identified in the 2012 K-State Master Plan Update (Figure 3-8). Besides efficient

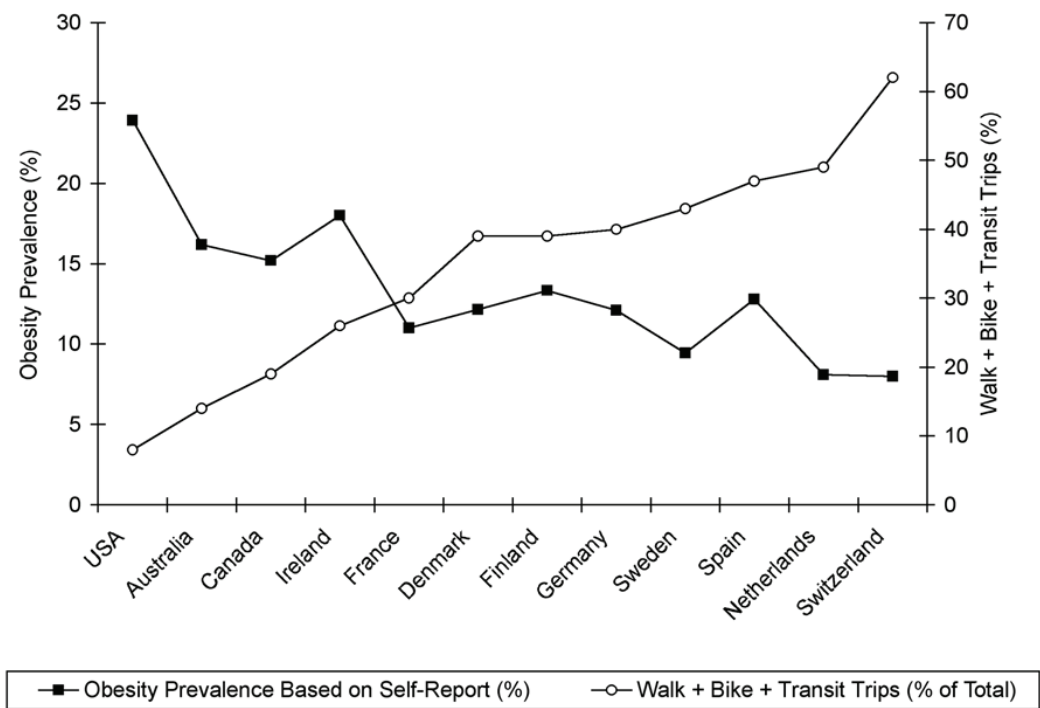
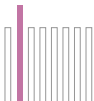
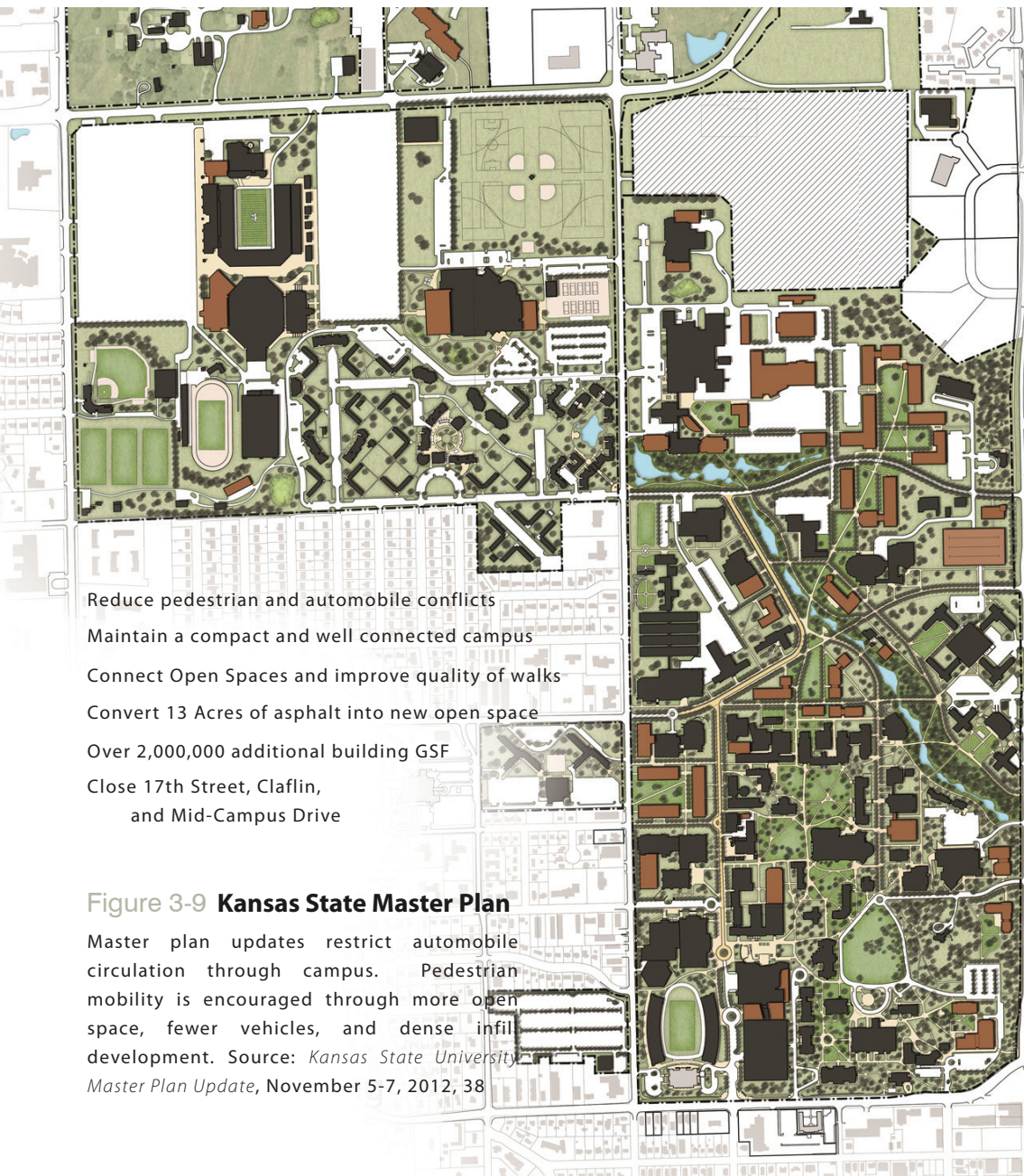


Figure 3-8 Negative Correlation between Obesity and Walking

Walking and biking is inversely related to obesity rates across Europe.

Source: David Bassett, *Walking, Cycling, And Obesity Rates in Europe, North America, and Australia*, 2008, 805





Reduce pedestrian and automobile conflicts
Maintain a compact and well connected campus
Connect Open Spaces and improve quality of walks
Convert 13 Acres of asphalt into new open space
Over 2,000,000 additional building GSF
Close 17th Street, Claflin,
and Mid-Campus Drive

Figure 3-9 Kansas State Master Plan

Master plan updates restrict automobile circulation through campus. Pedestrian mobility is encouraged through more open space, fewer vehicles, and dense infill development. Source: *Kansas State University Master Plan Update*, November 5-7, 2012, 38

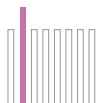
circulation, planners, and landscape architects can use routing to highlight aesthetic campus features, or offer route alternatives requiring various levels of exertion. According to Melissa Bopp in the Department of Kinesiology, the average student walks to campus 4.5 times a week compared to driving only 2.3 times a week (Bopp, 2012). An interdepartmental collaboration could combine knowledge of routing distances with physical exertion metrics to determine how many calories are burned on each trip. Furthermore major influences determining walkability such as safety, accessibility, or aesthetics could be determined to design optimized pedestrian routes.

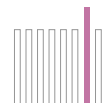
Aesthetic routes can also be determined for memorials or particular places of interest. Memorial trees located across campus commemorate an individual who advanced the University. Typically donated by the family, memorial trees hold special meaning for loved ones. Routing can be used to enhance commemoration of these individuals by providing specific guidance to a tree, but doing so through an aesthetically pleasing route. These special areas can influence routing including these stops in the most convenient way. Educational components can also be included in routing to navigate a pedestrian by a specimen species or a series of historic trees. Furthermore, routing plans can be arranged as self-guided tours of the campus including aesthetic stops, specific buildings, or offices. This may be useful for prospective students or faculty.

Lastly, routing can promote social sustainability by nurturing an atmosphere of safety. A strong focus of The Visionary Plan of 2025 was placed on building a strong sense of community achieved through a safe and pleasant environment both socially and environmentally (Kansas State Visionary Plan, 9). Certainly safety is a major concern across scales from the individual, to campus management, to emergency responders at the city level.

For several decades, mass shootings have frequently occurred on campuses. For students and security personnel unfamiliar with campus layouts, having electronic access to routing information can be life-saving or envelop precautionary measures (Follman, 2012). Besides exterior spaces, routing extends into the 3-D realm of complex interior spaces which may render quick response difficult (Lee, 2004).

Emergency evacuation routing creates test routes ahead of time to analyze corridor length, proximity to exits, and locations of automatic locking doors. Providing improved emergency response protocol will expedite emergency response and shift the mind set of reactive response to proactive planning.



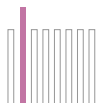


How does KSU Spatially Compare to other Universities?

Kansas State University is taking measures to promote pedestrian transit using GIS-based routing. Many other universities and colleges have taken this initial step and evolved their system to meet the requirements of emergency personnel, students, and faculty. Research was conducted to assess how other universities compare spatially in terms of campus size, number of buildings, and overall density. The selected universities have displayed excellence in data accessibility and distribution on an individual, campus, and community scale. The selection rationale is explained further in Section 5- Contextualize where these same universities will be analyzed according to data management techniques. Figure-ground imagery is compared at consistent scales to perceptually indicate campus composition. In these images, it is

important to observe the relationship of buildings to open space, density, proportion of space, and the sheer scale of the campus.

This assessment spatially relates Kansas State University to other schools who have completed routing plans or have proven effective in data management to promote emergency response. Upon comparison, it is clear Kansas State is a large university in terms of overall size and building square footage. A routing plan and accompanying data management is challenging for a university of this size. Due to the sheer size and age of the university, correct and flexible data management is imperative. Improving data collection, organization, access, and sharing protocols could increase efficiency and have significant benefits for the university.



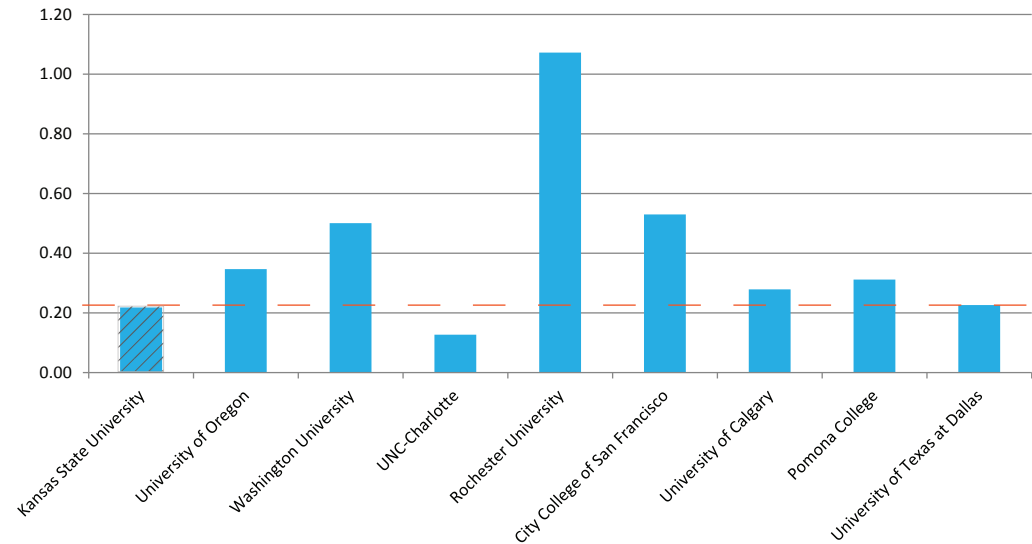
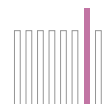


Figure 3-11 Floor Area Ratio

FAR is an overall measure of density. Rochester University is most dense with a large percentage of campus covered by building mass. Kansas State is on the low end, indicating our overall campus size is large compared to the building square footage.



Campus Comparison

	Kansas State University	University of Oregon	Washington University	UNC-Charlotte	
Graduate Enrollment	2,955	3,526	4,321	3,458	
Undergraduate Enrollment	19,612	12,170	6,328	16,259	
Total Enrollment	22,567	15,696	10,649	19,717	
On Campus Housing UG	3,800	3,125	3,000	4,312	
On Campus Housing Grad	432	-	-	46	
Land Coverage (Acres)	668	295	182	912	
Building Coverage (Sq Ft)	6,350,565	4,455,311	3,968,468	5,045,503	
Urban Population	52,281	156,185	319,294	751,087	
Enrollment to Pop Ratio	0.432	0.100	0.033	0.026	
Number of Buildings	102	80	81	73	
Floor Area Ratio	0.22	0.35	0.50	0.13	
Parking Spaces	15,188	3,328	4,800	11,515	
Percent living on campus	19	20	28	22	

Information used in these comparisons were supplied by the institutions represented via their web site or through interviews with campus personnel. The most current information available was attained.

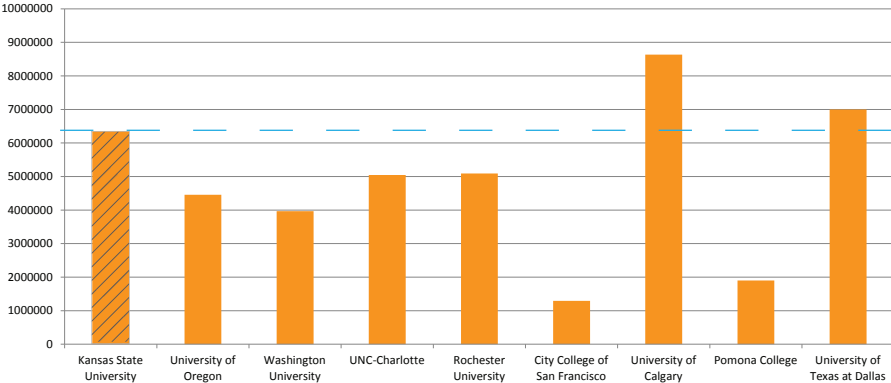
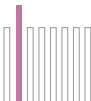


Figure 3-12 Building Coverage

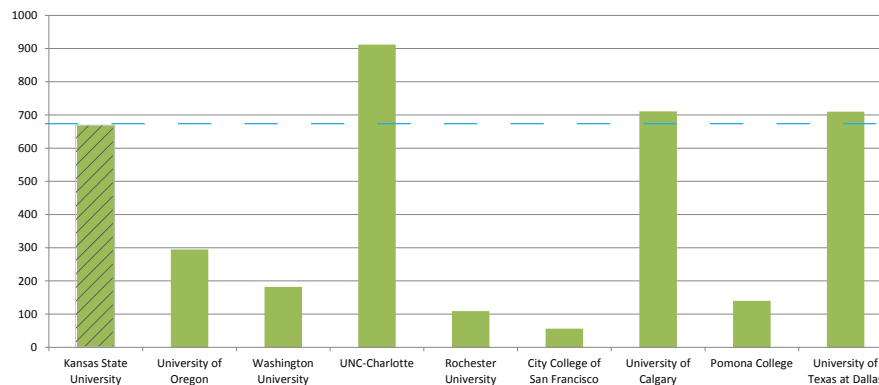
Square feet of building across all case studies indicates Kansas State has a higher volume proportionally.



Rochester University	City College of San Francisco	University of Calgary	Pomona College	University of Texas at Dallas
4,647	-	8,616	-	7,455
5,643	33,165	33,243	1,560	11,409
10,290	33,165	41,859	1,560	18,864
1,200	-	1,382	1,500	2,852
-	-	458	-	-
109	56	711	140	710
5,089,000	1,292,610	8,634,667	1,900,000	7,000,000
210,855	805,235	1,096,833	34,926	1,197,816
0.049	0.041	0.038	0.045	0.016
18	45	64	63	46
1.07	0.53	0.28	0.31	0.23
7,882	2,854	8,900	--	--
12	0	4	96	15

Figure 3-13 Land Coverage

Acres of land coverage across all case studies indicates Kansas State has a comparatively higher amount of land area.



22,567 Total Enrollment

668 Total Campus Acres

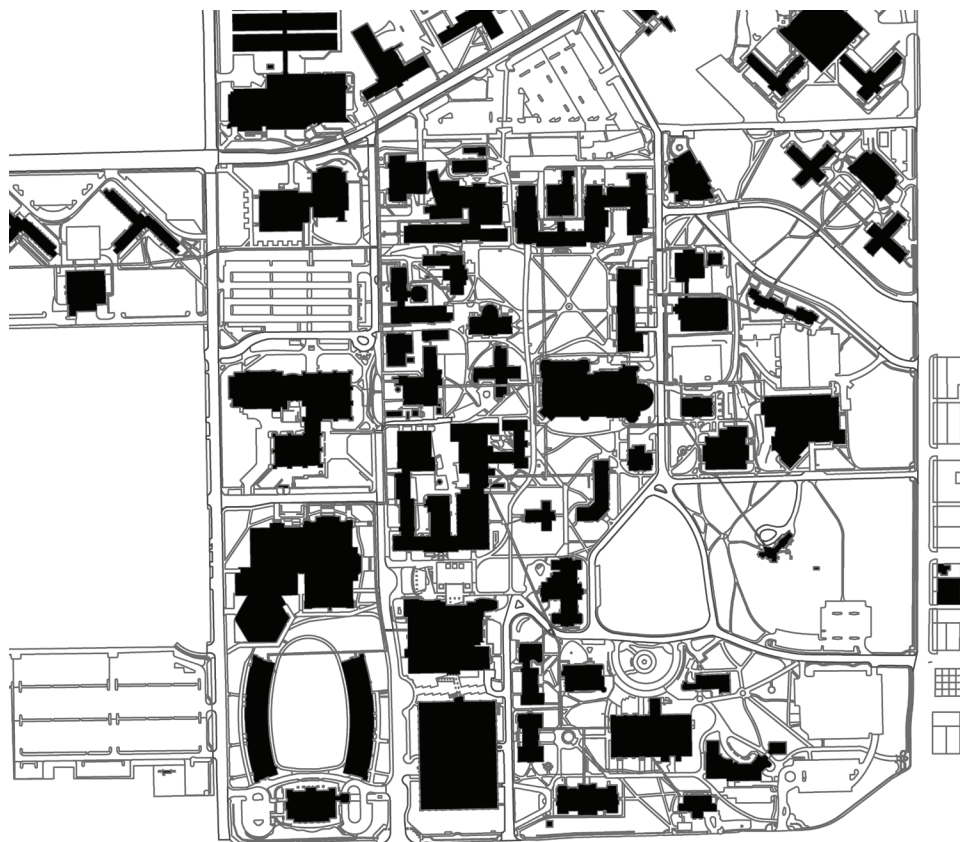
6,350,565 Feet of Building Coverage

52,281 Community Population

0.432 Enrollment to Pop Ratio

102 Number of Buildings

0.22 Floor Area Ratio



* Universities with similar spatial characteristics to K-State

Figure 3-14 **Kansas State University**
Prepared from Campus Basemap

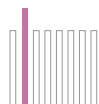




Figure 3-15 University of Oregon

<http://asg-architects.com/2007/07/research/case-studies-research/comparing-campuses/>

15,696 Total Enrollment

295 Total Campus Acres

4,455,311 Feet of Building Coverage

156,185 Community Population

0.100 Enrollment to Pop. Ratio

80 Number of Buildings

0.35 Floor Area Ratio



10,649 Total Enrollment

182 Total Campus Acres

3,968,468 Feet of Building Coverage

319,294 Community Population

0.033 Enrollment to Pop Ratio

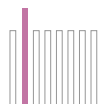
81 Number of Buildings

0.50 Floor Area Ratio



Figure 3-16 Washington University

<http://asg-architects.com/2007/07/research/case-studies-research/comparing-campuses/>



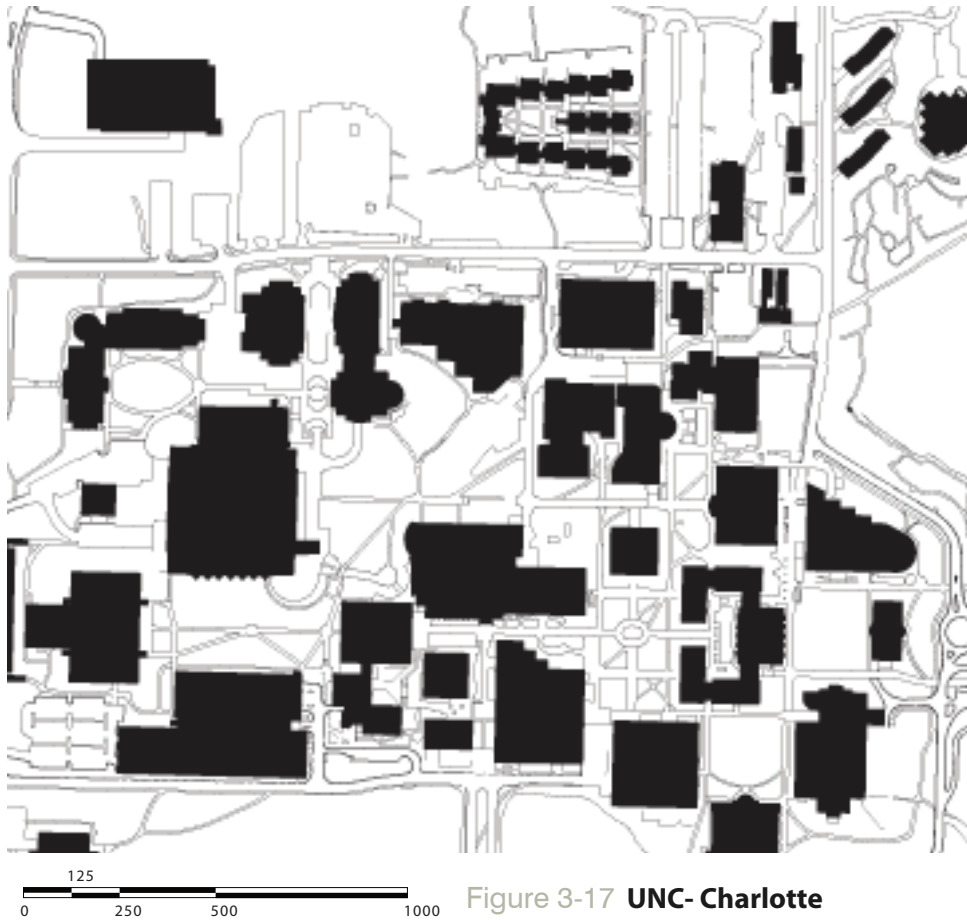


Figure 3-17 UNC- Charlotte

<http://asg-architects.com/2007/07/research/case-studies-research/comparing-campuses/>

19,717 Total Enrollment

912 Total Campus Acres

5,045,503 Feet of Building Coverage

751,087 Community Population

0.026 Enrollment to Pop. Ratio

73 Number of Buildings

0.13 Floor Area Ratio

10,290 Total Enrollment

109 Total Campus Acres

5,089,000 Feet of Building Coverage

210,855 Community Population

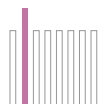
0.049 Enrollment to Pop Ratio

18 Number of Buildings

1.07 Floor Area Ratio



Figure 3-18 **Rochester University**
<http://asg-architects.com/2007/07/research/case-studies-research/comparing-campuses/>

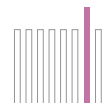




33,165	Total Enrollment
56	Total Campus Acres
1,292,610	Feet of Building Coverage
805,235	Community Population
0.041	Enrollment to Pop. Ratio
45	Number of Buildings
0.53	Floor Area Ratio



Figure 3-19 City College of San Francisco
Modified from OpenStreetMap US



41,859 Total Enrollment

711 Total Campus Acres

8,634,667 Feet of Building Coverage

1,096,833 Community Population

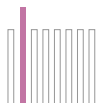
0.038 Enrollment to Pop Ratio

64 Number of Buildings

0.28 Floor Area Ratio



* Figure 3-20 **University of Calgary**
<http://asg-architects.com/2007/07/research/case-studies-research/comparing-campuses/>





1,560 Total Enrollment

140 Total Campus Acres

1,900,000 Feet of Building Coverage

34,926 Community Population

0.045 Enrollment to Pop. Ratio

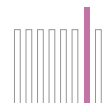
63 Number of Buildings

0.31 Floor Area Ratio



Figure 3-21 Pomona College

Modified from <http://www.scrippscollege.edu/about/images/map/2012-campus-map-large.png>



18,864 Total Enrollment

710 Total Campus Acres

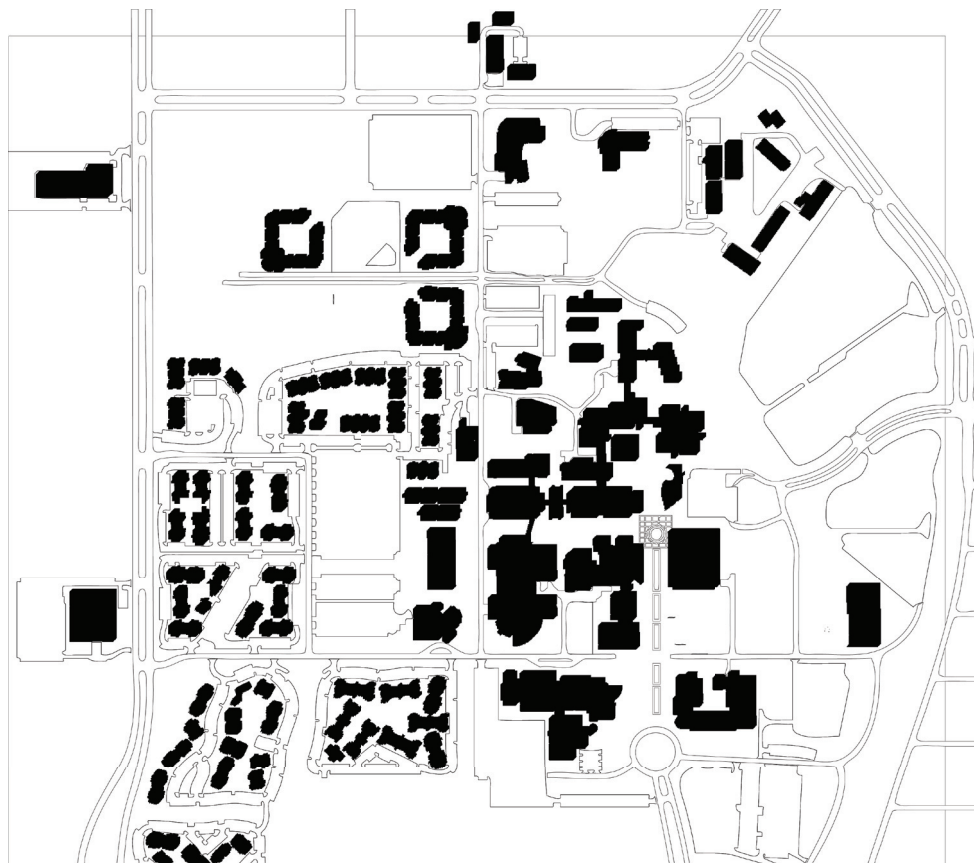
7,000,000 Feet of Building Coverage

1,197,816 Community Population

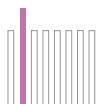
0.016 Enrollment to Pop Ratio

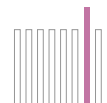
46 Number of Buildings

0.23 Floor Area Ratio



* **Figure 3-22 University of Texas at Dallas**
 Modified from <http://www.utdallas.edu/maps/map.png>





Project Relevance to KSU

Spatial data management will develop campus in three ways: efficiency, sustainability, and safety.

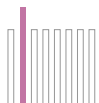
Efficiency

A growing desire for efficiency and sustainability has demanded an evolution in facility management. In the past, building and campus data has existed in many forms from AutoCAD drawings, paper copies, to complex spreadsheet formulas that were inefficient in how data was organized and distributed. It is estimated in 2002 up to \$5.1 billion was lost in the United States simply verifying the organization and accuracy of facility management data. (NIST, 2002) Another \$742 million dollars were lost converting and transforming data into a useable format. In order to attain Kansas State University's vision to "provide facilities and infrastructure to meet the evolving needs of the University while providing

information technology accessibly to all", a new form of data management is needed (Kansas State University, 2010, 31).

The first steps are: 1) conduct an inventory of all spatial data sources; and 2) aggregate facility data into a common data model. Having a model enables a coordinated view which has the potential to increase communication and collaboration across campus departments. For instance, aggregating campus data will reveal clusters of under and over utilized spaces, floors, or buildings, which can achieve efficient building layout while aligning uses between occupant and building.

Kansas State realizes the need for collaboration, "A shared awareness reduces the unknowns, leading to few project contingencies and risks and lower costs." (Kansas State University, 2010, 33) Having accurate and complete facility



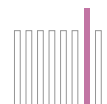
information for equipment, work requests, transactions, and costs enables efficient workflow for campus management while creating a culture of excellence resulting in flourishing sustainability. Data management has secondary impacts including routing for pedestrians across campus and creating a network for emergency response to a specific campus incident. Using a common database will increase the efficiency of campus facilities, improve safety during expedited emergency responses, and enhance pedestrian wayfinding.

Sustainability

An organized data structure alters the current run-to-fail ideology into a vision for efficiency and sustainability achieved through strengths, weaknesses, opportunities, and threats (SWOT) analysis, predictive modeling, and scenario-based testing. The predictive capacity adopts strategies for reliability-

based management, which will drastically increase service life and reduce operating costs. A common database will help the university better track deferred maintenance, prioritize improvements, and plan finances for long-term and on-going maintenance. A common database will achieve visionary goals of increasing awareness, optimizing facility performance, and developing information technology and utility infrastructure accessible to all (Kansas State University, 2010, 20).

Campus sustainability can be promoted in part through the analysis of tree viability over the last decade. A tree inventory was conducted in 2002 and many characteristics were documented including species, height, caliper, and notable characteristics. Another inventory and geospatial analysis will be conducted in fall of 2013 to help determine what conditions are causing trees to thrive



or die. Patterns may start to appear among species, and we can begin to understand the conditions in contributing to tree vitality. Also, vegetation and development patterns will start to appear when comparing over the last decade which will further enhanced with future inventories.

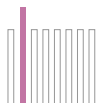
Safety

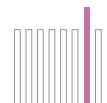
Developments in technology allow facility managers, emergency responders, and the public at large to increase data interoperability to make better-informed decisions. By aggregating all data into a GIS database, the geometries and tabular data of the built environment from multiple sources will be spatially represented. The efficiencies can be leveraged across scales from municipality, campus, building, to specific classrooms in times of emergency. “The first thing that happens when there’s a situation is the plan goes out the window. When the plan

goes out the window, the ability to collect all necessary data to form an overall picture of what is going on has to be a GIS application. I can’t see it happening any other way.” (Flemion, 2012) GIS-based routing provides the platform for data integration and access during these times allowing for situation awareness at a moment’s notice. Often getting to the scene is the most critical element in emergency response. (Gikas, 2012.) How the first responder initially reacts to an emergency dictates the success of the entire mission. GIS places data at the fingertips to shave off minutes critical for making informed decisions quickly.

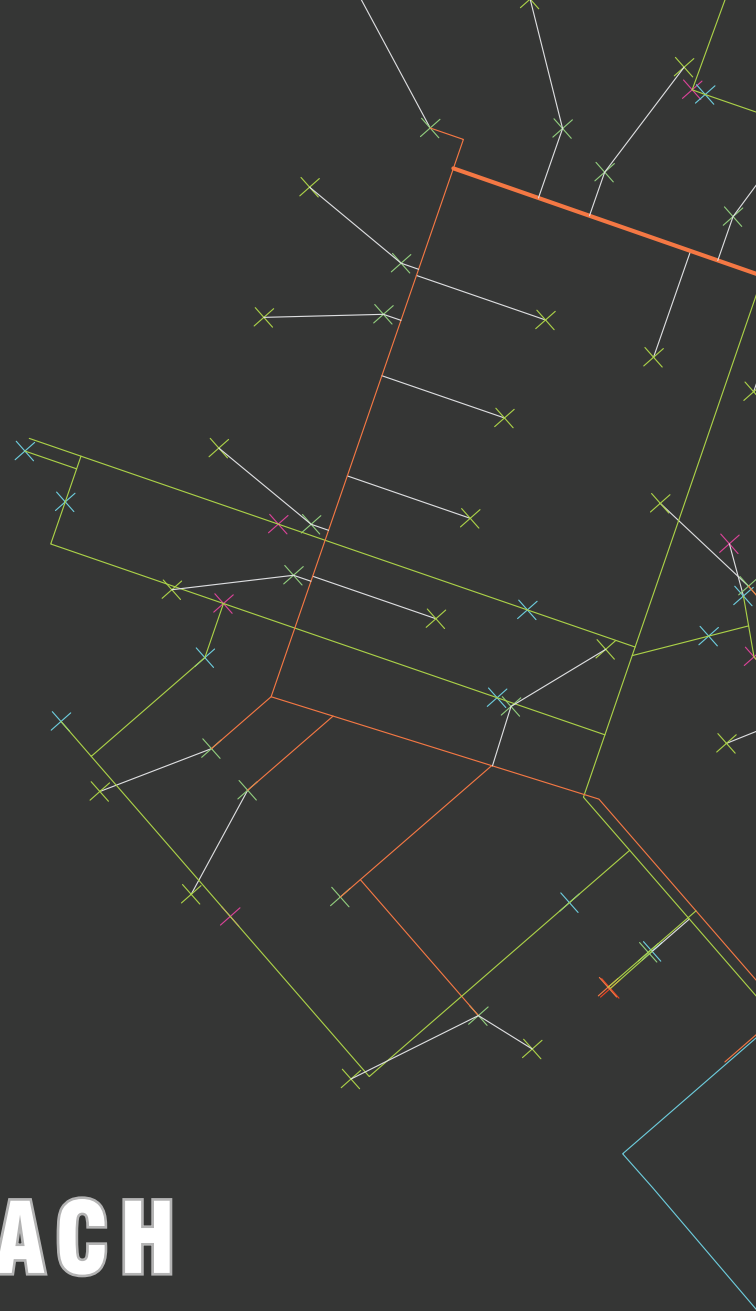
Key facility information will be provided to emergency responders so they can evaluate spatial conditions before arriving on site. For instance, a routing plan utilizing TIGER Census data for Manhattan’s roadways can be connected to address parcels, provided by Riley

County, to create a network dataset using vector edges and nodes. Vector analysis allows for distance calculations which can then be tied to speed and traffic congestion to quantify both route distance and time. The same method can be used for interiors as well, where hallway corridors correspond to roadways and addressed parcels correspond to classrooms. Also, fire hydrant and fire connections can be inventoried in the database with coordinate information to assess which hydrant is closest to the incident. Spatial analysis can answer questions such as: What is the quickest route from A to B? What is the ideal building entry? Can a 200 foot fire hose reach the incident? Where is the closest emergency phone? Optimizing data management will nurture a safer campus through more accessibility for emergency services and pedestrians, alike.





04 **APPROACH**



In order to assess how well a project area is performing, a current understanding of how practices operate is needed. For routing purposes, it is essential to understand data accessibility across all users of a system. Most importantly, how does Facilities and Planning manage data to accomplish daily operations? Secondly, how is data distributed to emergency responders throughout the city? Lastly, how do visitors to the campus access routing information? A baseline assessment for Kansas State was established through personal interviews to gain contextual understanding. The baseline was then compared to other institutions known for efficient data management and distribution. A comparison was made between existing versus best practices to identify gaps where Kansas State could optimize performance. The process used to test the project hypothesis is illustrated in Figure 4-2 Framework Walkthrough.

The overall research goal is to determine the best practices for data management achieving university goals of efficiency, sustainability, and health. To achieve this goal, a framework for geodesign developed by Carl Steinitz was adopted. The geodesign framework supplies the grounds for formulating the research approach progressing from “Contextualize”, to “Assess”, “Analyze”, and finally to “Evaluate”. Applying this framework allow conducting a baseline, determining best practices, and then adopting best practices. Sections “Introduce” and “Represent” precede the geodesign framework to provide the needed context.

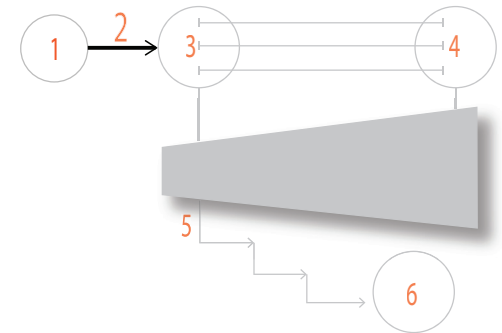
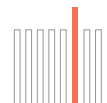


Figure 4-2 Research Framework

Approach is the second step of a six part research framework.



Research Methods

A series of seven steps were completed over the past year to provide Facilities, Planning, and Emergency Response with the essential tools for campus management and planning. The first four steps were concerned with the scope of the research, preparation of data, and scenario development to evaluate system validity. These five tasks included definition of goals through a baseline assessment, evaluation using case study research, collection and preparation of data, and then simulation testing. These initial steps provide a foundation for facility management and act as a template for future data flow. At the end of the project scope, completion of the following steps, five through seven, are essential for optimizing campus facility management, and will be completed in the future.

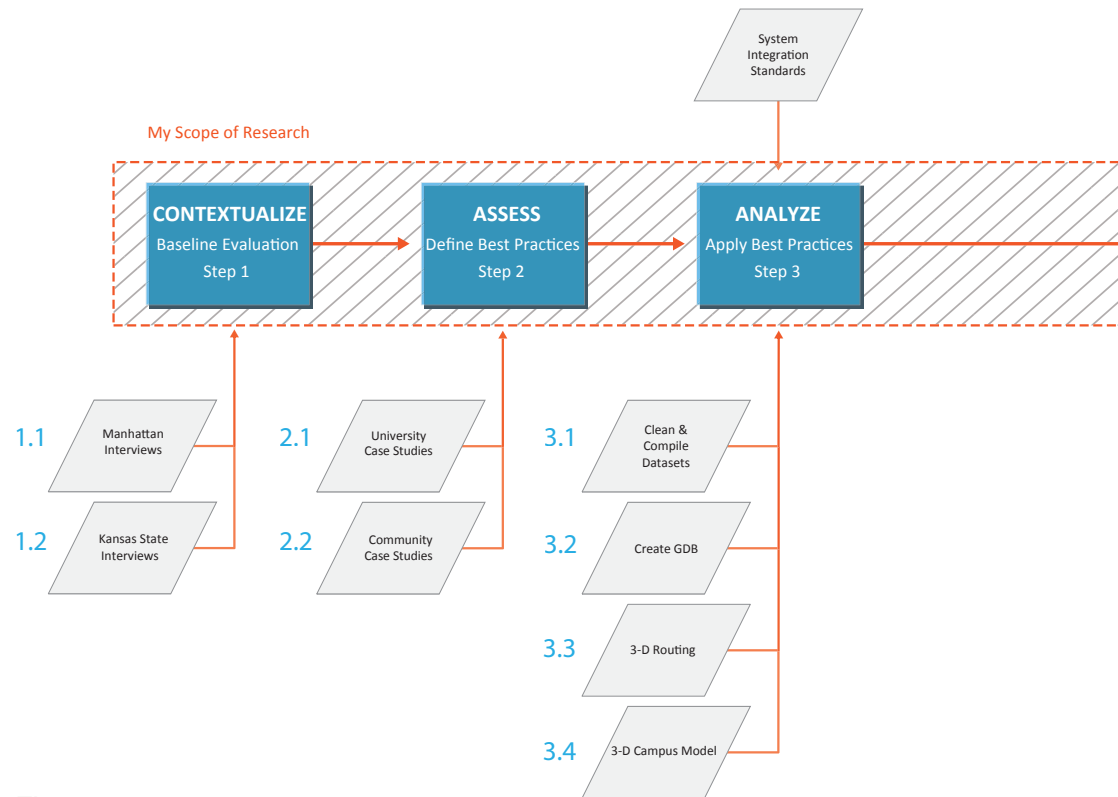
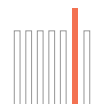
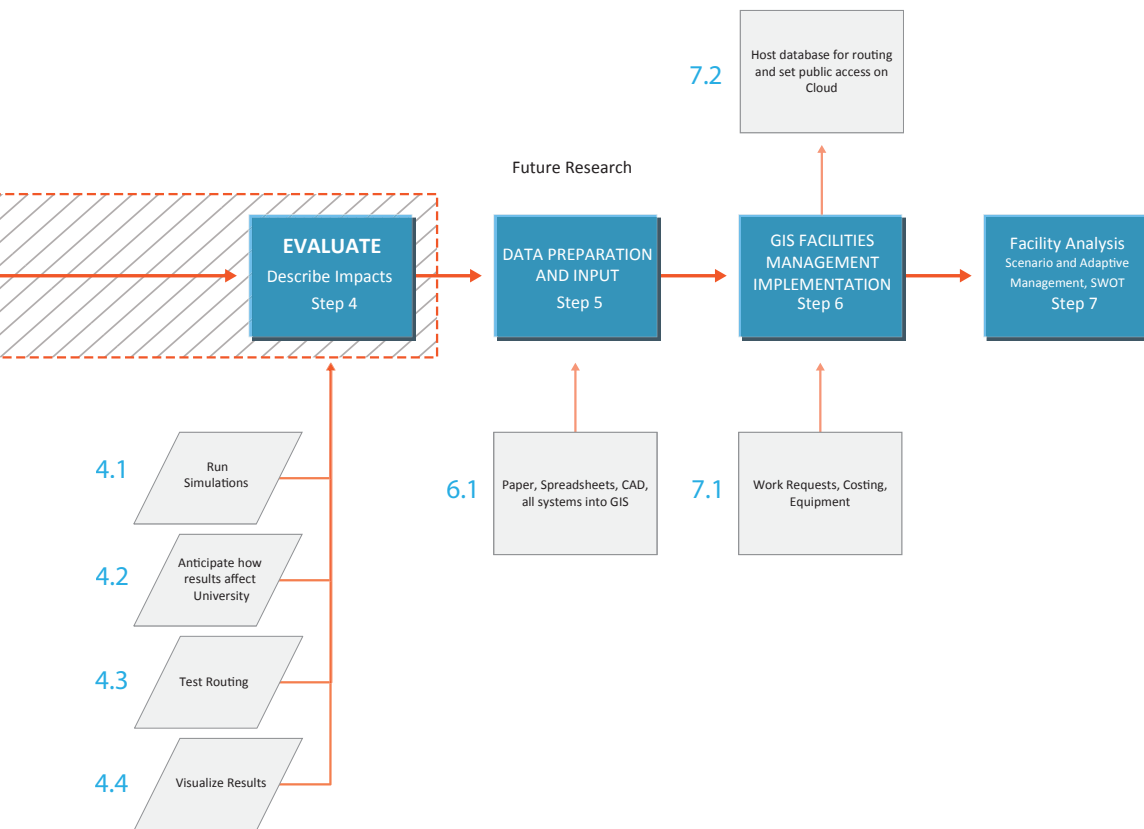


Figure 4-3 Framework Walkthrough

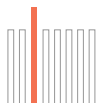


Contextualize

First, a baseline assessment for Kansas State was conducted to determine if a structured geodatabase was relevant. If the university already uses GIS to spatially document the campus and all departments work in a collaborative environment, then the need for a new system is not essential. Interviews with campus departments provided an understand of how the university currently functions. Also, it was desirable to understand departments openness to change related to a new system and how capable employees are with GIS software.

Assess

Secondly, case study research was conducted on both universities and communities throughout North America. In this phase of research, an investigation examined how GIS has been employed to solve spatial issues while ensuring maximum efficiency within the organization. This phase provided an understanding of best data management practices. Conducting case study interviews after the baseline assessment allowed comparisons where Kansas State University performed better and where other universities have a more complete system. After this phase, sufficient understanding existed to structure a database compatible with Kansas State University's visionary objectives of efficiency, health and safety, and



sustainability.

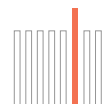
Analyze

The fourth phase of research applied the change model by adopting the best practices to Kansas State University. This was done through three stages: create a centralized geodatabase, create a 3-D routing network, and lastly create a 3-D campus model.

Evaluate

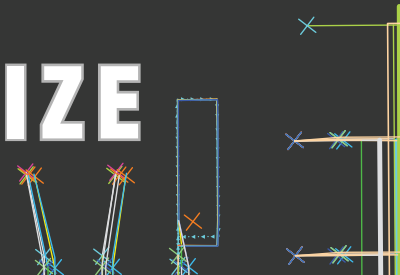
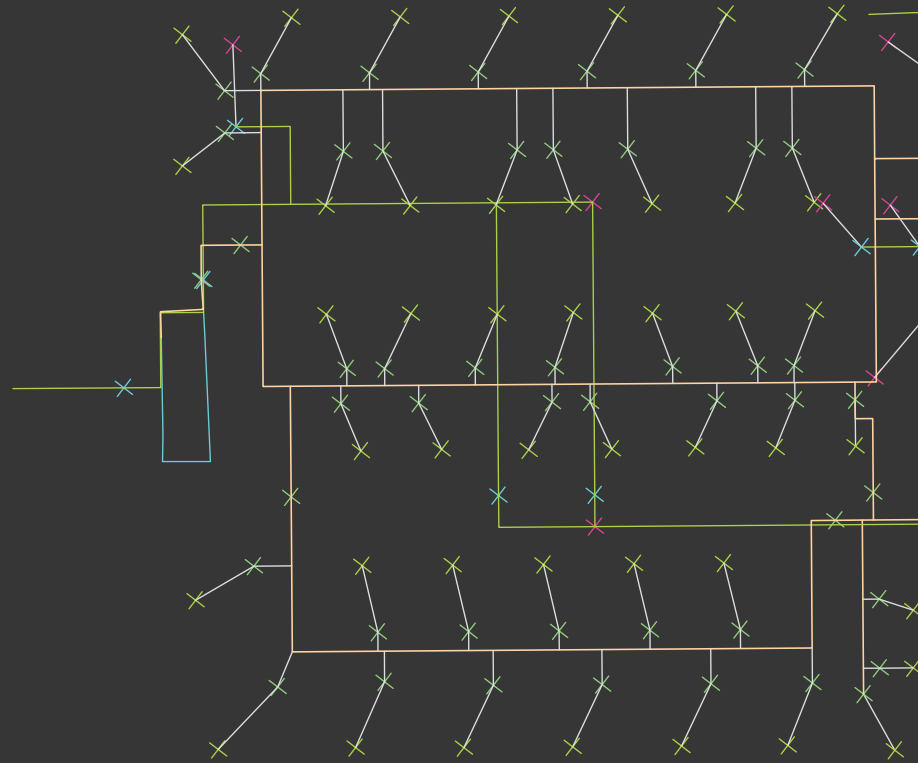
Running simulations in routing, service area calculations, and closest facility analysis verified the network. These tests analyzed the effectiveness of GIS as a means to promote the goals of the University.

This phase also focused on visualization of the data whether for routing, defining service areas, or delineating specific point features such as a fire hydrant.



05

CONTEXTUALIZE



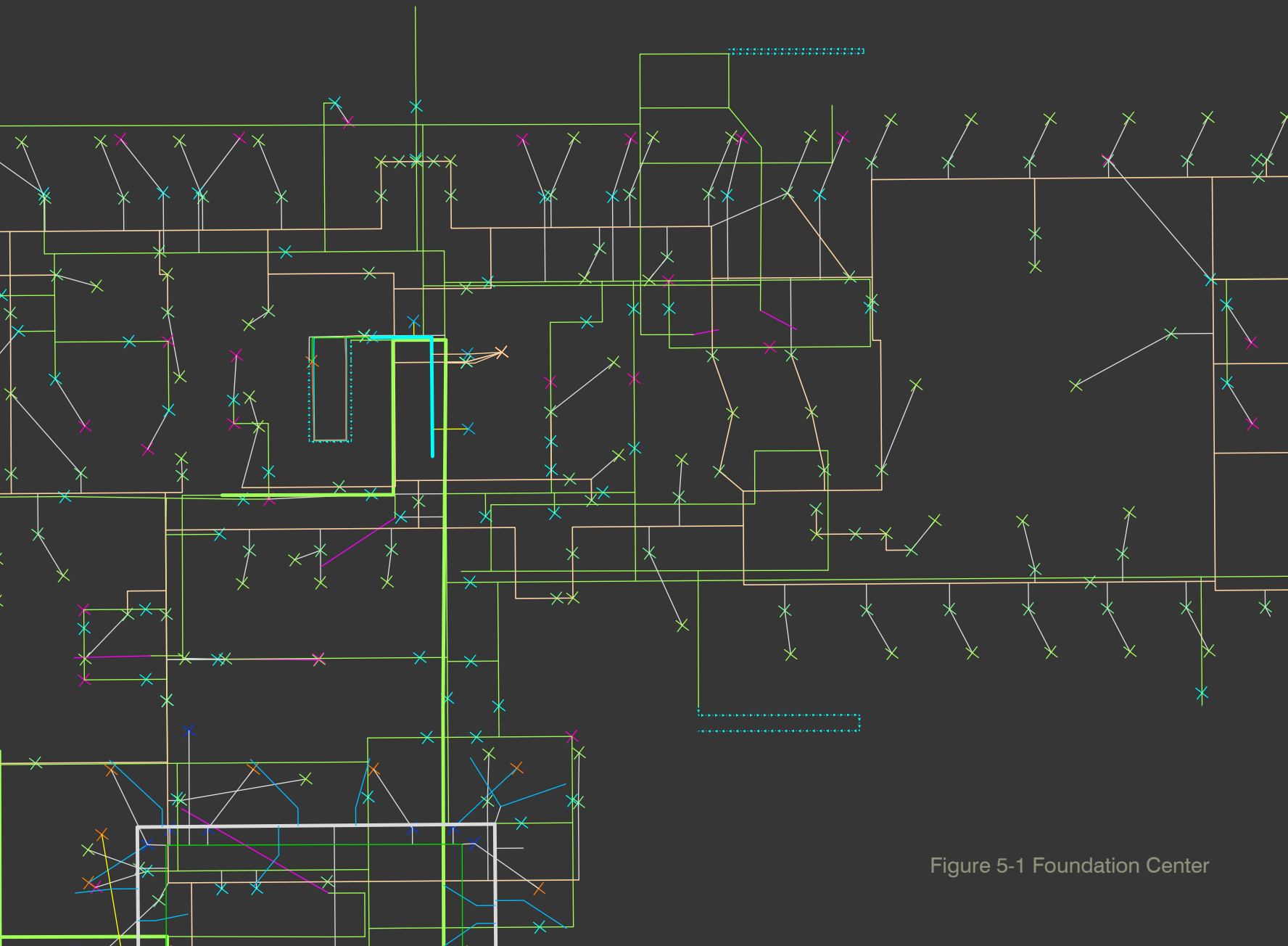


Figure 5-1 Foundation Center

The objective of this section is to determine how data management can promote efficiency, sustainability, and safety throughout the University. This section is composed of two parts. First, the context is evaluated for traditional practices concerning facility management and emergency response. These practices are not specific to any geography, rather they represent conventional norms. Secondly, a baseline assessment of current operations at Kansas State and Manhattan is conducted to understand how the university currently functions in both regards. After conducting a baseline, current operations at Kansas State can be compared with case studies recognized for optimizing facility management and emergency response across scales from community to university.

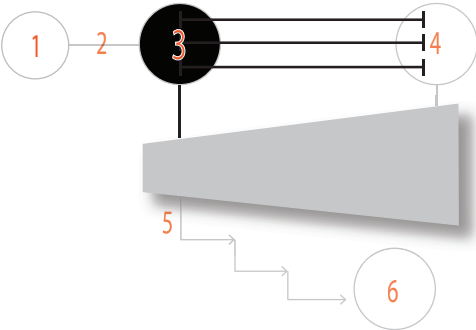


Figure 5-2 Research Framework
Contextualize is the third step of a six part research framework.

Facility Management

Traditional Practices

Trends in facility management over the last thirty years have not been favorable toward sustainability for built or natural environments. Over this time period, construction and maintenance of facilities account for 9% of annual US gross domestic product (Pacific Northwest National Laboratory, 2012). The largest

commercial facility growth was seen in educational sectors increasing by 50% since 1980, Figure 5-2. As more facilities are constructed, demands for water, energy, and waste removal increase; in 2010 alone, facilities “accounted for almost 40% of primary energy usage, 12% of water use, and 60% of all non-industrial waste. [Facility] appliances

accounted for 40% of US greenhouse gas emissions.” (National Research Council, 2012) Examining trends over the last thirty years prove the cumulative net impact for facility management is an unsustainable future model and must be altered. Experts agree, enabling technology such as GIS provides industry managers with the tools necessary for informed decision making and ultimately better stewards of the environment (Wallis, 2012).

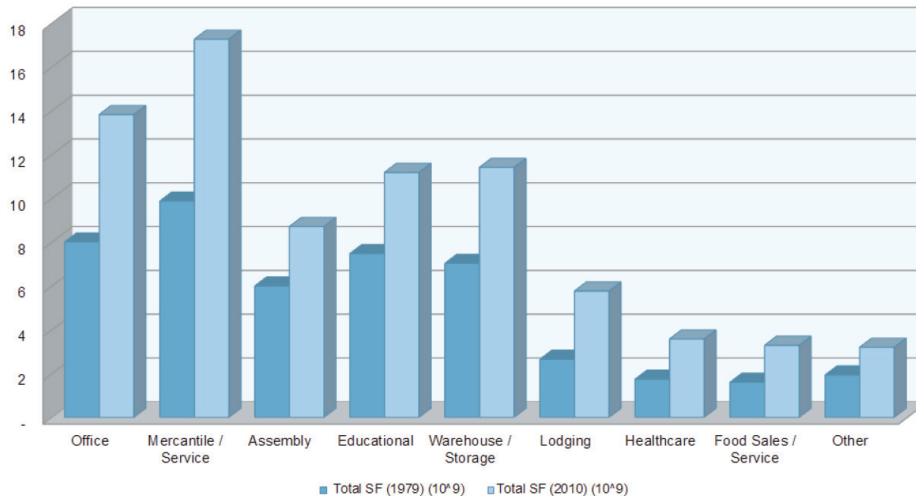
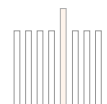


Figure 5-3 US Commercial Building Floor Space by Type (1979 and 2010)

Patrick Wallis, The Role of GIS Technology in Sustaining the Built Environment, 2012, 12

To reverse the trend in energy consumption, a new model for facility management must be deployed to direct Kansas State University toward a more sustainable future. A model utilizing Geographic Information Systems (GIS) will unify and centralize data making it accessible to all campus departments. A GIS database provides a flexible and efficient general platform for planning and analysis, especially with large datasets requiring constant updates such



as campus developments (Saleh and Sadoun, 2006). Over the last five years great advancements have been made in creating a common workspace for all data types such as AutoCAD and Building Information Models (BIM) (Wallis, 2012). Aggregating geospatial data enables managers of the built environment to gain holistic access to relevant facility information which supports fast, more accurate decision making. Refer to Appendix 2, Literature Matrix for a complete breakdown of the literature and techniques used for data integration.

and electrical infrastructure, structural integrity, and internal routing are strategic goals for increasing accessibility and safety for emergency responders. Emergency personnel such as fire, police, and emergency medical technicians will be equipped with the necessary information to locate the emergency in a specific building or classroom, direct the evacuation of all occupants out of harm, and assess the incident before stepping foot on campus (Environmental Systems Research Institute, 2005).

The compilation of data for facility managers and emergency responders has beneficial repercussions. Since September 11, 2001 Homeland Security has focused on enhancing response capability particularly in terms of situational assessment, awareness, and communication (Department of Homeland Security, 2008). Providing a centralized source for building data such as water

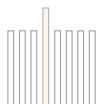




Figure 5-4 Literature Map

All benefits are leveraged through a centralized database.

Facility Management

Kansas State University Baseline Assessment

Interviews were conducted throughout the departments of Planning, Space Management, Facilities, Parking, and Campus Police to determine how data is stored, managed, updated, and distributed between departments. It is the people of the place who can perceive the conditions of a study area and determine if it functions well or not. These evaluations are based upon institutional knowledge and are often generated by job security, decline, or of change itself. (Stienitz, 2012, 38) Interviews evaluated the interest in creating a unified geodatabase with data shared between entities. Interviews with facility management personnel attempted to query how they currently maintain facilities, how work requests are handled, how they assess equipment failure, and how they divide the workload between employees. Opinions were solicited concerning the possible benefits associated with GIS (please refer

to Appendix 3, Facility Survey Questions). These same questions were asked to other communities and universities to get a sense of best practices, which is discussed in greater detail in Section 7 Analyze.

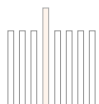
Initial questions probed how the current system is utilized and kept current. A set of follow up questions targeted potential interest in an aggregated dataset and how they might use a new system, their willingness to learn new technology, and interest in simulating scenarios. “For action to take place we must visualize and understand differences between “before” and “after,” (Steinitz, 2012, 46) Follow up interviews will gauge interest in creating a more sustainable and efficient campus even if it initially means more work to catalog and digitize campus infrastructure.

Trends started to appear related to data

accessibility, collaboration, and analytical capacity. Several variables also emerged that will be examined and used for the Manhattan assessment.

Data Accessibility

Data exchange is tricky between Facilities, Planning, and Management. What was once a unified department has been restructured to operate independently in terms of finances and responsibility. All of these departments operate directly under the Vice President for Administration and Finance. Due to this independence, each department feels proprietorship of the data and in most circumstances are not willing to distribute data. Data stays internal to the department and cannot be used by others. For instance, the Conservation Energy Shop on campus, who is responsible for overseeing the efficiency of energy, routinely views and edits utility maps for electrical infrastructure

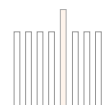


and electrical switches. The data, which stays up-to-date, will not be shared with campus Facilities or Planning who may need switch information to replace a piece of equipment. Instead a guess is made as to what switch controls what building. The other method is to walk around campus, locate a hard copy of the map, and then walk back with the map in hand to find the right switch.

Kansas State Facility Management operates completely with hard copy maps: 16-scale floor plans, paper irrigation plans, and infrastructure lines. Planning has a few CAD drawings for exterior infrastructure and floor plans. These drawings lack any spatial information. They are not smart objects containing attributed data for capacities, room numbers, room use, or department. Without data, spatial analysis is impossible.

Facility Asset Management Information Systems (FAMIS) is the current system used for Facilities as a database for all CAD documents. Basic building information in FAMIS includes buildings, floor, and room numbers. Additional data can be attributed such as department, room use, and capacity. (UNM, n.d.). FAMIS is used at K-State for asset management, work requests, inventory control, and space management. A new update was recently introduced and this provided an opportunity to shop products. The decision was made to transition to AiM, an Assetworks product. The choice was made because AiM has more potential for K-State applications in terms of tracking maintenance, dashboard visuals, and ad hoc reporting, as well as the same CAD integration FAMIS provided.

AiM will utilize the same Oracle database formerly used by FAMIS, allowing for an easy crossover. AiM is a table-based reporting system allowing easy data input and upkeep without extensive technical knowledge (AssetWorks, 2013). Restrictions can be set on who can assess and maintain data. Facilities will use the AiM system for complete project workflow. Everything will be integrated into the AiM system including room records, finishes, fixed and moveable equipment, asbestos, and fire codes. The Building Condition Assessment Survey conducted by campus employees in 2012 will be inventoried in the database. This survey cataloged all building components and equipment from “poor” to “excellent”. The ultimate goal for is to make a self-service system available on campus where the database can be accessed and work requests can be generated.



Collaboration

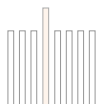
The independence of campus departments has stifled collaboration amongst the university as well as the community of Manhattan. This struggle between departments is recognized and a remedy has been discussed by creating a floating position directly under the Vice President who manages and distributes spatial data to the departments. This way Facilities, Planning, and Management will not have to focus on data management and can concentrate efforts on other tasks. The role of the Facility Manager can then evolve from a technician, to a manager and policy advisor who oversees campus-wide programs to address all phases of the management lifecycle. A lack of organized digital data intermixed with university politics have repressed any attempts for collaborative interchange.

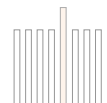
Analytical Capacity

Hoarding data eliminates the potential to spatially analyze the campus in a number of ways. It is not currently possible to accurately determine water usage, irrigation rates, or impacts of altering the irrigation schedule. Over 4.5 million square feet of building footage will be added over the next 20 years, with no way to determine associated impacts. Currently, there is one meter recording water use for the entire university, and campus facility workers are uncertain as to where campus connects into city water utilities. How will the campus know if they are building intelligently if data is not recorded, organized, distributed, and visualized from department to department? How will the shared goal of making K-State a top 25 public research institute by 2025 happen without a unified, informed front? The current mentality must be shifted to formulate a long-term vision, overcome resistance to change, and lead through informed decision

making.

Conducting a baseline for Manhattan, Kansas was done using the same evaluators applied to operational success for the university: data accessibility, collaboration, and analytical capacity. These criteria allowed a grounds for comparison to the university and also the best practices to be determined.





Emergency Management

Traditional Practices

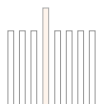
Emergency response has undergone a drastic transformation in terms of best practices for servicing a community. I identify the evolution of fire and police response in three stages. The first and most traditional methods utilize paper copies of information such as paper run books, street maps, and floor plans. The second phase is a shift to digital data: CAD files, electronic spreadsheets, and property information accessible through web services. The last and most advanced phase is that of an integrated, highly interoperable system allowing for data analysis, most typically a Geographic Information System (GIS) database.

Stage 1

Traditionally first responders have relied upon experience, practiced skill, and teamwork to fulfill their duties (Johnson and Davenhall, 2005). Experience coupled with numerous paper maps, reports, tables, and historical records were

the tools of choice. These maps visually communicated operational assignments, potential spread scenarios, and provided a visual reference for strategic response. They were used to answer questions such as: Where is the emergency? How do we get to the scene? How do we access the incident? Although effective, these disparate forms of data required a great deal of time to aggregate, prepare, and formulate into an effective plan for response. Keeping paper documentation up-to-date is even more problematic.

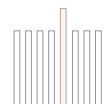
To test service areas and possible locations for new facilities, a fire vehicle was sent out with a stop watch to drive an area and mark travel times over the street network. This approach has many limitations including varying roadway speed, distances, time of day, and availability of crews (Johnson, 2000). Additional limitations emerge when street networks are constantly evolving.



Once again, paper maps must be used in combination with personal experience because it is difficult to represent one-way streets, traffic congestion multipliers, or 3D interior environments on paper.

As communities and populations grow, the role of fire service becomes increasingly demanding and complex. A tipping point occurred where traditional, paper maps were not enabling emergency responders to service their communities effectively. Fire service must be delivered with greater efficiency and economy than ever before. “Our ability to use old manual systems quickly is ending. The staff that’s stuck with a notebook on a fire truck- we just don’t have the time to mess with it. What is beginning, is to automate the decision making process by giving tools to the people at the particular levels who need them.” (Keith Richter, Fire Chief of Orange County Fire Authority, 2012) The pressing challenge placed on emergency

response requires effective planning, risk management, training, and deployment through preparation. To service dynamic communities, increasing amounts of floor plans, maps, and information is required for safer, faster, and informed deployment. Digital data replaced hard copy maps in most communities due in large part to technological advances and added strain of increasingly complex environments (ESRI, 2006).



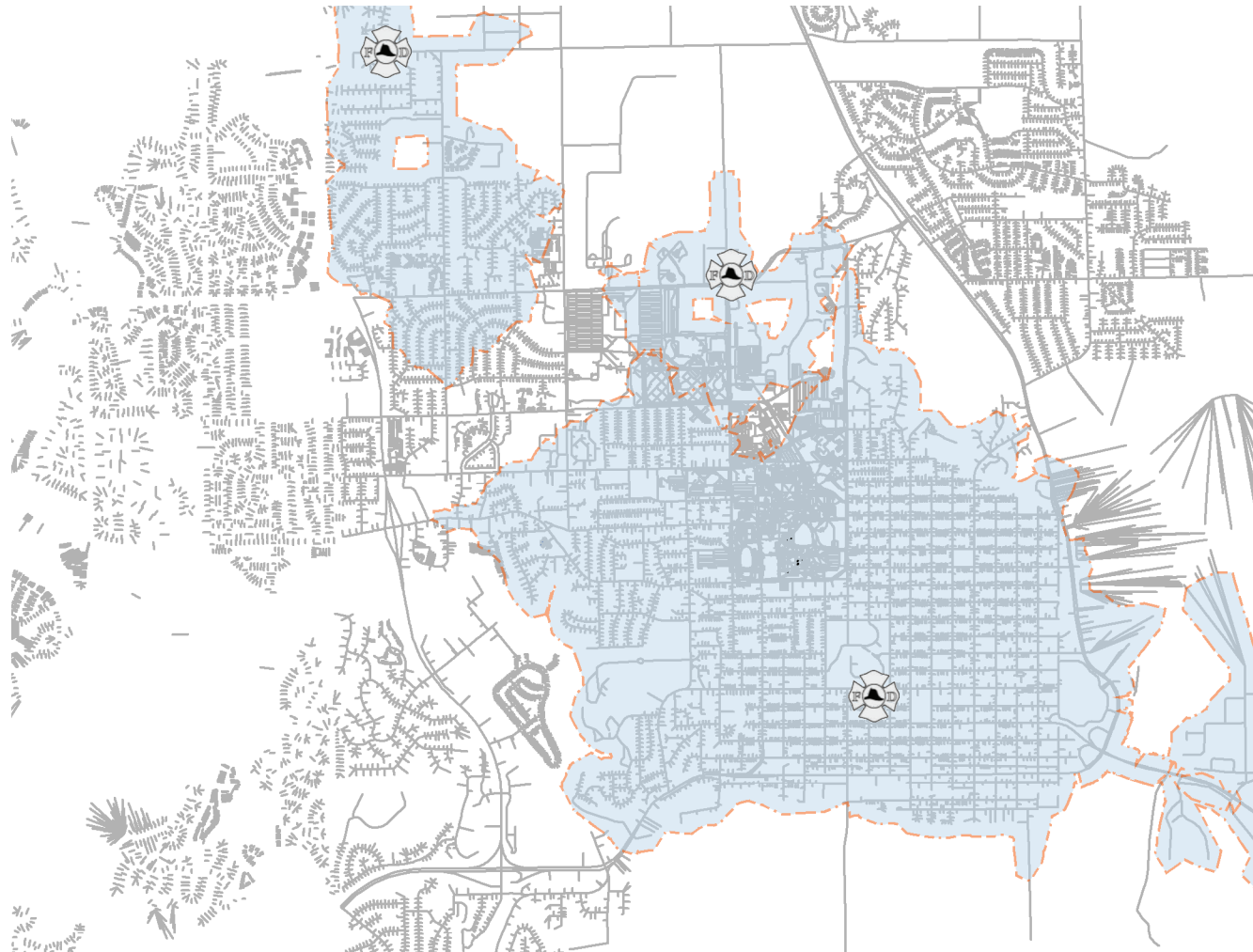


Figure 5-5 Service Area for Manhattan

A five minute respond time was calculated from the three fire stations in town. Gaps in coverage are noticeable throughout the north side of campus.

Stage 2

The decisions that must be made quickly require geospatial information such as building footprints, fire department connections, and fire hydrant locations. Often this information resides in separate locations and in different formats. Although fire response and accompanying decisions benefit from digital forms of data, this practice is also limited in terms of data access and organization. Digital information allows for a call to be georeferenced using computer aided dispatch (CAD) software (Price, 2010). At the dispatch center, a trained operator captures, interprets, records, and maps the incident with as much secondary information as possible. After identifying the locations, the CAD system matches the closest emergency resource with the call type and sends out the digital information with voice instructions. The era of digital data represented a huge transition over paper maps which were no longer needed in emergency vehicles to provide information; rather it could be sent and accessed enroute with a laptop.

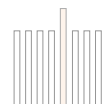
Stage 3

The challenge then becomes accessing copious amounts of spatial data efficiently at the right place and time. Volumes of data are often inaccessible due to lack of interoperability. GIS works to bring many forms of data together providing powerful analytical and visual capabilities. Models can then be made to virtually assess conditions to predict, plan, and monitor service delivery. Response times are critical for emergency personnel and can be assessed using GIS and routing. A quick response can represent the difference between life and death, between property protection and total loss. Traditionally, response times were gathered by driving the streets and recording times with a stopwatch. Now with GIS, response times can accurately be calculated down to the second and areas being serviced or subserved can be identified.

Service areas, or areas an emergency vehicle can travel within an allotted time, are calculated using network datasets, Figure 5-4. Information for streets,

sidewalks, building entries, stairwells, and elevators are connected and attributed with information on length. Speed limit, average daytime speed, historical traffic patterns, and one-way information are included, to name a few (ESRI, GIS for the Fire Service, 2012). The output of this system is a representation of response time capabilities which can be shared with stakeholders.

GIS is a shift tying layers of information together in a geographic context. An integrated platform fosters collaboration and data sharing across political jurisdiction, enables spatial analysis, and visualizes the information in a way meaningful to decision makers. GIS is an evolution from inventorying asset features and floor plans to analysis to determining how well the study area operates.



Emergency Management

Manhattan, Kansas Baseline Assessment

A baseline assessment for Manhattan, Kansas was conducted using the same evaluators employed for operational success at the university: data accessibility, collaboration, and analytical capacity. These criteria allowed a comparison to the university, along with a determination of best management practices.

Accessibility

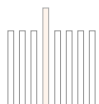
Dispatch for emergency services is still conducted using basemaps. The basemap created last summer, discussed in the Preface, is the most current map for campus routing. Other maps are used throughout Manhattan and are all stored at the dispatch center. Routing for emergency response is done through memory. The first phase in training a new fire or policeman involves memorizing streets, neighborhoods, and address ranges. This method has presented a problem recently. The experienced

veterans of the force retired, and a new, younger workforce took over with very limited knowledge of the area. Routing is made especially difficult in times of emergency and is purely attributable to the nature of the situation. Routing tests have proven this transition difficult. Recently a fire truck idled at an intersection for nearly three minutes unsure of which direction to go.

Spillman and Firehouse are the two software packages used by Fire, Police, and Emergency Services in Manhattan. Manhattan uses Spillman as an integrated solution to comprehensive data management for public safety agencies. The software provides a single-source database enabling users to input, store, and retrieve data from a centralized location (Spillman, 2013). Spillman has CAD and GIS environments capable of searching address parcels and pulling associated information such as property owner,

call history, and possible hazards. The Spillman system is confined to inventory assessments rather than providing analytical capabilities. For instance, when a call comes in, the dispatcher can map the incident and associated information, then identify the closest unit and send the information to the individual. A GIS-based system with analytical functions could automatically map the call, initiate a closest facility analysis, and then send all information, without a dispatcher routing the call and information. Often, analysis for emergency response depends upon a routing network to determine spatial proximities to and from an incident.

Firehouse software is used for staff management and record-entry management more so than a spatial mapping program such as Spillman. This software is similar to Spillman in that it works as an integrated solution for data management which can be shared



among users. Firehouse is used for incident reporting, recording staff activity, staff scheduling, occupancy plans, and equipment management (Firehouse, 2013, 3). Data is available on many platforms including smartphones, tablets, or an iPad for occupancy or hydrant inspections. Firehouse does not perform analysis, but FHANalytics is an effective way to plot graphs, charts, and dashboard visuals of existing circumstances.

Collaboration

Spillman and Firehouse are used by the MFD, RCPD, and EMS. This unified system allows for data sharing and serves as a repository for spatial data. Data can be accessed, but these systems only serve as an inventory and do not possess analytical capabilities. Unfortunately neither Spillman nor Firehouse software packages are used for facility management, and response data cannot be integrated into K-State's workflow

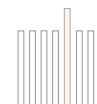
or vice versa. Currently, information exchange does not exist between the university and Manhattan primarily due to a disorganization of disparate forms of data. A GIS system could integrate all forms of spatial data across scales and jurisdictions to alleviate many of the issues inhibiting optimal practice.

Analytical Capacity

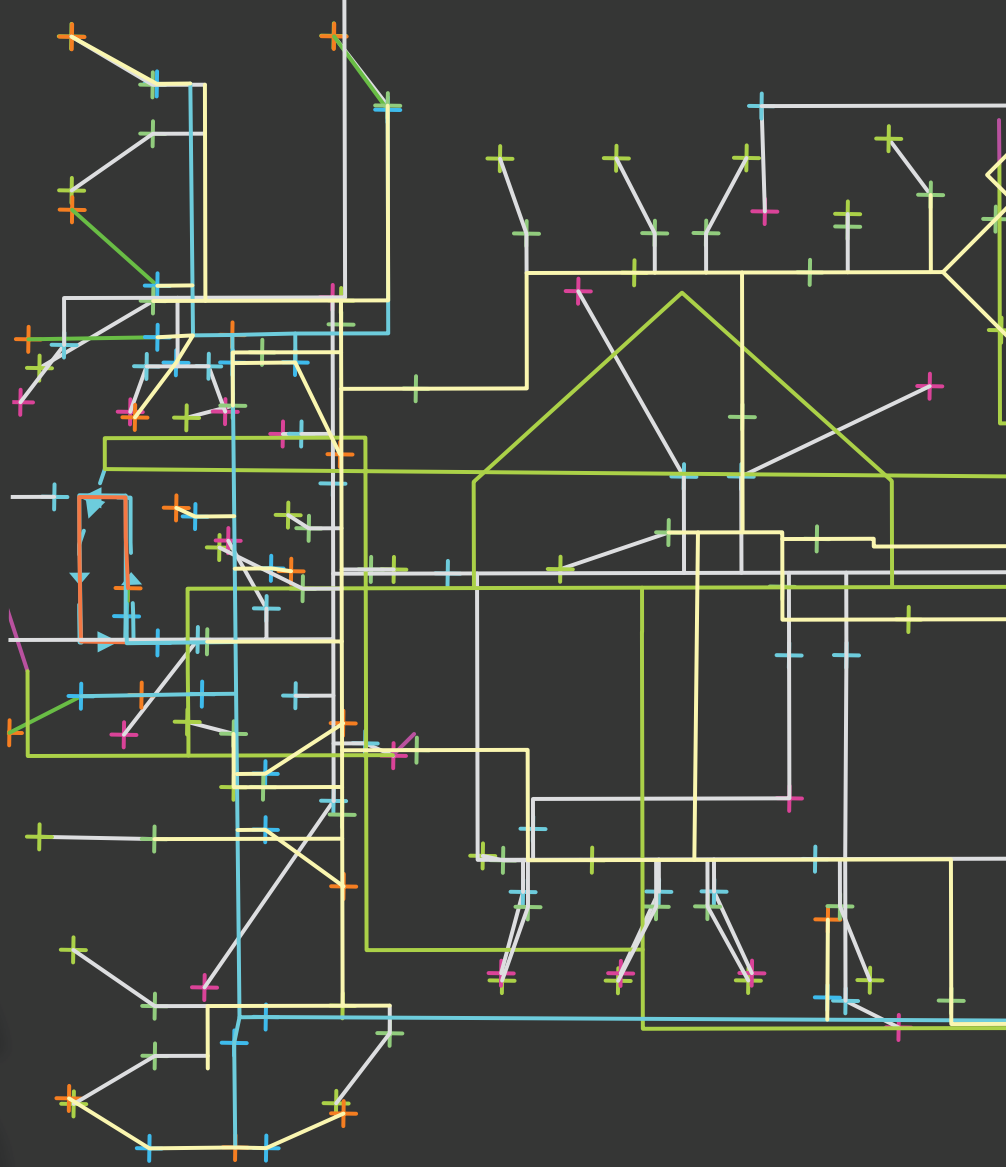
Recently there has been interest in retrofitting emergency vehicles with monitors or tablets to visualize routes and building information while driving to the scene. This will happen if a system is created that is easy to maintain and requires limited technical knowledge to use and update. MFD has focused on enabling minimally trained people to run spatial analyses. Many catastrophic events can be reduced or removed all together if the public are informed of their surroundings.

"The first thing that happens when

there's a situation, is the plan goes out the window. The ability to collect all the data necessary to form an overall picture of what's going on has to be a GIS application. I can't see it happening any other way, " (Martin Flemion, Director of Emergency Operations, City of Laurel, Maryland). GIS aggregates all forms of data into a common workspace, and then makes this information immediately accessible. Most important of all, a GIS database enables spatial analysis and provides ammunition for intelligent decision making. Routing plans, service area calculations, determining closest facility, and identifying important features such as hydrants are all made possible through GIS.



06 ASSESS



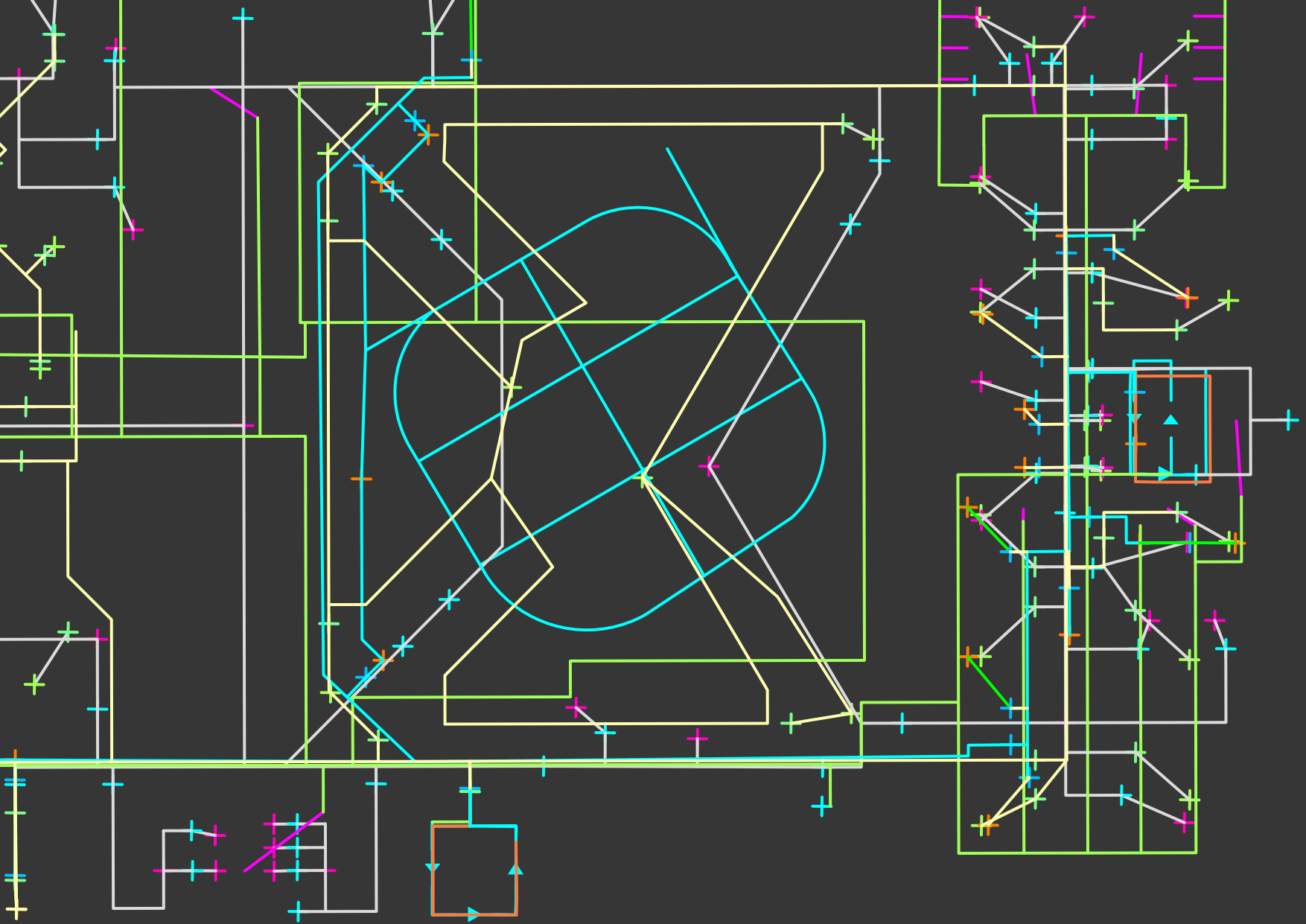


Figure 6-1 Nichols Hall

The main objective of the Assess Section is to define best practices for data management. This is done by researching exemplar case studies from universities and communities proven to be effective in this category. By understanding efficient techniques elsewhere, we can identify effective practices and provide a comparative pulse to evaluate areas where K-State can improve. The initial question is: Does this study area function well? In the traditional sense of providing services to a designated geography, yes, the study area functions well. Emergency response is able to service Manhattan, and Facilities is able to service campus. But are they servicing these areas as efficiently as they could? The answer is no; current practices and software do not provide optimization capabilities. For instance, currently it is not possible to determine the effects of any policy decision, update of equipment, or an expanded community or service area. The question then shifts

to: What can we do about it? How can we modify current practices to achieve goals of proactive, intelligent response?

In this section best practices for facility management, coupled with emergency response practices, will be identified using several case studies from universities and communities around North America. Best practices for emergency response are then compared with Manhattan; likewise, best practices for facility management are then applied to campus facilities.

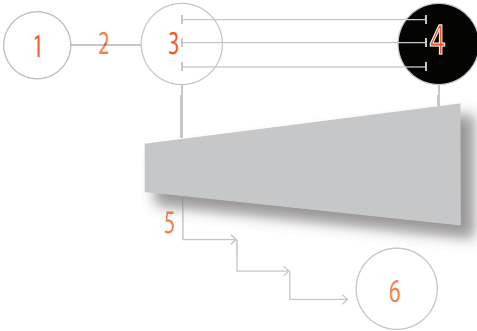


Figure 6-2 Research Framework

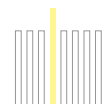
Assess is the fourth step of a six part research framework.

University Case Studies

The first step in building an operational and successful system for facility management includes assessing needs and understanding best management practices. A baseline assessment for KSU was conducted and documented in Section 5- Contextualize. Comparative case studies were then used to gauge how other universities manage data to establish workflows promoting efficiency, sustainability, and health. Where applicable, information garnered in the case study review was used to identify deficiencies of KSU and suggest prescriptions.

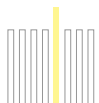
Recruitment Process

The procedures for selecting universities for comparison were largely based upon the amount of published reports the University had related to using GIS for facility management. More published universities typically have a more-established system with more data



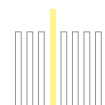
available regarding the success or failure of a GIS-based system. These universities are able to evaluate economics and sustainability of the system and can serve as a prototype for KSU as far as projected outcomes and implementation. Additionally, samples were gathered with a geographic range to eliminate the occurrence of possible bias for particular issues. Universities with a municipal population around 50,000 people, similar to Manhattan, that have taken proactive steps for including the community for data management were favored for selection. The case studies focus on data accessibility to promote health and safety, efficiency, or sustainability. These schools serve as an archetype for KSU due to their prioritization of data management at the university and community level; the methods for data management will be evaluated and adapted for KSU's master planning objectives. Overall, twelve schools were assessed, (Figure 6-2, University and Community Case Study Matrix).

Before selection, universities were plotted based upon primary focus: facility management, emergency response, and safety, Figure 6-3 University Scatterplot.



University and Community Case Study Selection Matrix				
University Name	Location	2012 Enrollment: Undergraduate and Postgraduate	Community Population:	Primary Focus
University of Texas, Dallas	Dallas, Texas	51,112	1,197,816	Efficiency
Washington University	St. Louis, Missouri	14,070	319,294	Safety
Frisco School District	Frisco, Texas		116,989	Safety
University of Oregon	Eugene, Oregon	24,447	156,185	Safety
Pomona College	Claremont, California	1,586	34,926	Sustainability
University of Calgary	Calgary, Alberta, Canada	31,327	1,096,833	Efficiency
San Francisco Community College	San Francisco, California	33,834	805,235	Sustainability
Rochester University	Rochester, New York	10,326	210,855	Efficiency
Kuwait University, Sabah Al-Salem	Kuwait City, Kuwait	37,702	151,060	Efficiency
UNC Charlotte	Charlotte, North Carolina	25,277	751,087	Efficiency
Community Name		Population (2010)		Primary Focus
Wilson, NC		49,167		Safety
Buffalo, NY		261,025		Safety
North Las Vegas, NV		229,224		Safety
Colorado Springs, CO		416,427		Safety
Orange County, California		3,010,232		Efficiency
Frisco, TX		116,989		Efficiency
Philadelphia, PA		1,526,006		Efficiency
Las Vegas, NV		583,756		Efficiency
Napa County, CA		138,088		Sustainability
San Francisco, CA		805,235		Sustainability
Moscow, ID		23,800		Sustainability

Figure 6-3 Case Study Matrix



EMERGENCY MANAGEMENT

FACILITY MANAGEMENT

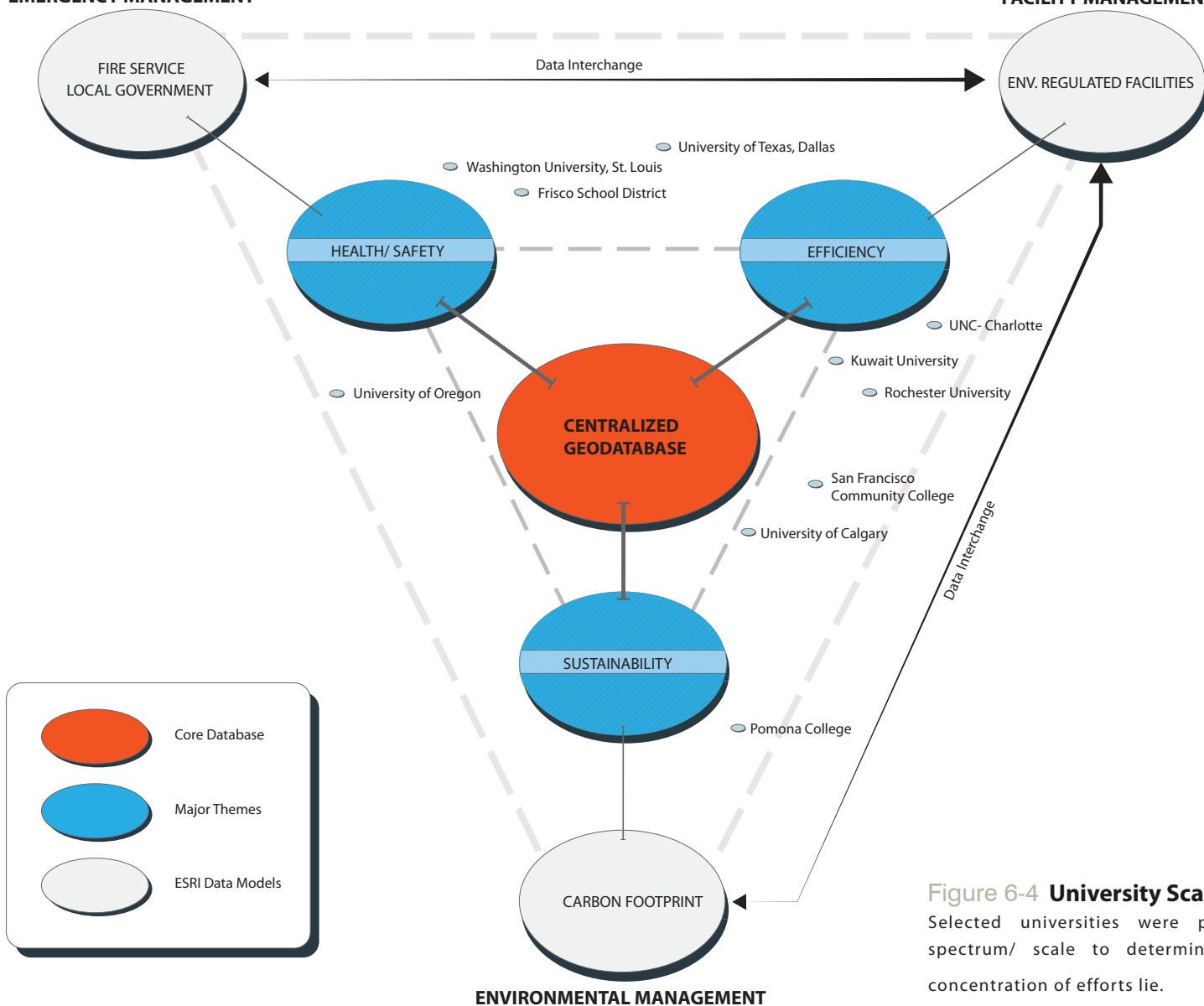
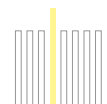


Figure 6-4 University Scatterplot

Selected universities were plotted on a spectrum/ scale to determine where the concentration of efforts lie.

Already trends are starting to appear in how data is managed and utilized. Data is widely shared between Emergency Management and Facility Management (Figure 6-3 University Scatterplot). Data is even commonly shared between Environmental and Facility Management but very little information exists on how to incorporate or combine data models between Emergency and Environmental Management. Few case studies focus on the interconnection between Emergency and Environmental Management. Additionally, the literature is sparse when investigating how to use similar data to promote health and environmental sustainability. Universities see facility management as the central organizer to effective emergency and environmental management. When facilities are mapped effectively, data can be communicated to other venues such as emergency or environmental management. This establishes a collaborative environment empowering data interchange benefiting all parties.



University Best Practices

Assessing best practices were conducted in the same manner as Kansas State's baseline in terms of evaluating data accessibility, collaboration, and analytical capacity. Evaluation using the same criteria ensures consistency and allows for direct comparison. We can measure collaboration qualitatively and directly compare differences. These three indicators provide a refined framework for evaluating other universities while providing guidance on what to identify and which practices are most desirable. It is then possible to directly assess areas of improvement and accurately target these methods with an established, proven practice. A framework helps define guidelines on what techniques to focus on, what practices are most effective, and what practices have room for improvement. Categorizing practices into these three categories provides an additional level of understanding to deeply investigate the success of certain methods.

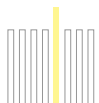
Data Accessibility

Data accessibility, in the context of university data management, refers to the ability for various campus departments to access essential data to perform their daily operations effectively. All case studies use ESRI ArcGIS software to understand campus geography through analysis and visualizations enabling intelligent decision making. GIS is used across scales from a building, campus, or community allowing seamless data integration uniting CAD, CMMS, and EAM which are commonly used for Facilities Management (Daily and Stockton, 2012).

Conventionally, the starting point for many campuses is exactly where KSU currently resides. Many forms of digital data float around, unorganized, and inaccessible by many who need it. The first step is to aggregate all data together into a central repository. University of Calgary has possibly taken the greatest strides, where they have integrated

university data with community data used for emergency response. The University feeds data to emergency responders for immediate informed response (McCaffrey and McElvaney, 2011). This has fostered a sincere relationship to encourage trust, advocate a team atmosphere, build consensus, and facilitate communication (ESRI, 2008). University of Rochester, Washington University in St. Louis, and Pomona College decided a GIS-based repository would serve the needs of the university and community best because it was already being utilized at the community level. Since both entities were using GIS, data sharing was made very easy.

Data acquisition by campus departments in need will streamline workflow. No longer will separate entities battle over data or fear repercussions from sharing data with outsiders. Proprietorship will no longer seize efficient management. At KSU, efficiencies optimizing data



accessibility can be made for work requests. Work requests for repairs can take weeks or months to complete due to inefficiencies in the system. The current workflow is as follows: log the request, manually inspect the reported scene, return to the Department of Facilities for the hardware, walk back to the scene, repair the hardware, and finally walk back to Facilities to log the repair.

An integrated system, like the University of Rochester in New York, will modify workflow to allow university staff to log an incident on their own, which then alerts Maintenance, where they can access the spatial database to determine the needed hardware, and then repair the request (Goldwater, 2006). Since the University of North Carolina- Charlotte has implemented a GIS database for the Department of Facilities, many other departments have jumped on board and agreed to log and upkeep data including Work Order Systems, Space Management,

Project Management, and Asset Management (Dinello, 2012). At UNCC, building and asset data will be combined with real estate and infrastructure data to create visual representations and improve the competitive advantage (Richardson, November 2010).

Collaboration

Collectively, all university case studies have an integrated GIS system with the surrounding community. They provide information to emergency response such as response maps, routing, utility information, and fire connections. “The City of Calgary also uses ArcGIS so data sharing is very easy. We supply the city and fire departments with the emergency response maps,” (McCaffrey, 2013).

The University of Washington in St. Louis was home to the 2008 Presidential Debate which required stringent security. The university has a coupled database shared with the city of St. Louis for

all emergency response (Richardson, October 2010). The St. Louis County Emergency Management office alongside the Department of Facilities loaded necessary detailed vector information including, streets, places of interest, and university facilities. If a situation arises, campus information can be directly accessed by emergency workers without having to tap the university database for information. Brad Averbeck, Facilities Manager for Washington University claims, “The fact that both were standardized on the same platform made what could have been a headache of a task into something very manageable.” Within two weeks of receiving funding for the project the database used to inform police and security, the 2008 Vice Presidential Debate Common Operational Picture, was complete and ready to use.

The University of Rochester and the City of Rochester, New York’s databases are so integrated they operate as a single



system. A virtual 3-D campus was used as a base for data integration, complete with infrastructure lines, 6" pixel aerial imagery, and modeled buildings (Dickman and Raus, 2011). This 3-D campus has been advantageous for fundraising, 20-year master planning, and 3-D analysis for solar gain. Currently CAD is used at KSU which can robustly model individual buildings, but it poses difficulties relating attributes to each other or to other data. (Goldwater, 2006, 4). University of North Carolina in Charlotte has focused on improving organizational collaboration and strategic decision making by merging all database information on campus into a unified GIS geodatabase. Unlike KSU, data belongs to the university and not the individual department.

Analytics

Analysis is enabled through an integrated GIS database. The number of analytical studies is infinite with organized data. Typically for a university, GIS is used by the Facilities Department to manage

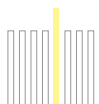
assets, infrastructure, and work requests. The case studies presented analysis in several areas, four of which are very applicable to KSU: irrigation, lighting, shadow studies, and routing.

Irrigation

Pomona College strategized on a possible GIS solution to campus sustainability goals. A campus wide audit was conducted for sustainability issues: permeable paving, native plant palettes, an efficient irrigation system, and landscape shading. The college geodatabase was used to assess options for achieving the goal of reducing water and energy use. Pomona created a terrain and basemap similar to what KSU already has. They ran a hydrology model to determine where the water was draining and possible areas to convert from hardscape to native vegetation. Converting to native plants reduced water demand. They further promoted water conservation by changing from spray irrigation to drip.

According to the 2011 Sustainability Action Plan, over a four year period, Pomona reduced water usage by nearly 15% by:

- Converting 5,148 square feet of shrub area from spray irrigation to drip
- Converting 3,346 square feet of groundcover area to mulch
- Converting 21,179 square feet of shrub area to mulch



Lighting

A major safety concern is the illumination of walkways at night. Public safety can be enhanced by identifying dark areas and proposing new lighting. A GIS model can be created to estimate light distribution based on the type and wattage of light fixtures. University of North Carolina-Charlotte conducted an analysis to determine the darkest walkways with the furthest proximity to building entries or emergency phones. Crime data was integrated into the analysis to determine the darkest areas with the highest crime rates. Efforts were then made to increasing lighting and surveillance at night.

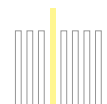
Shadow Analysis

University of Calgary has created a 3-D campus to understand the position of shadows on potential buildings. Generating a 3-D surface with building models, the position of the sun and can be tracked to assess shadows on a building or open space. This technique can specifically determine how long an open space will sit in shade and exactly

how much light a planting bed will receive throughout the year.

Routing

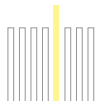
Routing may provide the most benefit from a wayfinding and risk management perspective. A university can enhance public safety, foster a more welcoming environment, and build a connected culture through a routing network. University of Calgary used up-to-date floor plans to create emergency preparedness and response maps which they supplied to police and fire services. The team was then able to stage hypothetical situations and calculate several possible evacuation routes based upon the type of emergency. The routing information was then posted on a centralized website accessible by facility managers, emergency responders, and the public (McCaffrey and McElvaney, 2011). To date, the interactive room finder website has been up and running for 18 months and has received over 1.5 million hits. “This was a simple idea that has evolved into an important service for our university. I truly feel like we have made a difference in moving forward to our goal



of a top five research university,” Tom McCaffrey (McCaffrey, 2012).

Takeaway Best Practices for Universities

1. Integrate all spatial data with a shared, enterprise-level GIS database
2. Create a network dataset for routing
3. Build a 3-D campus for visualization



Kansas State University Baseline Assessment

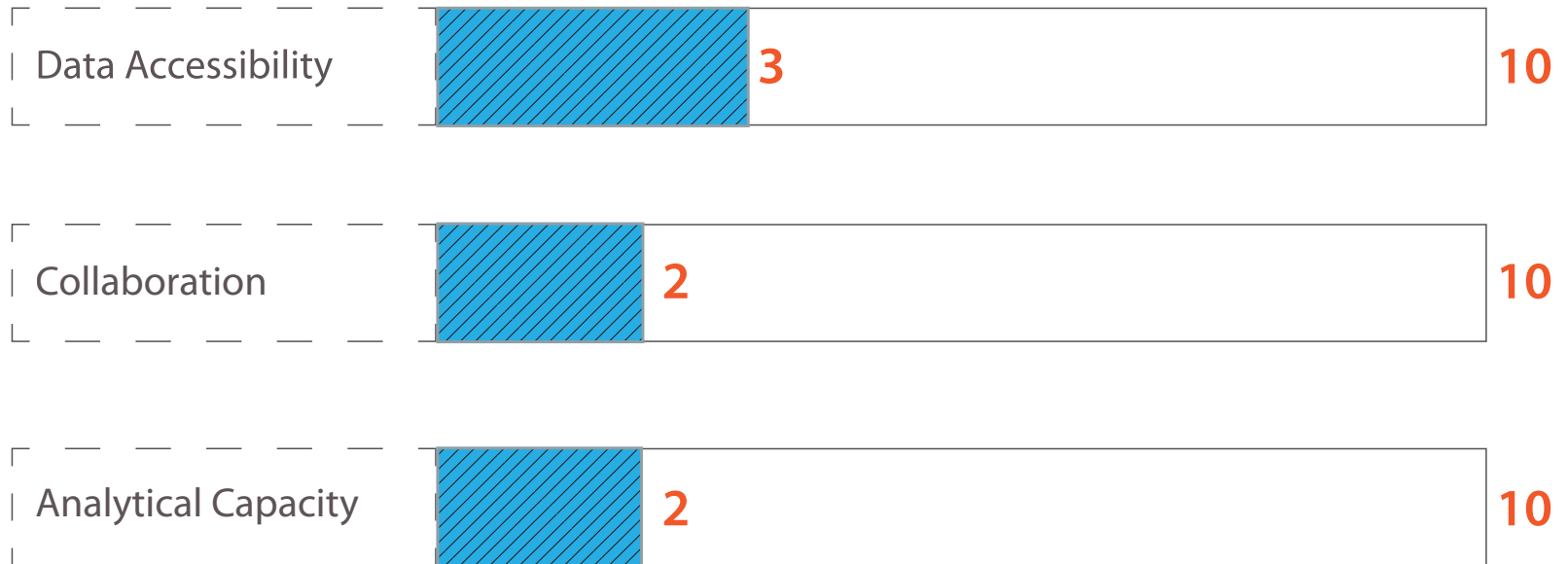
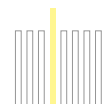


Figure 6-5 **Chart of Kansas State University Baseline Assessment**

Current data management techniques limit accessibility, collaboration, and analytical capacity. This is a quantification of a qualitative assessment.



EMERGENCY MANAGEMENT

FACILITY MANAGEMENT

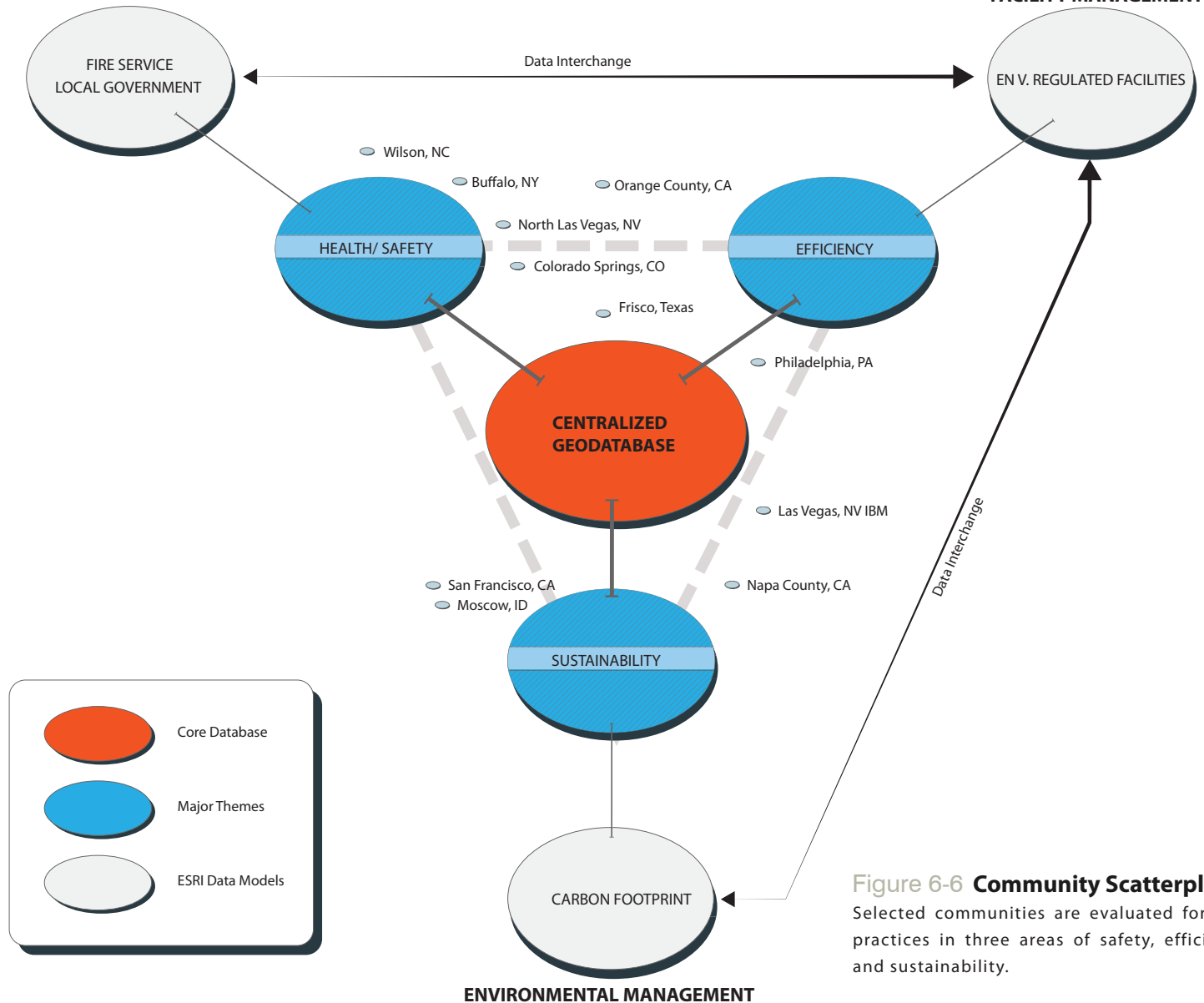


Figure 6-6 Community Scatterplot
Selected communities are evaluated for best practices in three areas of safety, efficiency, and sustainability.

Community Case Studies

Interviews were conducted with GIS managers in each community and university via email. Open-ended questions were asked to assess what problems they are able to solve using a GIS-based system, how the initiative was started, and how the system is maintained. A specific focus concentrated on how GIS is used for emergency response and if collaboration had been built between the community and the university.

Collaboration and data sharing are fundamental advantages to an organized data structure. Fire, police, and emergency services need access to campus data to make informed and timely decisions. A university data structure coupled with the community's emergency response system drastically increases the health and safety of the community at large. For this research, systems were examined which combined community and university data to guide structuring a new system for Manhattan. Again, objectives

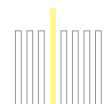
vary from institution to institution, and the data structure at KSU must be focused to achieve the Visionary Objectives of 2025.

Community case studies were selected with criteria similar to universities. Reviewing the literature gave an indication of the most proactive communities managing data using GIS. Communities were shown special interest if spatial data was shared between communities and the university to aid in emergency response or public wayfinding such as Calgary, Alberta, Canada. These communities display the possibilities for collaboration across departments and organizations and serve as a foundation for data structure. KSU's data structure varies because objectives differ from organization to organization, but these case studies provide an insight into how others have achieved their goals. Additionally, communities with similar characteristics to Manhattan, Kansas were favored for the survey: such as population around 50,000 people and a

university or college town proactive in GIS management.

Communities were placed on a scatterplot to examine where major foci of the research lie relative to safety, efficiency, or sustainability (Figure 6-5, Community Case Study Scatterplot). Similar trends to the universities are appearing where communities use facility data to support secondary objectives of sustainability or health and safety.

Case studies will be analyzed according to the three variables used to access the baseline: data accessibility, analytical capacity, and collaboration.



Community Best Practices

Best practices were subdivided into three areas to allow comparison to Manhattan's baseline: data accessibility, collaboration, and analytical capacity. Data accessibility refers to how data is sent by dispatch and received by emergency responders. Collaboration refers to how data is aggregated then exchanged between agencies such as police, EMS, and the public. Analytical capacity explains the capabilities of a fully integrated GIS system.

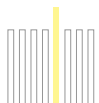
Data Accessibility

The main objective of emergency response is to protect the health, safety, and welfare of the community. A practice common to all case studies is the development of a comprehensive database. The structure varies across organizations, but it begins with analyzing the purpose of the system. This purpose is defined by the system users and decision makers, and then filtered by the anticipated results. An enterprise-level geodatabase stores all location

based information such as building asset information, fire hydrants, aerial imagery, hazardous material, and routing. The development of ArcGIS Api for Flex is a system implemented by Charlotte, Wilson, and Baltimore which allows access to the information en route to deploy responders more quickly, effectively, and safely.

GIS applies the geographic approach enabling emergency management professionals to collect enormous amounts of data and quickly transform them into actionable information (Figure 6-6, GIS Applies the Geographic Approach). This approach reduces response times, increases operational transparency, improves communication on all levels, and fosters comprehensive situational awareness.

The City of Buffalo, New York faced severe challenges in 2006; budgets were cut and firehouses were consolidated. This action



shifted the workforce and required many fire responders to relocate into unfamiliar areas (Coyne, 2008). This issue is common with the City of Manhattan where new responders are unfamiliar with the territory and have limited resources. There

was dire need for GIS to aid responders. Hydrant locations were georeferenced, routing was created for fire fighting vehicles, and building information was incorporated such as structural quality and building materials. Buffalo developed

an easy system used by responders which matches the 911 call to an address and creates a specific point for routing to the incident. Autocomplete typing tools aid in manual entry, and popular places such as schools or parks can be quickly selected from a drop down menu, making for an extremely easy system to use. Little to no training was required when the transition was made to GIS due to the development of an easy to use interface.

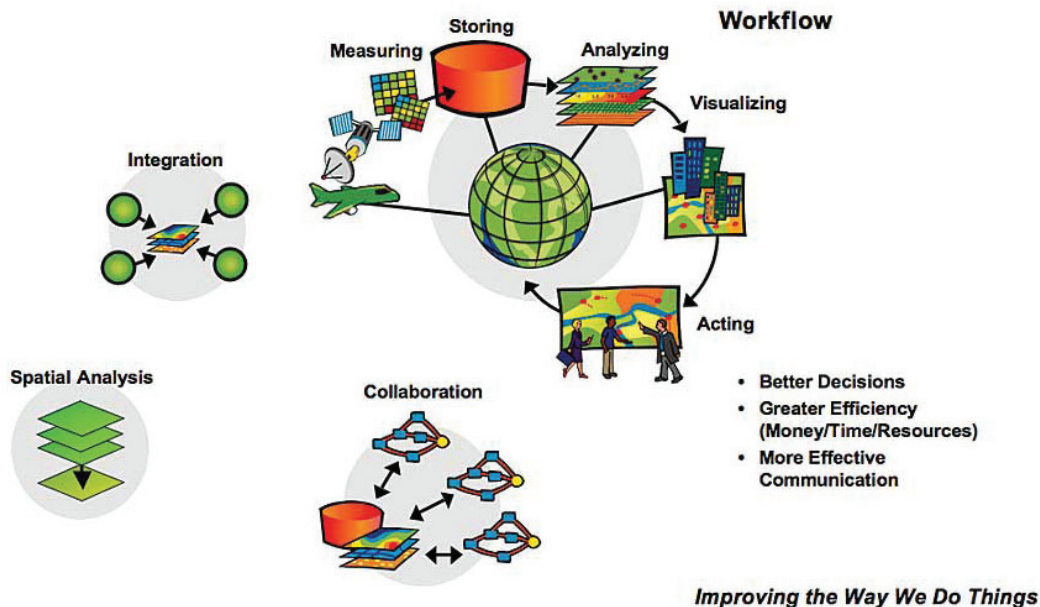


Figure 6-7 GIS Applies the Geographic Approach

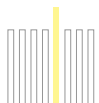
Source: Dangermond, 2007, <http://www.esri.com/news/arcnews/fall07articles/gis-the-geographic-approach.html>

Collaboration

It is not uncommon for local agencies to not share data, or share only parts of a dataset. This practice produces thousands of isolated information silos across the country and limits the amount of data interchange between departments or scales such as campus to community. Gathering data for enterprise GIS requires an immediate and concentrated effort to gain momentum and carry the project through to completion (ESRI, 2005).

“One of the greatest benefits of implementing a GIS program for the fire department was partnering with all departments in the city to share data throughout an enterprise. Long-term prevention and mitigation plans can now be developed to reduce both the potential and effort of an incident that may compromise our community,” Don Oliver, Fire Chief of Wilson, North Carolina.

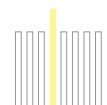
Years ago Baltimore responded to emergency situations in a similar manner as Manhattan does now. They used paper maps and fire books to route. The fire department realized there was room for improvement, for they were not servicing the 640,000 residents as effectively as possible (Johnson, 2005). They developed a way to push out building data quickly and easily using ArcGIS Api for Flex. The Flex system allowed GIS server resources such as maps, locators, feature services, and geoprocessing models, to be coupled with Flex components such as grids, trees, and charts. The application aids first responders by enabling visualization of where the incident is geographically, then retrieving data within a spatial proximity to create a full picture while driving to the scene. Fire staff can view over 4,000 building in the Baltimore area deemed “dangerous” by the city’s Housing Authority; room information can also be accessed complete with materiality and combustibility.



GIS has the ability to retrieve large amounts of data maintained by agencies outside of fire or police services. North Las Vegas has been able to leverage this data by integrating diverse datasets across political jurisdictions. The integration of data enables complex analyses and modeling to predict and assess service delivery based upon call history (Green, 2008). This information can then be shared with decision makers to promote effective planning decisions for the greater good of the community. Furthermore, the ability to collect data once and use it for multiple products results in optimal accuracy and efficiency. North Las Vegas has been able to visually contextualize incidents for all operations. It is easy to read and understand, and encourages communication between agencies as well as the public. Communication with the public in the form of maps or video facilitates transparency and encourages engagement in the decision making process. Web maps, for instance, illustrate emergency incidents over time enabling strategic plans optimizing access.

Analytical Capacity

Analysis precedes effective planning. We have the ability to identify spatial trends, impacts of a policy or design move, and perform modeling to predict future scenarios. Wilson, North Carolina has used GIS for over a decade to transform fire planning from a static document to a dynamic process (Oliver, 2011). The only way to achieve this is precise data management and collaboration between departments. Everyone is on the same page because everyone can access the same pool of data and respond in a coordinated effort. Data in isolation offers little in terms of answering a complex spatial question such as: Am I servicing my area within the designated response time? How long will it take to respond to an incident across town? What is the best way to get to the scene depending on time of day? Complex questions require analysis to understand the visible and invisible processes at play and to what degree they are influencing the situation. Integration enables better analysis.



Routing is a type of analysis conducted on a network dataset. GIS can quickly calculate and visualize a route from the station to the emergency call. This route is not static, and can be adjusted to calculate the shortest route, quickest route, avoid certain obstacles, restrict elevators, etc. depending upon the sophistication of the network dataset. Routing is one example of analysis achieved through data integration. Other examples of analysis examined by ESRI include:

- High EMS Demand Area Analysis- GIS can analyze historic EMS calls and identify patterns of high frequency. The spatial distribution of calls can then be compared with other important information and mitigation strategies can be planned.
- Planning Evacuation Zones- Evacuation routes from specific areas, ideal shelter locations, or emergency

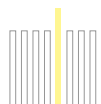
rescue areas can be analyzed using network datasets within GIS.

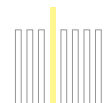
- Travel Times- GIS can identify the shortest route from one point to another. Many variables can be integrated into the network dataset including historic data patterns, day of the week, and one way directionality. Service areas can also be calculated to determine where a unit can travel within a given time period.
- Hard to Serve Areas- GIS can determine which areas of a community are difficult to serve due to long response times and obstacles. The network dataset can contain data describing why these areas are difficult to serve and possible remedies.
- Modeling- Calculate plume, explosion, flood, earthquake, and epidemic radii

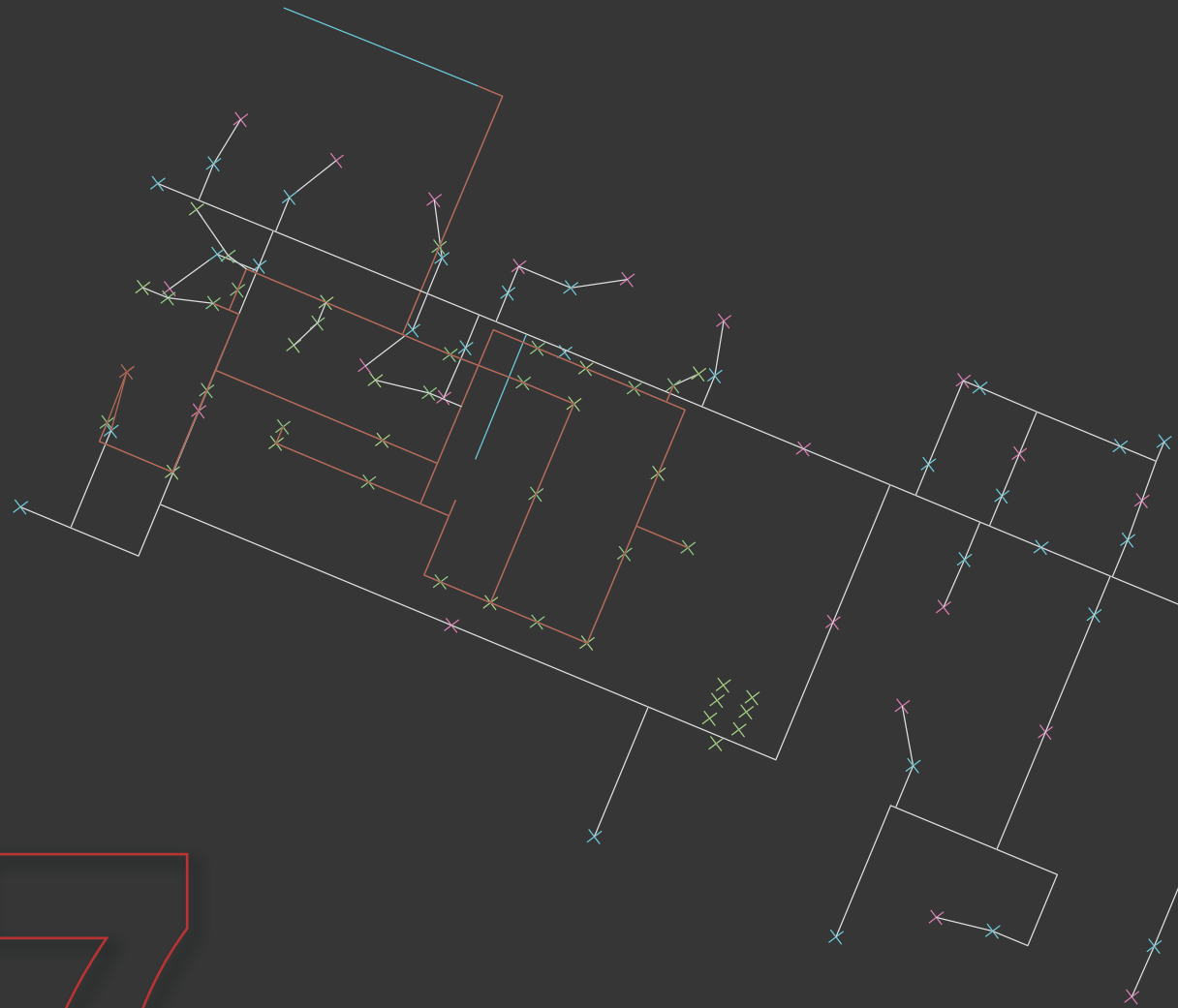
are all possible with a GIS system. Pair the model with other GIS data to analyze infrastructure damage, casualties, or other issues important for planning and response to potential or developing events (ESRI, *GIS Technology and Applications for the Fire Service*, 2006).

Takeaway Best Practices for Communities

1. Integrate data across agencies using an enterprise GIS Solution
2. Share Geodatabases with set privileges establishing who can access or modify datasets.
3. Create a Flex App for easy use eliminating technical training







07

ANALYZE

The Analyze section is composed of three parts all oriented toward applying best practices to Kansas State University. As previously described, the most beneficial practices optimizing efficiency, sustainability, and safety are achieved through three practices. First, a shared geodatabase between all campus departments must be created. Second, a 3-D network dataset must be created to build an architecture for data input. Third, a 3-D campus model must be created to visualize all information and analysis.

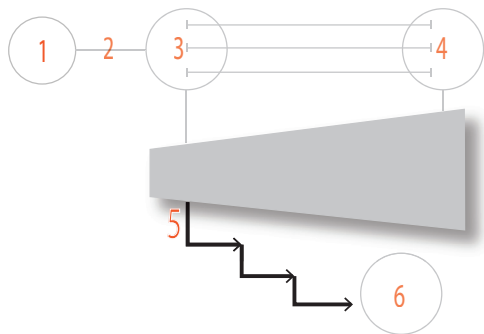


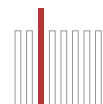
Figure 7-2 **Research Framework**

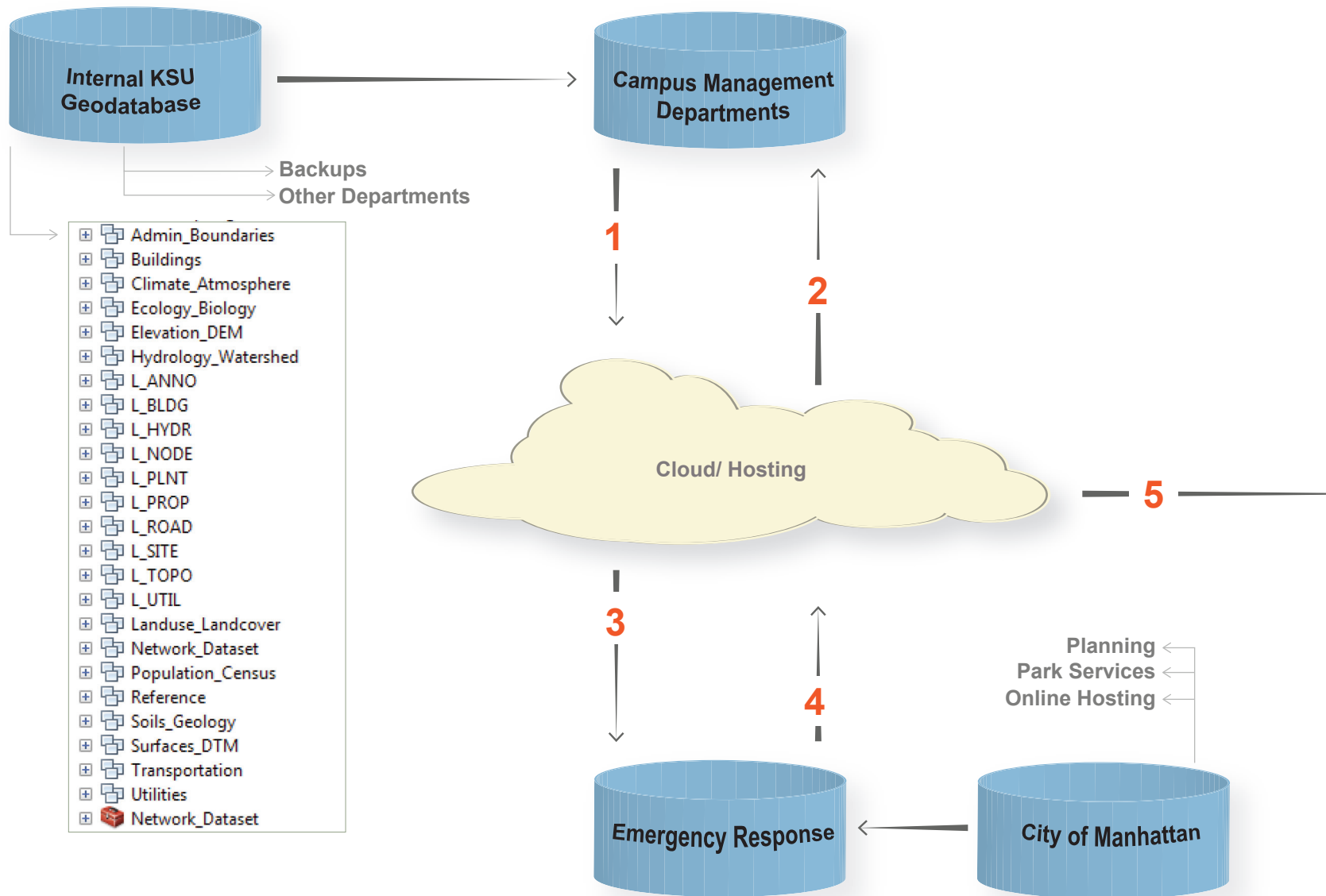
Analyze is the fifth step of a six part research framework.

Apply Best Practice 1: Create a Common Geodatabase

A master geodatabase will be the centralized location for all spatial data on campus: roadways, building information, interior and exterior infrastructure. Three workspaces will be created within the master database, one for each facility management, emergency response, and the public. One table space will be made fully public for routing pedestrians. Another table space will invite MFD and RCPD to access the database with routing and certain facility information such as structural, fire protection, and electrical components. The last table space will be fully accessible to all data including all facility management data. The database will feed each individual workspace allowing separate usergroups with individual restrictions and privileges. Please refer to Figure 7-2, Geodatabase Structure Diagram to visually digest the database structure. A highly integrated

system using GIS allows facility managers the ability to service work requests, autogenerate work plans, and run scenarios for new equipment to determine cost versus benefit.





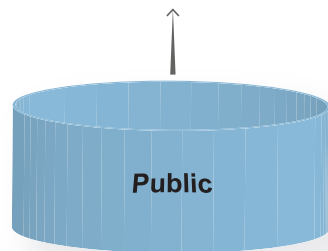
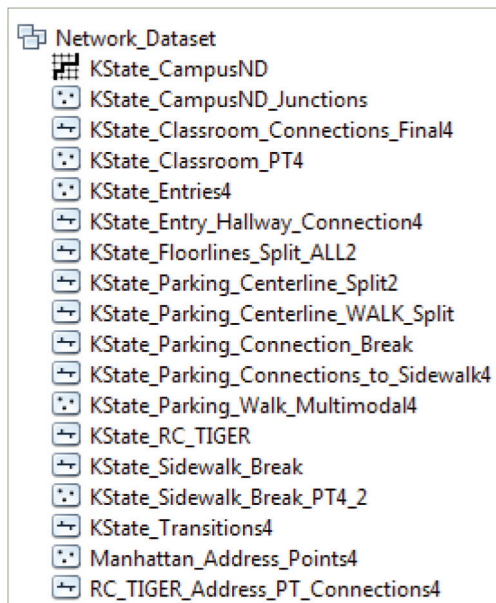


Figure 7-3 Geodatabase Structure

The structure of the geodatabase revolves around data integration and sharing. Three separate workspaces will provide access for pedestrians and emergency responders from Kansas State's database..

1 Management Data

- Building Data
- BISDM Assets
- Equipment
- Department Specific Infrastructure
- Network Dataset
- Plant and Vegetation Data

2 Data Exchange from Emergency Responce to Campus Management

- Building Data
- BISDM Assets
- Equipment
- Department Specific Infrastructure
- Network Dataset
- Plant and Vegetation Data

3 Emergency Response Data

- Fire Equipement Database
- Staffing
- Dispatch Protocol and Response Strategies
- Data Standardization
- Building Fire Codes

4 Data Exchange from Campus Management to Emergency Responce

- Building Data
- Equipment
- Fire Related Infrastructure and Assets
- Areas of Rescue
- Network Dataset

5 Data Exchange from Campus Management to the Public

- Network Dataset
- Classroom Information
- Select Floorplan Information
- Campus Art, Historic Data, and Aesthetically Pleasing Sites
- Tree Inventory
- Topography

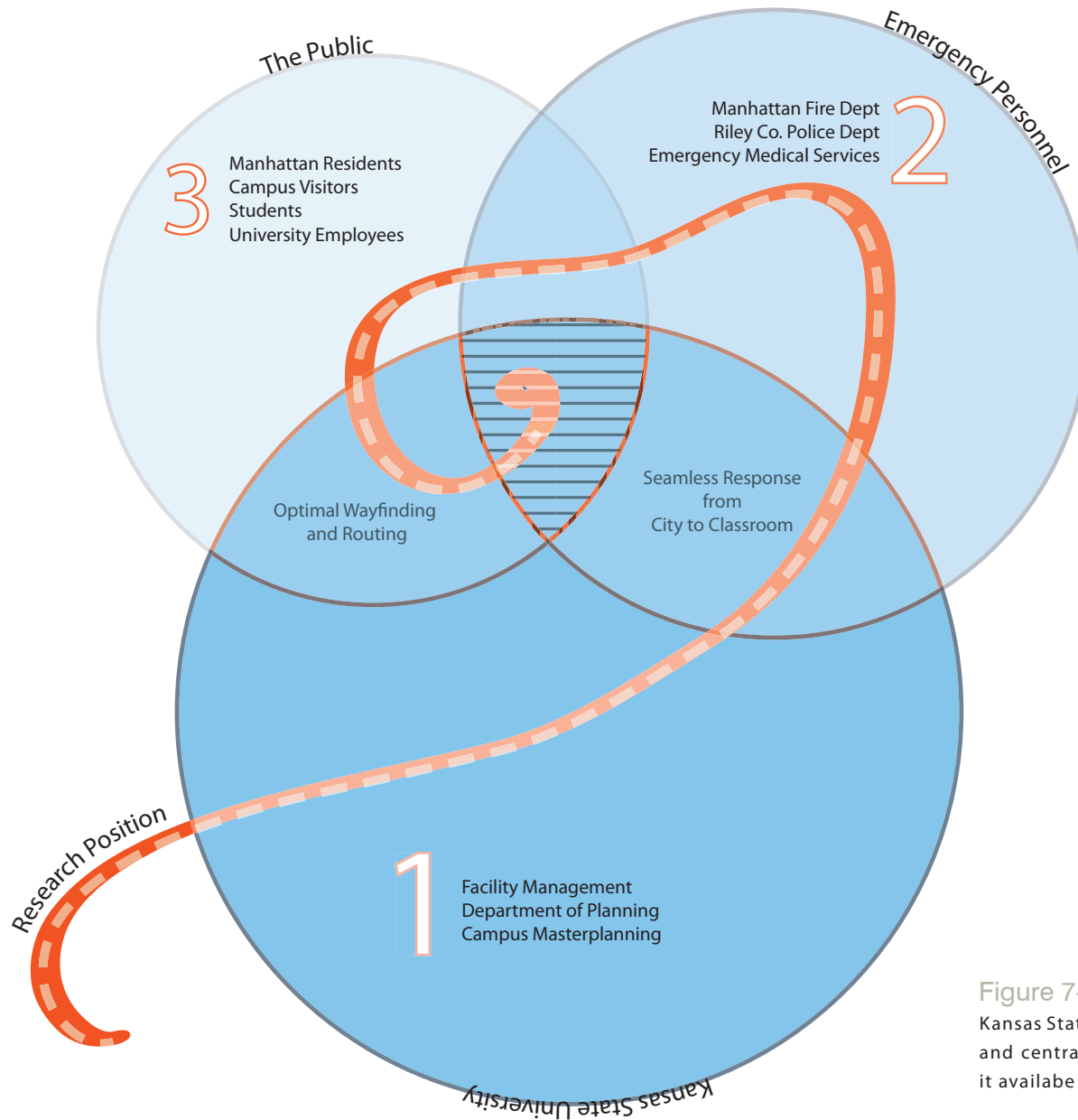


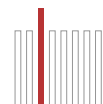
Figure 7-4 The Role of the Database

Kansas State scale, central role in the community, and central database will organize data making it available for all users.

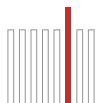
Common data organization enabling greater collaboration within KSU, and between KSU and the City of Manhattan should be initiated by KSU. The University has the highest concentration of people, most complicated facilities, the most interactions with other entities, as well as the most facility data available. Additionally, traditional methods for management do not allow for interface with the Manhattan Fire Department (MFD) or Riley County Police Department (RCPD), and have not focused on pedestrian navigation or wayfinding. Establishing a system through KSU allows for unparalleled collaboration between all entities and will craft seamless navigation from city to campus to classroom. KSU will provide certain datasets to the public for wayfinding and a more privileged dataset for emergency personnel, (Figure 7-3, the Role of the Database).

Preparing this system is crucial for understanding our built environment, and responding to the needs of those who occupy this environment. A shared understanding will provide a high level of

accessibility to campus for safe and wise emergency response, and more informed facilities management. Additionally, campus visitors will be able to navigate campus by foot to find a specific classroom, landmark, or parking lot.



Facility data organization will improve KSU in three ways: safety, efficiency, and sustainability. Figure 7-4 Data Interdependence Diagram demonstrates that data management is about teamwork and sharing resources relative to a larger perspective. Every piece of data relies upon the next and together they achieve possibilities unattainable alone. Although having building information is critical for facilities to properly inspect, maintain, or verify equipment, it also serves other purposes. The same information used by facility managers to maintain the system will be used by fire and police to identify closest hydrant, entry, or hazardous materials. Under this scenario, data is being utilized in many ways and serves a greater purpose. As data is collected, reorganized, and shared, unforeseen benefits to the university are unlocked. This value appreciates over time in terms of efficiency, sustainability, and safety.



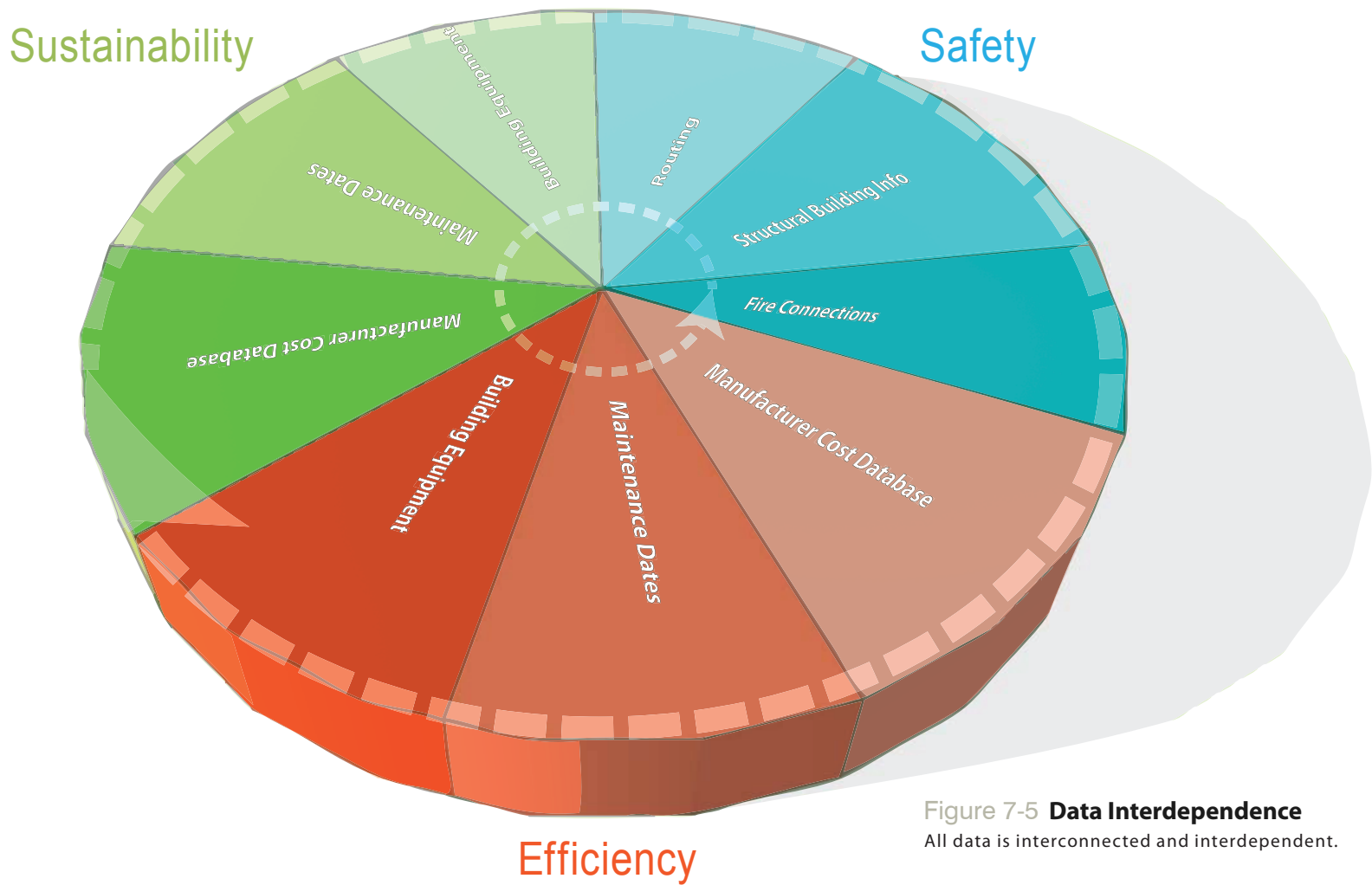


Figure 7-5 Data Interdependence
All data is interconnected and interdependent.

Data Collection and Preparation

In most cases, data is stored in multiple forms with a variety of software packages without an organized system for data management. Having data in many locations prevents facility managers and planners from querying, analyzing and reporting information for all buildings on campus. Data synchronization becomes an issue.

Data must be cleaned and compiled into a Geographic Information System (GIS) geodatabase, (Figure 7-5, Geodatabase Interoperability). Files will then be leveraged, extended, and connected in geographic space to empower users with the ability to answer spatial questions such as: How do I find the quickest route to my classroom? How can we safely evacuate buildings in case of an emergency? What is the most efficient piece of equipment, how much does it cost, and how long before I can expect a return on my investment?

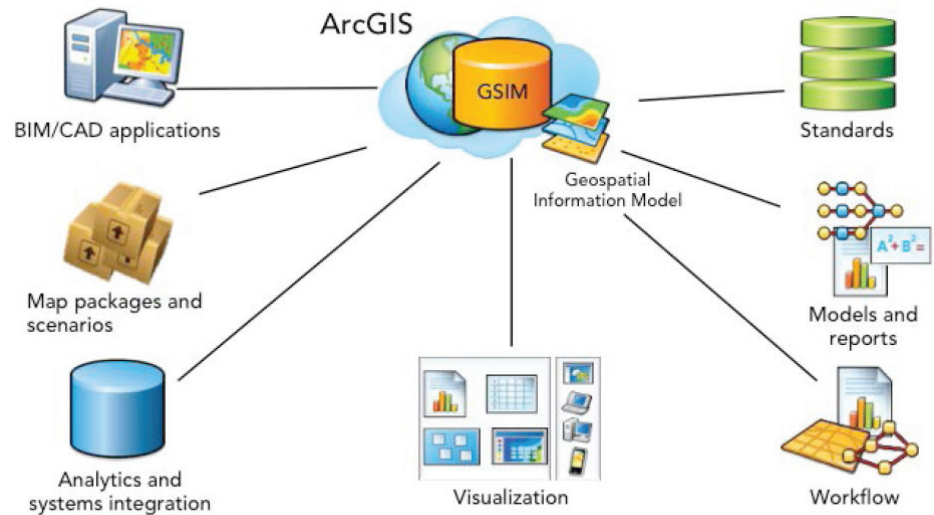


Figure 7-6 Context Map

Patrick Wallis, *The Role of GIS Technology in Sustaining the Built Environment*, 2012, 6

Data standards accepted by ESRI allow existing data to fit seamlessly into another dataset compiled by an outside organization. This allows the data to be exponentially expanded into the future and alleviates any questions for best practice. For instance, a two-dimensional network for routing will be established for Manhattan, Kansas. This routing plan

must be able to join to another network without any error, such as neighboring communities like Ogden. Likewise, routing through buildings on campus must follow standards to tie into networks from the City of Manhattan, MRD, RCPD, and surrounding jurisdictions. Standards allow for seamless response regardless of scale. What this means for students,

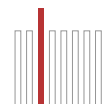
faculty, and visitors to the university is a complete vehicular routing plan tied directly to pedestrian routing plans to reduce stress about finding a particular location.

Additional benefits are harnessed with a geodatabase including increased pedestrian accessibility and wayfinding. Advancements can be achieved when organizing data into a universally shared workspace, such as an enterprise level geodatabase. Universities such as KSU can increase their visibility and encourage students and faculty from remote locations to participate in collaborative activities leveraged through GIS. Increasing data accessibility across departments will support a foundation for research to becoming a top 50 public research institution by 2025 (Kansas State University, 2010).

A complete GIS database will also provide new faculty, students, and visitors to the University an accommodating and welcoming environment by reducing

concerns for finding a building or specific classroom. Routing plans viewed through mobile devices will guide pedestrians around campus to a specific building entry, up a particular set of stairs or elevator, and down the hall to a classroom. Additionally, geolocated imagery added to the map will enable pedestrians to view photographs of their building, campus art, or other attractions. Research in spatial cognition has shown people rely upon landmarks in a wayfinding task (Elias, B. 2007). These objects act as an anchor helping to locate and orient oneself while navigating. All routing and imagery will be available via Kansas State's web page.

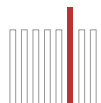
Traditional methods for facility management lack efficiency in large part to the inability to share data and work collaboratively between departments. Often many campus departments manage data internally and as they modify documents, another department may be unaware of updates. Several document versions then coexist, none of which may be entirely accurate. GIS is capable of



managing, integrating, manipulating, analyzing, and displaying geographically referenced information. Advances in GIS allow for a common workspace for many forms of data including AutoCAD, imagery, and spreadsheets. Collaboration prevents redigitization of files and allows for data interchange with the City of Manhattan, emergency responders, and the public. A GIS database will provide decision makers with the necessary tools to establish Kansas State University as a front-runner in sustainability, efficiency, and safety. The proposed GIS structure aims to achieve efficient, sustainable, and cost effective management for all building infrastructure while equipping emergency personnel with essential information for intelligent, expedited response.

An organized database with all spatial information will:

- Better accommodate ADA travel through automated methods for evaluating accessibility
- Reveal impediments or difficult areas to travel for those with aided mobility
- Open capabilities for evaluation in 4-D such as examining view corridors into a landscape throughout time
- Enables designers to determine what pedestrians are observing as they progress through a landscape
- Drastically increase safety and wayfinding throughout campus
- Allow for analysis of trees, planting beds, and green space to determine the amount of carbon sequestration throughout campus
- Allow for analysis of all trees on campus to determine what species thrive in certain conditions
- Enable analysis between existing sidewalks and areas in most need to determine optimal areas for sidewalk construction
- Open possibilities for health studies such as determining routes for maximum fitness



Apply Best Practice 2: Create Network Dataset for Routing

A second choice for best practices is a network dataset. Network datasets enable many types of transportation analysis including routing, service areas, Origin-Destination cost matrices, and location allocation. Additionally, a network provides a data architecture; it is a means of organizing and tying all data together in space. The network provides the skeleton for data input on which to build. One point feature has an exact time and distance from any other point feature which is highly relevant because one can then make decisions based upon that time or distance. Simple questions can be answered such as: How long will it take me to walk from Seaton Hall to Weber Hall? Integrating more data with the network allows increasingly complex questions to be answered such as: Where is the closest fire extinguisher? How can the extinguishers be distributed along the network to allow maximum access by

every classroom on the floor? How can they be serviced the most efficient way? A network dataset provides numerous benefits for the public, emergency responders, and facility managers.

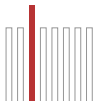
The first operation is determining the available data sources and the role they will play in the network. Building data

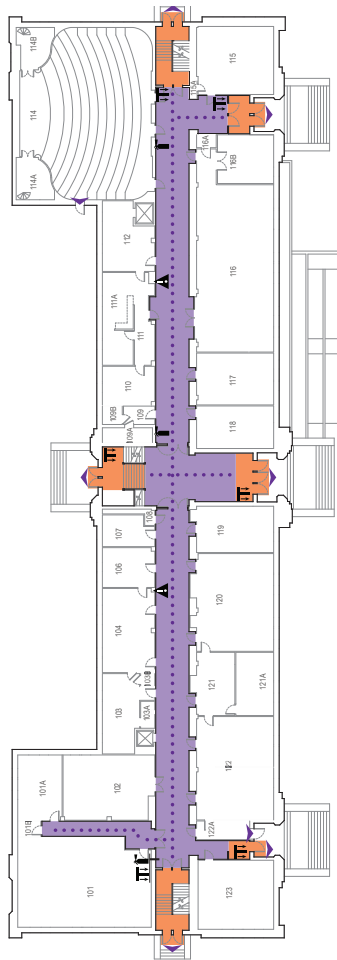
was available from the Department of Facilities and the Department of Space Management. The terrain was obtained from the data repository in the College of Design. The basemap created summer of 2012 was used to digitize sidewalk centerlines, roadways, and parking centerlines.

Required Datasets for Creating a Network Dataset

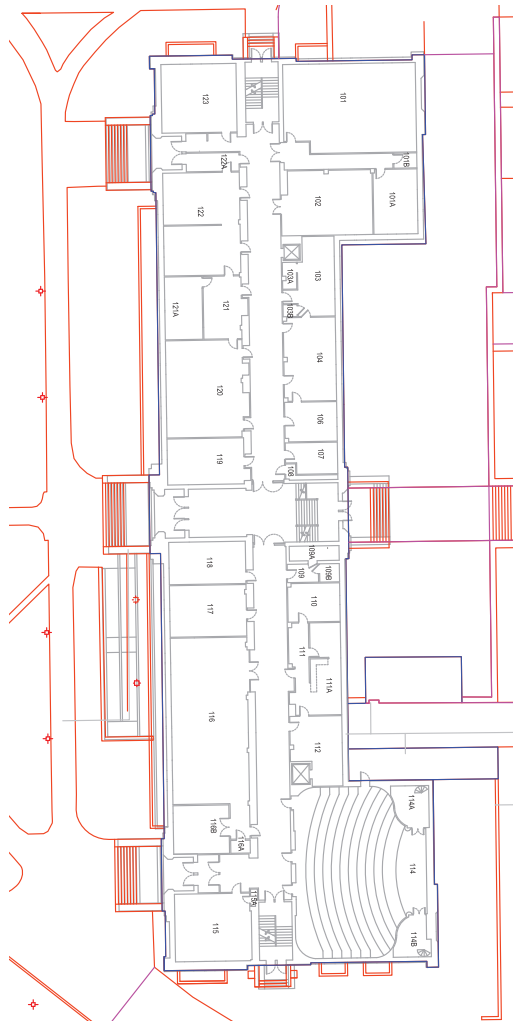
Acquired Datasets Name	Type	Description	Source
Floor plans	Polygon	Linework locating all interior polygons for classrooms, stairs, and hallways	Department of Facilities at Kansas State University
Parking Centerlines	Line	Contain information for parking lot permits, name, and aisle number	Landscape Architecture Geodatabase
Roadways	Line	TIGER Census Roadway File from 2011	US Census Bureau
Manhattan Parcel		Addressed parcel of all Manhattan Properties	Riley County GIS

Created Datasets Name	Type	Description	Drawn From
Classrooms	Point	Centroid containing all room and building information	Floor Plans
Room Entries	Point	Used as a junction to ensure routing through entryways	Floor Plans
Hallway Centerlines	Line	Main artery tying all interior components together	Floor Plans
Building Entries	Point	Junction connecting interior to exterior	Floor Plans
Sidewalks	Line	Lines traversing all navigable paths through campus	Campus Basemap
Parking Centerline and Sidewalk Connection	Point	Multimodal point used for interchange between auto and pedestrian networks	Campus Basemap

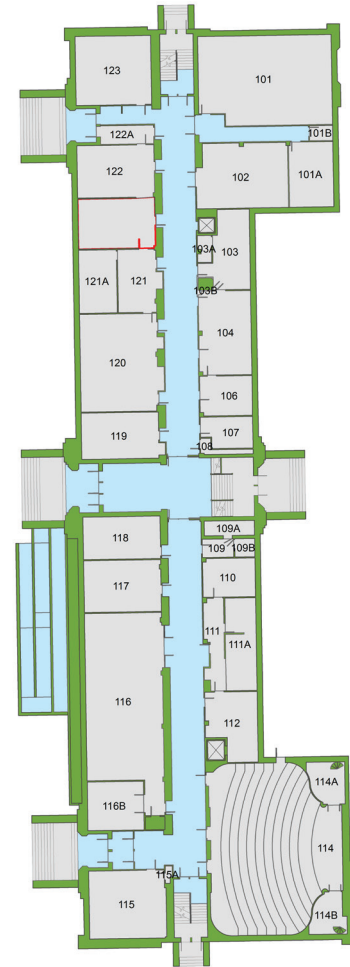




1 PDF Floor Plans



2 Spatially Referenced
AutoCAD Document

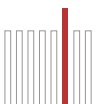


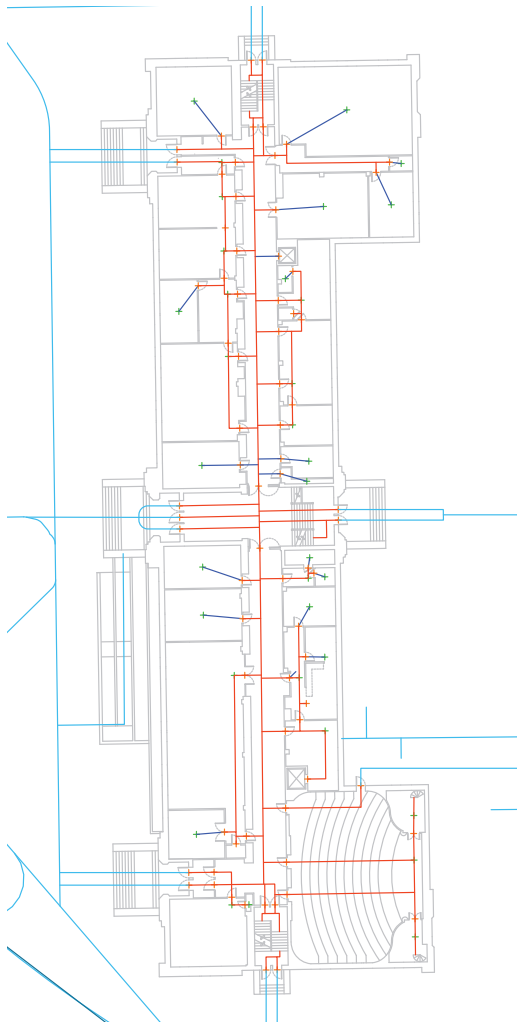
3 Attributions in ArcMap

Figure 7-7 Network Logic

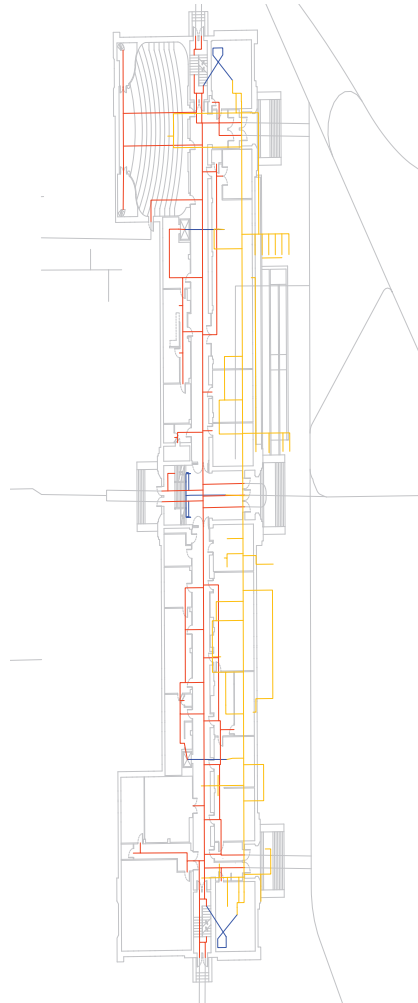
Steps required to build a network dataset from start to finish

127 ANALYZE

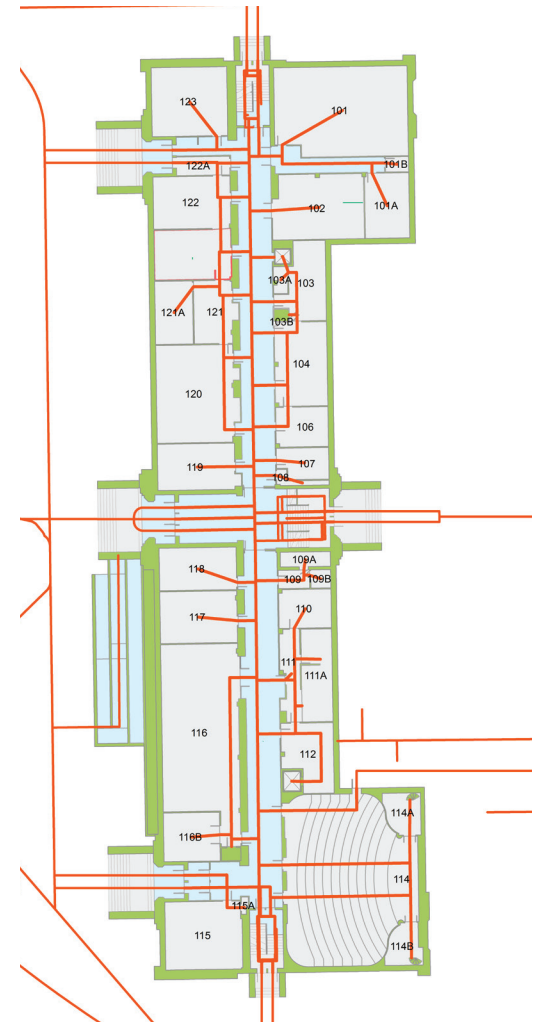




4 Create Necessary Layers
in AutoCAD



5 Connect Floors i
n AutoCAD



6 Build Network Dataset
in ArcMap

The following pages document the methods used in fall 2012 through spring 2013 to structure a campus geodatabase to support a demonstration of automated GIS routing.

Step 1: Illustrator to CAD

Departments of Facilities and Planning have long used paper copies of maps, (Figure 7-7). Recently, a project was undertaken by the Department of Facilities to digitize all building floor plans with evacuation routes and post these at building entries in case of an emergency. Developing a network dataset would allow users with mobile devices to get directions from *any point* to another within a building, throughout campus, or throughout all of Manhattan. Obtaining the evacuation maps was a starting point for developing a complete 3-D network dataset of campus, but the floor plans needed to be georeferenced. Existing in PDF form, these floor plans lacked scale and a

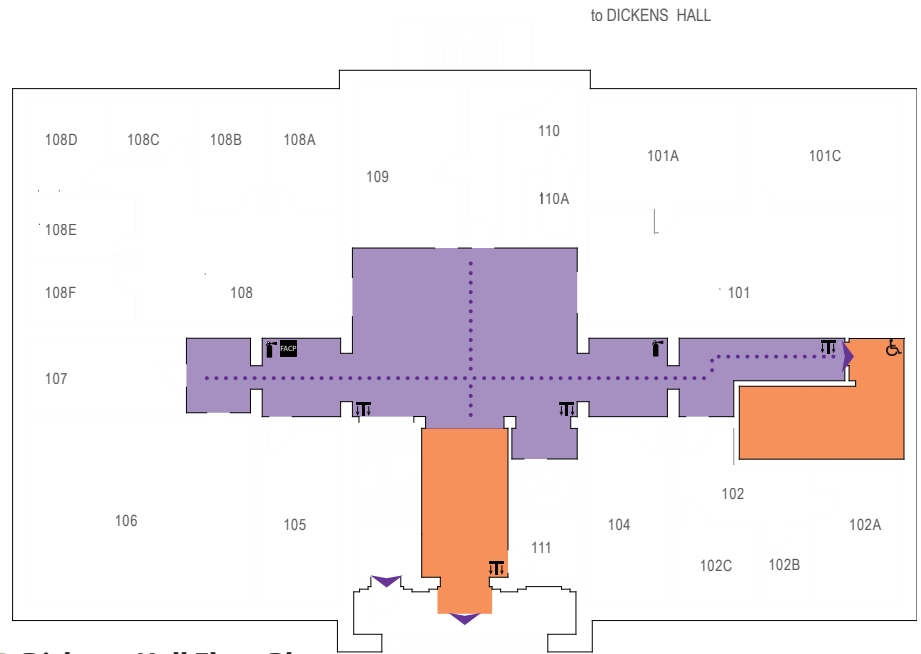
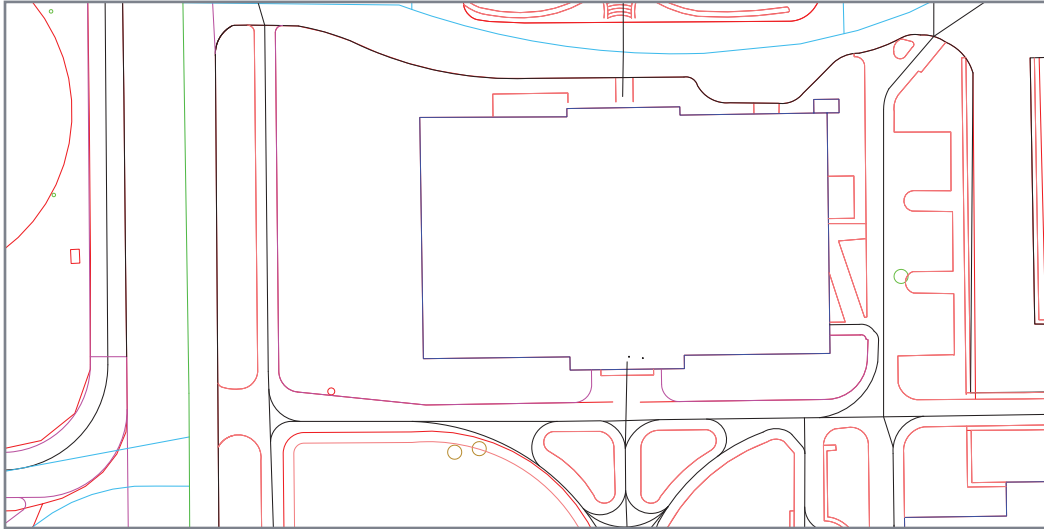


Figure 7-8 Dickens Hall Floor Plan

PDF floor plans designating evacuation routes and certain building assets.

geographic position. Using the basemap created in the summer of 2012, floor plans were aligned with the building footprint digitized from 6 inch pixel aerial imagery, (Figure 7-8). Note this method lacks a certain amount of precision. Corner points of the building were not surveyed or captured using GPS technology; they were simply drawn using the aerial imagery. A tolerance must be accepted when using floor plans for calculating on a micro

scale such as measuring the thickness of structural walls which is common practice in the Department of Space Management.



Strategy: Aligning floor plans with the basemap spatially referenced the classrooms, hallways, and accompanying assets for navigation purposes. AutoCAD 2012 is the most common tool used by Facilities and Management, so aligning data within this platform is mandatory. Data must be organized to be shared amongst the team.

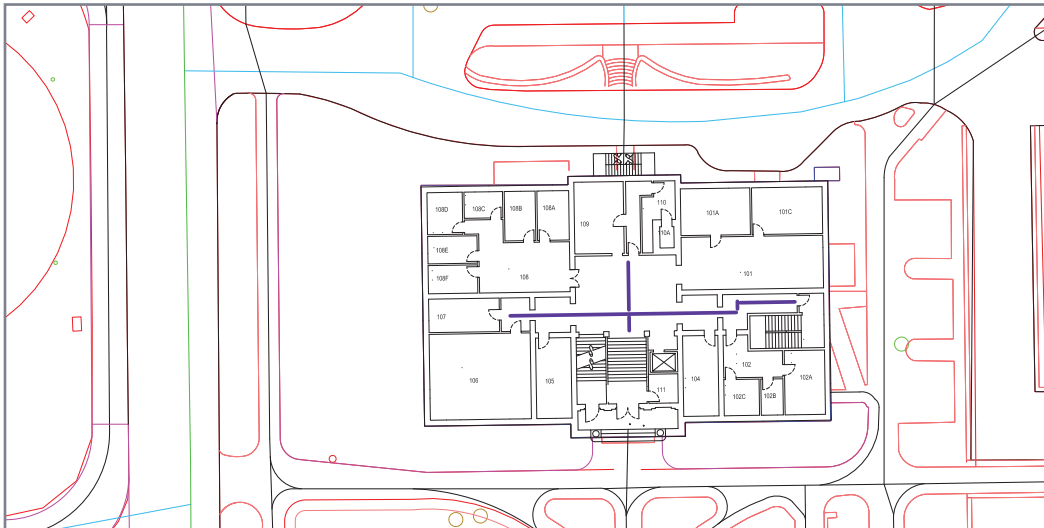


Figure 7-9 Aligning Floor Plans

All attainable floor plans were aligned with the campus basemap within AutoCAD 2013.

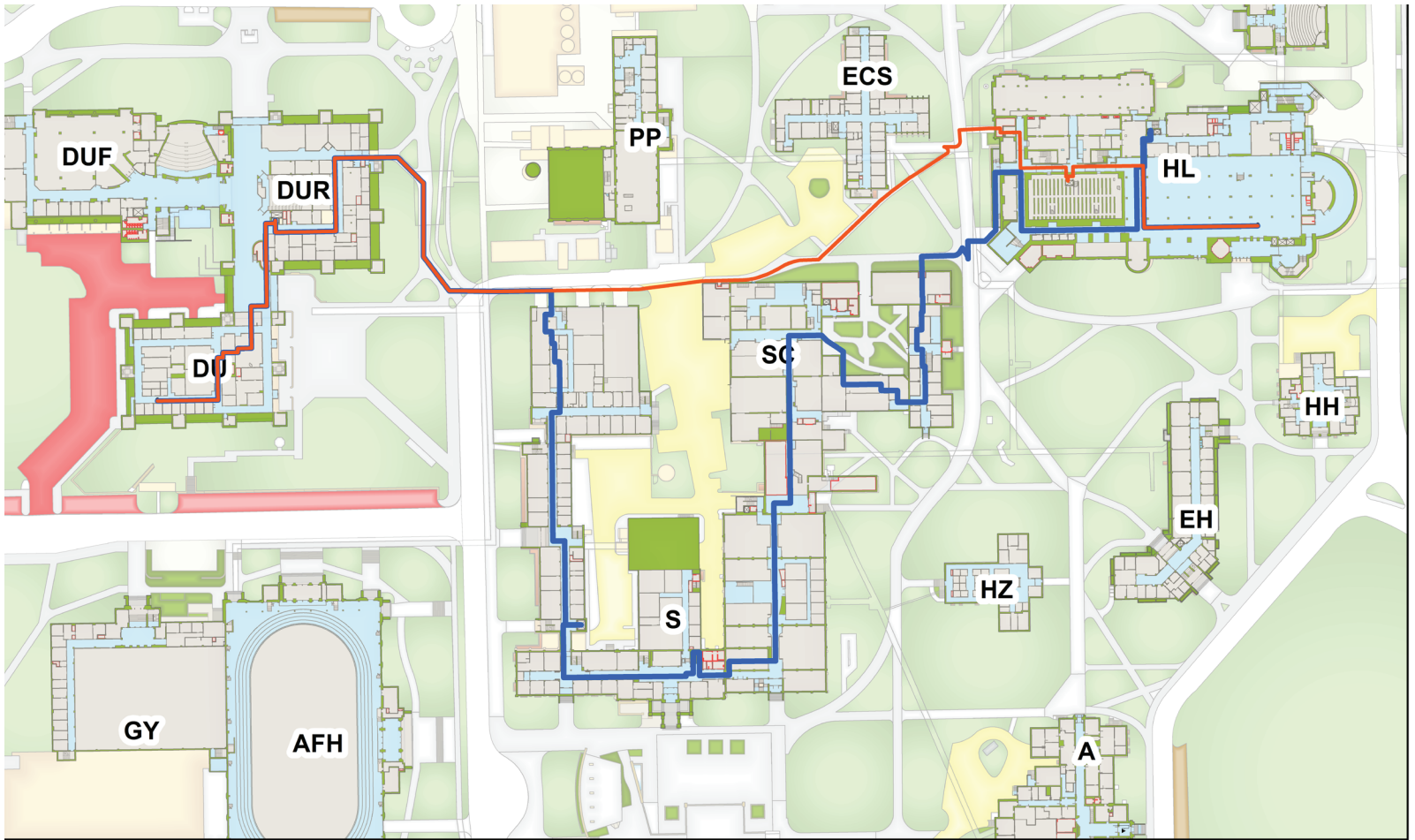


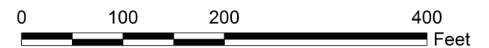
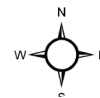
Figure 7-10 **Durland to Hale Route**

Route 1

Routing From Durland Hall to Hale Library by shortest distance

Route 2

Routing from Durland Hall to Hale Library, as before, but this time exterior sidewalks have a scaled cost, resulting in a routing favoring interior to buildings.



Step 2: Clean AutoCAD Files for Polygon Creation

Existing evacuation floor plans were drawn in Adobe Illustrator geometry and were not completely compatible with AutoCAD. Dashed lines and splines had to be converted to continuous polylines. In most instances, the dashed lines indicating door swings could not be converted into a continuous line. The door swings prevented each room from being a polygon separate from the hallways and other classrooms. Each interior and

exterior entry to every classroom and building had to be manually digitized to close each polygon. This operation was done manually and over 15,000 entries were drawn and attributed as ‘interior’ or ‘exterior’. These lines were converted into points and used as junctions for the Network Dataset. Furthermore, these lines can serve as “cost barriers” in routing procedures to navigate a pedestrian through campus favoring interior building paths. This would be helpful for routing on a day with inclement weather. In Figure 7-9, a route was calculated for this scenario.

Strategy: If closed polygons from the building floor plans can be acquired, then attributes can be assigned defining classrooms from hallways, stairs, elevators shafts, and so on, (Figure 7-10). This method was used for creating the campus basemap and ensures consistency in technique. Attribute assignments were very specific because this allows a larger capability for analysis. It is therefore possible to identify what percentage of the building is classroom space, approximate width of walls, or lengths of dead-end corridors.

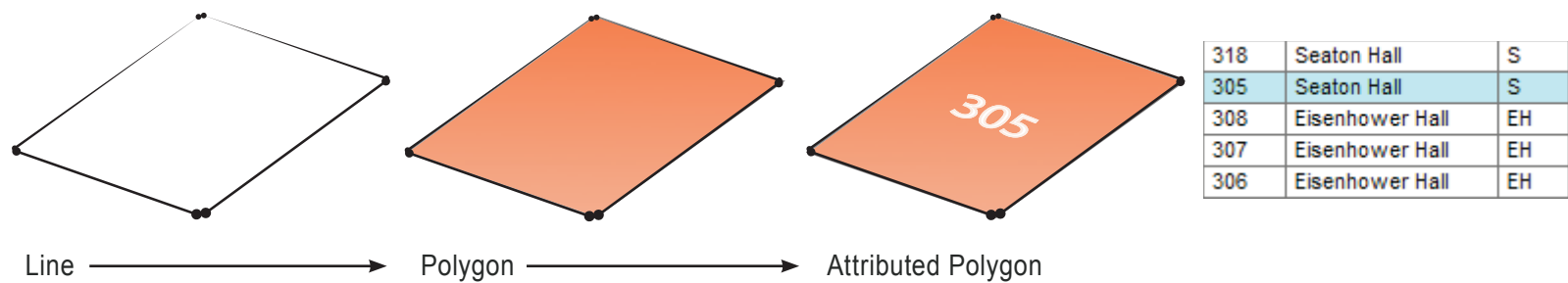


Figure 7-11 Line to polygon conversion

Starting with lines, we can convert this geometry into a closed polygon with attached information describing the shape such as room number.

Figure 7-12 **Closed Polygons with Room Numbers**

All room numbers were automatically numbered using the floor plans when polygons were created.

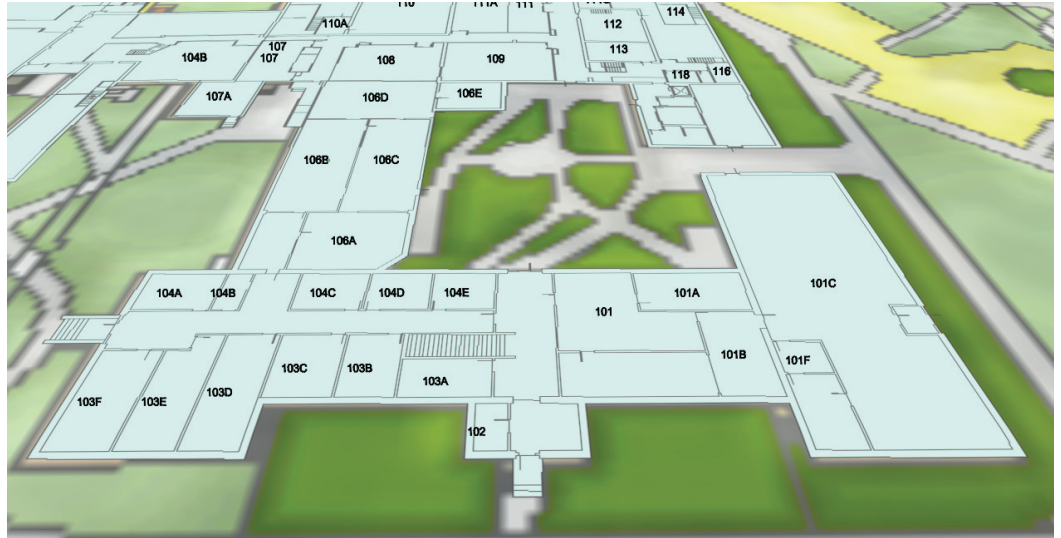
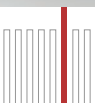
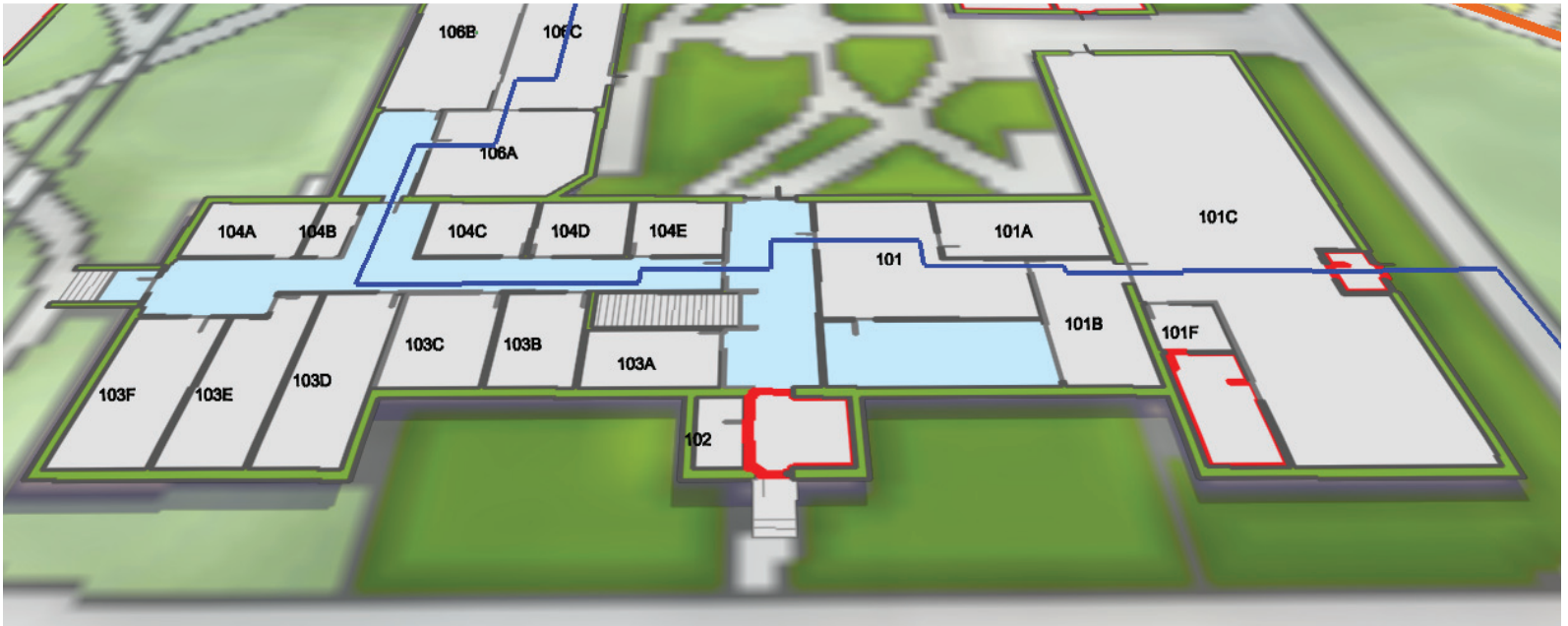


Figure 7-13 **Attributed Polygons**

The polygons were then attributed based upon type: classroom, hallway, stairs.



Step 3: Create Attributed Polygons

ESRI's ArcMap 10.1 was used to import the AutoCAD file and close the line work into polygons. The PDF floor plans originally used were annotated with room numbers, and GIS could recognize the annotation and automatically attribute the polygons with room numbers. This operation automatically assigned over 8,500 classrooms in 70 buildings with a number used for routing, (Figure 7-11). The next step was to assign attributes defining the polygons as a classroom, hallway, stairs, wall, elevator, elevator shaft, or ramp (image of created polygons). The 'Classroom' attribute was automatically assigned to all polygons with a room number. All other designations were assigned manually, (Figure 7-12).

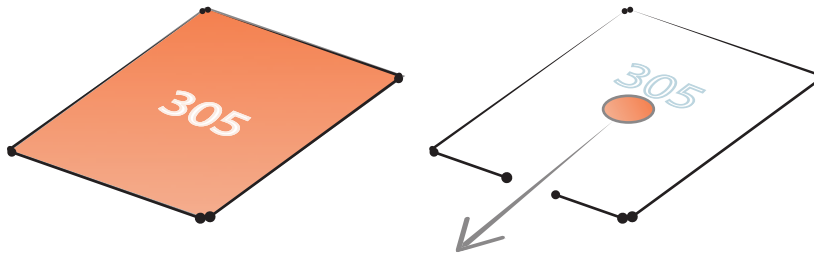


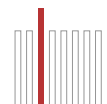
Figure 7-14 Polygon to Point

A copy of building floor plan polygons were then dissolved into one polygon for the overall building footprint. This new building footprint was spatially joined with data from the basemap for addressing, building information, and Riley County Police Dispatch information. Lines were converted to polygons using GIS, then annotated with room numbers, and finally spatially joined with building information. Routing will be made easy because each classroom now has a building name, building address, and class room number.

Attributing polygons granted the ability to separate polygons based upon any value. For example, 'classrooms' were selected and converted into a centroid and then used as a routing junction, (Figure

7-13). Hallway polygons were converted to centerlines using skeletonization techniques and also used for routing. Elevators were converted to points and connected vertically to symbolize elevator shafts. Stair polygons were used to digitize transitions from one floor to the next. All points were connected using GIS.

Strategy: Specific strategies were based upon geometries that GIS can calculate easily such as perimeter, area, and length. Stairs were assigned by creating a specific selection based upon a perimeter: area ratio. Stairs had a perimeter to area ratio of 2.4. Walls had a higher ratio due to large perimeters with less area. A higher perimeter to area ratio with a large perimeter overall, was a strong indication of a wall.



The Near Analysis tool was used to automatically draw a line between classroom centroids and the nearest entry point, (Figure 7-14). This model pulls AutoCAD files, converts them to feature classes, runs an 'Add X,Y Point' tool, determines the nearest feature, adds another X,Y point at the near point, then connects the two X,Y points together with a line feature. The last part of the model exports the new feature classes out into an AutoCAD file.

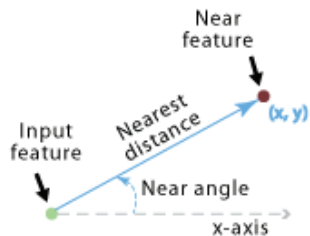


Figure 7-15 Near Analysis

<http://resources.arcgis.com/en/help/main/10.1/index.html#//00080000001q000000>

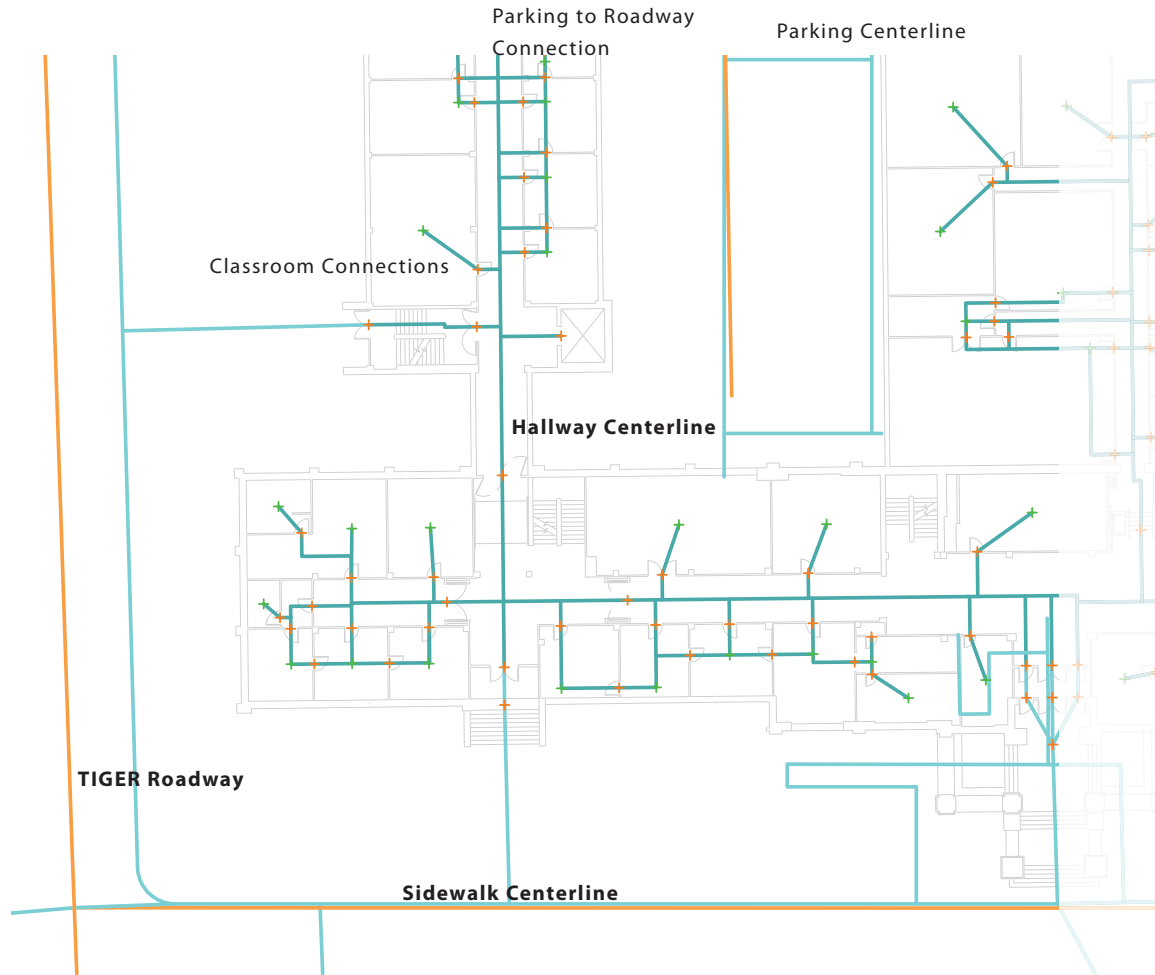


Figure 7-16 Network Dataset Architecture

TIGER roadways, sidewalk centerlines, and hallway centerlines were the features primarily organizing the network. All other secondary junctions and edges connected to these main features.

Step 4: Draw Hallway Centerline

Hallways must be drawn manually to verify accuracy. Techniques of skeletonization can turn polygon features into centerlines using thiessen polygons for surface creation, but this is not as accurate as needed for routing purposes. The centerlines must connect the exterior entries to the interior classroom entries, stairwell, and elevators. Hallway centerlines need to be the most accurate piece of geometry because they connect all internal elements. If connections are missed or the geometry is inaccurate, this

can have huge implications on emergency rescue workers servicing an area of a building. These spaces are often confined and navigating is much more complex than an outside environment.

Strategy: Hallways were digitized parallel to wall edges, (Figure 7-15). All turns in the linework were done so at 45 and 90 degree angles. The architecture of the network resembles that of the London rail map. Originally, the multitude of rail lines formed a spaghetti network of lines (London Rail-Image of rail before and after). In 1931, Harry Beck developed a rail map equally

as complex as its predecessor, but much more comprehensible, (Figure 7-17). This was due to the organized geometry in which the system was ordered. In complex microspatial environments, the crisscrossing of many lines resembles the complexity of the London rail network (Hethrington, 2013). Ordering principles must be established to maintain legibility and coherence if the network dataset were ever used for navigation maps.



Figure 7-17 London Rail ca. 1926

http://mapsof.net/uploads/static-maps/railway_historical_map_london.jpg



Figure 7-18 London Rail Presently

http://4.bp.blogspot.com/-ZINnhKAUg1o/TxGkx0hGrSI/AAAAAAAAAB5M/Gy2nhQEwSo/s1600/London_Train-Map_Pictures.gif

Step 5: Digitizing Transitions between Floors

Strategy: Ensure connection between all floors. Manually digitize all transitions and keep elevators distinct from stairs for intelligent routing. Elevators may be restricted in case of an emergency, so stairs would be the only way to access the scene. Stairs are obstacles for people with disabilities, so routing to classrooms must utilize elevators.

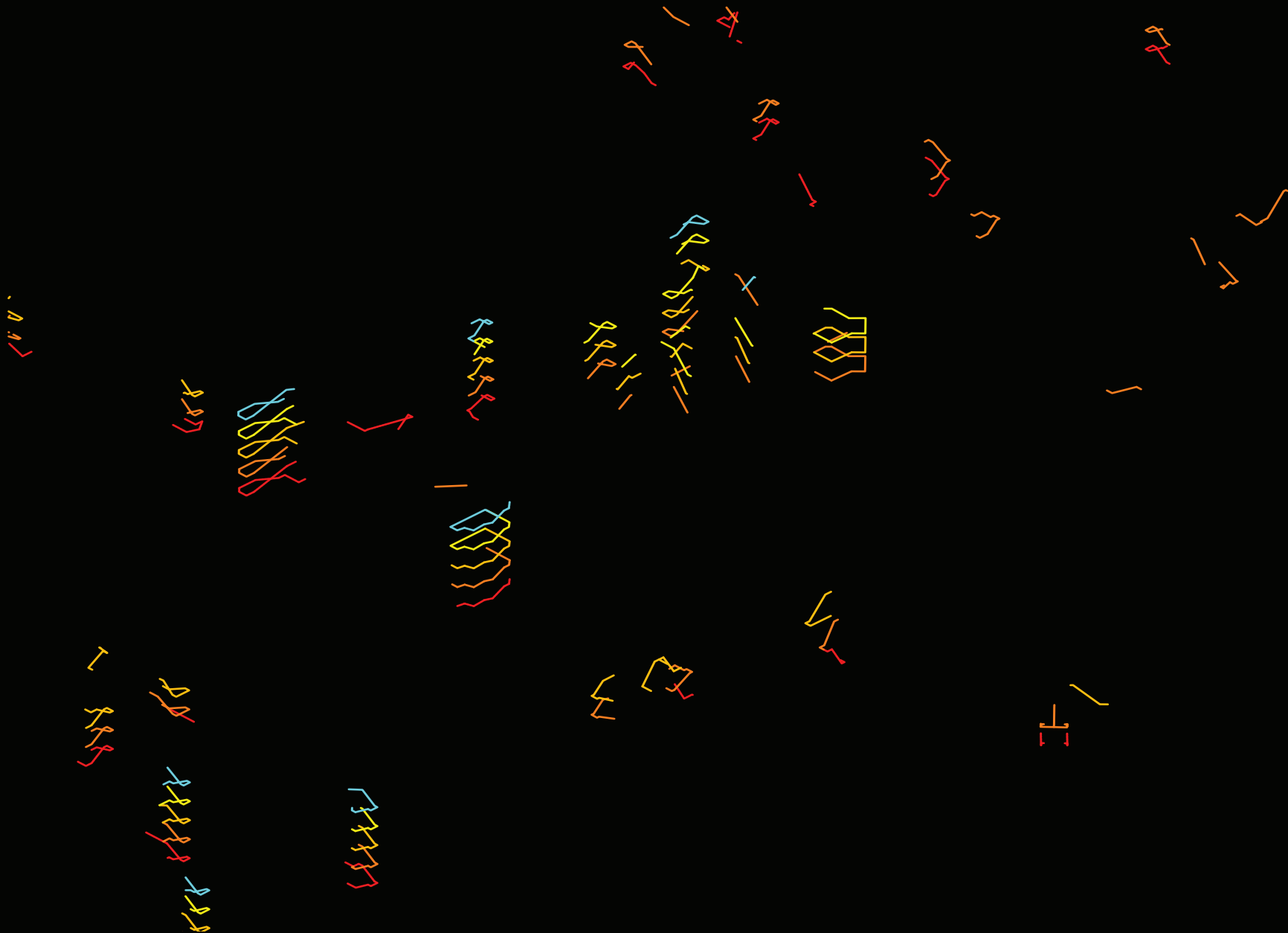
Elevators

Since elevators were attributed when polygons were created in Step 3, these polygons can be extracted and converted into point features. The points represent a junction in the network where one can change elevation from one floor to the next. Later when building the network, these

elevator junctions can be assigned a time delay to account for elevator operations or coded as a complete restriction in the event of an emergency. Similar to past steps, newly created points can be connected to the hallway centerline. The vertical transitions between floors were drawn manually in AutoCAD using the line command, Figure 7-18, Drawing Elevators. Drawing transitions manually ensured precise connections from floor to floor. Drawing transitions in AutoCAD is best practice because GIS can automatically read the geometry's elevation data when building the routing system.

Figure 7-19 Drawing Elevators

All elevator point features were connected with lines in AutoCAD. Red lines connect basement to first floor, orange connects floors one and two, yellow represents two to three, and so on.



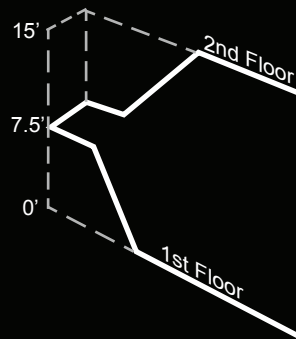


Figure 7-20 **Transitions Diagram**

Floors were connected by drawing lines from the bottom floor to a landing level and up to the top floor. Drawing stairs in this way ensures accurate walk times.

Figure 7-21 **Drawing Stairs**

Red stairs connect basement to first level, orange connects first to second, and so on. All buildings were under six floors.

Stairs

Stairs were connected to hallway centerlines manually in AutoCAD. In order to draw the stairs, one must determine where the staircase starts and what direction they are heading. I started at the basement level because I knew all stairs would go up toward the first floor. Flipping between floor plans I was able to understand where the stairs started, leveled for the landing, and ended, Figure 7-19. I then proceeded from first to second, second to third, etc. Drawing stairs in manually was the only way to ensure accuracy of landing locations, elevations changes, and staircase endpoints. Transitions were then examined in 3-D to verify connections and elevations, Figure 7-20.

Step 6: Build the Network Dataset

The following steps are adapted from the ArcGIS Desktop Help 10.1 for building a network dataset.

1. Select the source workspace

The collective geodatabase established in Best Practice 1 will be the source workspace. All data layers used for routing were exported from AutoCAD and organized under the Feature Dataset “Transportation”.

2. Identify the sources and the role they will play

3. Model Connectivity

It is important to understand the elements in the network and determine how different elements connect to each other. Routing expands across campus and includes all of Manhattan enabling someone to route from home to a specific classroom. First, one would drive by car to campus. Then,

they would get out their car and walk to their classroom. This simple trip includes two modes of transportation, and each mode must be defined by connectivity rules. Connectivity groups are used to model multimodal transportation systems. Line features are assigned one connectivity group, and each junction source can be assigned to one or more connectivity groups. Junctions that are assigned to multiple connectivity groups act as the interchange between modes, refer to Figure 7-21.

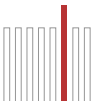
4. Define Attributes and Determine their value

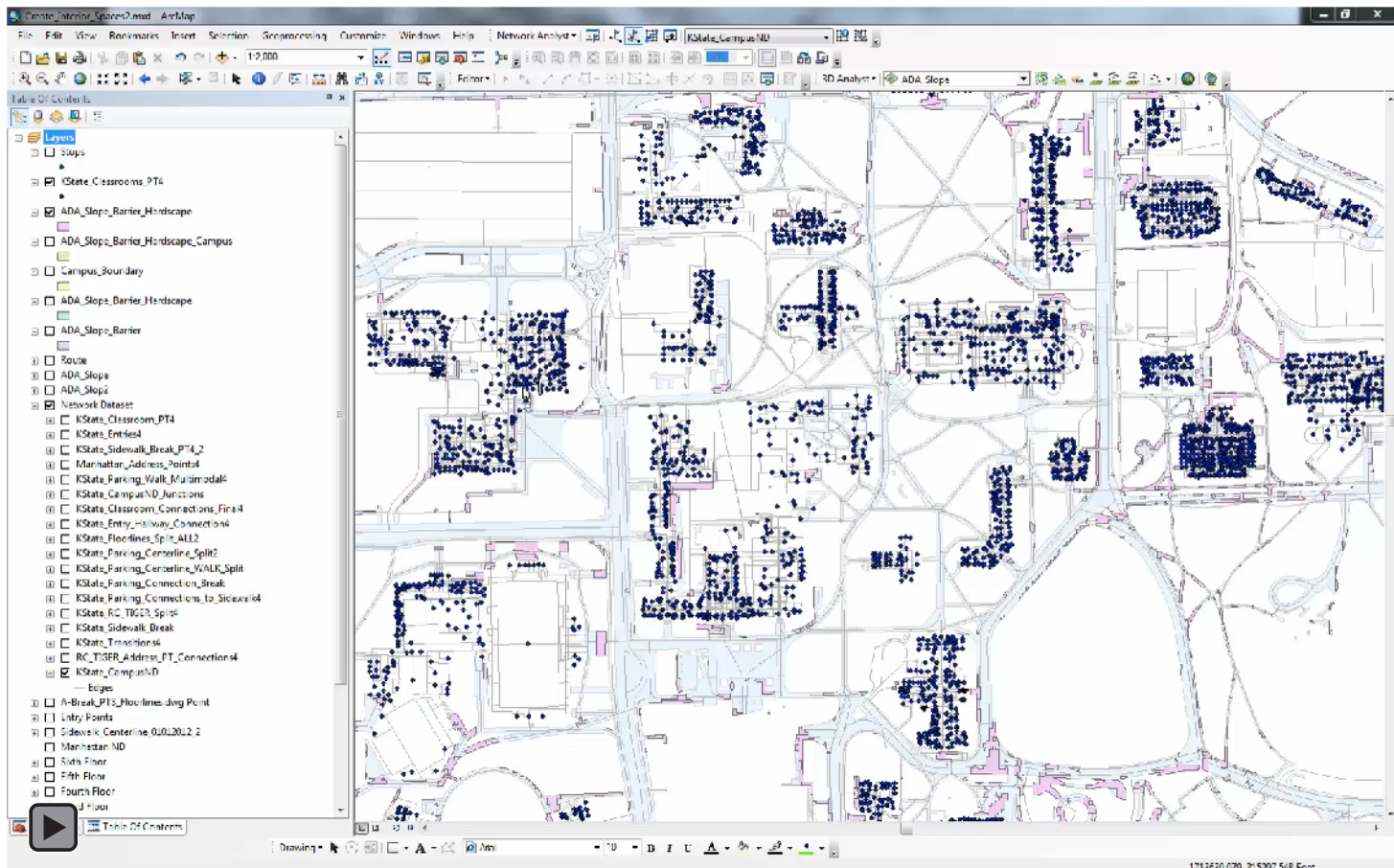
Identify any impedances to be used during the network analysis such as walls, stairs, or inaccessible entries. Determine the restrictions that will be used to control navigation over the network. Some of these impedances are simply an added cost of time or effort, others are completely impassible. Lastly, establish a hierarchy for the edge elements in the network.

1= Pedestrian
2= Automobile

Source	Connectivity Policy	1	2
KState_Classroom_Connections_Final4	Any Vertex	☒	☐
KState_Entry_Hallway_Connection4	Any Vertex	☒	☐
KState_Floorlines_Split_ALL2	Any Vertex	☒	☐
KState_Parking_Centerline_Split2	Any Vertex	☐	☒
KState_Parking_Centerline_WALK_Split	Any Vertex	☒	☐
KState_Parking_Connection_Break	Any Vertex	☒	☐
KState_Parking_Connections_to_Sidewalk4	Any Vertex	☒	☐
KState_RC_TIGER	End Point	☐	☒
KState_Sidewalk_Break	Any Vertex	☒	☐
KState_Transitions4	Any Vertex	☒	☐
RC_TIGER_Address_PT_Connections4	Any Vertex	☐	☒
KState_Classroom_PT4	Honor	☒	☐
KState_Entries4	Honor	☒	☐
KState_Parking_Walk_Multimodal4	Honor	☒	☒
KState_Sidewalk_Break_PT4_2	Honor	☒	☐
Manhattan_Address_Points4	Honor	☐	☒

Figure 7-22 Network Connectivity





5. Establish Restrictions

Routing can be specifically tuned to the needs of the user. Elevators, stairs, non-ADA entries, and slopes over 8.33% were all built into the network. Elevators are disabled during emergencies, so responders can route using stairs only. ADA routes can be configured to restrict certain entries, stairs, and extreme slopes. Additionally, slopes can be built into the network to route using extreme slopes as a preference to calculate more physically demanding routes.

In Figure 7-22, the shortest route is calculated between Cardwell Hall and Chemistry Hall. In this example, elevators were used because they constitute a shorter distance than taking the stairs. This is represented by the blue route. The orange route is recalculation using elevators as a restriction and taking only stairs.

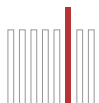
136,717 Junction Elements

349,520 Edge Elements

9,548 Classroom Points

340 Floors

63 Buildings



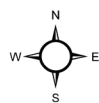
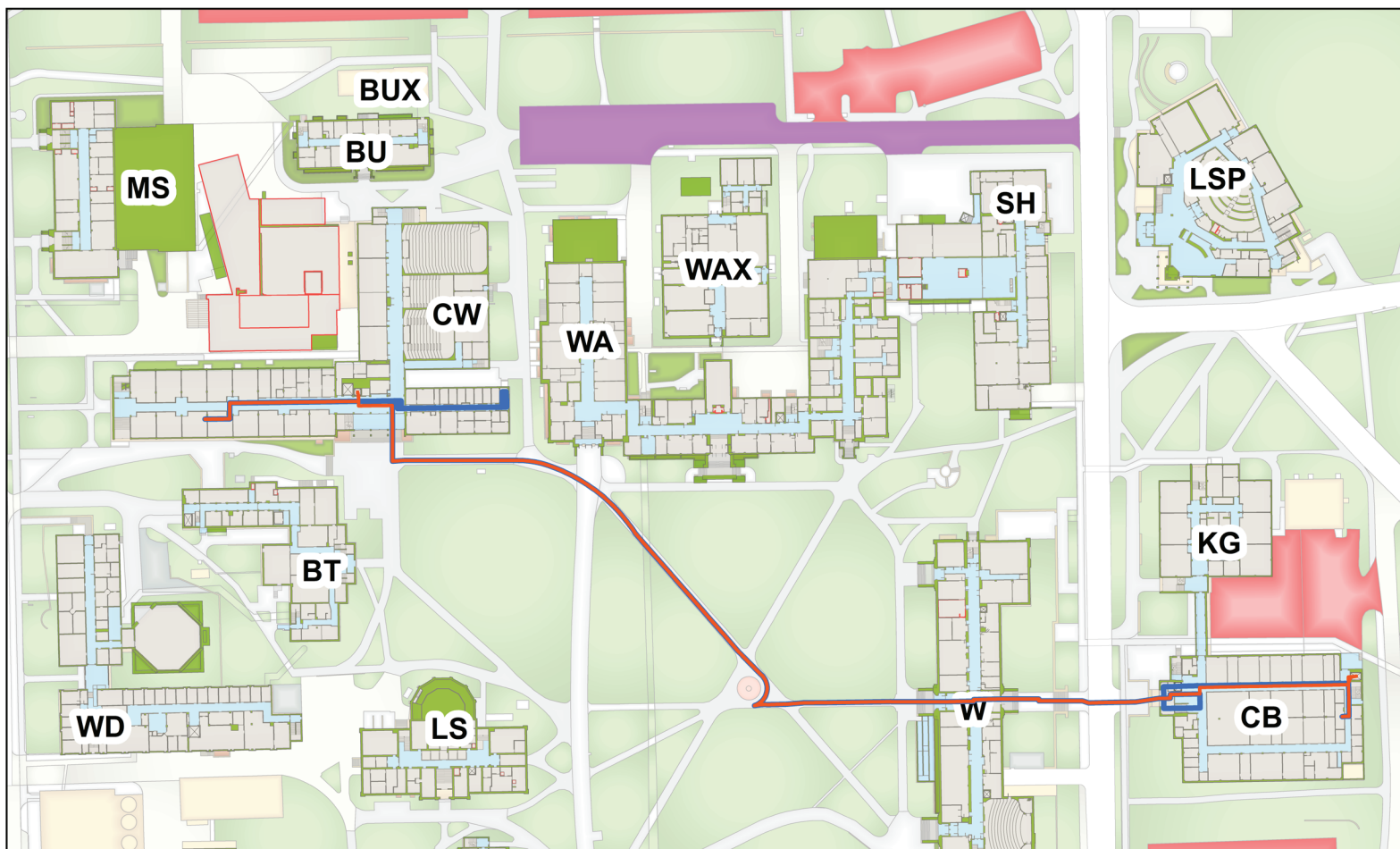


Figure 7-23 Cardwell to Chemistry

Two routes were calculated from the same origin to the same destination. The blue route utilizes the stairs, while the orange route follows the elevator.

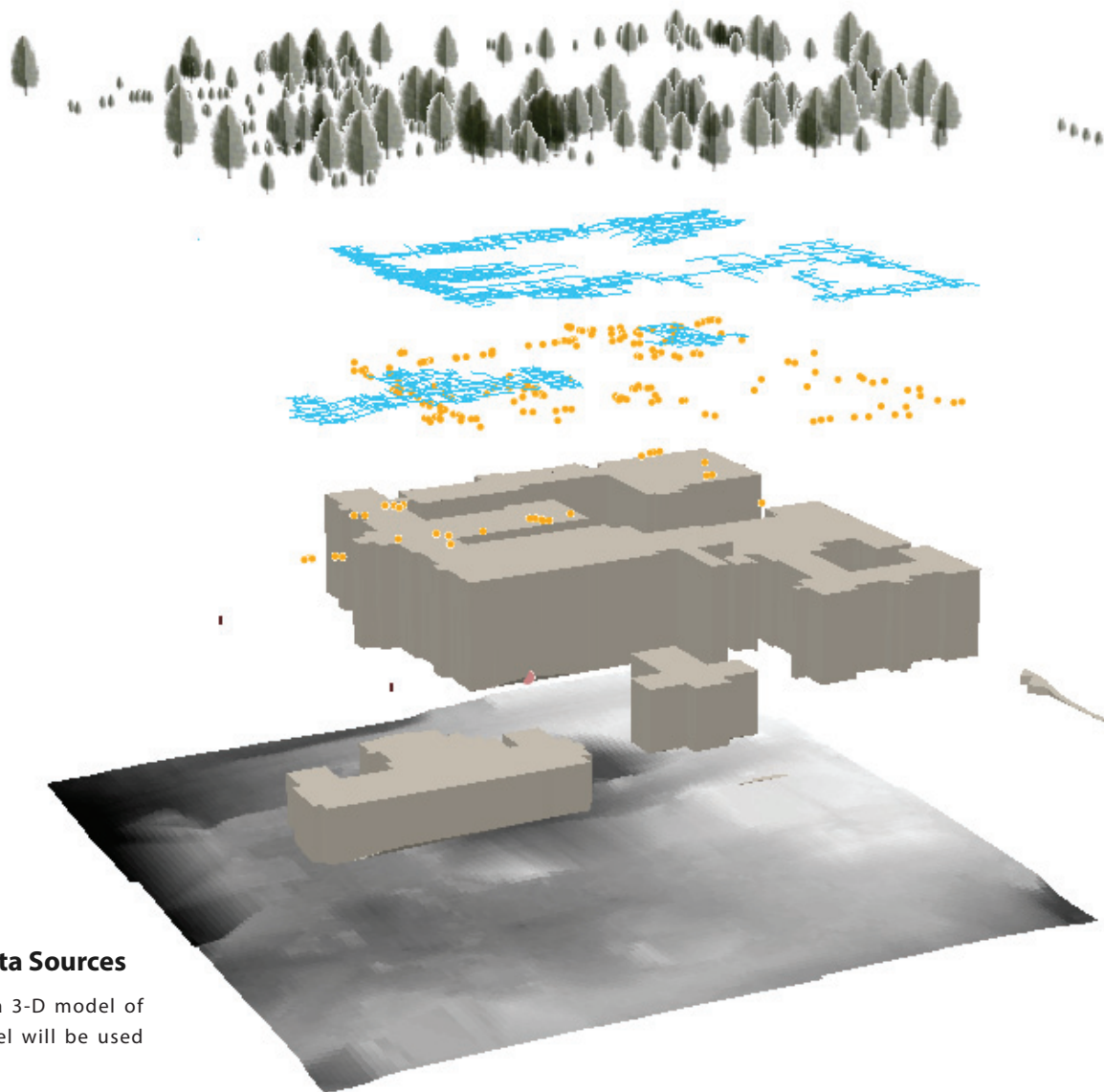


Figure 7-24 **3-D Campus Data Sources**

These layers were used to create a 3-D model of Kansas State University. The model will be used to visualize all analysis.

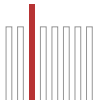
Data Layer:

Data Source:

Trees	Students in Woody Plants Course (2003-2004 academic year)
Routing	Created from Floor plans
Street Furniture	Department of Facilities Master CAD File
Buildings	2006 Students in Technical Module Courses
Basemap	Created from 2011 Aerial Imagery
LiDAR Terrain	Riley County

**Apply Best Practice 3:
Create a 3D Campus for
Visualization**

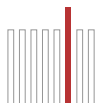
An effort was originally undertaken to create a 3-Dimensional campus model in coordination with the 2012-13 Master Plan update led by the private consultant, Ayers Saint Gross, for Kansas State University's 150th Anniversary. Unfortunately the model did not get created in time to aid in master planning efforts, but many of the required data sources were created and compiled. The layers used are defined in Figure 7-23, 3-D Campus Data Sources.



Building a virtual 3-D campus will provide a visual context for subsequent analysis. Sometimes it takes a trained eye to understand space from plan view. Take a look at the same route as before, from Cardwell Hall to Chemistry Hall, but this time visualize the route in 3-D, (Figure 7-24). Look at how clear the 3-D route is to follow compared to a 2-D map which is not readily understood by community members and decision makers. 3-D space is the common language of public and scientific researchers. As Steinitz explains in *A Framework for Geodesign*, public understanding decreases as scientific rigors increases. Creating a visual model evens the trajectory to align the public's understanding with the scientific complexity of geodesign.

A 3-D model can also be a tool for marketing and fund-raising. It is a means of gathering and organizing support for the community and university which often translates into increased funding. Capital projects can be visualized before construction and even analyzed to determine the impacts on the existing environment. Analysis on solar gain, impact on view corridors, and consistency of building architecture can all be conducted. A 3-D campus for Kansas State puts us at the forefront of campus visualization tools on par with the University of Rochester, University of North Carolina at Charlotte, and University of Calgary. Other schools have seen tremendous breakthroughs in reducing information silos and improving data accessibility. This will serve as a far superior base for data integration compared to previously used AutoCAD files.

Ultimately a model is another means to understand our environment. Facilities can use the model to visualize building assets, exterior features, or routing to streamline daily operations. Emergency responders can visualize situations and assess building information and fire hookups before arriving on scene. Lastly, pedestrians and campus visitors can use the model to visualize routing in 3-D and rarely get lost on campus. Everyone would be able to control their navigation experience through campus with many predefined parameters specifically tuned to the user.



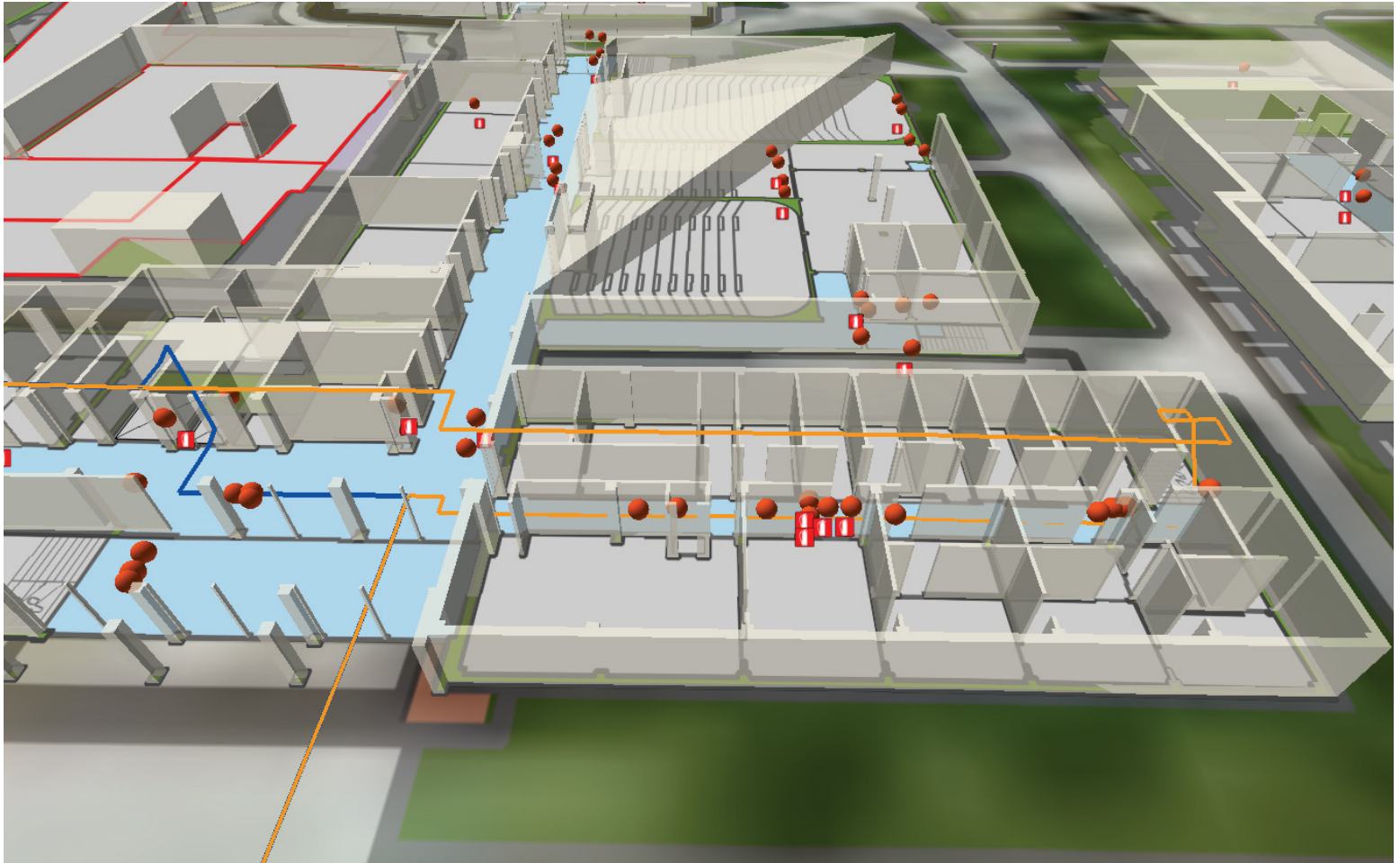
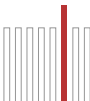


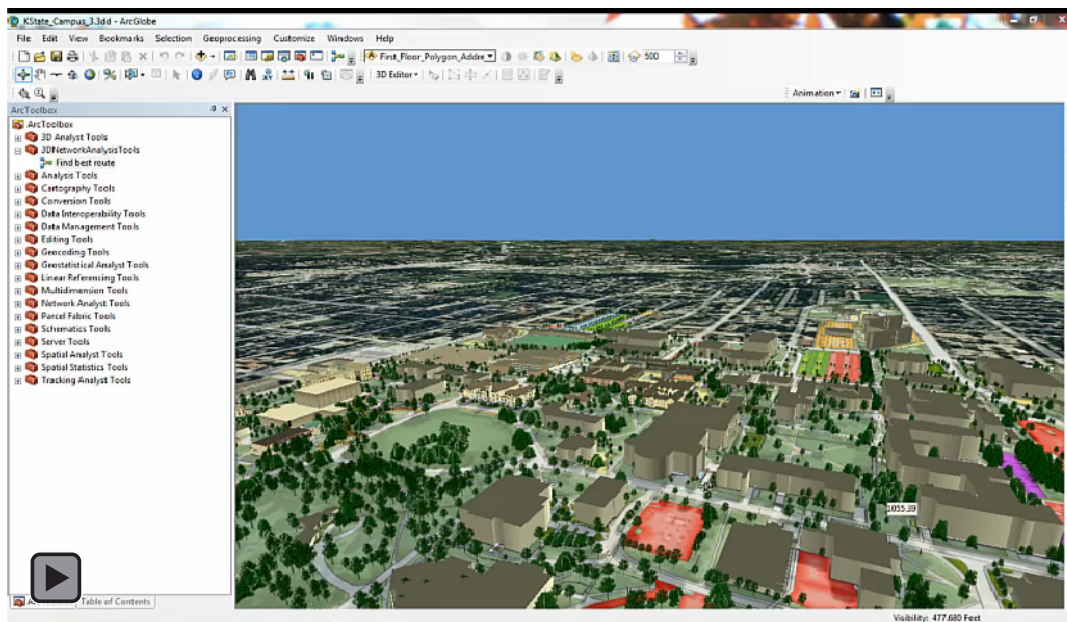
Figure 7-25 3-D Route from Cardwell to Chemistry

A route was calculated from Cardwell Hall to Chemistry Hall. The blue route is the shortest route and utilized elevators. Another route was calculated to emulate an emergency scenario utilizing only stairs. This is shown by the orange route.



Figure 7-26 **Bird's Eye of Campus Model**

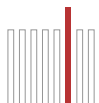




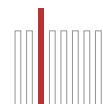
Mapping, 3D Modeling, and Route Network Completed to Date

To date, approximately 1,600 hours have been expended mapping and modeling the campus in 3-D and creating a routing model to demonstrate prior-of-concept. The following pages provide a “snapshot” overview breakdown of hours expended per task and estimate the overall effort remaining to entirely map, model, and build the campus routing network.

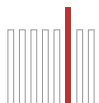
Task	Hours	Completion Percentage
Basemap	517	100.0%
Use aerial photos to delineate edges and transitions in ground plane	180	34.8%
Close all polygons	160	30.9%
Attribute polygons	45	8.7%
Annotate address ranges for road segments	80	15.5%
Address campus buildings	20	3.9%
Attribute parking lots with permit information	12	2.3%
Symbolize basemap and convert to representation	20	3.9%
Network Dataset	609	100.0%
1. PDF Floor plans	33	5.4%
Obtain facility floor plans	6	1.0%
Inspect PDF's and edit layers for AutoCAD	24	3.9%
Export PDF's as DWG's	3	0.5%
2. Spatially Reference Floor plans	145	23.8%
Import DWG's and align with basemap	20	3.3%
Remove all splines	12	2.0%
Clean AutoCAD files and close all polygons	30	4.9%
Close all building entries both interior and exterior	60	9.9%
Field Verify all entries	12	2.0%
Convert all graphics into point features for fire extinguishers, etc.	8	1.3%
Export to GIS and close all polygons for building interiors	3	0.5%



Task	Hours	Completion Percentage
3. Attribute polygons	94	15.4%
Attribute polygons with building name, address info, room number, room type	90	14.8%
Turn classrooms into points	1	0.2%
Turn doorways into points	1	0.2%
Connect classroom centroids to room entries	2	0.3%
4. Draw Hallway Centerline	210	34.5%
Obtain TIGER Census roadway data and attribute with necessary data fields	2	0.3%
Draft sidewalks	65	10.7%
Connect sidewalks to parking lots	8	1.3%
Draw centerlines for all floors	120	19.7%
Assign elevations for all linework	6	1.0%
Connect classroom points, classroom entries, hallway centerlines, and building entries	3	0.5%
Manually verify all elevations	3	0.5%
Assign elevations to sidewalk segments to connect basement, 2nd, and 3rd floor entries	3	0.5%



Task	Hours	Completion Percentage
5. Digitize transitions in AutoCAD	81	13.3%
Elevators		
Convert elevator polygons to points	1	0.2%
Connect points to hallway centerline	3	0.5%
Manually verify connections	3	0.5%
Connect elevator points vertically	2	0.3%
Stairs		
Digitize stairs and landings	45	7.4%
Assign elevations for all segments	8	1.3%
Connect end points to hallway centerline	12	2.0%
Manually verify connections	10	1.6%
6. Build Network Dataset	46	7.6%
Convert all arcs to straight line segments	8	1.3%
Break all linework at every intersection	5	0.8%
Assign attributes for floor number, From Z-Lev, To Z-Lev, speed, and handicap accessibility	6	1.0%
Check elevations of all AutoCAD layers	2	0.3%
Compress all layers and compile all similar fields such as: all classrooms on same layer with 'floor number' distinguishing points	18	3.0%
Add evaluators such as walk speed and walk time	3	0.5%
Configure restrictions and delays for example, elevators and ADA barriers	4	0.7%



Task

Hours

Completion Percentage

3D Model

- Obtain necessary layers
- Symbolize basemap
- Symbolize street furniture and trees
- Orient street furniture
- Extrude buildings based on building height
- Convert building to multipatch
- Obtain and model SketchUp buildings
- Substitute multipatch with SketchUp Models
- Add in and symbolize all building assets
- Modify ESRI data model for 3-D routing

135



2



1



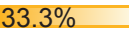
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3



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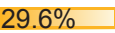
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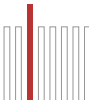
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3



2



The background of the slide is a dark gray surface featuring a complex architectural drawing. The drawing consists of various geometric shapes, including rectangles and lines, rendered in thin white, orange, and green lines. Small blue crosshair markers are scattered throughout the drawing, indicating specific points of interest. On the left side of the slide, there are three diagonal stripes in shades of orange and brown. The text '08' is prominently displayed in the lower-left area, rendered in a large, orange-outlined font.

08

EVALUATE

The Evaluate section tests the application of best practices. This includes testing the validity of network routing and the 3-D campus model. The analytical capabilities of the routing network and newly formed geodatabase will be tested, to see if results presented in the case study research can be replicated. Methods testing will answer the hypothesis that establishment of an organized data system will enhance campus efficiency, sustainability, and safety. Experiments include: a lighting analysis to determine dark areas, building egress analysis, walking tours around the college, and calculating emergency service areas. Additionally, a 5, 10, and 15 minute walking diagram from KSU's Master Plan will be revised, work requests will be simulated, and bioswale areas will be identified (Figure 8-2). All analyses are first conducted within ArcMap then sent to ArcGlobe for visualization of the 3-D campus.

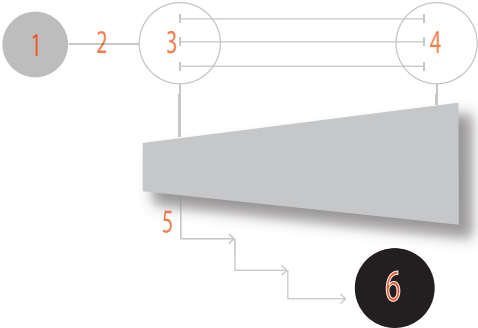


Figure 8-2 Research Framework
Evaluate is the last step of a six part research framework.

Efficiency



Sustainability



Safety

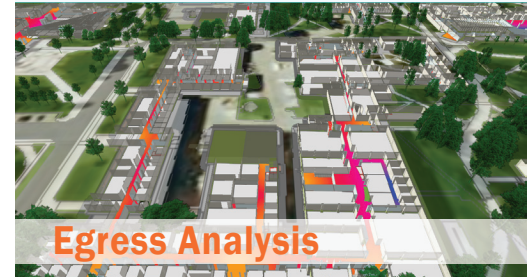


Figure 8-3 Types of Analysis

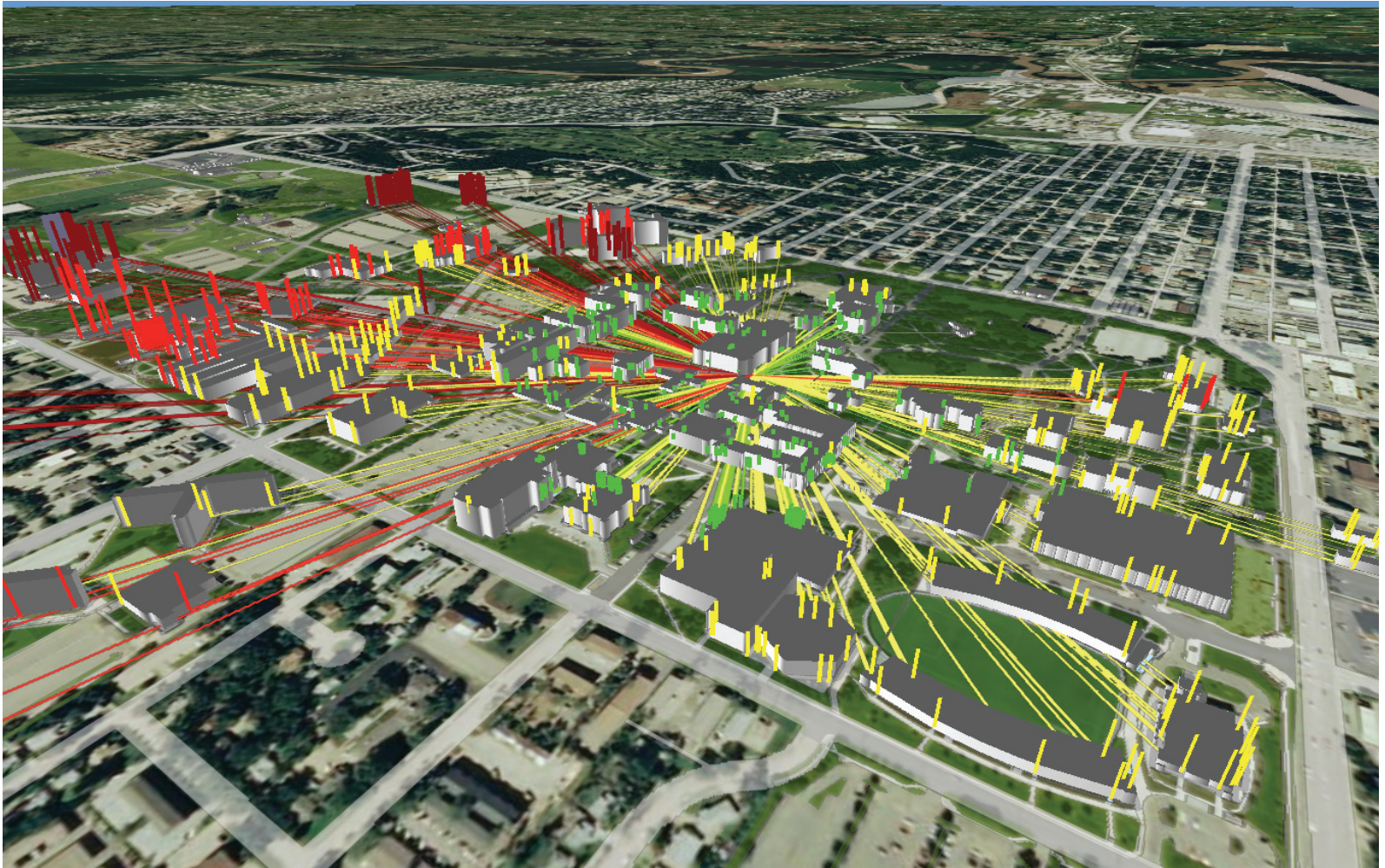


Figure 8-4 **Walking Proximities in 3-D**

Walking proximities are displayed in 3-D. Building entries are color coded and extruded based upon walking distance. Green is reachable within 5 minutes, yellow within 10, and red is reachable with 15 minutes of Hale Library.

Walking Proximity Analysis

Campus master planning efforts focus on developing a denser, pedestrian oriented core campus leveraging building adjacencies. Walk times accurately estimate how long it will take to get to class or reach a meeting across campus and plan accordingly. If certain areas of campus are not accessible within 10-15 minutes, curriculum must be planned accordingly.

Methods

An Origin-Destination cost matrix was calculated from the corner point of Hale Library to all exterior building entries across campus (Figure 8-4, Walking Proximities). The corner point of Hale was used because it was defined as the central point of campus in the master plan (Image 8-3, Walking Proximities in 3-D). The routed walk times were classified on ranges from 0-5, 5.01- 10, 10.01- 15, 15.01- 20, and 20+ minutes. The walk times were then spatially joined to the entries and extruded based upon walk times for easier reading (Figure 8-3).

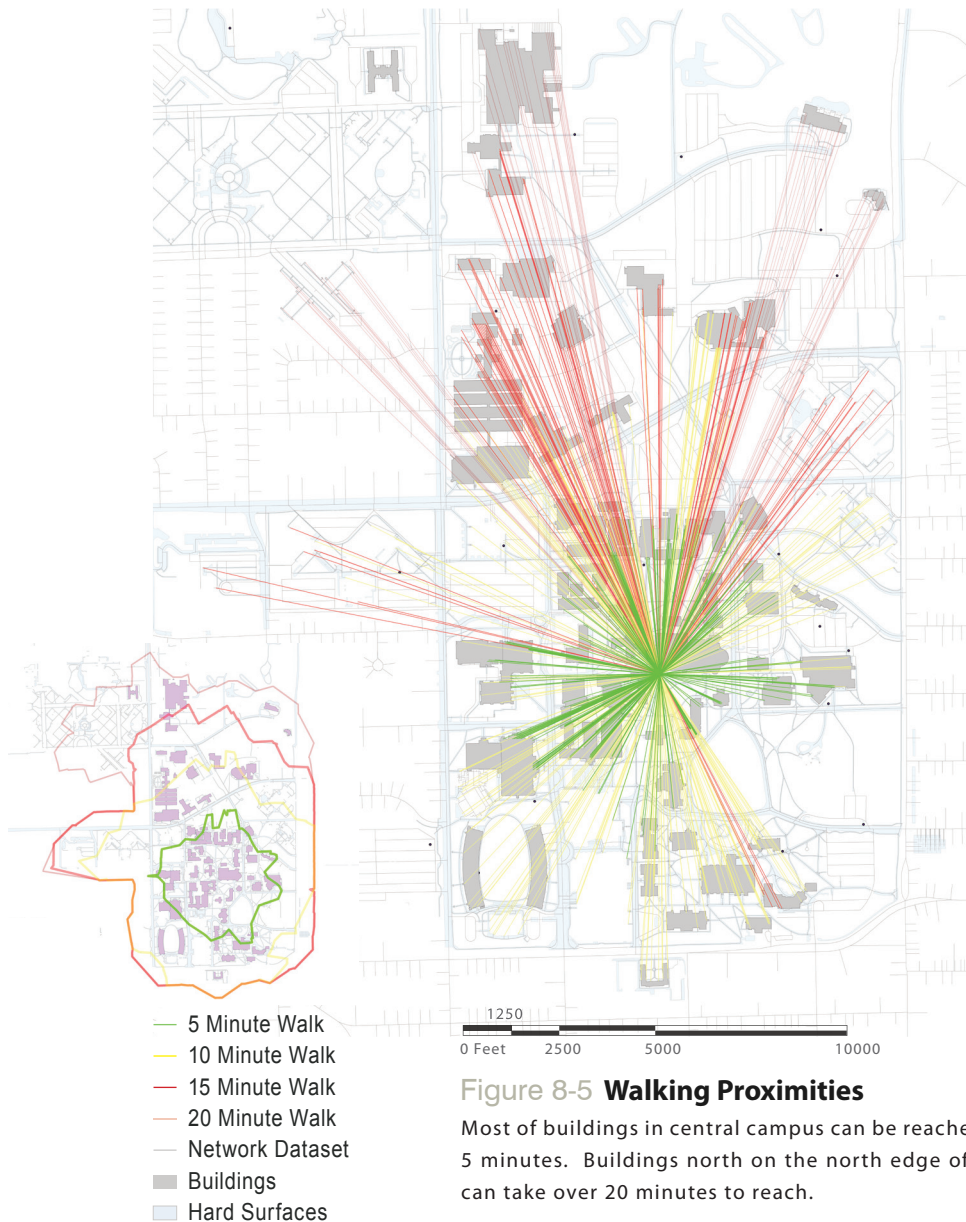


Figure 8-5 Walking Proximities

Most of buildings in central campus can be reached within 5 minutes. Buildings north on the north edge of campus can take over 20 minutes to reach.



Figure 8-6 Campus Infrastructure Map

All utilities and infrastructure can be managed using GIS. That can also be visualized in 3-D improving efficiency and ease of operation.

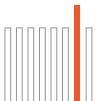




Figure 8-7 Maintenance Request

Asset information, such as fire extinguishers, can be inventoried, access, and visualized in 3-D to aid in maintenance requests.

Facility Work Request

Case study universities have been very successful at streamlining work requests across campus. KSU's current system can be made much more efficient by integrating all building equipment and asset information into the shared geodatabase. Equipment will then be spatially referenced and all information will be accessible in tabular form including manufacturer, part number, and last service date (Figure 8-6). Work plans can then be automatically generated for routine maintenance such as certifying fire extinguishers every year. Also, access to the system could be made online to allow faculty to directly report requests.

Methods

Using the floor plans, all asset information was pulled into the geodatabase. From here, all features can be accessed from the network dataset to provide routing to a specific piece of equipment. All equipment data could then be attributed to inform maintenance workers of required pieces and parts before leaving the shop.

Campus Tours

Tours of specific departments or memorials on campus can be created by an individual when routing is accessible online as a web service. A self-guided walking tour through the College of Architecture, Planning, and Design would promote social sustainability and allow visitors to educate themselves (Figure 8-8). Creating specific routes allows for a personal experience of campus. It would promote the University as well as individual departments. Social hotspots could be identified by integrating a Twitter feed into routing and calling out high activity points. Also, the KSU Tree Walk can be self-navigated to commemorate important people to the university and to highlight individual tree species (Figure 8-7). People could access a table of characteristics for each tree on their smartphone, and learn about the trees as they walk.

Methods

Routing for tours is made easy after creating a network dataset. Each stop

on the tour was fed into the network and routing was calculated based upon shortest distance or shortest time. Other restrictions can be placed on the route including ADA restrictions, preference for

interior routes over exterior, or preference to traverse terrain with more slope for exercise.

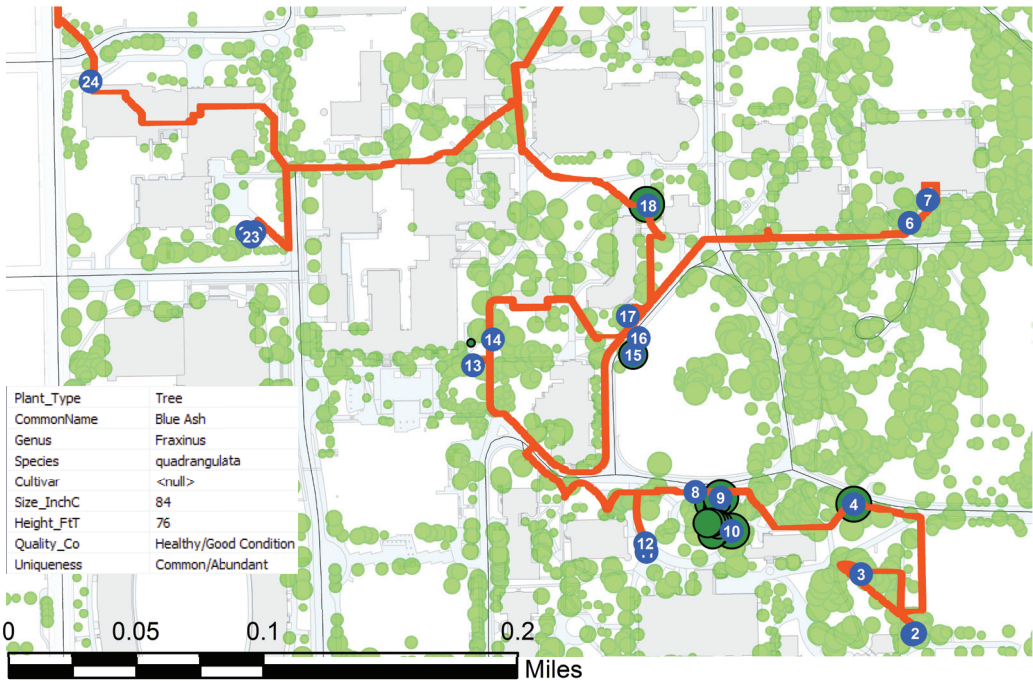
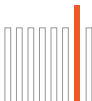
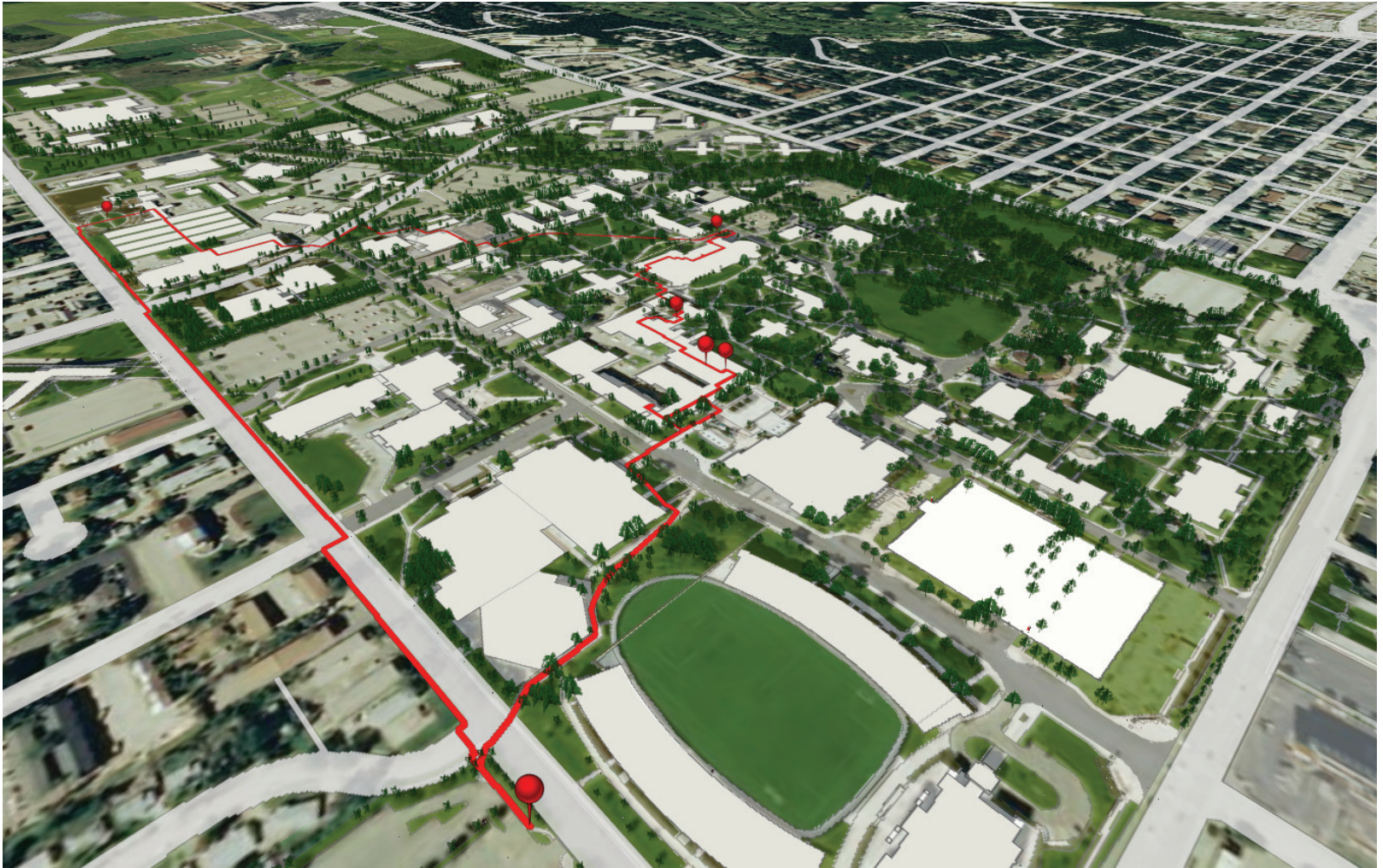


Figure 8-8 Tree Walk Tour

A route can be configured to hit every memorial tree on campus in the shortest distance. Additionally, tabular information can be assessed on every tree on campus.

Total Distance: 1 hour 28 minutes
Total Time: 3.32 miles





Origin: "O" Lot- Free Parking

Destination 1: Landscape Architecture Department Office (302 Seaton Hall)

Destination 2: Studios (106A Seaton Hall)

Destination 3: Post Bach Studios (106B Seaton Hall)

Destination 4: Library Help Desk (222 Hale Library)

Destination 5: K-State Gardens

Destination 6: Back to "O" Lot

Figure 8-9 Self-Guided Campus Tour

A tour can be configured and displayed using a model device if the routing is made accessible using a web-service.

Bioswale Identification

A major issue afflicting Manhattan is uncontrolled water. Just two years ago, a significant flood destroyed many homes. Kansas State University can help remedy the issue by converting many turf grass areas to native plants. Areas receiving a lot of drainage could be converted into bioswales to help ground water recharge. Also in years of drought these plants typically do not need irrigation. Thanks to the campus terrain and basemap, it is possible to identify low-lying areas and determine possible infiltration rates based upon square footage. Cost estimates could easily be determined as well.

Methods

Figure 8-10 Optimal Areas for Bioswales

Using a LiDAR surface, areas of water collection can be assessed. The highlighted areas are those point of collection lying in turf areas. They were then buffered by 50' to determine optimal areas for bioswales.

First a LiDAR surface was used to determine water runoff. Areas around campus were identified where water had a tendency to pool or flow slowly. All grass and planting areas were then extracted from the campus basemap. Likewise turf areas that had a high tendency to collect water were also extracted. The identified areas were selected to be appropriate for bioswales (Figure 8-9). The 3-D campus

created in ArcGlobe was exported into a rendering program, Eon Vue. Vegetation was placed in bioswale areas. The final images were rendered in Vue (Figure 8-10). This is an illustration into how a 3-D base can be used in multiple programs from analysis to visualization software packages.

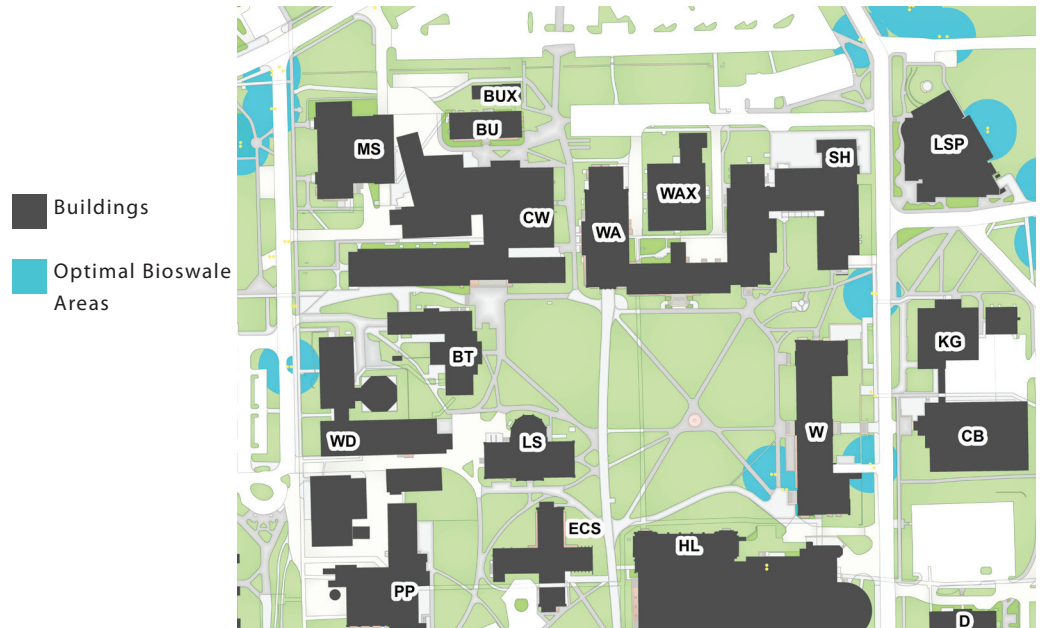




Figure 8-12 KSU Reference Map
1 in = 4000 feet

Figure 8-11 Bioswale Rendering
The 3-D campus model was exported to Eon Vue 11, and vegetation was added. The image was then rendered in Vue.

Egress Analysis

The value of an egress analysis is determining areas of a building farthest from entries. These areas signify the least accessible areas during emergency rescue. It is possible to identify building areas violating the 2009 International Building Code such as dead end corridors over 50 feet in length or over 20 feet in a building without sprinklers. IBC Code from 2009 has been adopted by Manhattan.

Methods

Hallways were extracted from floor plans. An euclidean distance was calculated to determine distances from building entries (Figure 8-11). Values were symbolized on a color ramp from 0 - 150 feet.

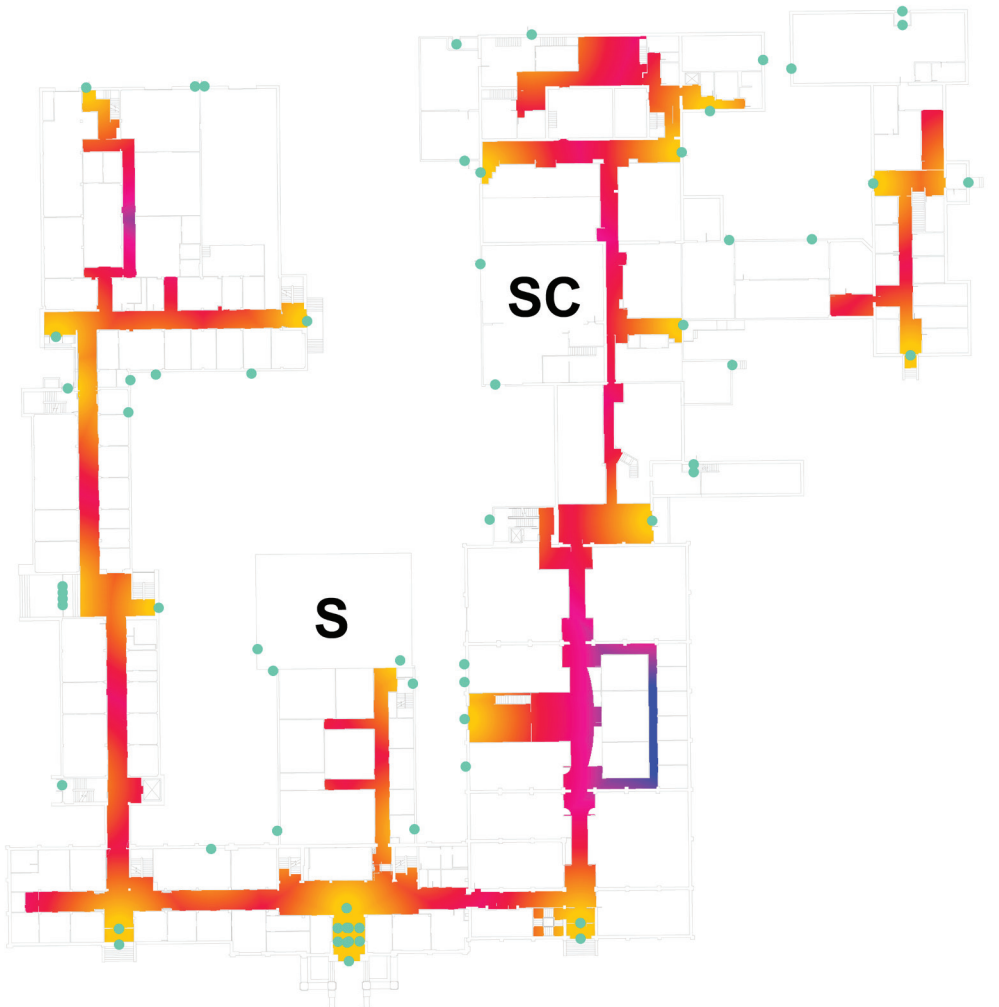


Figure 8-13 Egress Analysis

Seaton Hall and Seaton Court egress analysis showing the back hallway of offices are the farthest areas from building entries.

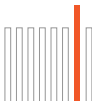




Figure 8-14 **Egress Analysis in 3-D**

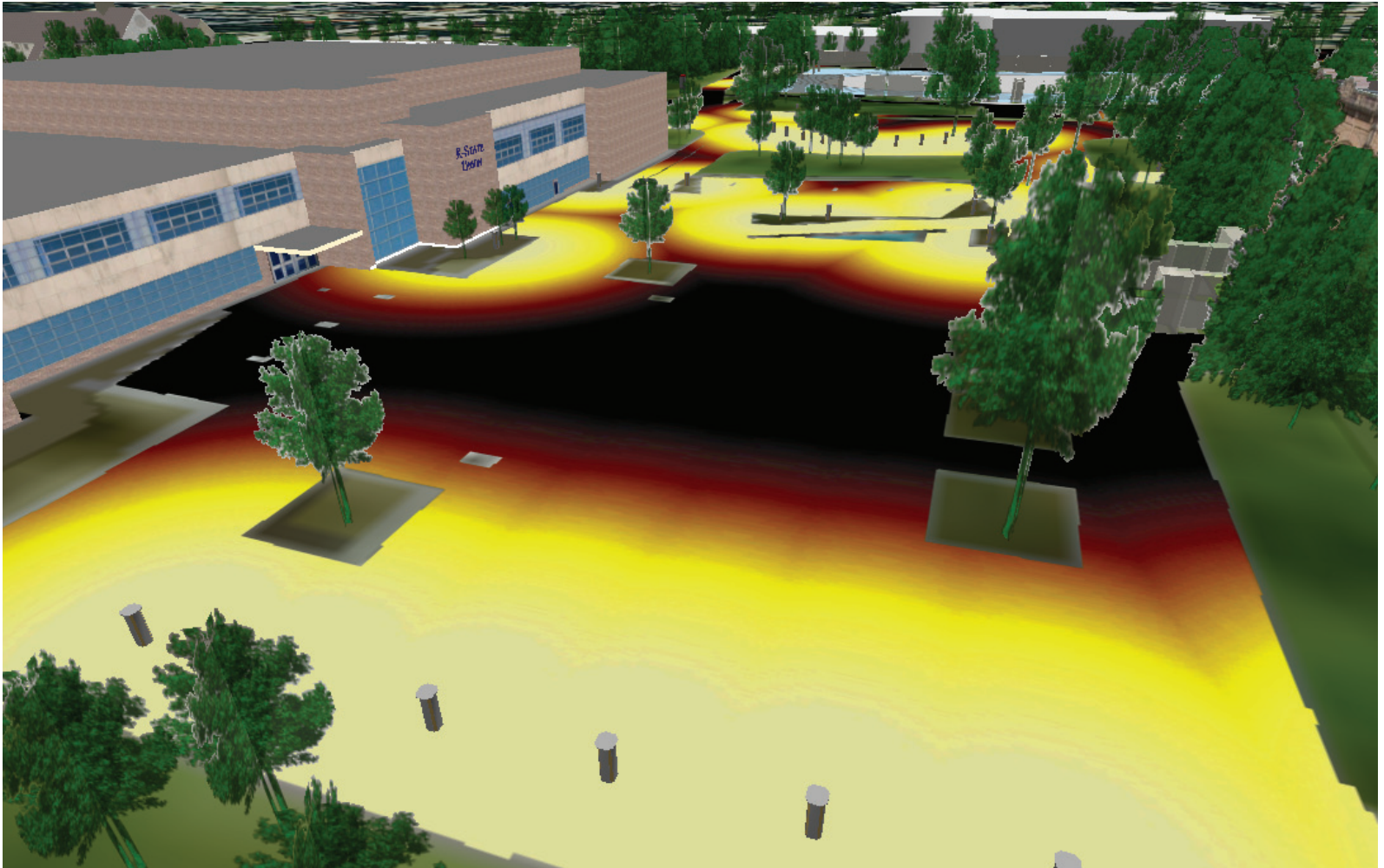


Figure 8-15 **Light Distribution at Night**

Bosco Plaza in front of Seaton Hall is well lit at periphery but lacks lighting on the interior of the space.

Street Light Study

Keeping walkways illuminated at night is a huge concern for campus planners. Reducing the number of dark areas on campus facilitates a safe environment and encourages pedestrian circulation at all times. A street light analysis identifies dark areas on campus and tells decision makers where to focus their efforts (Figure 8-13). This map can be enhanced by integrating crime data and running spatial autocorrelation to see what dark areas facilitate crime. This enhanced analysis tells decision makers where security cameras and emergency phones should be placed in addition to street lights. This analysis is made possible through a combined campus and emergency response database.

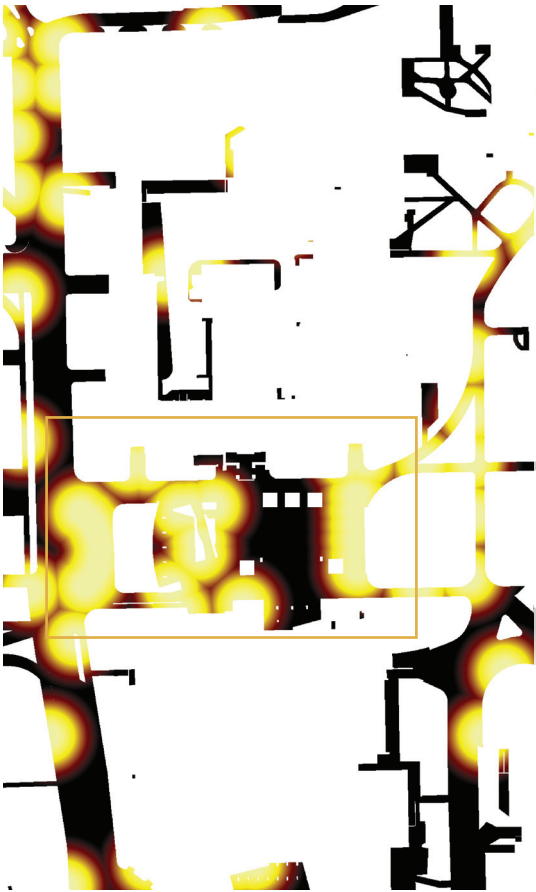


Figure 8-16 Street Light Study

Methods

The methods are very similar to the egress study, in that raster cells were analyzed by proximity to street lights. For easy calculations, a light spread of 50 feet was used for all street lights. The analysis could be enhanced to include specific street light types with specific light distribution patterns. This information was not available from the Department of Facilities.

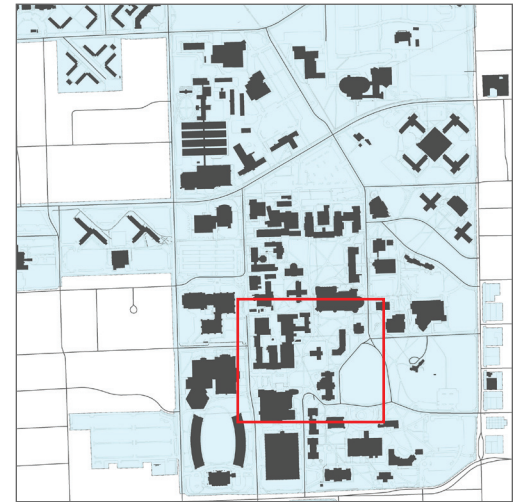


Figure 8-17 KSU Reference Map

1 in = 4000 feet

Closest Facility

Emergency responders throughout the country respond to incidents informed of the situation at hand. They can locate the scene in 3-D space, calculate accurate routing, and identify closest facilities: police unit, fire hydrant, or fire hookup. Responders are able to access this information on the fly, making their job safer and more effective. Lastly, responders are able to visualize all of this information in 3-D and have the ability to orbit around, zoom in/out, turn layers on/off, and even run analyses.

Methods

The scenario is a fire that has just been reported in Seaton Court 106B. In a flash, emergency responders have to determine the nearest firehouse, routing,

closest hookup, and distance from the hookup. Ideally when the call comes in, the X, Y position will be mapped by the dispatcher. A closest facility analysis from the incident will identify the closest firehouse and calculate the fastest route based upon historic traffic patterns for Manhattan, Kansas. Time of day and day of the week both affect the response time. Once the route to the scene is determined, another analysis is conducted with all fire department connections relative to the scene. Once the hookup has been identified, all accompanying information can be accessed including class type, gallons per minute, and any noted obstacles (Figure 8-15).

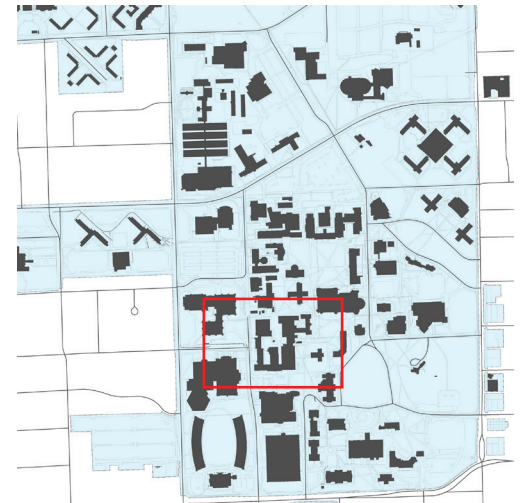


Figure 8-18 KSU Reference Map

1 in = 4000 feet

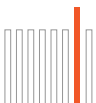


Figure 8-19 Closest Facility Analysis

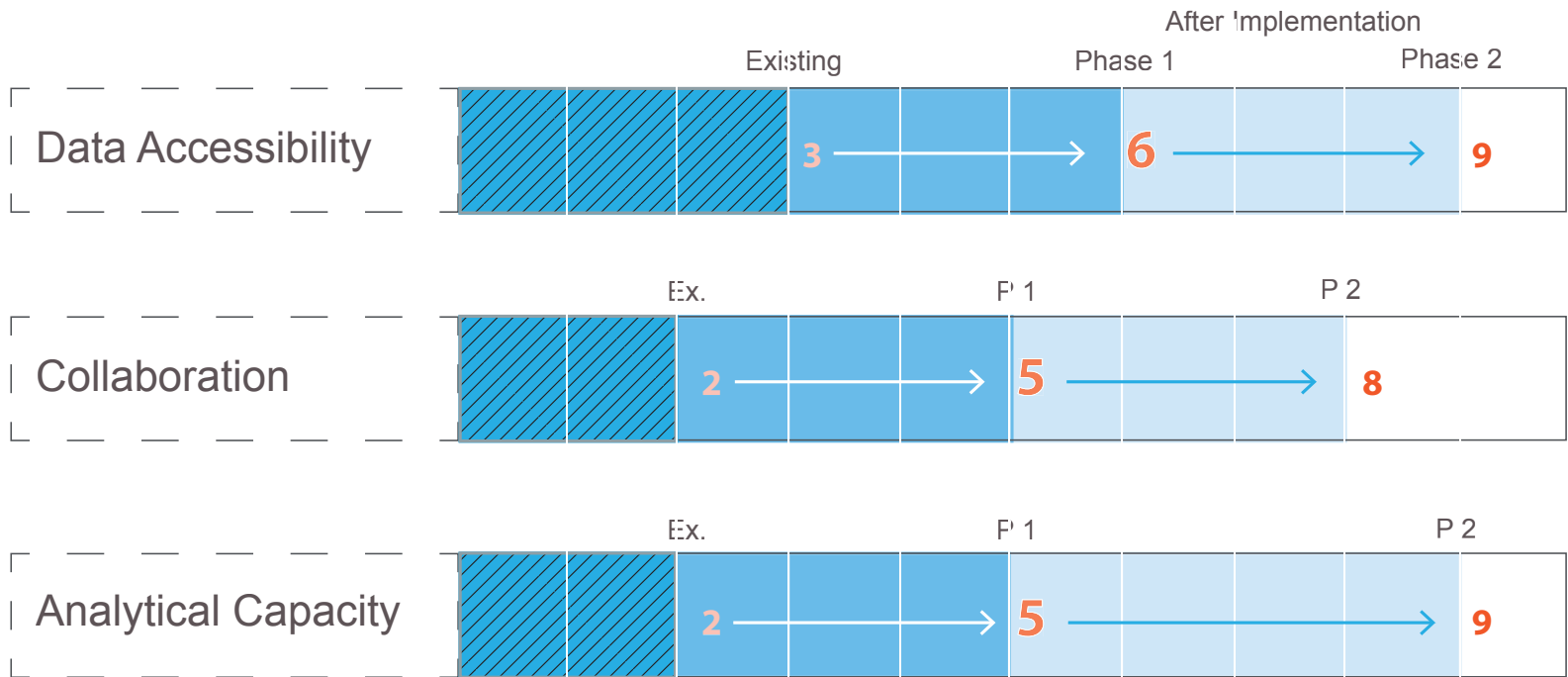
The green line represents a route from the closest fire station to 106 Seaton Hall. The brown line represents the closest fire hydrant to service the fire. All information is accessible in tabular form.

Name	SourceID	SourceOID	PosAlong	SideOfEdge	CurbApproach	Status
Fire Hydrant	KState_Sidewalk_Break	887	0.882812	Left Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	5119	0.788558	Right Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	4972	0.534169	Left Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	3200	0.001288	Left Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	5925	0.816614	Left Side	Either side of vehicle	OK
FDC	KState_Floorlines_Split_ALL2	15952	1	Left Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	10	0.260793	Left Side	Either side of vehicle	OK
Fire Hydrant	KState_Sidewalk_Break	3308	0.5453	Left Side	Either side of vehicle	OK
FDC	KState_Floorlines_Split_ALL2	8947	0	Left Side	Either side of vehicle	OK
FDC	KState_Transitions4	1665	0.918038	Left Side	Either side of vehicle	OK
FDC	KState_Floorlines_Split_ALL2	15461	0.088547	Right Side	Either side of vehicle	OK
FDC	KState_Floorlines_Split_ALL2	13470	0	Right Side	Either side of vehicle	OK

The ability to bring together spatial data and analyze trends, proximities, distributions, and run scenarios has drastic implications on the efficiency, sustainability, and safety of campus (Figure 8-16). Right now, Kansas State University is restricted in this sense. By creating a centralized database, a network dataset, and a 3-D campus model, this project makes significant strides toward achieving KSU's visionary goals.



Kansas State University Baseline Assessment Comparison

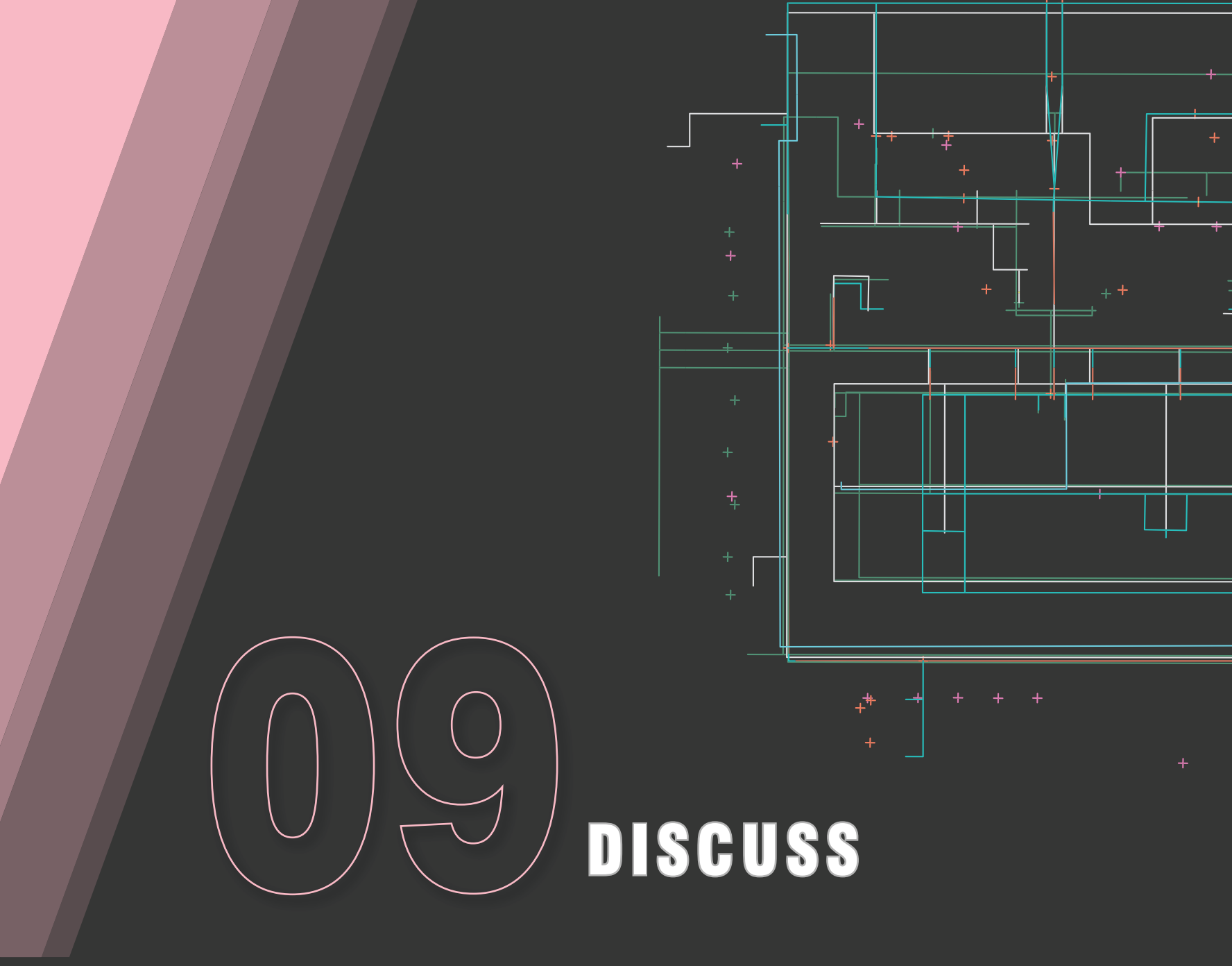


P 1 = Phase 1: Progress achievable by implementing GIS model structured, built, and documenting in this report

P 2 = Phase 2: Progress is achievable by advancing GIS model as outlined

Figure 8-20 Baseline Comparison

The best practices for data management have significantly increased Kansas States ability to access data, work collaboratively, and conduct spatial analysis on campus.



09

DISCUSS

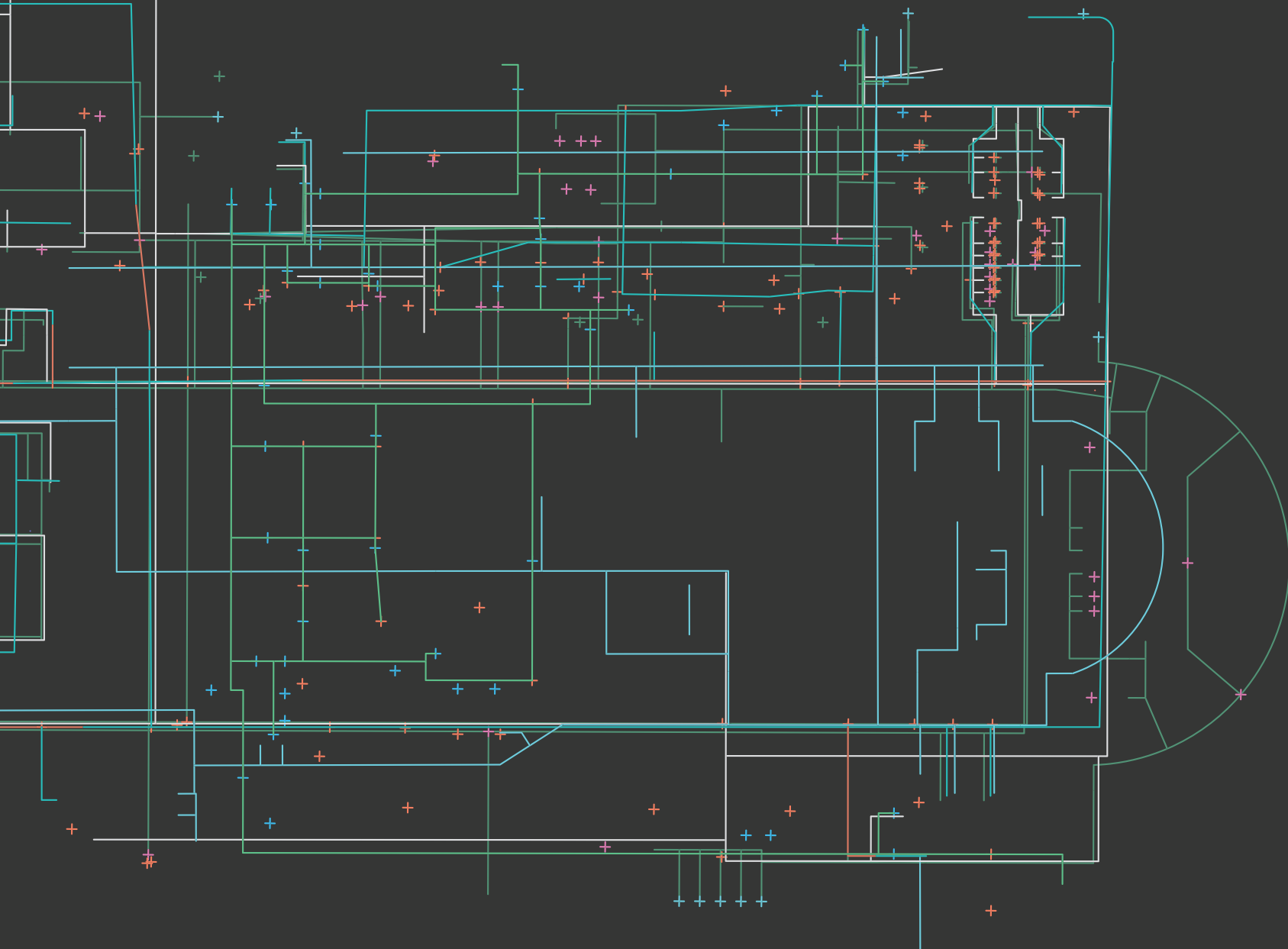


Figure 9-1 Hale Library

Conclusions

The research was conducted in three steps progressing from an initial baseline interview assessing how KSU currently manages data, to dissecting how other universities optimized their system, to ultimately applying the best practices to optimize safety, efficiency, and sustainability.

Baseline Evaluation

A baseline evaluation was conducted at KSU to determine how spatial data is currently accessed and distributed between departments, discussed in Chapter 5, “Contextualize”. Unanimously data exists in isolated silos proprietary to the department who created the data. Little to no interchange takes place, preventing the ability to work collaboratively to achieve shared

campus goals of promoting research and development. The community of Manhattan has similar issues with data organization and accessibility between emergency responders. The situation is further complicated when considering data interchange between the campus and community. Communication is limited between the two entities. Coordination must take place for both emergency responders and facility managers to optimize workflow and enable a safer, more efficient, and sustainable environments.

Dissecting Best Practices

After a baseline evaluation was conducted, a targeted research focus was undertaken to identify, understand, and dissect the best practices proven to advance campus safety, efficiency, and sustainability. This process is explained further in Chapter 6, “Assess”. Often, universities had focused

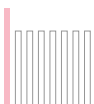


efforts in one category or another, but very few had considered uniting efforts to take a holistic approach. The case studies taking a unified approach were then investigated in further detail through personal interviews. Interviews provided a greater understanding for how practices were implemented at other universities which then established grounds for implementing at KSU. Three best practices were identified to promote the holistic goals of the university: creating a unified geodatabase, developing a 3D routing network, and modeling a 3D virtual campus.

Applying Best Practices to KSU

The three identified practices were applied to KSU, documented in Chapter 7, “Analyze”. Each practice was proven to promote university goals in the case studies, so replication of practice

ensured positive results for KSU. A unified geodatabase was structured to foster a working relationship between campus departments. The relationship can then be expanded to include the City of Manhattan and all emergency responders. An online web service makes the data accessible to these users and the public, as well as establishing restrictions on proprietary information. A routing network enables transportation analysis for decision makers while engaging the public in spatial processes. Emergency scenarios can be simulated ahead of time to develop efficient response protocol and ensure public safety. Facility managers can test scenarios to determine possible impacts of change, automate workflow, and streamline work requests. A 3D campus was modeled to facilitate public understanding and communicate analysis to decision makers. A virtual campus



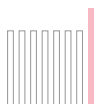
is additionally helpful for marketing, fundraising, and education. It enables an understanding of campus that is not possible in any other form ranging from the ability to visualize asset locations to the impacts of a new construction project. Experiments validating the database, routing network, and 3D campus were examined in Chapter 8, “Evaluate”.

Results and Findings

Testing the validity of the three implemented best practices reinforces the stated hypothesis in Chapter 1, “Introduce”. Organization of spatial data will promote safety, efficiency, and sustainability for Kansas State University. The testing of several scenarios demonstrated how a central data repository can be utilized to perform analysis which can then be visualized in 3D. Ultimately this analysis will provide information to decision makers to enact policy and encourage design to facilitate

an environment of safety, efficiency, and sustainability. Campus departments will use the system to streamline operations and provide situational awareness. Emergency personnel can access the campus data and display the information within a virtual environment to respond faster and more intelligently. The benefits trickle down to the public who can use the routing and virtual model to tour campus and perform basic spatial analysis by creating personalize routes.

Safety, efficiency, and sustainability are interrelated and advancements in one area have the ability to positively advance another. This assumption held true when applying best practices for KSU. The most optimal practices were drawn from universities promoting a holistic approach to campus planning. A unified database, routing, and virtual campus work in conjunction to promote university goals. The situation at KSU and Manhattan



specifically defined safety, efficiency, and sustainability as the most important factors advancing into the future. As explained in Chapter 2, “Introduce,” the vested interests and university goals defined the three focus areas, and the three applied practices advanced these aims.

Contributions

Each best practice provided distinct contributions for optimizing campus efficiency, sustainability, and safety.

Best Practice 1: Creating a Unified Geodatabase

- Established a working relationship internally between campus departments as well as the community
- Created a conversation for development in spatial analytics and geodesign
- Initiated discussion on how to

maximize capabilities of spatial data

- Educated and informed decision makers
- Automated workflows
- Overcame issues of scale and nested political jurisdictions with varying standards of care

Best Practice 2: Developing a 3D Routing Network

- Provided the ability to explore campus in a self-directed manner
- Provided a direct means of wayfinding reducing extra time and stress associated with finding an unknown location
- Enabled transportation analysis for many users which can then directly influence policy and design for campus and community
- Built upon a common geodatabase by providing a structure for data integration and organization

Best Practice 3: Modeling a 3D Virtual Campus

- Provided the ability to visualize analysis and routing options
- Provided a platform for understanding an communication between technicians, decision makers, and the public
- Enabled all campus users an ability to investigate campus virtually



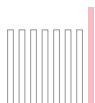
Limitations of Methodology

The major limitations of this study are time, money, and requirements for technical expertise.

- The project will take longer than six months to complete.
- Facility management data and routing was only input for 70 buildings due to time constraints and lack of floorplans. These buildings act as a template for future building data input.
- Eventually, staff will have to be trained to use GIS and how to input data into the database.
- A GIS specialist will have to maintain the system and coordination between departments.
- A single, solitary person can manage the system, but many people will be required for data preparation.
- As with any piece of technology, it is subject to malfunctions such as the server or Cloud losing service and

data becoming unavailable for an undefined duration of time.

- Data interoperability allows for dynamic file updates, but the system must undergo regular maintenance to purge old and irrelevant data.



Limitations to Implementation

Limitations to implementation exist primarily in four areas: ease of use, data integration, cost, and system capabilities. Please refer to Figure 9-2, Variables for Implementation Diagram.

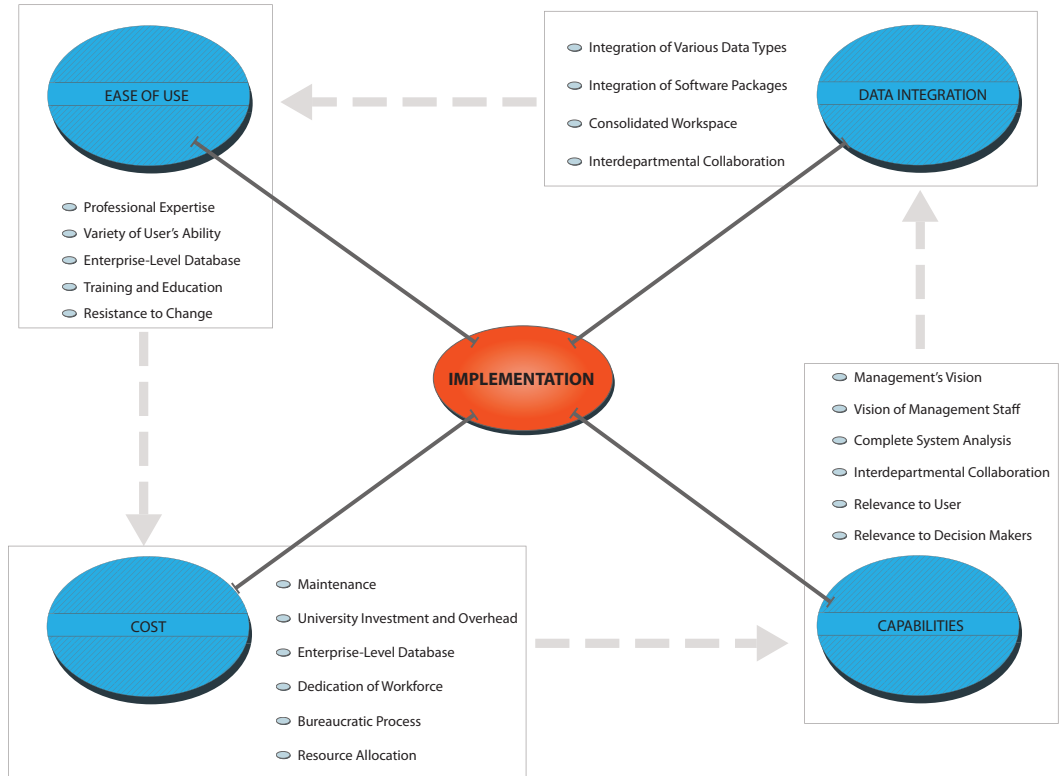


Figure 9-2 Variables for Implementation

Data Completion Diagram

Description

Data Collection

	Completed/ Total	Percentage Completed
Electronic floor plans	340/ 550	62%
Attributed basemap	668/ 668 Acres	100%
Attributed floor plans	340/102	62%
Geolocate building assets	2,400/3,885	62%

Modeling Features

Buildings	45/102	44%
Sculptures and art installations		0%
Hardscape edges: retaining walls, stairs, etc.		10%

Network Dataset

Roadways	16,153	100%
Parking centerlines	1,593	100%
Campus sidewalks	6,498	100%
Hallway centerlines	40,179	62%
Designate every intersection as a junction	136,717 total	100%
Classroom points	9,548/ 15,500 (est.)	62%
Stairs and elevators	3,159	68%
Building entries	12,785	66%



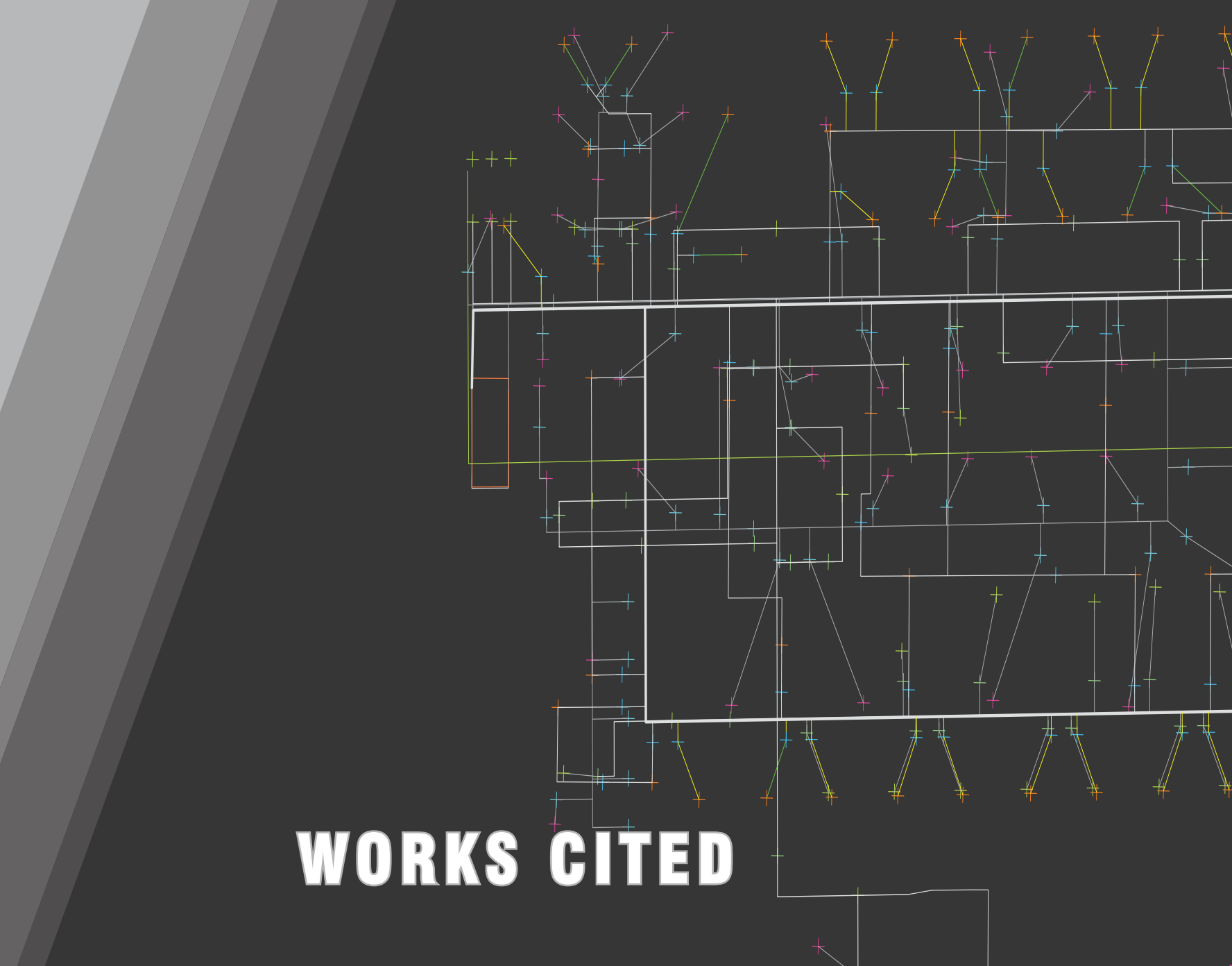
Future Work:

The completion of a 3D network dataset expanding campus equips future transportation analysis on both pedestrian and automobile modes. Pedestrian routes can be expanded to include campus dormitories and apartments, and then hosted online as a web-based service. This same system could be coupled with the emergency response database for Manhattan to promote informed emergency response.

Other areas worthy of expansion stemming from this project include:

- Advance the 3D campus model
- Further digitization of interior and exterior assets
- Integrate new construction projects and campus expansions
- Implement enterprise level solution for data exchange
- Create online web services for the public to access
- Integrate campus art for wayfinding purposes
- Model 3D exterior features such as overhead structures and walls
- Further transportation analysis to determine deficiencies in service areas
- Further AiM integration using AutoCAD



The background features a dark gray area on the right containing a complex technical drawing of a building floor plan. This drawing includes numerous white lines for walls and rooms, with various colored lines (yellow, green, blue, pink) and small crosshair markers indicating specific points or dimensions. On the left side, there are several overlapping diagonal bands in shades of gray.

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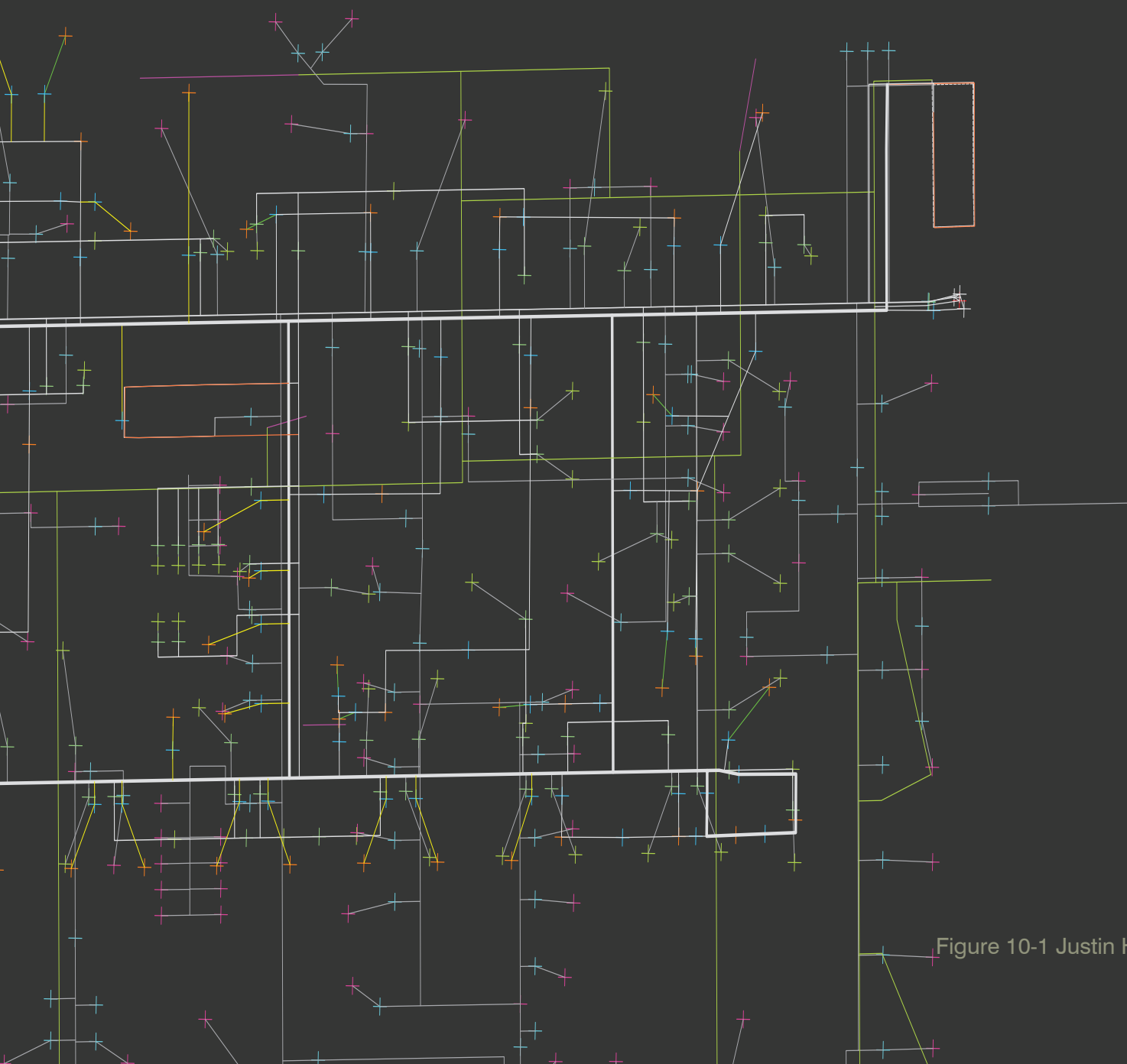


Figure 10-1 Justin Hall

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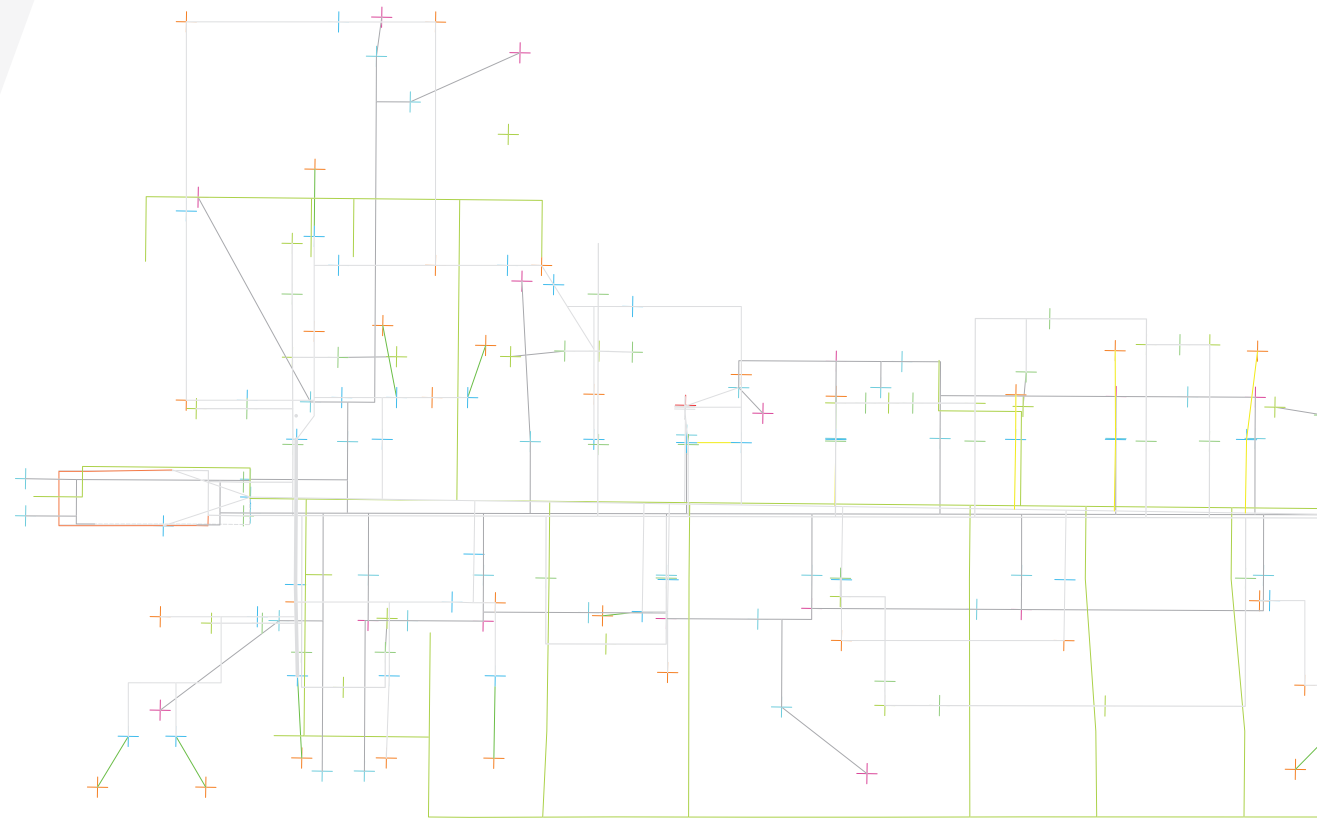
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APPENDICES

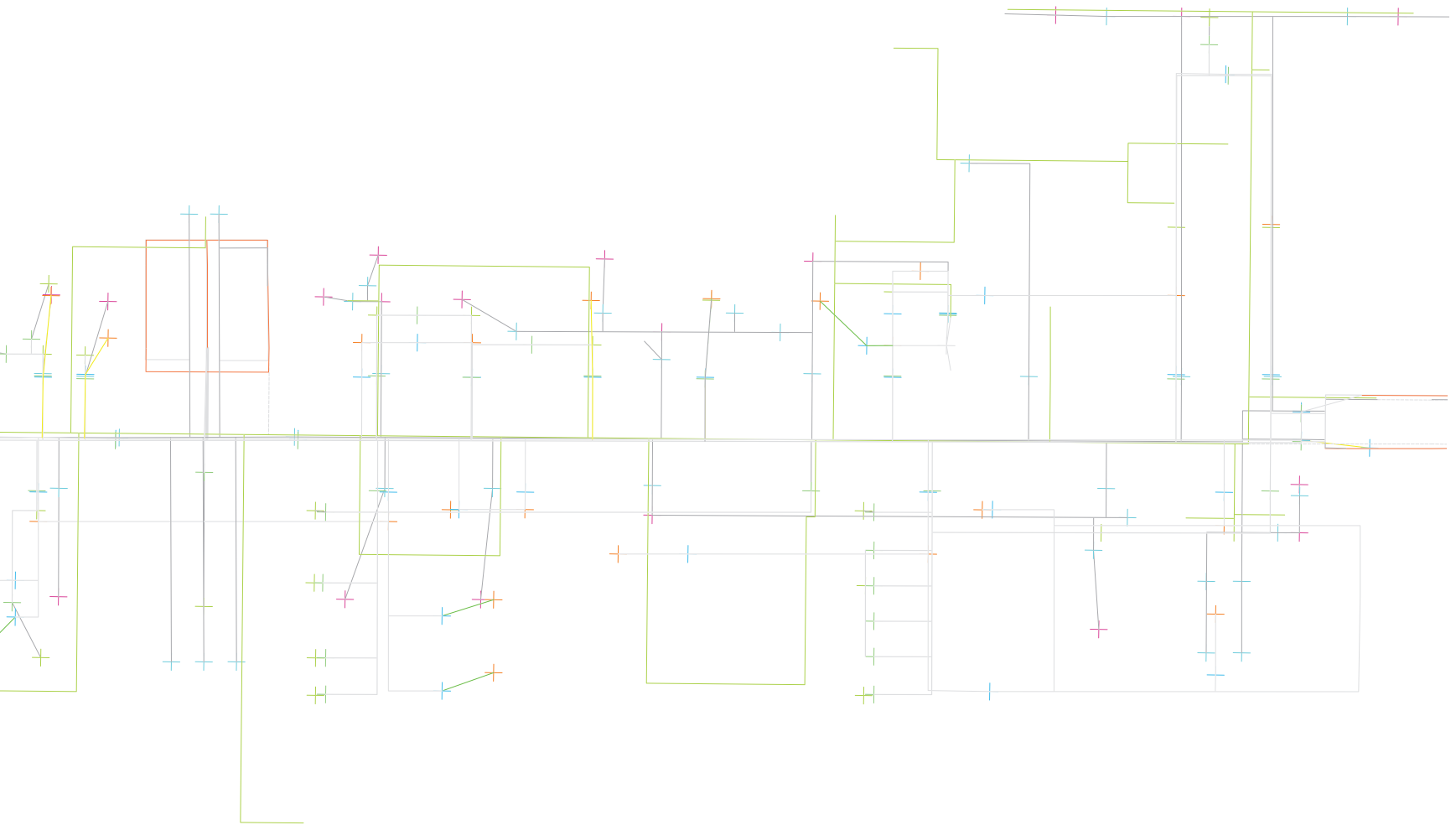


Figure 10-1 Dickens Hall

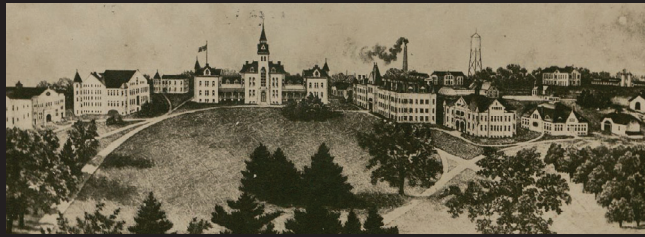
1870



1885



1893



1914



KSU Historic Imagery

1940



1950



1984



All Imagery was retrieved from the
University Archives, 506 Hale Library

1872

- Henry Worrall Plan
- Original campus with 9 buildings
- The Kansas Industrialist, 1941, "April 12, 1872 a road was located to complete a highway around the College farm, now the main campus."
- Manhattan's Population was 700 people

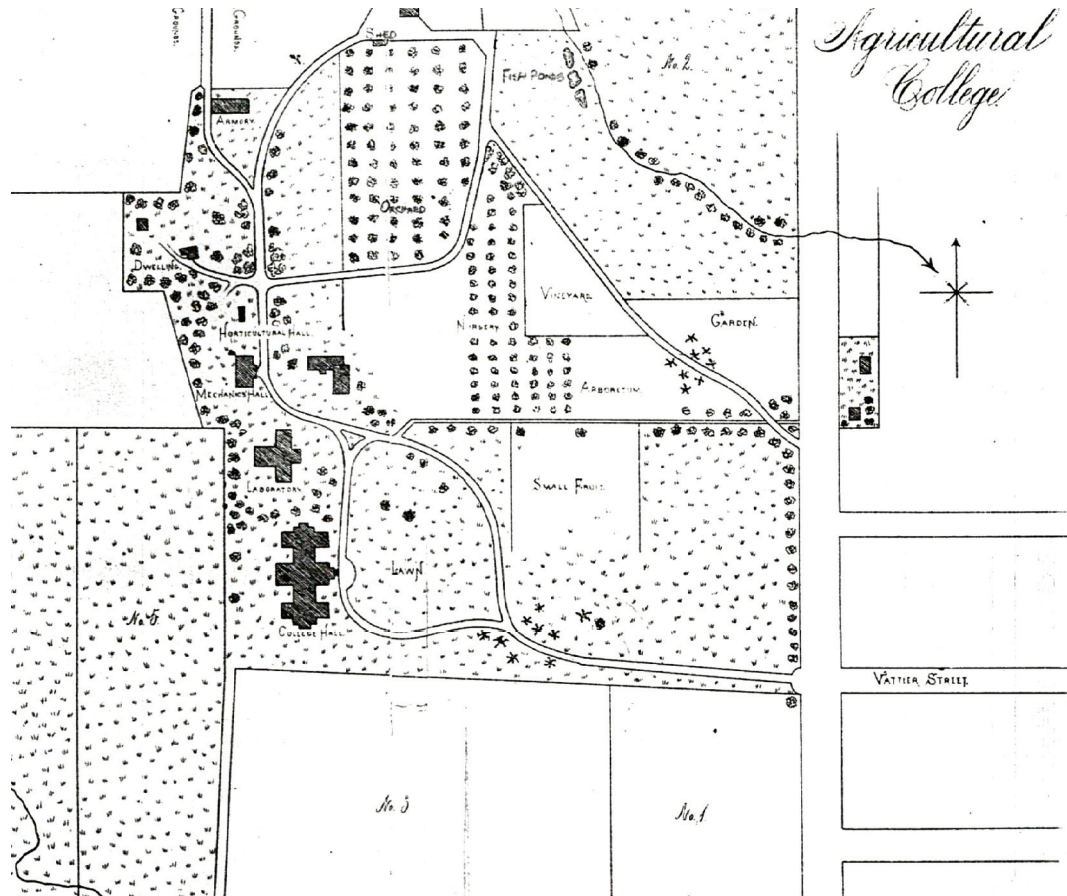
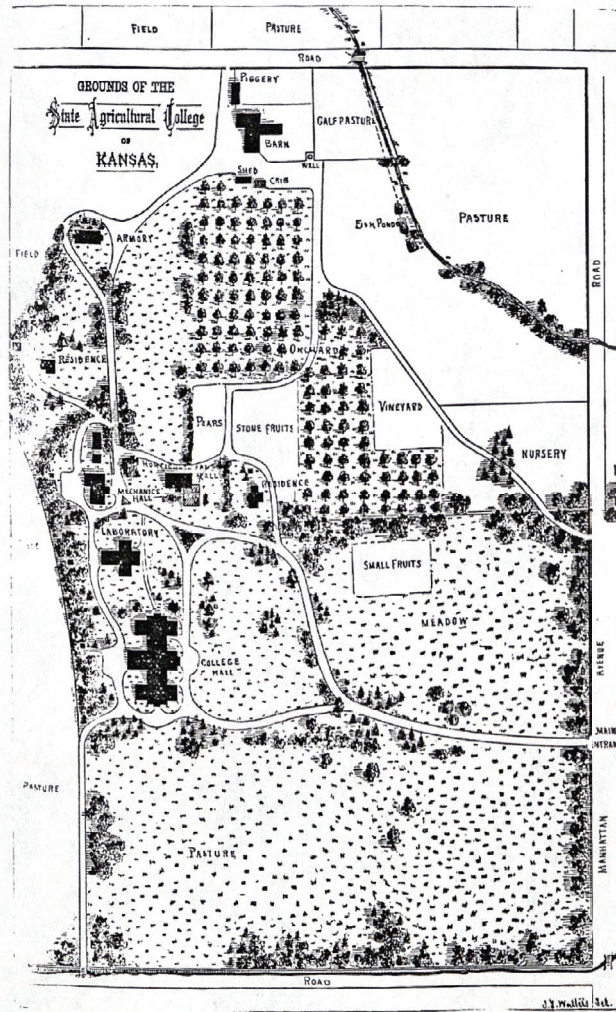


Figure 10-2 1872 Plan of Campus

Kansas State University Library Archive



1885

- The Maximillian Kern Plan was created in 1885
- Trees were planted amongst the buildings
- a new road connected the backside of Anderson Hall
- Two new parcels to the south were acquired
- “Naturalistic idea in a more sophisticated and practical form.”

Figure 10-3 1885 Maximillian Kern Plan

Kansas State University Library Archive

1893

- Kansas State Agricultural College Campus Map
- One building was added to ten total
- New walks were built by Anderson Hall
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doluptatet ex eium nihilig nihilig
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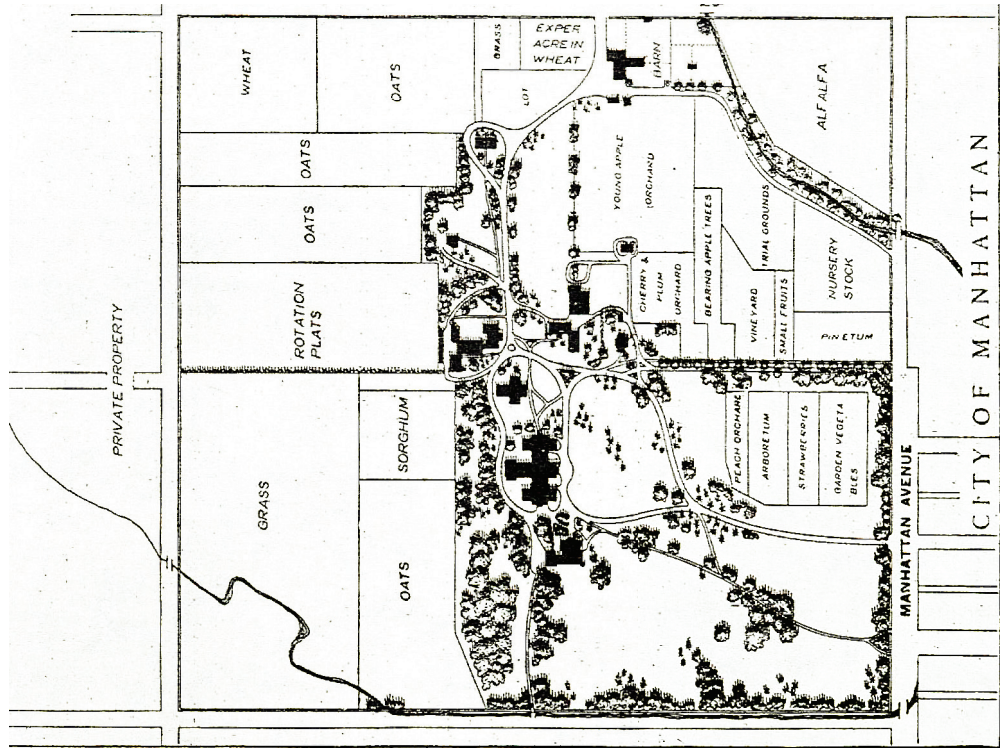
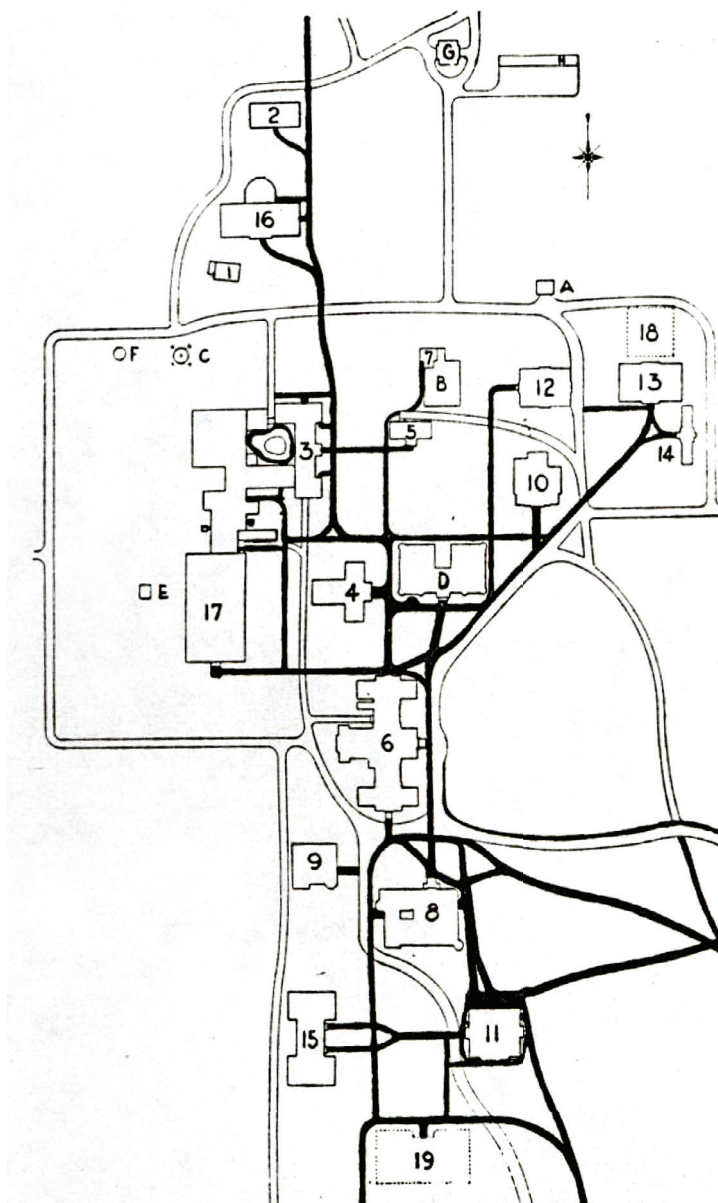


Figure 10-4 **KSAC Campus Map**

Kansas State University Library Archive



1909

- Ten new buildings were built and all were connected with walkways
- Most of the original central campus is formed

Figure 10-5 **1909 Campus Map**

Kansas State University Library Archive

1914

- Frank Waugh Plan was commissioned but dropped
- “While master planning was coming into vogue in the rest of the country, KSAC fell behind in planning,” (Brent Bowman and Associates, October 1992)

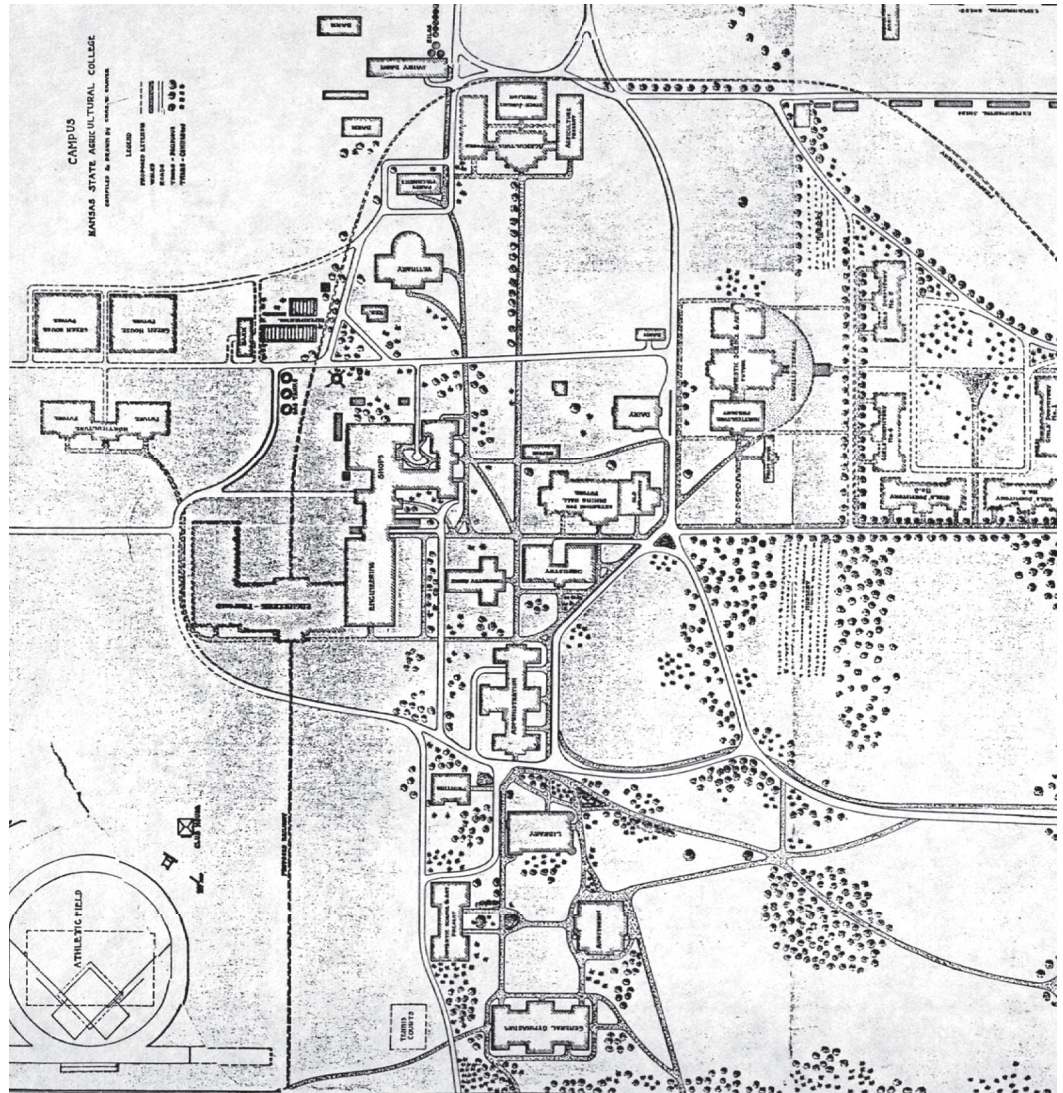


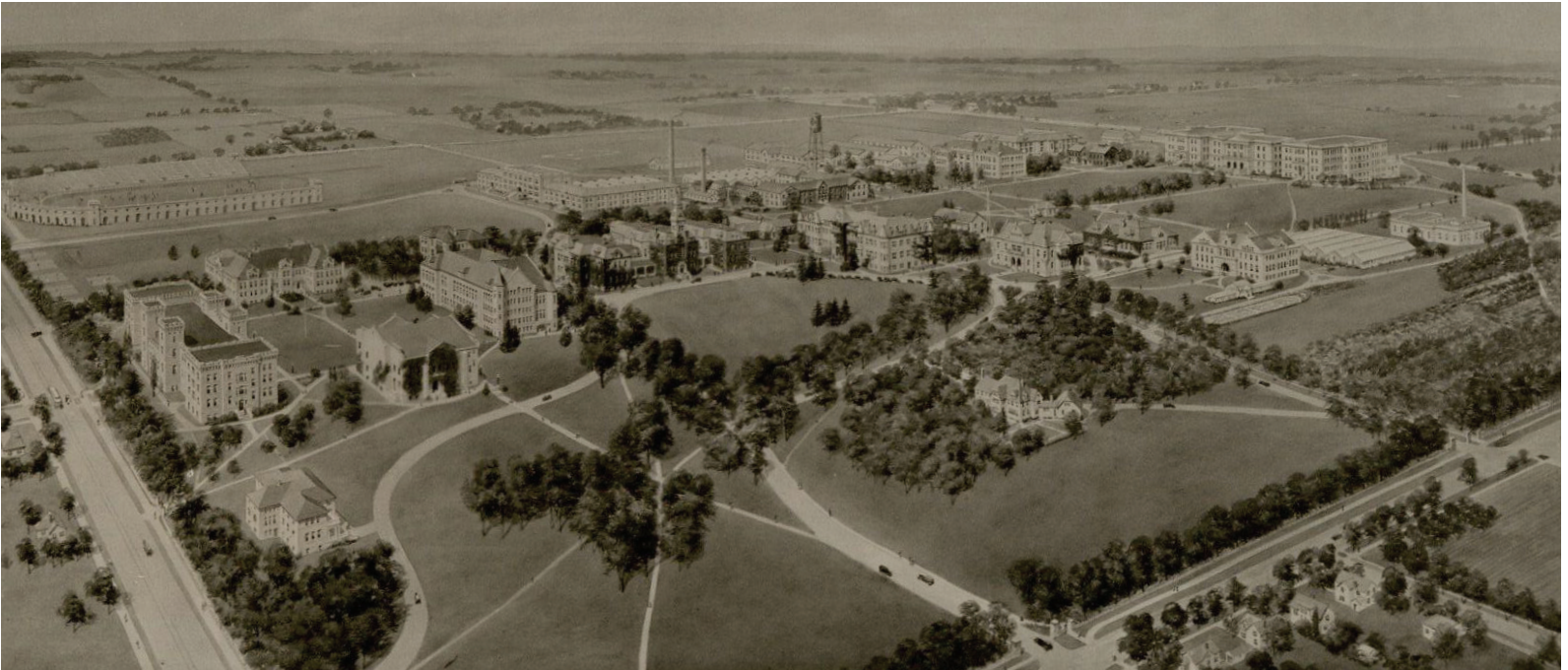
Figure 10-6 **1914 Campus Map**
Kansas State University Library Archive

1931

Figure 10-7 1931 Aerial Image

Kansas State University Library Archive

- Paul Weigel Plan
- Reinforced the idea of an ellipse with loose, open quadrangles and a naturalistic “arboretum environment”
- Many buildings were developed around the periphery such as Thompson Hall, Old Stadium, and Waters Hall
- A new road was built outside of Thompson



1952

- Huge campus and community growth

Manhattan 1940: 11,659

Manhattan 1950: 19,056

KSAC Enrollment 1940: 4,910

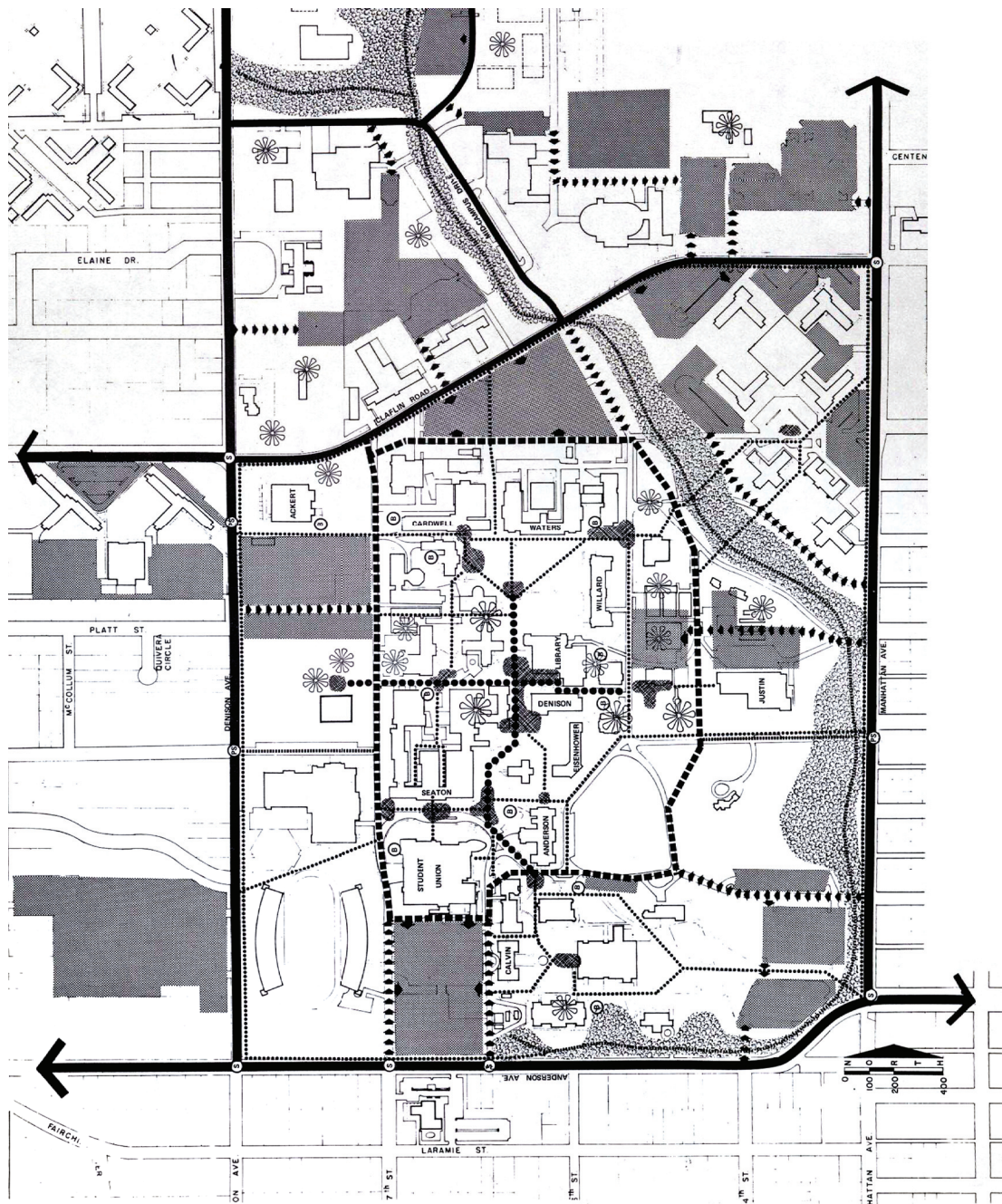
KSAC Enrollment 1950: 6,867

- Most development west of 17th street of north of Claflin was new
- Petticoat Lane was built to connect Claflin
- Large areas of open space remain consistent from earlier plans
- lots of street trees had been established as a result of the 1931 Plan
- All roads had been named

Figure 10-8 **1952 Hare and Hare Plan**

Kansas State University Library Archive





1974

- Circulation Plan primarily focused on pedestrian circulation and parking
- The campus plan adopted goals of the Long Range Transportation Plan of 1972 including:

Goal 1: Reduce the intrusion of all motor vehicles on the main campus

Goal 3: Bicycle usage should be encouraged

Goal 4: Pedestrian circulation and access should be improved

Figure 10-9 Pedestrian Circulation Map from 1973 Ray Weisenburger Plan

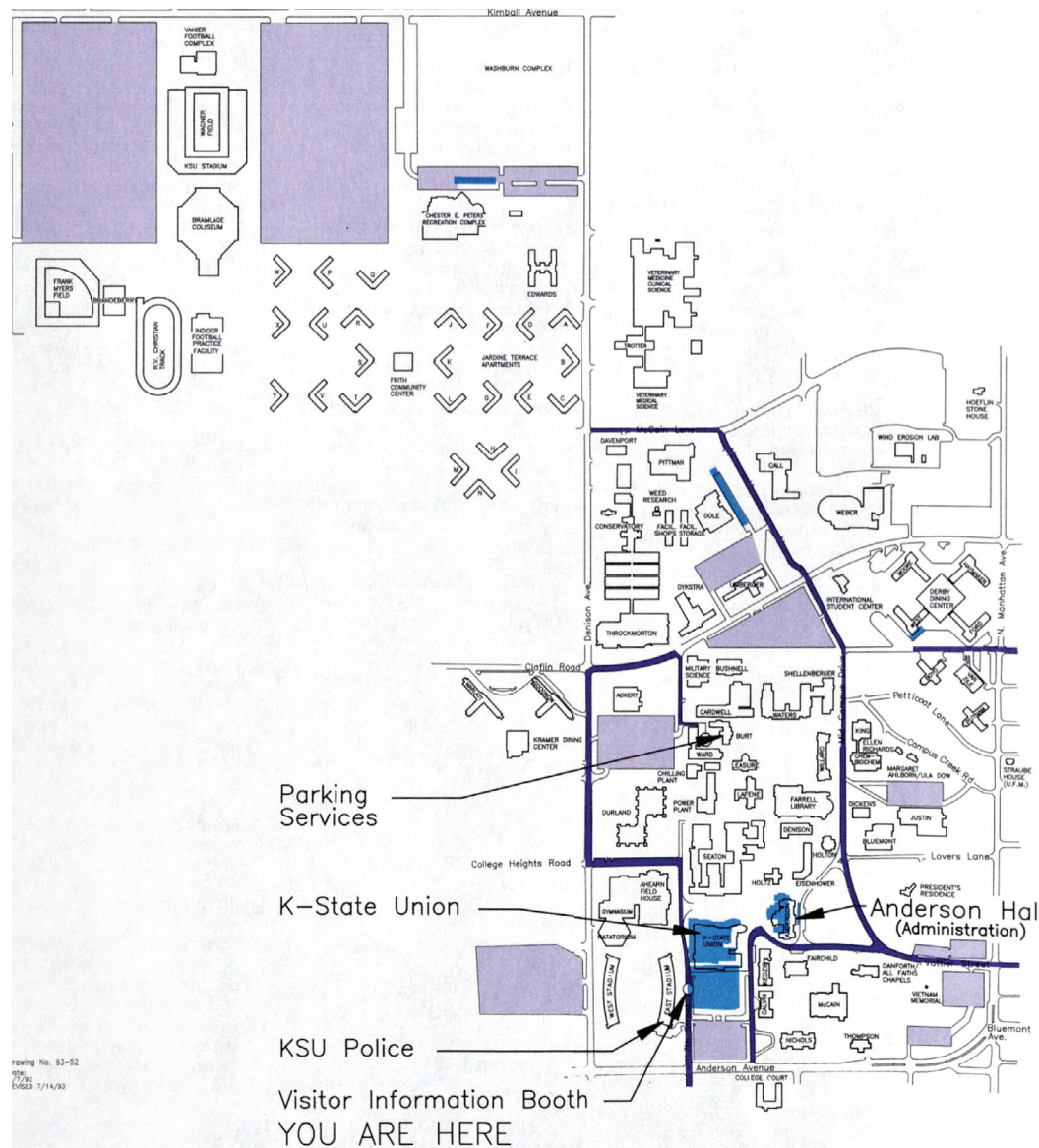
Kansas State University Library Archive

1995 Master Plan

- Many strategies and suggestions were focused on improving pedestrian circulation
- Claflin Avenue was continued through
- Several new buildings north of Claflin had been built
- In 1992, Vattier Street was closed beyond Anderson Hall and Bosco Plaza was built in front of Seaton Hall
- In 1992, over \$4 million was invested for ADA building renovations
- In 2000, Mid Campus Drive was converted to a one-way to control automobile traffic

Figure 10-10 **1993 Campus Map**

Kansas State University Library Archive





2003 Master Plan

- Campus goals focused on reinforcing a pedestrian oriented campus and improve quality of open space
- “expand campus, maintain a core for pedestrians and bicyclists. The proposed parking garage will help in pushing out the perimeter to achieve our goal.
- The plan pushed to close Claflin Avenue through campus which has not been done.
- “If you have ever been down those roads during a class change, [you realize] that we need to reduce the pedestrian-car conflict,” Jackie McClaskey, Campus Facilities

Figure 10-11 **2003 Aerial Image**

Source: “Manhattan.” 39°11’16.79”N and 96°34’49.98” W. March 2003. March 24, 2013.

Literature Matrix

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
Environmental and Social Research	2005		The primary responsibility of governmental agencies is to protect	The benefits of an enterprise-level GIS database were explained. Next,
Birgit Elias	2007	landmarks; conflation;	The goal is to create a database which will automatically generate routes for pedestrians enriched with landmarks along the way. This article started to explore the entries to buildings and how to make connections between the points (entries and exits) and the routing network.	Elias focused on creating a 2-D pedestrian routing plan from a train station to a specific store within a nearby mall. Establish coordinate system; construct closed polygon in GIS for analysis; inventory accessible areas; entrances and exits modeled as boundary points of the polygons; create network connection points
Kansas State University	2010	research, interdepartmental collaboration, improving facility infrastructure	Kansas State will become a top 50 research institution by the year 2025 if the University achieves six goals.	Seven themes were formed determined to achieve the overall objective of improving Kansas State's research foundation to top 50 status by 2025. Each theme is followed by a set of assumptions, actions, and expected outcomes.

Deductions	Commonalities with other research	Primary Sources
GIS is an incredibly diverse tool which can be harnessed for disaster and	This article stresses the way in which GIS can practically improve any communities emergency	Environmental Systems Research Institute
Using this article as a guide, it would be pretty easy to create a 2-D routing plan with only the first level of buildings available. The article doesn't say a word about 3-D navigation until the very end where he addresses future research.	The 2D routing techniques explain are widely accepted as far as geometric data integration to create networks for pedestrian travel. The argument was posed that using landmarks for wayfinding devices defeats the need for positioning and localization of pedestrians.	Wenie Yuan, Marcus Schneider
The University is dedicated to improving its standing as a premier public research institution.	Kansas State is heading in a direction consistent with other universities determined on a more efficient, safer, and sustainable future.	

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
Kouyoumgian, Victoria	2011	public vs. private cloud, Saas, ArcOnline, ArcMobile, Arc Server	Computing with the cloud have several benefits including pay-per-use plans for customers and the cloud is reliable and flexible enough to handle large amount of traffic.	A neutral stance was taken to first explain what cloud computing is. The introduction was followed by a discussion of benefits and risks associated with cloud computing. The Cloud has several variations and all were explained briefly. Lastly, two case studies were presented discussing how the cloud is used in practice.
Lorenz, et al.	2006	Cells and Nodes; Web Ontology Language, Graphing, WIRG	The guiding principle of this project is to create a model that is entirely flexible that will allow inputs to be updated and added if when additional datasets are created (for building interiors).	This article focuses on combining quantitative with qualitative spatial information in a hybrid structure. Using angular and distal expressions we can enrich the routing within a local frame of reference such as "2nd door on right". This is done by subdividing corridors and hallways into cells. An interface node allows the connection of two separate graphs in the hierarchy. (a connection from one level to another) These interface nodes may represent access points to a staircase, lift, doors, etc.

Deductions	Commonalities with other research	Primary Sources
Cloud computing allows several options to improve facility productivity and efficiency including Arc Online, ArcServer, SaaS, and ArcMobile.	The cloud is an effective means for distributing and managing data over several facilities making the application perfect for universities. This system reduces expenses while freeing up valuable IT resources to concentrate on other tasks.	Case Study Citations: Dennis Morgan Zach Paton, Shalem Medical Supply
This is the first article I've seen which emphasizes a distinction between different types of nodes. For example, rooms and corridors are both nodes, but with different labels. Maintaining a list of doors and windows in a room. Corridors, on the other hand, are essentially one-dimensional for which maintenance of doors on the left and right.	Consistent with other articles is the use of Nodes and Edges connecting nodes. Two dimensionally, the building is partitioned into cells (rooms) and the doors and passageways are represented as nodes. Doors marked as nodes represent possibilities for a person to move from one cell to another.	Lee, Zlatanova, Yuan, Schneider

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
National Research Council	2012	Timely Facility Investments, Management Plan, Facility Efficiency	Federal facilities are deteriorating and they raise economic, operational, and environmental concerns due to neglected maintenance and unreliable data.	A case was presented that the current practice for facility management is insufficient. Building allocation is unbalanced, investments are untimely, and maintenance is deferred for extended periods of time. An investment strategy would provide relief from degrading circumstances' proven by Life-Cycle Cost analyses.
Bassam, Saleh and Sadoun, Balqies	2006	Database Systems, Data Management, Statistical Analysis	The application of GIS if ideal for the University setting where ever changing data in many platforms need to aggregated into a common portal.	GIS was used to structure all campus data for Al-Balqa' Applied University (BAU). AutoCAD files were converted into Geomedia file using CAD server Scheme file for analysis. A warehouse connection in Geomedia was created as a CAD extension.

Deductions	Commonalities with other research	Primary Sources
Degraded facilities pose risks a risk to the federal government and all affiliated entities. The main concern is the jeopardization of the health, safety, and welfare of the public. Through strategic investment and cost analysis, more efficient management is achievable.	Federal agencies need to implement a risk-based strategy for facility maintenance and improvements. Through timely investments achievements can be made in condition, facility life, regulatory compliance, and efficient operations.	GAO (Governmental Accountability Office)
This analysis was conducted in 2006 and very basis spatial analysis was conducted such as buffering polygons, weighted overlays, and classifications. The Arc technology has advanced drastically since this time, but the article proves the point that data aggregation is powerful when established early and maintained into the future.	Arc products from ESRI were not used in this project at all. A spatial database was created inside CAD and linked to Geomedia. Spatial and statistical analysis were easily conducted once all data was compiled into the database.	Douven, Clapp, Rodriques, Thralls

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
Steinitz, Carl	2012	geodesign, design process, representation, process, evaluation, change, impact, and decision models	Steinitz's envisions the design process as answering six fundamental questions about data collection, processing, and visualization.	Steinitz's envisions the design process as answering six fundamental questions about data collection, processing, and visualization. Three iterations are required. The first pass defines the project scope and understand why a project might be undertaken. Second pass specifically answers how a project will be investigated. Third round answers the what and where of existing and proposed conditions.
Stockton, Shelli	2012	NASA, Efficiency, Location-Allocation, Space Optimization	NASA was faced with budget cuts up to 25% in 2004, so they had to develop forward-thinking options to downsize the infrastructure. NASA in combination with ESRI proposed reorganization scenarios to test the space optimization within each facility.	The project did not follow the scientific research method rather this case study was an excellent example on how an organization of great size and prominence can utilize GIS to achieve goals in efficiency similar to Kansas State University.

Deductions	Commonalities with other research	Primary Sources
Three situations occur in geodesign: case memory the deductive approach, the inductive approach and somewhere in between. Deductive assumes a "case memory" where the final product is envisioned at the start and reverse engineered. Inductive approach is one where a general sense of the goals are understood, but the form these processes will yield are completely unforeseen.	Carl Steinitz is leading the discussion on how to ask good questions to understand how a landscape functions before determining the best design alternative. Similar to Ian McHarg, Steinitz recognizes the interconnectedness of ecosystems and requires understanding of the biophysical systems to achieve effective environmental designs.	McHarg, Rogers, Steinitz, Toth
NASA was able to reduce operating and maintenance costs by over one million dollars a year. Additionally tools in space optimization are changing the entire landscape of industry and academia.	The diversity of GIS is on display again. New tools are constantly developed by ESRI and users alike, making the geospatial processing world truly limitless.	Brad Ball, Former GIS team leader at NASA

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
Wallis, Patrick	2012		Patrick Wallis introduces the argument that our current practices for facility management have not been kind to the natural environment. He makes a compelling case for the use of GIS for sustaining our built environment	The argument was defined very clearly for how inefficient and degraded our facilities have become and how GIS can remedy the situation. Through value engineering and long-range planning facility managers can begin to understand the ramification of investing in effective data management.
Yoders, Jeffery	2012	Representation, Process, Evaluation, Change, Impact, and Decision Models	Utilizing all data from the city including property information, subsurface infrastructure, 3-D buildings, will result in a safer environment for the City of Philadelphia.	Philadelphia realized to effectively serve to city, they needed a more efficient data structure. PenBay Solutions was brought in to gain an understanding of the situation, then they began modeling the cities infrastructure in 3-D. The subsurface infrastructure mapping is one of the first projects of its kind.
Yuan, Wengie and Schneider, Markus	2010		This article focuses on constructing a routing plan for building interiors according to the geometric structure and using shortest-route algorithm. In the described DPG (Direct Path Graph) the nodes are the access points (doorways), not the cell themselves. The entry points contain no data on Room Number, so a query cannot be used to directly answer navigation questions.	A really nice critique of the CoINS model was discussed and how it can be used to eliminate unnecessary nodes from the route. Additionally, the traditional node-link model does not take indoor architecture into consideration.

Deductions	Commonalities with other research	Primary Sources
GIS used as an enabling technology provides a common awareness to improve environmental stewardship, sustainability, and efficiency.	Efficiencies associated with GIS data management were discussed in a convincing fashion. Many types of analysis were explored and the software was demonstrated effectively to showcase the potential of the software.	US Department of Commerce, Federal Facilities Council, ESRI
Philadelphia has a vision to become the safest city in America, and they are taking a proactive initiative toward achieving that goal. The most effective data management systems are managed using Arc products.	GIS for facility management, asset inventories, emergency planning, and property plans is on display again in Philadelphia.	
Additional nodes will have to be digitized to account for indoor architecture. The network would be established in a hierarchy of hallways, room entries, room centroids.	Common Terminology: A simple cell would be a typical classroom with only one entry. A complex cell would be similar to many of the offices within Seaton Court which are contained within a studio space. An open cell would take a form similar to Pierce Commons with no designated entry. A connector would be any staircase, elevator, escalator, or any connection between a floor and an access point.	Lorenz, Werner, Park

Author	Year	Keywords	Standpoint/ Theory	Framework and Methods
Accessibility, Disability, Pedestrian, Routing, GIS		peripatetic (unaided mobility), aided mobility (cane, walker, crutches) and wheelchair users	This paper provides the design and implementation of a web-based system used by pedestrians with differing abilities for routing.	Routing was converted to svg file. Then the svg was parsed up into the three Java networks. Then the shortest path algorithm was run on the three networks. Doing this, they were able to convert this to xml and imbed this within an HTML page. Doing so enabled web-users to access the system. The interesting thing is that U-Access does not recalculate the model each time. It only chooses the edges and nodes between an origin and a destination. This saves computational overhead and makes the web-browser much faster to load.

Deductions	Commonalities with other research	Primary Sources
Their analysis examined the routing of wheelchair pedestrians and with the construction on a single ramp, you could save over 400 meters. I think this is the selling point of the research and what relates my project back to design. After I evaluate the system, I can develop recommendations based upon hitches in the system. What carriers completely reroute aided-mobility or wheelchair users?	This is another strategy for routing pedestrians but with a specific focus on aided mobility and wheelchair users. Node-path connections were made which seems to be a standard routing method.	Golledge, Matthews, Miller



Data Management Interview
Kansas State Baseline

*Thank you for your time.
All information will be kept confidential unless personal consent is granted to release information.*

Name: _____ **Supervisor:** _____
(optional) (optional)

Department: _____ **Position:** _____

1.	What are your responsibilities and daily duties?		
2.	What programs do you currently use in your position- ArcGIS, AutoCAD, Revit, Excel?		
3.	How is data organized or managed? Is there a common database which people pull file from?		
4.	Are blueprints and hard copies of building information still utilized?	Yes	No
5.	Are you familiar with enterprise level databases?	Yes	No
6.	Is the data structure organized? Are you available to get the data you need to fulfill your responsibilities?	Yes	No

7.	To the best of your knowledge, does K-State collaborate and share data with the City, emergency response, or any other entity?	Yes	No
	In this section, please rate the following statements:	Strongly agree	Strongly disagree
8.	Many programs and platforms are used to manage data throughout campus	1	4
9.	Data is commonly shared between departments on campus	1	4
10.	I feel comfortable navigating the GIS interface- ArcMap, Catalog, Scene	1	4
11.	I commonly use GIS for my daily duties	1	4
12.	I would be willing to learn new software if it results in more efficiency	1	4
13.	Kansas State University has a willing attitude toward advancing best practices for employees	1	4
	Employees do not necessarily stay in one department for extended periods of time. This has an impact on data management practices.	1	4
	Data upkeep is a primary concern when organizing data in a centralize location.	1	4
	Web-based application complete with routing and facility information would be a helpful visualization tool.	1	4
14.	A 3-Dimensional routing plan would be helpful in finding room locations.	1	4
15.	I would utilize a routing plan if easy to use and readily available.	1	4
16.	What are your suggestions for making campus data more accessible?		
17.	If a centralized database for Kansas State were achieved where all campus departments could pull files from, would you utilize the database?		

18.	How much impact do you foresee a centralized database providing?				
19.	There has been interest on behalf of KState for an enterprise-level database, what steps have been made at this point to make this happen, if any?				
	In this section, please rate the following items for Kansas State:	Excellent	Good	Fair	Poor
	Obtaining data quickly	1	2	3	4
	Obtaining data painlessly	1	2	3	4
	University's Long Term Vision	1	2	3	4
	Interdepartmental Collaboration	1	2	3	4
	Universities willingness to adopt best practices	1	2	3	4
	Please list any additional comments that you would like to offer:				

Additional comments and suggestions are encouraged.

Use the space provided below for any additional comments.



Data Management Interview

University Case Study

Thank you for your time.

All information will be kept confidential unless personal consent is granted to release information.

Name: _____ **University:** _____
(optional)

Department: _____ **Position:** _____

1. What are your responsibilities and daily duties?
2. What programs do you currently use in your position- ArcGIS, AutoCAD, Revit, Excel?
3. How is data organized or managed? Is there a common database which people pull file from?
4. Are blueprints and hard copies of building information still utilized?
5. Are you familiar with enterprise level databases?
6. Is the data structure organized? Are you available to get the data you need to fulfill your responsibilities?

Yes	No
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Yes	No
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Yes	No
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7.	To the best of your knowledge, does K-State collaborate and share data with the City, emergency response, or any other entity?	Yes	No
	In this section, please rate the following statements:	Strongly agree	Somewhat agree
8.	Many programs and platforms are used to manage data throughout campus	1	2
9.	Data is commonly shared between departments on campus	1	2
	Employees do not necessarily stay in one department for extended periods of time. This has an impact on data management practices.	1	2
	Data upkeep is a primary concern when organizing data in a centralize location.	1	2
10.	Every investment requires key players to be on board. How was support built throughout the university/ college for this project?		
11.	You are now able to view all utilities campus-wide. How has this been used to empower efficient facility management? What problems are you solving?		
12.	What indicators do you use to evaluate the success of the system?		
13.	Where do you see this project advancing into the future?		

14.	Has the university/college partnered with the City to provide data to emergency responders or the public?					
	15.	In this section, please rate the following items for your institution:	Excellent	Good	Fair	Poor
		Obtaining data quickly	1	2	3	4
		Obtaining data painlessly	1	2	3	4
		University's Long Term Vision	1	2	3	4
		Interdepartmental Collaboration	1	2	3	4
		Universities willingness to adopt best practices	1	2	3	4
Please list any additional comments that you would like to offer:						

Additional comments and suggestions are encouraged.

Use the space provided below for any additional comments.