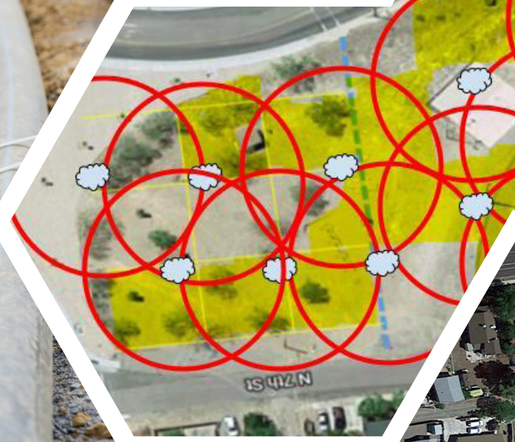
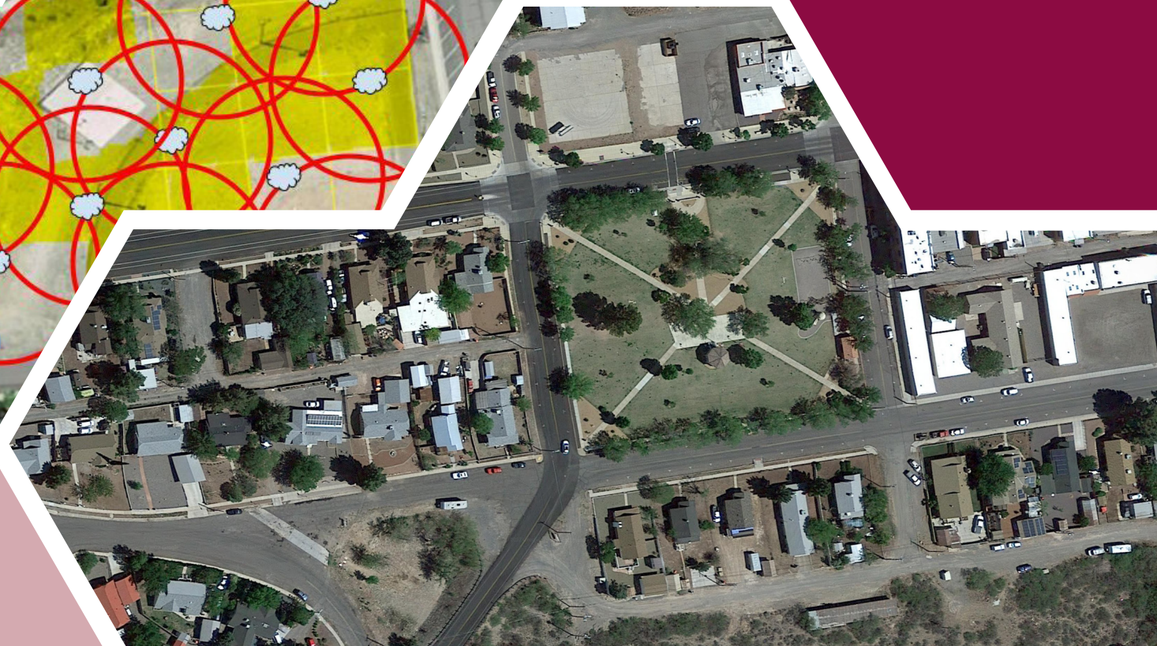
Smart Towns: Enhancing Parks and Internet Infrastructure

A Fall 2020 - Fall 2021
Collaborative Project with
Arizona State University's
Project Cities & the
Town of Clarkdale

ASU Sustainable Cities Network
Arizona State University

Project Cities





PART 1:

Project and Community Introduction

GET TO KNOW THE PROJECT

ABOUT ASU PROJECT CITIES

ABOUT THE TOWN OF CLARKDALE

EXECUTIVE SUMMARY

KEY STUDENT RECOMMENDATIONS

SUSTAINABLE DEVELOPMENT GOALS

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This report represents original work prepared for the Town of Clarkdale by students participating in courses aligned with Arizona State University's Project Cities program. Findings, information, and recommendations are those of students and are not necessarily of Arizona State University. Student reports are not peer reviewed for statistical or computational accuracy, or comprehensively fact-checked, in the same fashion as academic journal articles. Editor's notes are provided throughout the report to highlight instances where Project Cities staff, ASU faculty, municipal staff, or any other reviewer felt the need to further clarify information or comment on student conclusions. Project partners should use care when using student reports as justification for future actions. Text and images contained in this report may not be used without permission from Project Cities.

Cover images:

Project Cities,
FSE 104/404 Students,
StreetSounds, and
Google Earth

ACKNOWLEDGMENTS

Town of Clarkdale

Robyn Prud'homme-Bauer, Mayor

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On behalf of the Julie Ann Wrigley Global Futures Laboratory, the Global Institute of Sustainability and Innovation, and the School of Sustainability, we extend a heartfelt thank you to the Town of Clarkdale for enthusiastically engaging with students and faculty throughout the semester. These projects provide valuable real-world experience for our students and we hope that their perspectives shine light on opportunities to continuously improve Clarkdale's future livelihood and community well-being.

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links.asu.edu/PCClarkdaleSmartTowns20-21

ABOUT PROJECT CITIES

The ASU Project Cities program uses an innovative, new approach to traditional university-community partnerships. Through a curated relationship over the course of an academic year, selected Community Partners work with Project Cities faculty and students to co-create strategies for better environmental, economic, and social balance in the places we call home. Students from multiple disciplines research difficult challenges chosen by the city and propose innovative sustainable solutions in consultation with city staff. This is a win-win partnership, which also allows students to reinforce classroom learning and practice professional skills in a real-world client-based project. Project Cities is a member of Educational Partnerships for Innovation in Communities Network (EPIC-N), a growing coalition of more than 35 educational institutions partnering with local government agencies across the United States and around the world.

ABOUT SUSTAINABLE CITIES NETWORK

Project Cities is a program of ASU's Sustainable Cities Network. This network was founded in 2008 to support communities in sharing knowledge and coordinating efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and connect ASU's research to front-line challenges facing local communities. Network members come from Arizona cities, towns, counties, and Native American communities, and cover a broad range of professional disciplines. Together, these members work to create a more sustainable region and state. In 2012, the network was awarded the Pacific Southwest Region's 2012 Green Government Award by the U.S. EPA for its efforts. For more information, visit *sustainablecities.asu.edu.*

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ASU Sustainable Cities Network
Arizona State University

Project Cities

Sustainability through local action

ABOUT CLARKDALE

The Town of Clarkdale, Arizona is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master-planned community in the state of Arizona and was developed with a "Live, work, play" ideology intended to provide its residents with a wholesome living experience. Clarkdale has just over 4,300 residents who thrive in the fresh, clean air of the Verde Valley.

CLARKDALE TEAM

Project Cities Community Liaison

Ruth Mayday, Community Development Department Director

Clarkdale Project Leads

Ruth Mayday, Community Development Director

Maher Hazine, Public Works Director

Tracie Hlavinka, Town Manager (Fall 2020 - Spring 2021)

Rob Sweeney, Interim Town Manager

Joni Westcott, Community Services Supervisor

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Celebrating historic charm. Creating a prosperous future.

clarkdale.az.gov

Town of Clarkdale

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March 30, 2022

Dear Town of Clarkdale Residents :

On behalf of the Town Council and the Town of Clarkdale, we would like to express our appreciation to all who have been involved with the ASU Sustainable Cities Project. Over the past two years, the Town has been fortunate to work with nearly 100 students across disciplines to develop strategies for improving the lives of Clarkdale residents. Their efforts support the work of Town staff and is vital to the planning and development of a Clarkdale that will meet the needs of all its residents.

Our continued partnership is important to the Town of Clarkdale. Because we are a small town with a small staff, our capacity to research and produce in-depth documents is limited; the ability to work with the students and faculty at ASU provides us with the expertise we need to accomplish our goals for our community, while providing the students with hands-on, documentable experience in the public sector.

The Town of Clarkdale looks forward to our continued collaboration with Sustainable Cities Program and another successful year with the students at ASU.

Sincerely,

Robyn Prudhomme-Bauer, Mayor

Susan Guthrie, Town Manger

Clarkdale, Arizona

Proud partner of

ASU Sustainable Cities Network
Arizona State University

Project Cities

Verde River at Box Canyon

Demographics

total population: **4,424**

36% of residents are over the age of 65

median age: **56.27**

78% of residents are homeowners

67.1% of the population has some college education, 31.75% are college graduates

median yearly income: **$45,304**

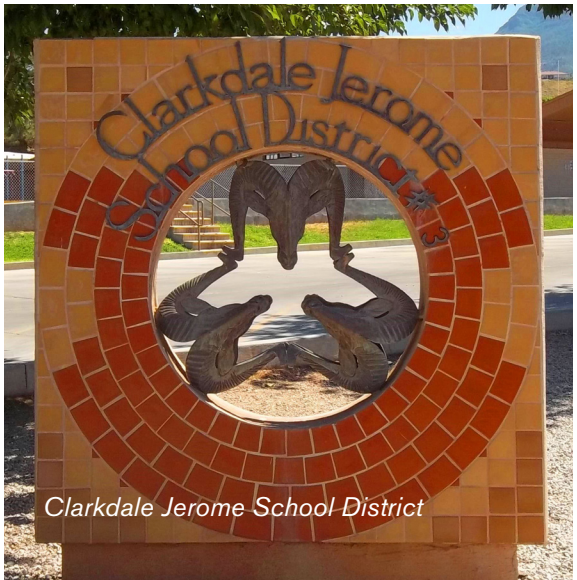
Schools

Clarkdale is home to the Yavapai College Verde Campus and the Small Business Development Center. Yavapai College has one of the leading viticulture and enology schools in the Southwest. High school students in Clarkdale attend Mingus Union High School, and the Clarkdale-Jerome Elementary School boasts an excellent reputation for educating students from Kindergarten through 8th grade.

Sustainability

In Clarkdale's 2013 General Plan, the City identified four main sustainability objectives: **water use, ecological design, sustainable construction** and **mixed use development**. In 2019, Clarkdale announced its partnership with ASU's Project Cities to enliven the Central Business District with a sustainability orientation.

Clarkdale Park



Clarkdale Jerome School District

Tuzigoot National Monument

History

The Town of Clarkdale is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master planned community in the State of Arizona. The town was founded to house the employees of the smelter in Clarkdale, as well as the mine workers from Jerome. Ahead of its time, Clarkdale boasted underground utilities, sewers, paved streets, stylish homes and a thriving commercial center.

The main town site was located on a ridge overlooking the industrial smelter complex and was developed with residential homes, including upper and lower-income housing, a commercial area, an administrative center, schools, recreational and cultural facilities, and parks. They intended to include all the parts typically found in a small town within a comprehensive planned design. Today, the original town site of Clarkdale is recognized as a Historic District on the National Register of Historic Places.

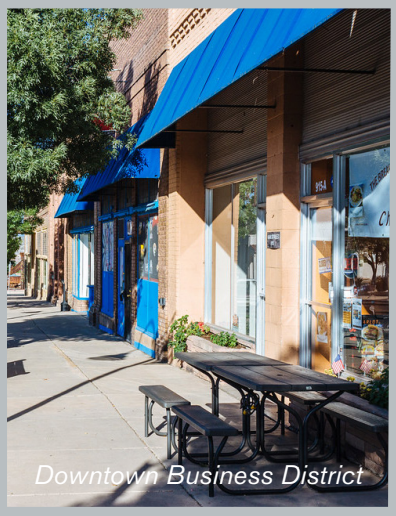
The original rail line that served the smelter is now host to a scenic excursion train, the Verde Canyon Railroad, which allows travelers a four-hour round trip to view the protected ecosystem of the Sycamore Canyon Wilderness Area and Verde River firsthand. In addition to the excursion branch, the Arizona Central Railroad (the parent company of the Verde Canyon Railroad) ships materials by rail to Salt River Materials Group, a local cement manufacturer.

Verde Canyon Railroad

Attractions

Hop aboard the Verde Canyon Railroad for the longest-running nature show along the Verde River. Spot bald eagles and enjoy an array of special events onboard throughout the year. Experience the Arizona Copper Art Museum housed in the restored Clarkdale High School with its dazzling array of thousands of gorgeous copper artifacts (some of which you can touch). Float the Verde River with experienced local river outfitters and enjoy unspoiled riparian areas adjacent to the Audubon Important Birding Area in Tavasci Marsh. Dance the night away every weekend to live music. Explore the Tuzigoot National Monument featuring the ruins of an ancient Sinagua Indian pueblo. Savor local terroir at Clarkdale's wineries, the Chateau Tumbleweed tasting room and winery or the Southwest Wine Center in the heart of Yavapai College's Verde Campus in Clarkdale.

Downtown Business District


Downtown Business District

The historic Downtown Business District boasts many treasured historic assets and is the center of Clarkdale's government, cultural and historic core. The Town and downtown-area business owners have invested heavily to keep the town core thriving. As of 2019, there are four vacant properties in the Business District that pose opportunities for redevelopment, including a former grocery store, apartments, and the old Grand Theatre. $1.5 million in streetscape improvements in the Downtown Business District were completed in March 2005.

Clarkdale revitalization plan

1. Develop a strategy to **encourage public and private investment**
2. Produce a **report of building conditions** including a revitalization plan for each building, cost estimates on the repairs and possible funding sources
3. Develop a **parking, pedestrian and bicycle connection plan**
4. Identify creative use of existing spaces to **promote foot traffic** in the area

Business Highlights

- Clarkdale has 83 businesses
- Workforce is composed of 45% blue collar; 54% white collar
- 90% of businesses have less than 20 employees
- Annual events, such as Clarktoberfest, the Car Show, wine festivals, and multiple block parties, are anchored in the historic business district


Historic Downtown Mainstreet

Leading industries as of 2019

Public Administration

167 Jobs

Education

110 Jobs

Information

108 Jobs

Transportation & Warehousing

87 Jobs

Kayaking on the Verde River

Local ecology

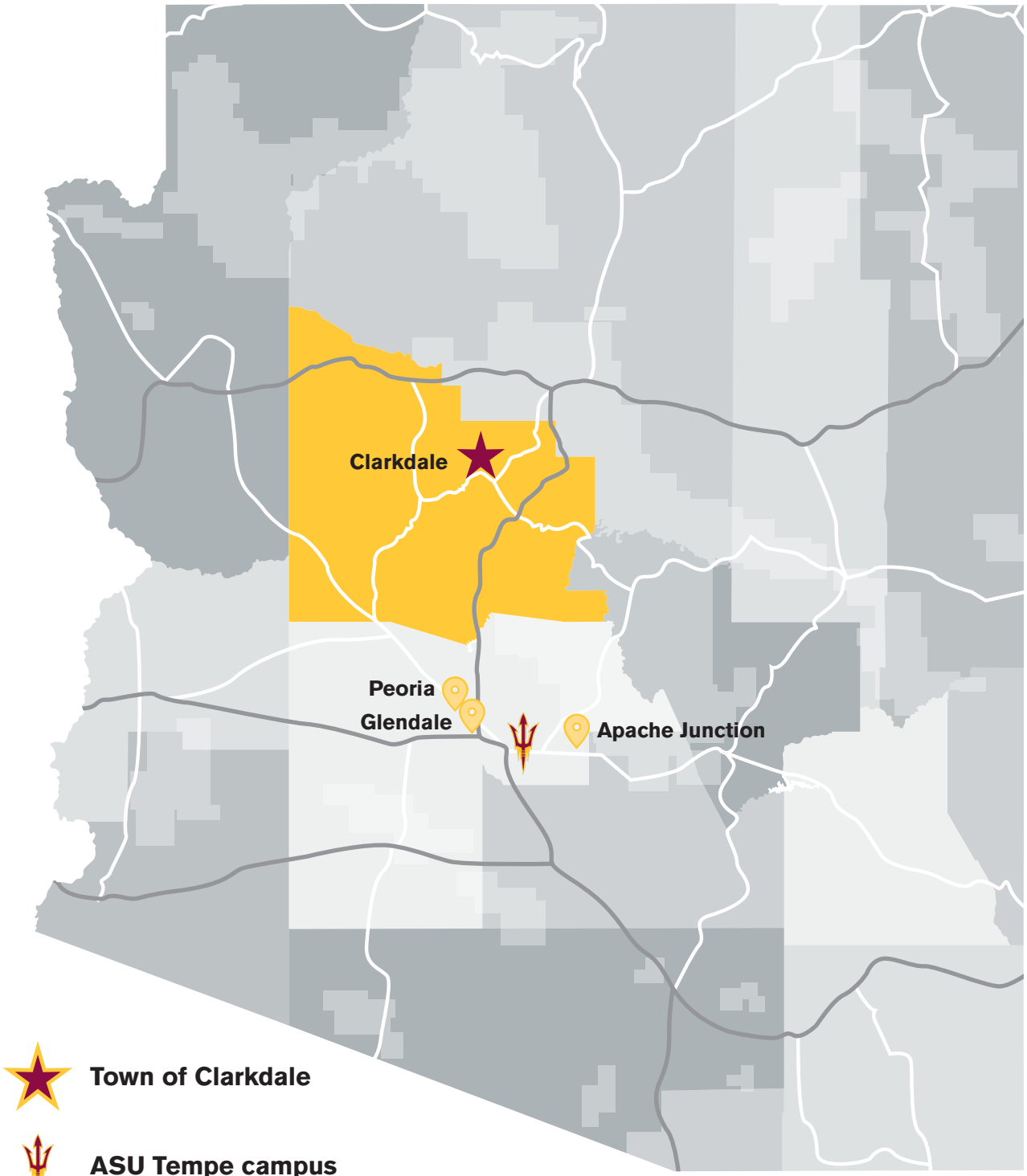
The Verde River bisects the north portion of Clarkdale at a low elevation of around 3,300 feet. The west side of the town boundary is located along the foothills of Mingus Mountain in the Black Hills Range at a high elevation of approximately 4,600 feet above sea level. On the northeast border of Clarkdale, the National Park service operates the 42-acre Tuzigoot National Monument, an 800-year-old Sinagua pueblo, which is surrounded by hiking trails and hosts a complete museum. Tavasci Marsh borders Tuzigoot National Monument and has been designated as an Important Birding Area by the North American Audubon Society. Arizona State Parks also manages the Tuzigoot River Access Point along the Verde River in Clarkdale. The town is surrounded by the Prescott National Forest to the west and the Coconino National Forest to the east. In addition, trust lands of the Yavapai-Apache Nation are located within the town boundary.

Local wildlife

Verde River

Sycamore Canyon

MAP OF PROJECT CITIES PARTNER COMMUNITIES IN ARIZONA



The following report summarizes and draws highlights from work and research conducted by students in FSE 104/404 EPICS Gold, for the Fall 2020, Spring 2021, and Fall 2021 partnership between ASU's Project Cities and the Town of Clarkdale.

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleSmartTowns20-21

ASU Sustainable Cities Network
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Project Cities

Sustainability through local action

EXECUTIVE SUMMARY

The Town of Clarkdale lies in the Coconino Forest in north-central Arizona, housing just over 4,000 residents in an intimate community centralized around the Clarkdale Town Park and Town Clubhouse. Considering the increase in remote working and learning due to the COVID-19 pandemic, the Town recognizes the opportunity to enhance and build out its internet infrastructure to grow as a “smart town.”

In partnership with ASU Project Cities and the Engineering Projects in Community Service (EPICS) program, students in the **FSE 104/404:** EPICS Gold course split into two groups to investigate smart town infrastructure features. Over the Fall 2020, Spring 2021, and Fall 2021 semesters, students conducted research and built off previous semesters' work to provide feasible recommendations for internet infrastructure and key technology for the community’s public spaces.

Smart infrastructure: Students in the smart infrastructure group started in the Fall 2020 semester by examining the internet infrastructure need for Clarkdale’s K-12 students for remote learning. Students conducted a needs assessment of the Town of Clarkdale and the School District through surveys and identification of stakeholders. The Fall 2020 students ended with a brainstorming session to propose initial solutions for the Town of Clarkdale. The Spring 2021 students built on the previous semester’s work by refining the needs assessment and stakeholder profiles and identifying potential internet systems.

Smart parks: Students in this group sought to integrate smart technology in the Town Park and Selna-Mongini Park. Clarkdale seeks to transform these community spaces into “smart town" hubs where residents can access reliable internet and enjoy local events. Fall 2020 students researched PA systems for the parks and created an evaluation matrix based on specific criteria. Spring 2021 students explored the feasibility of Wi-Fi infrastructure for the two parks. The group identified potential modem systems and created a design schematic for hardware placement. Fall 2021 students expanded on this work by investigating mesh Wi-Fi options, outlining features of different hardware options, and providing placement schematics for Selna-Mongini park.

The following recommendations and summary reports intend to provide Clarkdale with data and tools to inform its implementation of smart features throughout the community. In the student summary sections, student researchers followed the iterative EPICS design process to draw out and refine key recommendations for the Town of Clarkdale.

KEY STUDENT RECOMMENDATIONS

Recommendations for community-wide internet infrastructure	Read more
Favor wireless solutions over wireline solutions, wireline technology is more expensive and disruptive to install.	pp.28-32, 39-40
Investigate the use of federal grants to implement broadband connection for the Clarkdale Clubhouse.	pp.25, 28-30, 33
Design clear criteria for the internet infrastructure, including factors such as cost, feasibility of implementation, and effectiveness of the system.	pp.42-43
Seek out private companies who could partner with Clarkdale to provide flexible and affordable Wi-Fi solutions.	pp.31, 39
Consider strengthening the existing mobile hotspot program. Some options include reconsidering the existing hotspot bus route or schedule, or deploying autonomous robots with hotspots to cover more area.	pp.24, 31, 39
Further investigate Wi-Fi balloons and satellite internet to determine if they are feasible for future implementation in Clarkdale.	p.39
Favor solutions that employ synchronization or spectrum reuse to limit interference with satellite signals.	pp.39-40
Ensure any new internet infrastructure features a range up to at least 20 miles.	p.39
Consider Clarkdale's weather conditions when selecting hardware for new infrastructure.	pp.29, 32, 39, 53, 57
Weigh the pros and cons of different internet systems, such as DSL, Cable, Fiber, and Starlink, before deciding on a final system to implement.	p.40

KEY STUDENT RECOMMENDATIONS

Recommendations for designing smart parks	Read more
Identify a PA system that includes speakers, mixing console, microphones, XLR cables, and speaker stands for an enhanced PA system experience.	pp.51-52
Prioritize benefits to residents and town officials when deciding which PA system to purchase for the parks.	pp. 42-43
Review the student-developed tiered cost tables for each suggested PA system to help identify budgetary constraints and purchasing options.	pp.46-47, 51-52
Favor mixing consoles with a large number of channels to maximize the use of the speaker system.	pp.47-48
Consider the Yamaha MG 12XU and QSC TouchMix-16 mixers for park speaker systems.	pp.47, 52
Place the speaker PA system in Clarkdale Town Park center square to reach maximum sound coverage.	pp.41, 44, 50
Consider implementing one of the suggested speaker systems, the JBL SRX835P, Electro-Voice EKX-15P, or the QSC CP8, as part of a cohesive PA system.	pp.45-46, 51-52
Consider utilizing *StreetSounds* as a vendor for a community speaker system, which boasts easily mountable speakers and wireless control.	p.51
Consider placing Wi-Fi range extenders to supplement access points throughout the parks to provide stronger Wi-Fi connectivity over a larger area.	pp.53-54, 56
Investigate the cost feasibility of a mesh Wi-Fi system since it allows for a seamless connection. A mesh Wi-Fi system can be initially expensive, but can be less expensive per square inch covered.	pp.53-57
Strategically locate mesh Wi-Fi access points so coverage areas overlap to provide maximum service.	p.56
Install the Cisco Meraki MR76 Wi-Fi hardware as part of a mesh Wi-Fi system for its superior performance, future-proof capabilities, and cloud management options.	pp.57-58

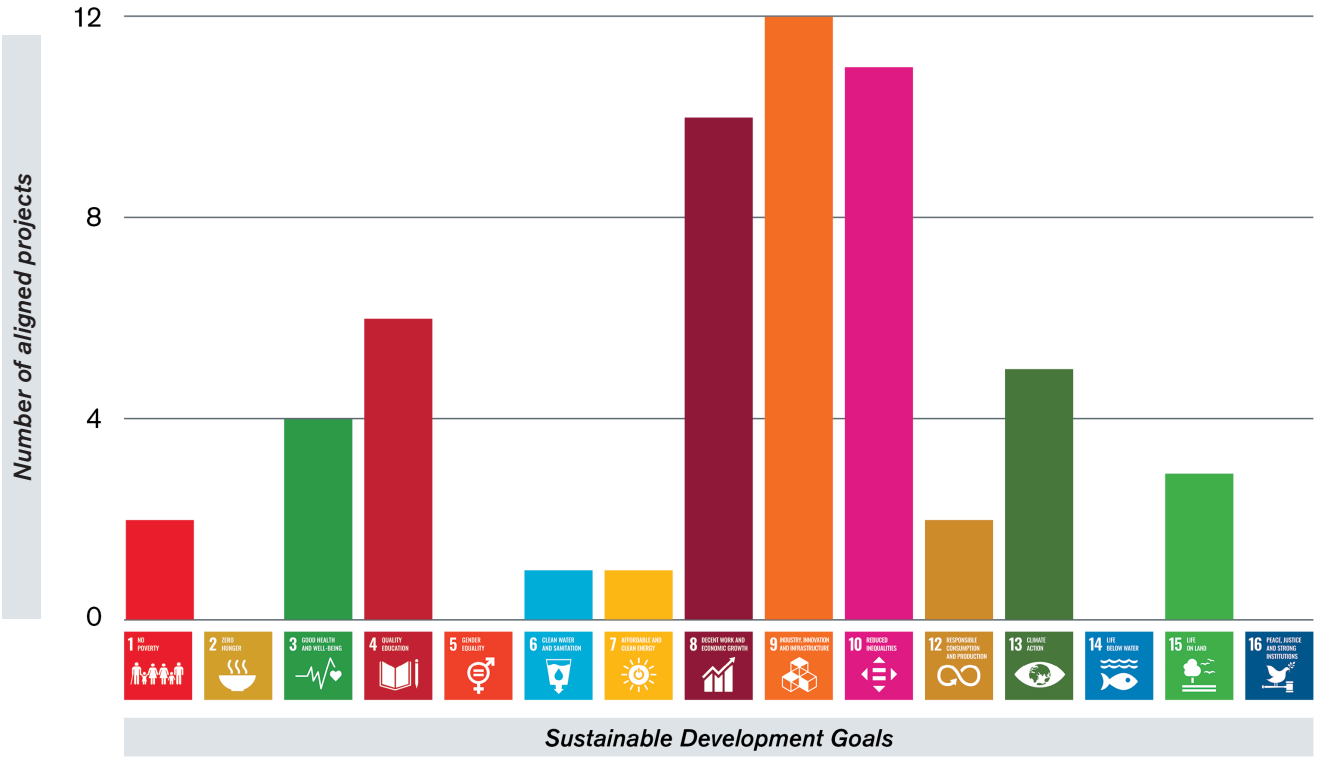
TOWN OF CLARKDALE PROJECTS: ALIGNMENT WITH THE UNITED NATIONS'

SUSTAINABLE DEVELOPMENT GOALS

As the leading international framework for sustainable decision-making, the 17 Sustainable Development Goals (SDGs) lay out a path for partnerships toward global peace and prosperity. The SDGs provide a set of goals and metrics for project impact to be measured, offering an illustration of the benefits experienced by the cities, towns, and students who participate in a Project Cities partnership. For details on the SDGs, visit **sdgs.un.org/goals.**

Every project in the PC program aligns with SDGs 11 and 17.

The figure below illustrates SDG project alignment throughout the Town of Clarkdale's partnership with Project Cities, through the Fall 2021 semester.



TOP THREE GOALS ADDRESSED IN THE FOLLOWING REPORT

The students involved in this project aimed to assist Clarkdale in exploring internet infrastructure and community park enhancement options. By analyzing stakeholder needs and researching applicable technologies, the project provides Clarkdale with foundations to grow as a "smart town."

Goal 4: Quality Education

"Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."

Internet access has become increasingly important for education in both K-12 and college settings. As Clarkdale expands its internet infrastructure, students can better access educational systems.

Goal 9: Industry, Innovation and Infrastructure

"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."

Building up technology resources via internet and park enhancements can make it simpler in the future to continue growing and updating town resources and amenities.

Goal 10: Reduced Inequalities

"Reduce inequality within and among countries."

As the world continues to grow digital, accessible internet ensures more equal opportunity amongst residents. Additionally, Wi-Fi and sound systems in the town parks can help make community events more enjoyable for everyone.

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PART 2:

Increasing Accessibility Through Smart Technology

IDENTIFYING POSSIBILITIES FOR CLARKDALE TO GROW AS A "SMART TOWN" VIA INNOVATIVE INTERNET INFRASTRUCTURE AND COMMUNITY PARK ENHANCEMENTS

FSE 104/404: EPICS GOLD

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INTRODUCTION

Clarkdale is searching for opportunities to pursue "smart town" technologies, including high-speed internet infrastructure and community park enhancements. Throughout the Fall 2020, Spring 2021, and Fall 2021 semesters, ASU EPICS students divided into two groups in order to best focus on each topic, internet infrastructures and park technologies. Following the research methods section, this report is divided by topic, each featuring unique recommendations and insights.

RESEARCH METHODS

Students followed the EPICS design process to inform their research and findings. The EPICS design process is an iterative process that allows for the students to loop back to previous phases as the project develops (Figure 1). The students started with project identification, followed by a needs assessment informed through communications with the Clarkdale project lead. Through surveys and communications with the community liaison, students researched various internet systems and PA broadcast systems, as well as developed a decision-making matrix regarding the studied technology.

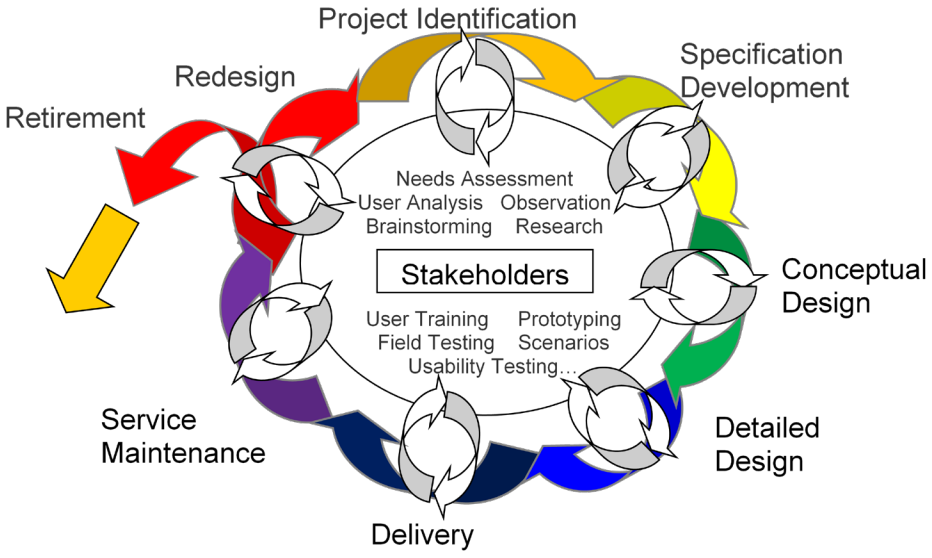

Figure 1 *Diagram of the iterative design process utilized in the EPICS program*

INTERNET INFRASTRUCTURE

Background

Clarkdale is a small, rural community in Arizona's Verde Valley that is seeking solutions to increased demand on its internet. The Town's geographic context makes it challenging to implement underground internet systems, as the soil is very hard. The current internet infrastructure has caused some students to rely on mobile hotspots located on buses that drive around areas of need. This project aims to deliver a more reliable solution that effectively serves the Clarkdale students. Clarkdale also seeks a long-term solution, which EPICS students help define by researching stakeholder needs and feasible options.

Figure 2 *The Clarkdale Memorial Clubhouse, one location students consider for enhanced internet infrastructure in their process, by City of Clarkdale*

During the first semester, Fall 2020, students spent the majority of their time in the project identification and specification development phases of the design process. The first few weeks consisted of creating an initial profile and needs assessment of project stakeholders. As students communicated with the community partner, they further defined the project problem and analyzed specific requirements. Due to the wide scope of the topic, students decided to focus their work on internet solutions to help area students. This prompted additional research around the local school system and its students. To successfully tackle all aspects of the project, students adopted a phased approach. Phase 1 consists of providing internet to area students and Phase 2 involves data collection and evaluation of the solution's success. This data can be used for Phase 3, town-wide implementation of the solution.

Project identification

Problem statement

Clarkdale's existing internet, currently provided by Telecom and cable companies, does not always meet community needs. The Clarkdale community liaison asked students to conduct an analysis of the internet available in the Town Clubhouse to see if it is suitable for large gatherings, such as prom and remote learning. Following this analysis, students researched various options for improvement.

Needs assessment

The current state of the community partner is that the town of Clarkdale does not have reliable internet. As a result, many local residents struggle to access the internet, as bandwidth is vulnerable and insufficient for current usage. This is problematic as internet use in daily life grows increasingly necessary. Additionally, the Town is unsure of the current capacities of their local radio stations and broadband, and if it can support a large number of users for public and private events.

In the future, the Town would like to see reliable internet access across the community, including local businesses, homes, and schools. The hope is that this upgraded infrastructure will attract more business and residents to move to Clarkdale. In the short-term, the community liaison specified that she would like to see internet access for the local students improve, online classes are more prevalent since the COVID-19 pandemic. In the long-term, Clarkdale would like to implement an online platform and upgrade its internet infrastructure to fiber optic cables throughout the area. The Town can use the research in this report to apply for grants or request different internet providers to service Clarkdale. The students' initial goal is to evaluate the existing internet conditions in the Town Clubhouse and determine if further broadband implementation is necessary.

Identifying stakeholders

Primary stakeholder: Town of Clarkdale

Clarkdale is a small community with a population of about 4,400, and the whole town is roughly 7.5 square miles. It was founded over a hundred years ago in 1912, and is Arizona's first master-planned community. Today, the Town is making strides toward creating a community that is able to modernize and adapt to changing times. Through improved infrastructure, Clarkdale hopes to be in a position where it can continue to celebrate its history while creating an atmosphere that is welcoming of the future.

Through the Town's partnership with ASU, Clarkdale's short-term goal is to have reliable internet access for the students and faculty of the Clarkdale-Jerome School District. In the long-term, Clarkdale aims to leverage its improved internet infrastructure to attract new residents and businesses, and ultimately expand the Town. Clarkdale's mission is to "…provide visionary, innovative, sensible governance; responsible and resourceful delivery of services; and a sustainable quality of life in an engaged community of citizens and enterprises" (Welcome to Clarkdale, AZ, n.d.).

Figure 3 *Aerial view of Clarkdale downtown area, from Google Earth*

Editor's Note

Students in this group originally intended to personally test the internet bandwidth at multiple locations throughout Clarkdale. However, extenuating circumstances due to the COVID-19 pandemic prevented this testing from being completed.

Those that will be most affected by this project are the citizens of Clarkdale. Hopefully, this project is the first step on a path towards in-home high-speed internet for all local residents. In the short-term, the project intends to recommend updates that may be implemented in a community building, such as the Town Clubhouse, which may provide ample bandwidth for a large number of people whenever needed. This provides Wi-Fi for those without in-home or nearby internet access.

Primary stakeholder: Clarkdale-Jerome School District

The Clarkdale-Jerome School District currently serves children from kindergarten through 8th grade. The school hosts roughly 475 students with an average student-to-teacher ratio of 25:1. It offers various extracurricular programs and opportunities for students to learn and succeed. Danny Brown, the District Superintendent, was the project point of contact for school- and district-related communication.

Figure 4 *Clarkdale-Jerome school district welcome monument*

The school district wants to provide the best learning experience possible to their students. Due to the shift toward online learning amidst the COVID-19 pandemic, students are much more reliant on the internet to access their schoolwork. To ensure student success, the district is looking for solutions that will meet internet needs for the subset of their student population that does not have a stable internet connection. The mission of the school district is "to achieve high academic excellence; to cultivate personal accountabilities for all; and to encourage citizenship and respect" (Clarkdale Jerome School and School District in Clarkdale Arizona, n.d.).

Secondary stakeholder: Project Cities

ASU Project Cities is part of ASU's Sustainable Cities Network. The organization facilitates a university-community partnership between ASU students and Arizona municipalities. The mission of Project Cities is to assist communities with the advancement of sustainability initiatives by connecting students, faculty, and academic courses to sustainability projects prioritized by community stakeholders. According to the program website, the organization's goals are to:

- Create long-term, mutually beneficial partnerships between ASU and local communities
- Engage students in hands-on learning projects with communities that prepare them for future careers
- Facilitate cross-disciplinary research and project opportunities for ASU scientists and scholars

Social context of community partner

Clarkdale is a historical town with somewhat limited internet infrastructure. However, the spread of COVID-19 and the subsequent transition to online school has highlighted the necessity of reliable internet, especially for students with unreliable at-home service.

On a broader scale, the recent pandemic has led to an increase in distance learning, thus presenting the Town with an opportunity to update their internet infrastructure. Along with online school, it has become increasingly clear how integral the internet is to everyday life (jobs, networking, education, etc). Clarkdale seeks to expand its residential housing and attract new industries to grow the community sustainably. However, many companies do not see it as profitable to update the area infrastructure, due to factors such as the rough terrain and general opposition to cell-towers in the community.

PESTLE analysis

Figures 5 and 6 on the following page display the PESTLE analysis from the Fall 2020 and Spring 2021 groups of students.

Editor's Note

A PESTLE analysis is a project decision making tool that takes various factors into consideration, including political, economic, social, technological, legal, and environmental. Students in the EPICS program utilize this tool to identify and inform decision making for the project.

Fall 2020 PESTLE analysis of Clarkdale's internet infrastructure	
Factor	***Details***
Political	The current mayor of Clarkdale is Mayor Robyn Prud'homme-Bauer who oversees all town policies for town government, programs, and ordinances. The Planning Division of the Clarkdale government oversees local property development.
Economic	The current internet provider for Clarkdale, Sparklight, does not find it financially advantageous to invest in Clarkdale and provide wireline technology because of the mountainous local terrain and relatively low number of prospective users.
Social	Residents do not want a product that interferes with the scenic views of the town. The Town mostly wants an internet solution that can best address the lack of communication/ social media that can be taken care of with adequate internet services.
Technological	The current internet state in Clarkdale is not suited for multiple users and the Town has addressed the need for multi-user products for their children in the household. There are occasional lapses with the current internet providers. Residents face problems with internet service outages after bad weather. There are no local providers who can supply services with speeds above 5MB.
Legal	The Town currently has an official contract with Sparklight, the most common service option.
Environmental	The Town currently employs satellite services which do not affect the environment much.

Figure 5 *The Fall 2020 student group's internet infrastructure PESTLE analysis highlights the current limitations of local internet capabilities*

Spring 2021 PESTLE analysis of Clarkdale's internet infrastructure	
Factor	***Details***
Political	If funds are needed to buy better equipment and/or more bandwidth, the Town may need to pursue grants or other funding.
Economic	The school specifically may need to invest funds for better internet. If direct funding is not available, grants or other opportunities may need to be pursued.
Social	Gathering information from community partners can be difficult due to busy schedules and distance of students from the Town.
Technological	Finding internet solutions that will provide proper bandwidth at the most economical price may depend on currently available technology options.
Legal	The Town could install a local service tower to provide internet all around Clarkdale, but there would be legal issues of finding land and building on that land.
Environmental	The environmental aspect of building a service tower would need to be evaluated. Environmental, habitat, and aesthetic impacts should all be considered.

Figure 6 *The Spring 2021 student group's internet infrastructure PESTLE analysis highlights funding limitations of enhancing local internet infrastructure*

Stakeholder requirements

School solution

- Must reach and help all the youth that do not have internet or have an unreliable connection that makes it harder for them to attend and do well in online school and homework.
- The residents want to keep the scenery clear, there must not be anything that disrupts the scenery.
- Must be quickly installed, as schools want students to have reliable internet access as soon as possible.

Research

- Must include statistics on how well students did before the pandemic and as they were forced to rely on the internet to attend school.
- Needs to argue the importance of the internet for the town and argue that the internet is a necessity and not a commodity.

Time/cost constraints

Project overall budget

- Community partner has not delivered a budget
- $500 per semester is available to students from ASU EPICS to help facilitate research

Schedule and deadlines

Fall 2020 semester timeline

- Project identification
    - Week 1: Getting familiar with team
    - Week 2: Gather initial stakeholder profile and needs assessment
- Specification development
    - Week 7-9: Brainstorming and research
    - Week 10-11: Design analysis and settling on initial conceptual design
- Semester deadline: December 4, 2020

Spring 2021 semester timeline

- Project identification
    - Week 1: Getting familiar with team
    - Week 2: Gather initial stakeholder profile and needs assessment
- Specification development
    - Week 7-9: Brainstorming and research
    - Week 10-11: Design analysis and settling on initial conceptual design
- Semester deadline: April 30, 2021

Project phases

Phase 1: Internet for education

Students realized addressing all of Clarkdale's needs at once is not feasible, so they focused the work toward helping a small radius of families with students who attend the Clarkdale-Jerome school. Students first reached out to Danny Brown, the Superintendent of the Clarkdale-Jerome School District.

From this initial meeting, students learned the district had significant problems transitioning from an in-person learning environment to a virtual environment. Like many other schools undergoing the same challenges, teachers had to be trained on new technology in a limited timeframe, and teaching methods had to adapt to student needs. The district also experienced problems with hotspots and overuse issues, causing unstable online experiences.

To address these issues, students explored various wireless infrastructures available in the market that can maximize the efficiency of existing lines and satellite services around the Clarkdale area. The goal is to slowly transition away from relying on hotspots and wireline technology and create a solution that is user friendly for the students and teachers of Clarkdale. In addition, students reached out to private companies who have products that provide flexible solutions for rural communities, including Sparklight, Mimosa, and HughesNet.

Students recommend the final solution to be a wireless product rather than a wireline solution, as wireline technology is expensive, and many communities are unable to receive federal funds for it unless there is a plan in place to meet the minimum speed of 25 Mbps (megabits per second). Installing wireline technology is also a lengthy process that involves a number of complicated steps including permits, securing skilled labor, and planning for backup links in the eventuality of accidents. However, it should be noted that wireline technology can be advantageous in some cases, as there are many options leveraged for short-range or long-range projects. Wireline technology can also be used for target networking and sending signals to a specific group of people, effectively employs multiple users without interference, and there are many associated products that can withstand harsh weather conditions.

Figure 7 *Wireline technology requires more disruptive installation processes, like that shown here, than wireless product options*

Editor's Note
Due to time constraints, students were only able to act on the survey portion of the data collection plan, and had to cancel the planned performance data and testimonial gathering.

Phase 2: Data collection

In this phase, data is collected on how the proposed solutions may affect the social and academic success of students within the school district. This will be achieved through surveys of the students and their families, performance data from the school district, and testimonials. In this way, students will be able to both qualitatively and quantitatively assess how the proposed solutions impact the Clarkdale students, as well as demonstrate the necessity of the internet in this modern era.

In addition, by demonstrating the great impact of internet accessibility on this subset of the Clarkdale population, students can make a case for the need of new internet infrastructure throughout the town. This type of data can be a valuable asset when seeking grant funding or other assistance to act on the proposed infrastructure updates.

Phase 3: Town-wide implementation

Phase 3 theoretically involves updating internet infrastructure over the next few years and attracting residents to the "smart town" of Clarkdale. After gathering data in Phase 2, students intend to present their findings to the Clarkdale Broadband Action Team (BAT), which can then use the information to apply for federal grants, continue research on increasing broadband connection, and convince companies to invest in Clarkdale. The BAT can also communicate with professional consultants and advisors to assess if the scaled down project is feasible for helping the larger Clarkdale community and other areas facing similar problems.

Specification development

Stakeholder profile

The population of Clarkdale has increased to over 4,000 in recent years. Median resident age is above 55, indicating the town population trends older. A relatively low percentage of Clarkdale families (under 20%) have children under the age of 18. The town also trends mostly white. Students are focusing on the community's student-aged population for this project. The general direction of the project intends to focus on implementing a cost-friendly design for Clarkdale residents.

Editor's Note
Original information listed in the stakeholder profile was inconsistent with U.S. Census data. The content was summarized to provide a snapshot of community demographics while redacting incorrect figures.

Similar stakeholders and solutions

Kazakhstan

One example of another community trying to solve similar problems of improving the current internet infrastructure and digitizing technology is the Digital Kazakhstan Program. The Kazakh government allocated $41 million U.S. dollars to improve internet infrastructure and digitize services and data throughout the country. The Digital Kazakhstan Program was implemented in 2019 over five areas in Kazakhstan. The program digitized economic sectors, helped digitize the government, and developed a high-speed and secure internet infrastructure for the transfer, storage, and processing of data.

Part of the project involves constructing more fiber-optic communication lines in rural areas. With digital technology playing an important role in the development of the country's economy, the Digital Kazakhstan Program can help increase the competitiveness of Kazakhstan's economy and quality of life through the progressive development of the digital ecosystem. The program has five main goals:

1. Develop and implement digital technologies in key sectors of the country's economy.
2. Expand infocommunication infrastructure, which will provide Kazakhstan citizens with ubiquitous broadband Internet access and mobile communication 4G (in the future 5G).
3. Improve the quality and increase the number of public services provided online. This will reduce bureaucracy and corruption, as well as make government agencies more efficient and open.
4. Create new opportunities and favorable conditions for entrepreneurs through active assistance in the development of e-commerce.
5. Increase the overall digital literacy of the population, which will contribute to the development of the domestic IT sector, as well as improve the quality of education and healthcare in Kazakhstan.

Figure 8 *Additional details on each goal of the Digital Kazakhstan Program are available online at* **https://digitalkz.kz/en/**

South Africa

The South African government is partnering with the World Economic Forum to launch South African Internet for All, a project that aims to bring millions of South Africans, including those in rural areas, online for the first time. The project addresses barriers that prevent universal internet access, including infrastructure, connectivity, affordability, skills and awareness, and relevant content. The plan focuses on extending internet and communications technology (ICT) infrastructure to underserved areas, lowering the costs of being online, digitizing local content, and providing ICT and digital skills. The project also focuses on inequities faced by black people in technological fields and will aim to facilitate greater involvement of the black community in the Information and Communication Technologies (ICT) sector. The project aims for network improvement across the country and fiber deployment in major urban areas.

Facebook

Facebook has also made a goal to help expand global internet access. The company plans to use technologies involving AI controlled drone chains that can coordinate internet projection efficiently to provide the most service to the most people. Another design Facebook considered was high-powered lasers that could transmit information over large distances in a similar manner that optical cables relay information. This allows information to be transmitted the fastest way possible, at the speed of light.

Solution evaluation criteria

The evaluation criteria currently concern cost, speed of implementation, and effectiveness of the solution. Throughout the conceptual design phase, the criteria is expanded into a greater decision matrix for evaluating the solutions.

School solution criteria:

- **Cost:** The lower the cost, the easier it will be for the Town to implement.
- **Implementation speed:** The Town seeks solutions that can be implemented quickly.
- **Effectiveness:** Solutions should provide superior internet connection and accessibility.

Survey results

Demographics

Students distributed a survey to Clarkdale residents to gather information on creating human-centered solutions. Respondents were asked about basic demographics, including age, gender, employment status, education, and income, to build an idea of what kind of people need the internet the most. Overall, the most common respondents were women between the ages of 44-74, split between full-time employment or retirement. The majority of surveyed residents also completed a college degree and their income was in the middle to upper end from $50,000 to $149,000. Respondents were then asked if there were any school-aged people in their homes, to which approximately one-third of participants had at least one school-aged person in their household.

Local character

When asked about what made Clarkdale unique, the majority of participants most commonly mentioned its small-town atmosphere, historic integrity, and close-knit community. Although the residents of Clarkdale want to engage in energy-efficient practices and find it extremely important, they admitted that they usually do not daily. The majority of their engagement in energy-efficient practices came from solar or water sustainability practices. Concerning building a public park with educational sustainability features, respondents felt the most important features included a natural source of water, plants, recreational amenities, parking, and safety. For a new industrial region, key features included internet, water, energy sources, and job creation.

Internet usage

Participants were also asked about their internet usage, and common responses included communication/social media, working from home, and video streaming (Figure 9). During peak usage of household internet, three devices were commonly used simultaneously (Figure 10). On a typical day, many residents reported their devices are connected to the internet for 5-24 hours (Figure 11). However, only 32% percent reported satisfaction with the quality of their service (Figure 12). Finally, when asked to comment on their satisfaction with the internet quality, residents commonly mentioned they thought internet issues stem from Clarkdale's rural location and general lack of advanced internet infrastructure. One resident stated, “There is no good infrastructure in our area. No options for cable, DSL service only offers 3-5MB speed, and satellite is not viable for my situation.” Other residents mentioned switching to other internet providers was too expensive and just as unreliable.

In summary, the results of this survey show that the residents of Clarkdale need internet solutions, with the majority of them either working from home or housing students with online schooling. In addition, respondents spend a lot of time on the internet, ranging from 5-24 hours a day on multiple devices. This does not reflect the entire population of Clarkdale however, because this survey was conducted electronically, those who did not have access to the internet at the time were unable to complete it, so results may be even biased to those with working internet. It may be beneficial to continue these survey efforts in the future, reaching other residents and building a fuller image of the internet needs in the community.

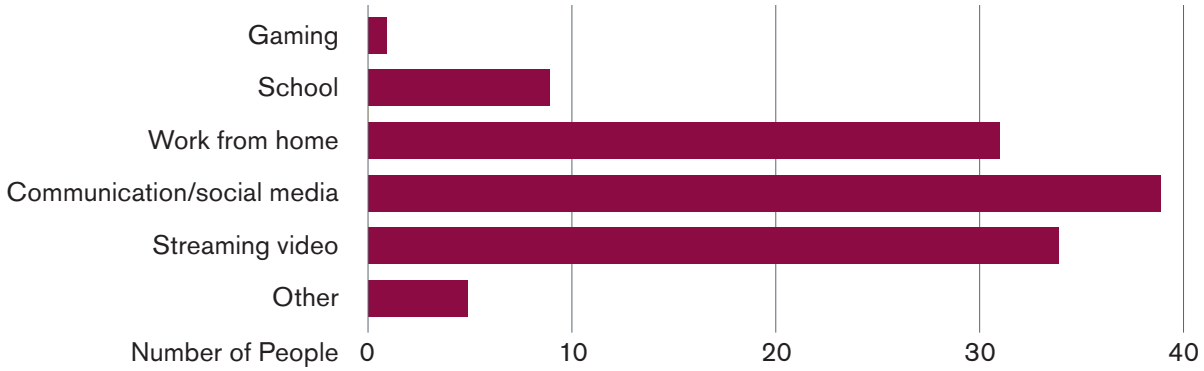

Figure 9 *Internet use in Clarkdale homes*
"In your household, what are the primary uses of internet service?"

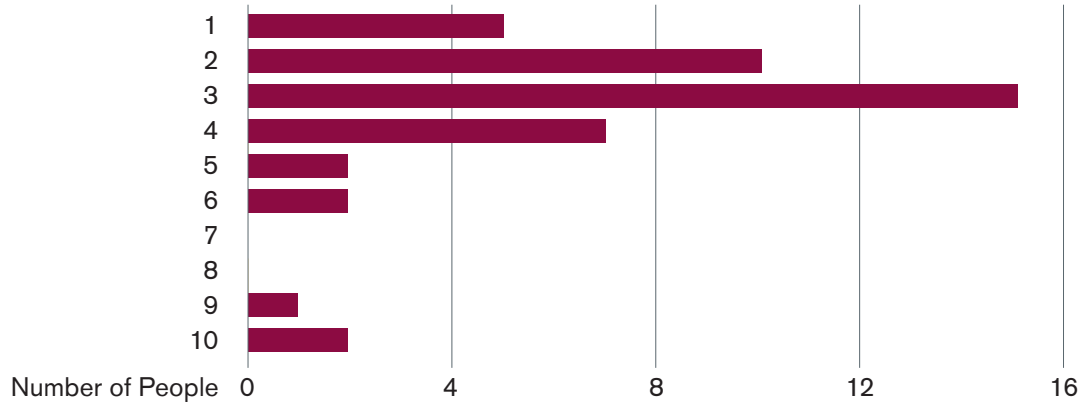

Figure 10 *Number of devices used in Clarkdale homes*
"In your household, how many devices are typically using internet service during peak usage?"

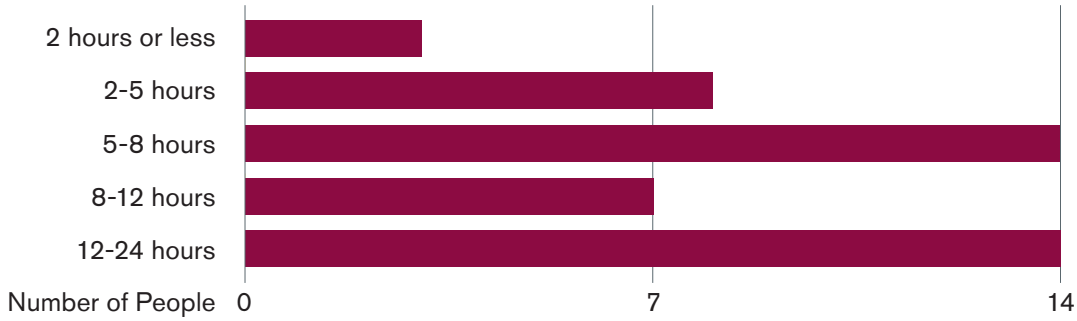

Figure 11 *Connection times in Clarkdale*
"How many hours per day would you estimate devices in your household are connected to the internet?"

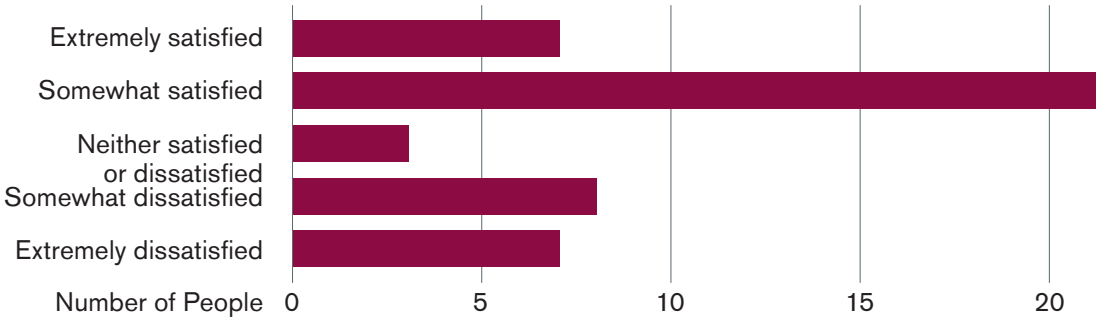

Figure 12 *Internet satisfaction in Clarkdale*
"How satisfied are you with the quality of the internet service provided to your household?"

Recommendations

Figures 13 and 14 contain ideas and possible solutions developed by students from each semester that range from simple to complex. Each proposed solution carries its own pros and cons, and should be further analyzed for feasibility before deciding to implement.

Fall 2020 solutions	
Solution	***Details***
Mobile hotspot system	These solutions focus on the current implemented solutions and improving the Mobile Hotspot system. ▪ Some ideas were as simple as providing more convenience for students who have to go out of their way to reach the range of the buses such as shades or rearranging their route schedule and system. There was a concern that these might be too simple of a route or does not solve the problem. ▪ More complex ideas included using Wi-Fi range extenders or autonomous robots with hotspots that could travel across town. However, the robot may have difficulty navigating the terrain of Clarkdale.
Broader solutions	▪ Wi-Fi Balloon - Similar to the Google Loons, this solution would involve using stratospheric balloons to provide internet to rural areas. However, this solution may be too broad and out of the project's scope. ▪ Satellite Internet - This solution would involve use of communication satellites to provide internet connectivity. However, this solution is too broad but may lead us in the direction of similar or more achievable solutions.
Fixed wireless internet	▪ It is important to seek out and contact private companies with flexible solutions and options for rural, low-budget communities. ▪ Finding solutions that employ synchronization or spectrum reuse would be advantageous, as this limits interference with satellite signals and allows for users to take advantage of different signals. ▪ Internet infrastructure should have a range around 1-20 miles serving 30-50 clients per sector. ▪ Hardware should be rugged and able to withstand the typical community weather, including extreme heat. ▪ It is possible to take advantage of beam forming/directing signals in a certain way such that energy is focused to certain clients. ▪ Solutions should effectively employ multiple users without interference.

Figure 13 *Potential internet infrastructure solutions brainstormed by the Fall 2020 research group*

Spring 2021 solutions					
Solution	***Timeline***	***Buy-in cost***	***Recurring cost***	***Bandwidth***	***Speed***
DSL	Can begin immediately, and would likely take over a year.	~$3,000 per home	$45 per month	~20-50 Mbps	~40-60 ms
Cable	N/A	~$3,000 per home	~$100 per month	~1000 Mbps	~30 ms
Fiber	N/A	~$3,000 per home + $3 per foot traversed	~$100 per month	~1000 Mbps (Will continue to scale)	~15 ms
Starlink	Expected to expand operations to Clarkdale in mid-to-late 2021.	$499 per household	$99 per month	Currently ~100 Mbps, intended to rise to ~300, will likely continue to rise. It is reasonable to expect the typical family to have more than enough bandwidth on 300 Mbps.	~20-40 ms, connection point is not stationary, latency depends on distance to nearest satellite. As more satellites are launched, the average comes nearer to 20 ms.

Figure 14 *Potential internet infrastructure solutions brainstormed by the Spring 2021 research group*

SMART PARKS

Background

The Town of Clarkdale is interested in integrating technology into two of its community parks: the Clarkdale Town Park and the Selna-Mongini Park. More specifically, to create a plan for a new Wi-Fi and speaker system that could be installed at both parks. The project aims to transform these public spaces into "smart town" hubs where the public can access and enjoy useful technology.

A Town plan to upgrade the Selna-Mongini park is already underway, and the Clarkdale Town Park hosts festivals and events throughout the year. Clarkdale wants to be able to use a sound system during these events to communicate over large crowds of people, as well as play music throughout the day to create an inviting atmosphere. Part of this project will address these needs by researching feasible sound system options. Additionally, the Clarkdale Town Park already has a Wi-Fi system, but it becomes overloaded during busy community events and fails to work properly. Researching possible upgrades for this public Wi-Fi system is also a major project priority.

Project identification

This project intends to update existing technologies as well as implement new amenities at the Clarkdale Town Park and Selna-Mongini Park. The Town Park holds various public and private events throughout the year, however it lacks key resources to effectively gather and organize community members. Currently, people must gather in tight groups around the central pavilion to hear announcements. To provide a more comfortable experience, students aim to research public address (PA) systems for the Town Park, and public Wi-Fi network options for both parks, to help town staff enhance their events and provide effective public internet.

Stakeholders

The primary stakeholders for this project are the residents and visitors of Clarkdale. Residents use the local parks for various activities and the project aims to enhance these community assets based on local needs. Secondary stakeholders to consider include businesses or event organizers.

Specification development

Clarkdale has an estimated population of about 4,391 people with a population density of about 424.33 people per square mile. There are two parks being considered in this project: Clarkdale Town Park and Selna-Mongini Park. Since a large portion of Clarkdale's economy stems from tourism, enhancing the experience of visiting either park may improve the local economy and overall quality of life in the town.

Students began the project specification process by considering a diverse set of renovations that could be relevant to either the Town Park or Selna-Mongini Park. Some initial ideas included:

- Park benches with solar panels that function as bench shading and can generate power to charge cell phones or other devices
- Autonomous lawn mower that can cut park grass, similar to the way a Roomba vacuum works
- Electronic art displays, such as LED screens
- Automatic sprinkler systems

Following this brainstorming phase, students consulted with the Town of Clarkdale to learn more about what specific renovations are sought.

Decision matrix

The Town of Clarkdale seeks feasible amenities that can be used for their large events at the Clarkdale Town Park, and as a result, the students' objective was to design an amenity that would enhance the community events held in Clarkdale. According to the Clarkdale community liaison, most of the local residents attend the events hosted in the Town Park, so students wanted to research amenities that can cater to large groups of people. However, other than this request from the community partner, the rest of the amenity evaluation criteria was up to student discretion.

Evaluation criteria developed by students includes:

- Ease of implementation
- Benefit to residents
- Benefit to town officials
- Prior knowledge
- Potential maintenance

The criteria with the most significance was “benefit to residents” and “benefit to Town officials.” Both were weighted at 25% because students wanted to ensure both customer groups would have good use of the amenities and meet their needs. The next highest weight at 20% was “ease of implementation.” The team wanted a project that could be finished by the end of the next semester to deliver to the community partner in a timely manner. The next lowest was “prior knowledge” and “potential maintenance,” with weights of 15% and 10%, respectively. These last two criteria were based on the team’s preference to work on a design that was familiar and did not require heavy maintenance by the Town. Figure 15 shows the student decision matrix and how each considered technology was ranked.

Clarkdale Town Park amenity decision matrix

Criteria	*Weight*	*Speaker/ PA System*	*Park Wi-Fi*	*Solar Powered Benches*	*New Sprinkler System*
Ease of implementation	0.2	4	3	2	1
Benefit to residents	0.25	3	4	5	2
Benefit to town officials	0.25	5	4	1	4
Prior knowledge	0.15	2	2	2	1
Potential maintenance	0.1	5	1	3	2
Total		**3.6**	**3**	**2.5**	**2.05**
Scale: 1-5 5=high 1=low					

Figure 15 *The Fall 2020 student group developed the decision matrix to further narrow the project scope, which helped show a PA system and Wi-Fi to be most feasible*

Through stakeholder conversations, students learned solar-powered benches are likely not the best solution to implement in either park. Residents of a small town may not walk around with laptops in the parks and likely would not need to charge them. Most parks also have existing sprinkler systems that run on a timer, so students decided that was not as important of a solution to pursue. With this, the students decided to focus the project research on public announcement (PA) speaker systems and Wi-Fi upgrades.

Public announcement system: Clarkdale Town Park

Stakeholder requirements

Stakeholder requirements are broad, so there is a lot of freedom to introduce various technologies to the parks. However, the main challenge at the Town Park is the lack of a speaker system, which is crucial for community events. The park hosts many groups that would benefit from an effective sound system, including bands and local festivals.

Time and cost constraints

The project has no set time and cost constraints. Students are considering technologies from multiple price points, but prioritize quality for the most part. The time constraint is left open, but students recognize sooner is better for addressing the Town Park needs.

PESTLE analysis

Speaker/public announcement (PA) system PESTLE analysis

Factor	*Details*
Political	If the broadcasting system is faulty, the local government will not be able to throw events that engage the community at large, which could cause less support for government projects.
Economic	If the broadcasting system is faulty, it is more difficult to advertise any sponsors the government may have during their public events, which may make sponsors less likely to contribute, making events more expensive.
Social	Going to a park with live music playing and fast, reliable Wi-Fi is enjoyable, and if either of these systems fail on the user, the park experience may seem diminished.
Technological	Any new technology that is installed must work from the existing outlets and voltage supply at the park, which may have to be shared with other technologies already in the park.
Legal	The volume of the broadcasting system has the potential to conflict with Clarkdale's noise ordinance to shut off all loud noises after 9:00 p.m.
Environmental	Any wired connections made between electrical components at the park may disrupt the natural beauty of the park. Any digging needed to install components could also cause cosmetic issues, even if they are temporary.

Figure 16 *The PESTLE analysis highlights potential PA system limitations such as installation processes and system maintenance*

Speaker/PA system decision matrix

After extensive product research, the student team created a design decision matrix to better analyze different speaker sets. Five different speakers were compared with five criteria, including price, portability, frequency response, maximum peak sound pressure level (SPL), and speaker cone size.

Students wanted to suggest budget-friendly products, so price was weighted the highest at 30%. The next highest criteria with a weight of 25% was frequency response, which is the range of frequencies a speaker can output. The higher the frequency response range, the higher the score. Maximum peak sound pressure level is the highest decibel level a speaker can reach before distortion, which students ranked third highest with a weight of 20%. Speakers with a higher maximum peak sound pressure level were rated higher. Speaker cone size is associated with the size of the speaker's active area and was weighted at 15%. Again, the speakers with the larger speaker cone size were rated higher. The lowest weighted criteria, with a weight of 10%, was portability. Speakers with a smaller weight and smaller dimensions were scored higher than others.

The team found three suitable speakers in three different price ranges to present to the Town of Clarkdale. The suggested speakers include the JBL SRX835P, Electro-Voice EKX-15P, and QSC CP8, shown from left to right, respectively, in Figure 17. Figure 18 shows the decision matrix where students compared five feasible speaker systems, and Figure 19 lists the specifications of the top three system choices.

Figure 17 *Top-rated speakers according to student decision matrix*

Speaker system decision matrix						
Criteria	***Weight***	***QSC KW153***	***JBL SRX835P***	***Electro-Voice EKX-15P***	***QSC K10.2***	***QSC CP8***
Price	0.3	1	2	3	4	5
Portability	0.1	1	2	3	4	5
Frequency range	0.25	4	5	3	2	2
Maximum peak sound performance level	0.2	4	5	4	3	3
Coverage pattern	0.15	5	5	5	3	1
Total:		**2.95**	**3.8**	**3.5**	**3.15**	**3.25**
Scale: 1-5 5=high 1=low						

Figure 18 *Speaker decision matrix comparing five feasible options for Clarkdale Town Park*

Speaker system top choices			
	JBL SRX 835P	***Electro-Voice EKX-15P***	***QSC CP8***
Price	$1,599	$899	$399
Frequency response range	41 Hz to 20 kHz (±3 dB)	55 Hz to 18 kHz (±3 dB)	56 Hz to 20 kHz (±6 dB)
Maximum sound pressure level	137 dB	134 dB	124 dB
Dimensions (HxWxD)	18.74" x 21.4" x 38.74"	27" x 17" x 17"	16.2" x 10.7" x 10.1"
Net weight	85 lbs.	53.9 lbs.	25.5 lbs.
Cone size	15"	15"	8"

Figure 19 *Top three speaker systems identified via decision matrix*

Mixing console decision matrix

Mixing consoles control the speaker outputs and inputs, ensuring proper system function. The criteria the team used to compare mixing consoles include price, portability, and number of channels. Price and portability were weighted similar to those in the speaker design matrix. Price had the highest weight, while portability had the lowest. The number of channels was focused on the number of inputs and outputs the mixing channel possessed. The team favored consoles with a larger number of channels as it maximizes the system's usage. The two best consoles chosen were the Yamaha MG12XU and QSC TouchMix-16. Similar to the team's speaker choices, the two mixing consoles are in different price ranges to consider. The design matrix for the consoles and specifications of the two consoles chosen are displayed in Figures 20 and 21.

Mixing console decision matrix

Criteria	*Weight*	*Yamaha MG12XU*	*QSC TouchMix-16*	*Behringer X32*	*Soundcraft Signature 22 MTK*
Price	0.55	4	3	1	2
Portability	0.15	3	4	1	2
Number of channels	0.3	1	2	3	4
Total:		**2.95**	**2.85**	**1.6**	**2.6**
Scale: 1-5 5=high 1=low					

Figure 20 *Mixing console decision matrix comparing four feasible options for Clarkdale Town Park*

Mixing console top choices

	Yamaha MG12XU	*QSC TouchMix-16*
Price	$344.99	$1,439.99
Dimensions (HxWxD)	4.7" x 12.13" x 16.61"	2.3" x 14.2" x 11.5"
Net weight	9.3 lbs.	5.9 lbs.

Figure 21 *Top two mixing consoles identified via decision matrix*

Mixing console user manual

The decision matrix and price comparison helped students determine the Yamaha MG12XU as the best mixing console choice for Clarkdale's needs. To fully understand and set up the speaker system, mixing console, and any other sound equipment, a user manual is available for the Yamaha MG12XU mixing console. Included in the manual are three critical sections: powering system, sound, and effects. Each section contains detailed procedures for setting up the mixing console and getting all devices and cables connected. With each set of procedures in each section, there is a relevant visual diagram, which is needed for reference when reading through the instructions.

Preparing Power Supply:

1. Make sure the power switch on the unit is set to the "o" position.
2. Connect the included power cord to the [AC IN] jack on the rear panel.
3. Plug the power cord into a power outlet.

Connections:

1. Turn all the faders and [GAIN] knobs completely down.
2. Connect the microphones, speakers, and other instruments you intend to use.
    a. The peripherals are connected on the front panel of the mixing console.

Powering System:

1. Power on the devices in the following order to prevent an unwanted burst of noise from the speakers: peripherals (speakers, microphones), mixing console, power amps.
    a. Reverse order when powering off.

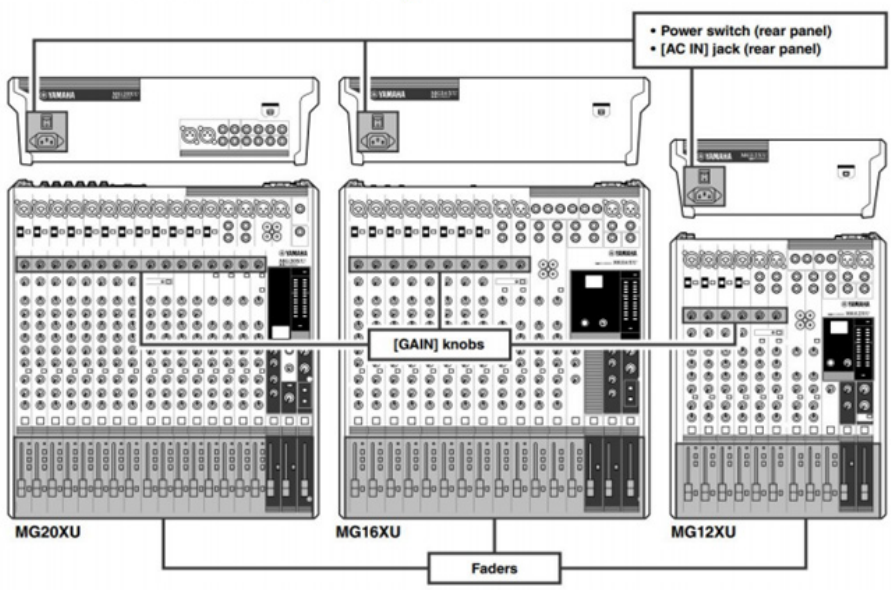

Figure 22 *Yamaha MG12XU mixing console manual excerpt, powering system section*

Getting Sound to the Speakers:

1. Turn on the [PFL] switches for each channel you are using.
2. While speaking into the microphone, adjust the input signal with the [GAIN] knob until it goes past the "0" position on the level meter only occasionally.
3. Turn on the [ON] switches for each channel you are using.
4. Turn on the [ST] switches for each channel you are using.
5. Turn off all [PFL] switches.
6. Turn on the [ON] switch for the [STEREO] master.
7. Raise the [STEREO] master fader to the "0" position.
8. Set the channel faders to create the desired initial balance.
9. Adjust the overall volume of the [STEREO] master fader.

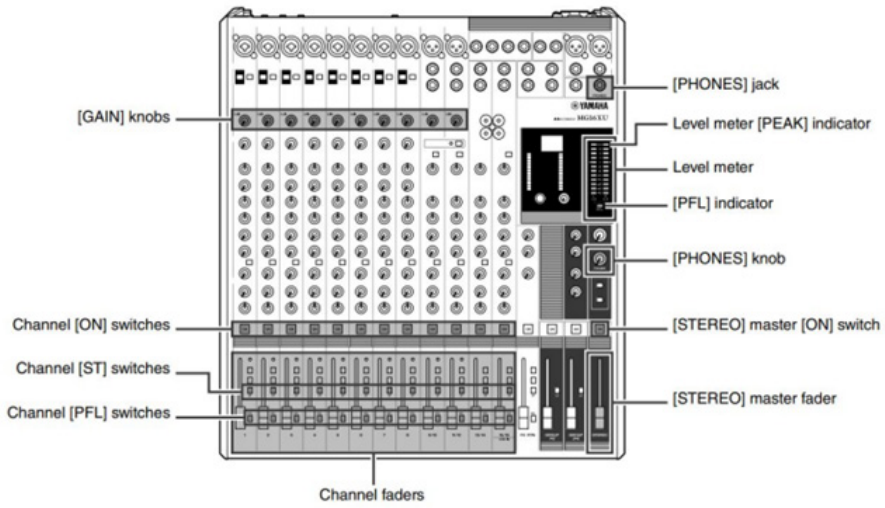

Figure 23 *Yamaha MG12XU mixing console manual excerpt, sound section*

Using the Built-in Effects:

1. Turn the [PROGRAM] knob to select the desired effect, and then press the knob to enable it.
2. Turn on the [ON] switch for [FX RTN].
3. Turn on the [ST] switch for [FX RTN].
4. Raise the [FX RTN] fader to the "0" position.
5. Use the [AUX (2, 4)/FX] knobs to adjust the effect depth for each channel.
6. Use the [FX RTN] fader to adjust the overall effect depth of the selected effect.

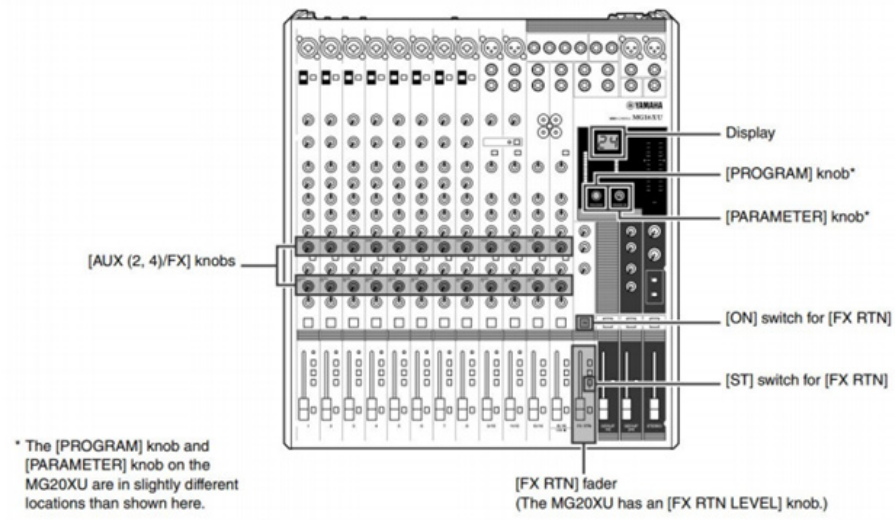

Figure 24 *Yamaha MG12XU mixing console manual excerpt, effects section*

Design schematic

Since the team was unable to visit Clarkdale, Google Maps was used to create a rough schematic for a speaker system. The main point of interest is the center square and gazebo of Clarkdale Town Park. This area is primarily used for large gatherings and is the focal point of coverage from the speakers. The quality of sound depends on speaker choice and placement to optimize sound deliveries. According to Jame Feenstra from ProSoundWeb, 1,000 watts of speaker power is needed to cover 1,000 square feet. Using Google Maps students calculated the park's center square area to approximately 2,400 square feet. Using a 1,500 watt speaker, two speakers could cover this area with quality sound.

Figure 25 *Aerial view of Clarkdale Park with suggested speaker range in yellow, base image via Google Earth*

StreetSounds speakers

Students also investigated an outside company called StreetSounds to see if they could provide a permanent speaker system for the Clarkdale Town Park. StreetSounds specializes in installing speaker systems in small towns similar to Clarkdale. When researching outside companies, StreetSounds seemed like the most viable option as their products are easily installed, wirelessly connected, and there is no need for physical digging during installation. The speakers can be attached to light posts and are powered through a 110 V power source. They are connected through a wireless repeater that sends signals sequentially to one another. The speakers can be controlled through any mobile device, and can also be connected to the mixing consoles previously identified. This setup could allow Clarkdale to stream music passively as well as output live music or announcements.

Figure 26 *Example of StreetSounds hardware installed on a walkway lightpost*

Recommended speaker system delivery

Budgetary constraints were not specified for this project, so students listed potential costs for three different recommended speaker systems (Figures 27-29). Systems were separated into three tiers: high-end, medium-end, and low-end. The tiers were separated by both price and quality; for example, the high-end speaker system would create the best sound quality while also being the most expensive. Along with the speakers and mixing console, each recommended system includes microphones, XLR cables, and speaker stands. By creating a tier system, students aimed to provide decision flexibility based on cost.

High-end sound system cost estimate			
Component	***Product***	***Quantity***	***Cost***
Microphone	Sennheiser E835 dynamic cardioid vocal microphone	2	$199.90
XLR Cables	Gearlux XLR microphone cable male to female 25' fully balanced premium cable	3	$34.99
Speaker stands	Pair of PA speaker stands by Hola! Music, professional heavy-duty tripod structure, 4'-6' adjustable height, model HPS-500PA	2	$79.99
Speaker	JBL SRX 835P	2	$3,198
Mixing console	QSC TouchMix-16	1	$1,439.99
Total: $4,952.87			

Figure 27 *High-end speaker system cost for Clarkdale Park, by Fall 2021 student group*

Mid-end sound system cost estimate			
Component	***Product***	***Quantity***	***Cost***
Microphone	Behringer Ultravoice XM1800S dynamic cardioid vocal and instrument microphones, set of 3	3	$59.99
XLR Cables	GLS Audio 25' microphone cable patch cords, XLR male to female cables	5	$89.85
Speaker stands	Rockville Pair RVES1 adjustable tripod DJ PA speaker stands	2	$49.95
Speaker	Electro-Voice EKX-15P	2	$1,798
Mixing console	Yamaha MG12XU	1	$344.99
Total: $2,342.78			

Figure 28 *Mid-end speaker system cost for Clarkdale Park, by Fall 2021 student group*

Low-end sound system cost estimate			
Component	***Product***	***Quantity***	***Cost***
Microphone	Amazon Basics dynamic vocal microphone, cardioid	2	$41.98
XLR Cables	Amazon Basics XLR male to female microphone cable, 10'	4	$38.12
Speaker stands	Pyle universal speaker stand mount heavy duty tripod with adjustable height	2	$55.68
Speaker	QSC CP8	2	$799.98
Mixing console	Yamaha MG12XU	1	$344.99
Total: $1,280.75			

Figure 29 *Low-end speaker system cost for Clarkdale Park, by Fall 2021 student group*

Public Wi-Fi: Clarkdale Town Park & Selna-Mongini Park

Stakeholder requirements

The Clarkdale Town Park has an existing Wi-Fi system, but it often cannot support high bandwidth demands that come with larger community events. This can also be a great challenge for vendors that participate in events and need reliable Wi-Fi to conduct their services or entertainment. Clarkdale noted that Town Park events play a large part in Clarkdale's tourism, and faster public Wi-Fi could help make these events more enjoyable for everyone. A Wi-Fi system for Selna-Mongini Park was also determined to be a valuable option to research.

While Clarkdale did not necessarily provide specific Wi-Fi system requirements, some constraints and factors that students consider include the durability of the system, and its resistance to harsh weather. Additionally, the Wi-Fi system must be secure enough so that components cannot be easily stolen. Cost is also important to consider, especially since the Town aims to install systems at two separate parks.

Figure 30 *Clarkdale is considering Wi-Fi upgrades for two parks, Selna-Mongini (left) and the Clarkdale Town Park (right)*

Wi-Fi system options

There are many different solutions for delivering a stable Wi-Fi connection to a large area. Some options include installing Wi-Fi range extenders or access points to help broadcast existing signals further, or mesh Wi-Fi systems where multiple access points are strategically placed to provide stronger connectivity over a larger area. These two main options were analyzed to see which one best suited Clarkdale's needs.

Mesh Wi-Fi

Mesh Wi-Fi is made up of multiple nodes, where the main node is the router node. The nodes all communicate with each other, allowing for a strong, robust, and seamless connection. This is helpful if any Wi-Fi nodes get damaged or malfunction, as the system will sense the compromised node and redirect the signal to another node. This does cause a decrease in signal strength and connection speed, but it is not substantial and the setup ensures Wi-Fi does not shut fully down. While initially expensive for smaller scale implementations, mesh Wi-Fi becomes cheaper per square inch covered.

Router plus access points

Wi-Fi routers with access points (APs) work best in a home or small office environment, as signal interruptions can last longer in larger environments. This is because APs only communicate with each other one at a time. This significantly decreases signal speed and strength based on the successive AP that is connecting. Another downside to access points is they are very expensive to implement on a large scale.

Based on the research conducted, students determined mesh Wi-Fi was the best option for Clarkdale. It should be noted, the size and number of trees surrounding the parks could potentially have an effect on Wi-Fi signal strength.

Planning considerations

Some minimum specifications were settled to ensure a high-quality experience in using Wi-Fi at the park. To simplify the planning of necessary hardware and minimize the cost of installing Wi-Fi, by using the approximate dimensions of both parks and the typical range of 92 meters of an outdoor router, an approximate number of connection points necessary for either park was calculated.

Clarkdale Town Park requires a minimum of three and maximum of four total connection points (a router, plus two to three access points or Wi-Fi extenders). Selna-Mongini park would require a minimum of four, maximum of six connection points (a being the router, plus three to five access points or Wi-Fi extenders). Access points are physical cables, whereas Wi-Fi extenders are wireless but vulnerable to interference. The choice will ultimately be the Town's preference.

A minimum of 5 Mbps of bandwidth is required for streaming music in the parks, while good bandwidth for browsing the internet is about 50 Mbps. The final necessary bandwidth for Clarkdale ultimately depends on what the Town prefers to be available in either park. Bandwidth can be tested through a mesh test, which takes only a few seconds. Figure 31 provides general parameters for mesh tests.

Mesh test guidelines	
Rating	***Speed***
Great	More than 100 Mbps
Ok	Between 50 and 100 Mbps
Weak	Less than 50 Mbps

Figure 31 *Guidelines for mesh test results*

Modem options

The service provider for internet in Clarkdale is Sparklight. Any internet modems used for the parks must be compatible with Sparklight. Students researched feasible modem choices and divided them into mid-range and high range options, displayed in Figure 32.

Modem top choices		
	Netgear Cable Modem CM500	***Netgear Cable Modem CM600***
Price	$59.99 (Mid-range)	$94.99 (High-range)
Channels (down/upstream)	16/4	24/8
Maximum speed (down/upload)	680/130 Mbps	960/240 Mbps
DOCSIS Edition	DOCSIS 3.0	DOCSIS 3.0

Figure 32 *Mid-range and high-range Wi-Fi modem options*

Wi-Fi system schematic

Figure 33 shows a suggested Wi-Fi schematic, or visual representation of the placement of connection points across the park. To facilitate functional Wi-Fi across the area, multiple factors should be considered. First, the size of Selna-Mongini Park determines the number of connection points used. Students visually estimated the park area using Google Maps, totaling approximately 40 acres. The second consideration is how the connection points function within the network. It is critical to understand that each unit must be in communication (within the illustrated circle) with at least one other unit. Each unit can cover approximately 7.759 acres according to the following calculations:

Editor's Note
Students overestimated the area of Selna-Mongini Park, which is approximately 2.4 acres. The Town should recalculate the number of necessary connection points to form a more accurate schematic before moving forward with this portion of the project.

πr^2 = 3.14 x 10,000 m^2 = 31,400 m^2 = 7.759 acres (fitting a circle into square acres)

With this proposed overlapping system, the units provide better coverage and create a failsafe buffer. If a unit needs to be serviced, there is likely an overlapping unit that can help cover that zone for the time being. The schematic below is a rough estimate of the placement of connection units based on visual observation. More precise information about the acreage of the park and computer software assistance can help provide a more detailed, exact schematic identifying ideal locations for each unit.

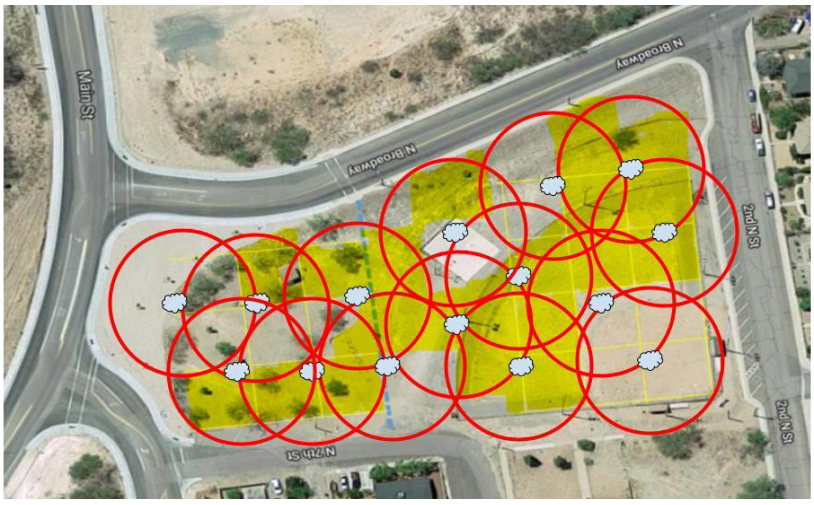

Figure 33 *Selna-Mongini Park Wi-Fi Schematic, with each cloud icon representing a connection point and each circle representing that unit's coverage*

Recommended Wi-Fi system delivery

Figure 34 summarizes each considered Wi-Fi option for an outdoor mesh Wi-Fi system to be installed in Clarkdale's parks. Students recommend the CISCO Meraki MR 76 Wi-Fi System as a primary choice for Clarkdale's needs. This system appears to be the best option based on its cost and coverage area. For the CISCO Meraki Wi-Fi, the only hardware needed is the connection units and their corresponding cloud licenses. Some key features of this Wi-Fi system are listed below, gathered from the Norstar Networks information page on the Meraki system (Norstar Networks, 2020).

- **Multi-site management** - Powerful and intuitive multi-site management via the cloud eliminates the cost and complexity of on-site wireless controllers or centralized management tools.
- **Automatic provisioning** - Zero-touch provisioning shortens deployment and configuration time to minutes. There is no need to manually stage APs or perform manual configuration and provisioning. CISCO Meraki APs use Auto Radio Frequency to self-configure and optimize RF settings for maximum performance, even in dense and challenging environments.
- **Future-proof** - Seamless over-the-web upgrades deliver significant new features to current products. New feature updates are added automatically, such as visibility, analytics, security, and troubleshooting tools to enhance administrator efficiency.
- **Unmatched visibility** - Administrators can quickly create access control and application usage policies, optimizing both the end-user experience and network security.
- **End-to-end management** - WAN, LAN, wireless LAN, and mobile device management under one roof.

Coverage and range are highly dependent on the environment (radio frequency interference, weather, etc.) and the antenna types, which makes definitive ranges harder to predict. However, barring radio interferences and physical obstructions, Meraki access points equipped with omnidirectional antennas typically reach a range of at least 100 meters, or 328 feet.

Wi-Fi choices and specifications					
	Aironet 1562	*Catalyst 9124*	*AP 1130*	*Meraki MR 86*	*Meraki MR 76*
Wi-Fi 6?	No	Yes	No	Yes	**Yes**
Maximum clients	N/A	400	<200	512	**512**
Range	7 dBi (800')	7 dBi (800')	5 dBi (500')	4/7 dBi (300'/800')	**4/7 dBi (300'/800')**
Operating temperature	-40° - 149° F	-40° - 149° F	-40° - 131° F	-40° - 131° F	**-40° - 131° F**
Dimensions	9" x 6.8" x 4.3"	10.2" x 9.2" x 3.2"	7.71" x 7.71" x 2.12"	11.81" x 6.02" x 2.16"	**11.81" x 6.02" x 2.16"**
Notes	Local management	Local management	N/A	More dense/ cloud management	**More open/ cloud management**
Pricing	$1,455	$2,400	$1,129	$2,450 + $400/3 years	**$1,299 + $400/3 years**

Figure 34 *Compared Wi-Fi options, with the Meraki MR 76 highlighted for its superior performance*

CONCLUSION

Clarkdale recognizes the opportunity to grow as a "smart town." Integrating new technologies into the everyday fabric of the community can help individual residents with basic needs like internet access, as well as draw the community together by making events more accessible and enjoyable through PA systems and public Wi-Fi networks. Students in the ASU EPICS program across three semesters took on the challenge of assessing Clarkdale's specific needs, researching applicable products and developing decision matrices to assist town leadership in reviewing the plethora of technology choices available.

The need for high-quality internet infrastructure grew even more apparent as the COVID-19 pandemic shifted many schools and workplaces online. As a central community location, the Clarkdale Clubhouse is primed for the development and implementation of wireless internet. Over the Fall 2020 and Spring 2021 semesters, the EPICS Internet Infrastructure group of students worked to identify new opportunities for internet provision, ranging from wireless to cable solutions.

This project could be continued in many ways, including into a conceptual design phase, further researching identified solutions, and developing a functional decomposition based on the prior brainstorming section. Once those aspects of the solution have been defined, they could be narrowed further with a decision matrix. These future steps can help best inform a successful solution for accessible internet.

Figure 35 *View of Downtown Clarkdale, with the historic post office in the foreground and Town Clubhouse in the background*

Throughout the Fall 2020, Spring 2021, and Fall 2021 semesters, additional small groups of EPICS students focused on implementing smart technologies to Clarkdale's Town Park and Selna-Mongini Park. Installing public Wi-Fi and speaker/PA systems at these community focal points could enhance town events, as well as provide everyday amenities. Students conducted research following the iterative EPICS design process, identifying stakeholders, conducting a PESTLE analysis, and drafting initial designs for PA systems and Wi-Fi schematics. Potential systems were identified in various price ranges for Clarkdale to consider. Recommendations for this section were drawn from researched technology systems, and stakeholder needs. The project aims to provide feasible infrastructure systems that enhance the experience in the parks for Clarkdale residents and visitors. In future semesters, the project could progress into the design phase to develop a detailed plan for each park.

In summary, "smart town" technologies can help Clarkdale best serve its citizens by providing widespread, high-speed internet, and enhancing community events and recreation. The student groups intend for their recommendations to lay a foundation for Clarkdale in progressing toward its technology infrastructure goals.

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