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CAR COMPANIES ARE GOING TO OWN AND OPERATE THE POLLUTION. AND THE REASON FOR THIS IS SIMPLE. IF THE CLEANER THAN MOST OF THE CARS AND TRUCKS WE DRIVE, OR AN ADVERTISER-BASED MODEL, WHICH WOULD MAKE FOLLOW A FEE-FOR-SERVICE MODEL LIKE THE CURRENT REMAINS TO BE SEEN WHETHER MOBILITY SERVICES WILL MAKE VEHICLES AND INSTEAD OF SELLING THEM AS PART OF A SHIFT IN THE AUTO INDUSTRY TOWARD THE PROVISION OF MOBILITY SERVICES, WHERE COMPANIES

IN MIND TO SUCH AN EXTENT THE CITY, JUST AS THEY ARE ALLOWED TO RIDE HORSES WITH

SMALL TOWNS WENT FROM ACCOMMODATING BICYCLISTS AND PEDESTRIANS, AS WELL AS MERCHANTABILITY AND PROFIT, AS WELL AS THE POTENTIAL FOR SAFETY AND LIABILITY. DRIVING CARS WILL ALSO BECOME WHAT IT ONCE WAS AT THE BEGINNING OF THE 20TH CENTURY: AN EXPENSIVE HOBBY. THE EXPENSE WILL COME LARGE FROM HIGH INSURANCE RATES, WHICH INCREASE AS THE INSURED POOL OF HIGH-RISK DRIVERS SHRINKS AS MORE PEOPLE SWITCH TO MOBILITY SERVICES. AND LIKE STABBING HORSES, STORING CARS WILL TYPICALLY HAPPEN OUTSIDE OF URBAN AND SUBURBAN AREAS. EVENTUALLY, DRIVERS WILL BE BANNED FROM METROPOLITAN AREAS EXCEPT FOR THE POLICE AND OTHER EMERGENCY PERSONNEL, WHO WILL BE ABLE TO CONTINUE DRIVING CARS IN THE CITY, JUST AS THEY ARE ALLOWED TO RIDE HORSES THERE.

THE AUTONOMOUS VEHICLE, MOBILITY SERVICE REVOLUTION - CAN BECOME CONSTRUCTED FROM A HORSE-DRAWN TRANSPORTATION SYSTEM TO A CAR-POWERED ONE TOOK ROUGHLY TWO DECADES IN THE EARLY 20TH CENTURY. WHERE OLD PHOTOS SHOW ALMOST NO CARS ON URBAN STREETS IN THE EARLY 1900S AND ALMOST NO HORSE-DRAWN VEHICLES THERE BY THE EARLY 1920S. THE TRANSITION FROM DRIVEN VEHICLES TO AV'S MAY TAKE THAT LONG - OR LESS TIME, GIVEN THE GREATER SPEED WITH WHICH THE 21ST CENTURY OPERATES AND THE SIGNIFICANT PROFITS THAT CAR COMPANIES WILL REALISE AS THEY SHIFT FROM BEING GOODS-PRODUCING TO SERVICE-PROVIDING BUSINESSES.

THE AUTONOMOUS VEHICLE, PUBLIC REALM AV-ready roads will likely combine aspects of both the horse-drawn carriage road, with its pervious surface, and the horse-powered car or truck-road, with its impervious surface. To handle the repetitive wear of precisely guided AVs, roads will need to have wear-resistant tracks or grade beams with high-strength concrete to ensure greater longevity. Those tracks, which accommodate the AV’s tires, will constitute only about 10-33% of the road's surface. The remainder of the road can then have a pervious surface, which in turn will allow stormwater to percolate into the road bed and recharge the aquifers below. This in turn will enable cities to abandon their expensive and environmentally damaging stormwater sewer systems, a savings that can be used instead for help pay for Av infrastructure. For large storm events, former surface parking lots – many of which will no longer be needed as the demand for parking greatly diminishes in a mobility service future – can be constructed into pervious and retention ponds that can hold large amounts of rain water when necessary.

THE DRAWS ON THE FOLLOWING PAGES SHOW THE WORK THAT THE STUDENTS AND STAFF OF THE MINNESOTA DESIGN CENTER HAVE DONE TO ILLUSTRATE THE NATURE OF AV-ready ally, local streets, collector streets, and arterial streets. WE ILLUSTRATE THE PERVERSIVE AND IMPERVIOUS MATERIALS AND THEIR COMPOSITION IN AV-ready streets and the phases of work as we transition from streets designed to accommodate drivers to ones designed to handle Avs. WE ALSO SHOW THE ELEMENTS OF AN AV-ready street and the zones within the public right away for Avs, bikes, scooters, and pedestrians, as well as safety and infrastructure and street planting possible in these streets.

With each street type, we provide an overview of the existing condition and its Av alternative, with calculations related to planting, stormwater retention, heat island effects, and material costs. We also show cross-sections through each street type to indicate the below-grade conditions of Av-ready streets and how they compare to what we do now. In all cases, the Av-ready streets outperform existing ones in several areas: carbon sequestration, stormwater runoff, heat island mitigation, and material costs. And while we do not calculate the savings that come from abandoning the storm sewer system, that too will be a considerable amount of money.

CONCLUSION The full transition of our streets and roads from the accommodation of horses to cars took longer than the transition to the vehicles themselves. Many rural areas still have dirt or gravel roads over a hundred years after the shift in our transportation system. The transition of our current road infrastructure to one that is Av-ready will likely take a long time to evolve as well. Which is why we need to begin now. The auto industry is moving rapidly to an Av-ready mobility service business model and once these vehicles become common, their negative impacts on our roads will quickly become apparent. With major investments in transportation-related infrastructure underway or about to begin in many nations around the world, we need to stop putting in 20th century streets, based on out-of-date assumptions about street design and vehicle needs, and start installing Av-ready streets in preparation for what is to come. We hope the material in this publication will help communities move in that direction.

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DESIGNING FOR FUTURE STREETS

RESEARCH ASSUMPTIONS
STREET TYPES
STREET MATERIALS
STREET PHASES
STREET ELEMENTS
STREET ZONES
AUTONOMOUS VEHICLE
PEDESTRIAN AND PUBLIC REALM
STREET SYSTEMS
GREEN INFRASTRUCTURE
NATIVE PLANTS

Local Street

Right-of-Way
RESEARCH ASSUMPTIONS

**POLICY ASSUMPTIONS**
- Autonomous Vehicles (AV’s) will:
  - offer a safer, cleaner, and cheaper alternative to cars
  - become prevalent by 2040 as driven cars are banned from metropolitan streets
  - rely upon on-demand platforms that people can use to access mobility
  - be part of a mobility-as-a-service (MaaS) model, reducing transportation costs
  - largely eliminate the need for parking as vehicles remain in continuous operation
  - greatly reduce the number of vehicles on the road as they increase in efficiency
  - respond to people on-demand, challenging fixed schedule transit systems

**PUBLIC REALM**
- AV-ready streets will:
  - have concrete, grade-beam tracks and pervious, planted surfaces
  - have fewer and narrower lanes than those today, allowing more space for people
  - be equipped with real-time information, and integrated sensor technologies
  - become places for neighborhood gatherings and community destinations
  - accommodate diverse modes of transportation as travel lanes decrease in width
  - provide space for community uses never possible on busy streets before

**CLIMATE CHANGE**
- AV’s will:
  - help reduce heat island effects, as streets become healthier and shade
  - help reduce carbon emissions because of the electric drivetrain on cars
  - handle much of the first-mile/last-mile need with on-demand services
  - reduce stormwater run-off as streets become more pervious
  - increase green space as well as the storage capacity of major storm events

(1 - Google’s Autonomous Vehicle, 2 - NACTO’s Blueprint for Autonomous Urbanism, 3 - MDC’s Future Streets, 4 - Boulder, Colorado, 5 - Detroit, Michigan)
STREET TYPES

ALLEY (20’ - 0”, typical)
Service and rear access streets, typically found in urban areas and residential neighborhoods.

LOCAL (40’ - 0”, typical)
Residential streets with pedestrian sidewalk and street parking on both sides.

COLLECTOR (60’ - 0”, typical)
Streets connecting residential streets to commercial and industrial areas. Surface parking lots, street parking, public transportations (multi-modal transitways), shared bicycle lanes, and wider pedestrian sidewalks are often found adjacent to collector streets.

ARTERAL (80’ - 0”, typical)
Streets connecting high volume traffic (interstates, highways, boulevards) to and from urban areas/downtowns. Surface parking lots, street parking, parking ramps, public transportations (multi-modal transitways), shared and dedicated bicycle lanes, and wider pedestrian sidewalks are often found adjacent to arterial streets.

SHARED GREEN (varies)
Streets that incorporate Green Infrastructure (Green and Blue strategies) to reduce and manage stormwater. These strategies are meant to improve water quality, reduce runoff and heat island effect, restore native ecosystem, provide public space, and preserve natural landscape in urban areas.

(Alley, Local, Collector, and Arterial Streets - Minneapolis, Minnesota, Shared Green Street - Detroit, Michigan)
STREET MATERIALS
ASSEMBLY AND COMPOSITION

- ASPHALT CONCRETE PAVEMENT (AC)
- BASE AGGREGATE (ROCK) (BA)
- COARSE AGGREGATE (Recycled Asphalt Concrete Pavement) (CA)
- PERMEABLE PAVERS/PLANTING SOIL (See Green Infrastructure and Street Planting) (PP)
- REINFORCED CONCRETE (AV TRACKS) (Sloped Edges and Heated) (SG)
- SUB-GRADE (SG)

EXISTING STREET

SHARED GREEN STREET
In the first phase of transitioning from driver-oriented to AV-ready streets and from car-oriented parking requirements to a future of mobility services involves assessing the location of below-ground utilities and the amount of surface paving materials that can be reused as part of the new construction. With 30% of the land area in most municipalities devoted to the movement and parking of cars, the amount of material available for reuse will be substantial.

In the second phase, the streets become a hybrid of both driven vehicles and AVs, each with their own dedicated lanes in order to avoid accidents in which driven run into AVs—and almost never the other way around. This phase also begins to see mobility services rendering surface parking lots superfluous as that land gets repurposed as stormwater retention ponds, urban greenhouses, solar or wind farms, and other uses of benefit to communities.

By the third phase, the AV-ready streets are in place, with concrete grade-beam tracks for the AVs and pervious paving or planted medians covering the remainder of the road surface. Reused concrete and asphalt from the previous streets form the aggregate base and subsurface for the new roads. Also, new development begins to fill in where surface parking lots formerly stood, increasing the tax base of the municipality.

By the fourth phase, the transition to fully automated streets is complete. Driven cars are no longer allowed on urban and suburban streets because of the hazard they create for both AVs as well as bicyclists and pedestrians. Meanwhile, dedicated bike lanes have been created on most streets to encourage self-propelled transportation, and sidewalks have become much wider as the number and width of AV lanes have decreased.
AV TRACKS
AV tracks are designed to collect and store regenerative energy from braking and idling AVs and produce generative energy from moving AVs. The energy generated can be used to heat the concrete slab tracks, to power the street bollards, and/or provide access to charging stations in public spaces along the shared green street.

SMART BOLLARDS
In addition to physically separating AV traffic from pedestrians, smart bollards are integrated with advanced technologies making rides safer and more comfortable. Bollards are wired with motion sensor technology that indicate (signalize when on-coming traffic/movement (an AV, a cyclist, and/or small vehicle) is approaching and/or departing as well as when a pedestrian is crossing the shared green street, walking along the sidewalk, and/or standing in the middle of the shared green street. These smart bollards alert bystanders if there is an emergency nearby or if physical assistance is requested or needed. The diagram below highlights other features that can be found in a smart bollard.
**STREET ZONES AUTONOMOUS VEHICLE**

1. **AV TRACKS**
   Two primary AV tracks (6'-0" OC) run parallel in the center of the shared green street. These tracks branch off at designated Pick-up/ Drop-off Areas along the shared green street’s edges. AV tracks run in both directions, unless due to congestion or scheduled disruption, AV may run in the same direction.

2. **AV PICK-UP/ DROP-OFF ZONE**
   There are two Pick-up/ Drop-off Areas on each side of the shared green street. The smaller designated area is dedicated for the quick pick-up and drop-off of individuals (A). The larger designated area is dedicated for the quick pick-up and drop-off of individuals, pick-up and drop-offs that require additional time and/or assistance, and for multi-users - Public Transportation (B).
STREET ZONES
PEDESTRIAN AND PUBLIC REALM

1 PEDESTRIAN ZONE
A shared green street consists of three primary pedestrian zones: Pedestrian Sidewalk (A), Pedestrian Waiting Area (B), and Pedestrian Crosswalk (C). These areas are located along the perimeter of the shared green street and are designated for pedestrians only and/or pedestrian operated small vehicles.

2 DEDICATED BICYCLE LANE AND/OR DEDICATED SMALL VEHICLE LANE
These lanes are located on the outer edge of the shared green street. All shared green streets have dedicated bicycle lanes and are part of a larger and more extensive bicycle network. As the shared green streets widen, some shared green streets will have both dedicated bicycle lanes and dedicated small vehicle lanes.

3 FLEXIBLE GREEN SPACE
Under-utilized, unused, and/or available spaces adjacent to pedestrian sidewalk can be converted into productive and active green spaces or passive Green Infrastructure.
BIORETENTION (RAIN GARDEN)
The narrower vehicular right-of-way of AV-ready streets allows for the installation of bioretention areas between the road and sidewalk, allowing stormwater to recharge the aquifer and to support the growth of street trees that provide shade for pedestrians, while lowering the heat island effect.

INFILTRATION TRENCH
The rain gardens and pervious paving of the road and sidewalks allow the capture of stormwater in retention basins below ground and enabling it to percolate back into the soil. Infiltration trenches can also nourish the roots of trees and other street planting, while filtering out pollutants from the roadways.

PERMEABLE PAVEMENT
A range of permeable pavement is possible now that the AV’s follow their own, dedicated concrete tracks. And once the curb-and-gutter stormwater system is abandoned, the installation of permeable pavement allows for a continuous surface, with different types of pavers demarcating vehicular, bike, and pedestrian zones.

VEGETATIVE SWALE
One of the greatest challenges for AV-ready streets is the control of pedestrians crossing at will along a street, knowing that the AV will not strike them. Vegetative swales in the middle of the road can discourage crossings and funnel pedestrians to a few places along a block where crossings are allowed.

WETLAND
The replacement of former surface parking with constructed wetlands has several benefits: it provides green space and diverse habitat, it reduces heat island effects, and it absorbs excess runoff during large storm events. The wetlands serve in lieu of the stormwater sewers, offering more environmental benefit at a much lower cost.

SUGGESTED PLANTS
(See Street Planting - Native Plants)
STREET SYSTEMS
NATIVE PLANTS

**TREES AND SHRUBS**
Restoring the urban tree canopy and providing continuous shade to sidewalks makes trees an essential part of AV-ready streets. The type of tree and shrub will depend upon the climate and maintenance requirements of each native specimen.

**FORBS AND HERBS**
The greater space that AV’s allow for activities other than vehicular movement provides opportunities, for example, to plant edible species and to think about the street accommodating urban gardens.

**RUSHES AND SEDGES**
These plant types can tolerate extreme conditions sometimes found along urban and suburban streets. Sedges do well on green roofs and rushes can thrive in rain gardens and wetlands, where other plants cannot.

**GRASSES**
Native grasses are among the heartiest plants to install along AV-ready streets. Their deep roots make them able to tolerate long periods without rain and they require very little maintenance once they are established.
FUTURE STREETS

ALLEY STREET
EXISTING STREET
SHARED GREEN STREET
LOCAL STREET
EXISTING STREET
SHARED GREEN STREET
COLLECTOR STREET
EXISTING STREET
SHARED GREEN STREET
ARTERIAL STREET
EXISTING STREET
SHARED GREEN STREET
ALLEY STREET

EXISTING
In cities served by alleys, these infrastructure corridors – typically 20 to 25 feet wide – rarely get the attention or maintenance of other streets. While some alleys are dirt or surfaced with gravel, most have asphalt paving, with garages and surface parking spaces along them. Trash and recycling bins as well as utility lines dominate the alley landscape, with few trees or other planting except what might exist in adjacent back yards. In some cities, the alleys are publicly owned and in others, they are privately owned as easements private property, making property owners responsible for their upkeep and repair.

SHARED GREEN STREET (FUTURE)
In the near future, car companies will begin providing us with mobility for a fee or as part of a subscription or advertiser service. The emergence of these mobility services will have a dramatic impact on the nature and role of alleys. Most of the garages along alleys, for example, will be available for uses other than storing vehicles, uses that might include accessory dwelling units, production workshops, business start-up space, and childcare facilities among many other possibilities. The alley itself will also become greener, with AV tracks and the rest of the right-of-way having pervious pavement. Open lots might become space for urban agriculture or wetlands and former driveways might become places to plant trees to shade the pedestrian-oriented activities there. In addition to trash and recycling bins, the alleys might also have containers for the secure delivery of packages.

EXISTING ALLEY STREET
- Area: 12,000 SF (20’ x 600’)
- Impervious Surface: 12,000 SF (100%)
- Pervious Surface: 0 SF (0%)

SHARED GREEN STREET
- Area: 12,000 SF (20’ x 600’)
- Impervious Surface: 5,400 SF (45%)
- Pervious Surface: 6,600 SF (55%)
ALLEY STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 30,576 CF
- Reserve: 0 CF
- Difference: -30,576 CF
- Runoff is captured off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 12,000 SF (100%)
- Cost: $178,025.40

PROGRAMS
Existing Alley Street
Alley Surface Parking
Residential Driveway
Street Boundary
ALLEY STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LBS/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 36,576 CF
- Reserve: 0 CF
- Difference: -36,576 CF
- Runoff is captured off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 12,000 SF (100%)
- Cost: $178,025.40

PROGRAMS
Existing Alley Street
Alley Surface Parking
Residential Driveway
Single Family Residential
Detached Garage
Street Boundary
SHARED GREEN STREET
ALLEY STREET (FUTURE)

PLANTING
- Area: 2,522 SF
- Trees: 12 (20'-0" OC)
- Carbon Sequestration: 7,128 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 36,576 CF
- Reserve: 13,200 CF
- Difference: -17,375 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 57% of the runoff
- Vegetative swale and Bioretention can accommodate for additional runoff

HEAT ISLAND INDEX
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading

MATERIAL COST
(Material cost does not include labor)
- Impervious: 5,400 SF (45%)
- Pervious: 6,600 SF (55%)
- Cost: $238,258.72
- Cost increased by $60,233.32 (134%); Although the cost increased significantly, the Alley Street becomes more inviting, active, and livable

PROGRAMS
Linear Park/ Neighborhood Plaza
Autonomous Vehicle Tracks
Shared Communal Space/ Court Yard
Vegetative Swale and Infiltration Trench
Shared Pedestrian/ Bicycle Sidewalk
Bioretention and Wetland
- Street Boundary
**SHARED GREEN STREET**

**ALLEY STREET (FUTURE)**

- **PLANTING**
  - Area: 2,522 SF
  - Trees: 12 (20'-0" OC)
  - Carbon Sequestration: 7,128 LB/YR

- **STORMWATER**
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 36,576 CF
  - Reserve: 13,200 CF
  - Difference: -23,376 CF
  - Runoff is captured on site
  - Permeable Pavement and Infiltration Trenches can accommodate for 57% of the runoff
  - Vegetative swale and Bioretention can accommodate for additional runoff

- **HEAT ISLAND INDEX**
  - Heat is reflected
  - Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading

- **MATERIAL COST**
  (Material cost does not include labor)
  - Impervious: 5,400 SF (45%)
  - Pervious: 6,600 SF (55%)
  - Cost: $238,258.72
  - Cost increased by $50,233.32 (134%); Although the cost increased significantly, the Alley Street becomes more inviting, active, and livable

- **PROGRAMS**
  - Autonomous Vehicle Tracks
  - Shared Communal Spaces/ Court Yard
  - Vegetative Swale and Infiltration Trench Receiving and Delivery Post
  - Shared Pedestrian/ Bicycle Sidewalk
  - Bioretention and Wetland
  - Single Family Residential
  - Adaptive Reuse Structure

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**Shared Green Street (Varies)**

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LOCAL STREET

EXISTING
Local streets constitute the largest number of roadways in cities and suburbs and they are typically underutilized in terms of the traffic they handle and the parking they provide. Except in the densest neighborhoods, local streets often have few cars and ample parking space, and they show the excess capacity that exists in our transportation infrastructure, especially when serving properties that also have rear alleys. The excessive width of many local streets taxes the budgets of municipalities that must maintain and repave them, and it also reduces the amount of space in the public right-of-way for other uses.

SHARED GREEN STREET (FUTURE)
When AV’s become the dominant mode of vehicular transportation, local streets will change in several ways. These streets will only need one pair of tracks in each direction, with planting or pervious pavers in lanes that need only be eight-feet wide. This will allow for space to drop off and pick up people and packages, once on-street parking disappears. Dedicated bike lanes can also be installed in the space formerly occupied by parked cars. The narrowing of the right-of-way devoted to vehicles will provide more space for pedestrians. Some cities may also decide to reduce the amount of infrastructure they have to maintain by ceding some local streets to the adjacent property owners, who can use the right-of-way for non-transportation uses like community gardens, wetlands, and play space.
LOCAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 34,652.8 CF
- Reserve: 0 CF
- Difference: -34,652.8 CF
- Runoff is captured on site; redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 24,000 SF (100%)
- Cost: $1,030,039.92

PROGRAMS
- Existing Local Street
- Pedestrian Sidewalk
- Local Residential Street Parking
- Street Boundary
LOCAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
- Stormwater calculations are based on a 10-year rainfall event in Minnesota
- Volume: 34,652.8 CF
- Reserve: 0 CF
- Difference: -34,652.8 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
- Material cost does not include labor
- Impervious: 24,000 SF (100%)
  - Cost: $1,030,039.92

PROGRAMS
- Existing Local Street
- Pedestrian Sidewalk
- Local/ Residential Street Parking
- Single Family Residential Detached Garage
- Street Boundary
SHARED GREEN STREET
LOCAL STREET (FUTURE)

- PLANTING
  - Area: 15,947 SF
  - Tree: 44
  - Carbon Sequestration: 28,058 LB/YR

- STORMWATER
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 34,652.8 CF
  - Reserve: 41,360 CF
  - Difference: +6,707.48 CF
  - Runoff is captured on site
  - Permeable Pavement and Infiltration Trenches can accommodate for 100% of the runoff
  - Vegetative swale and Bioretention can accommodate for additional runoff
  - Stormwater Drainage System can be capped and/or decommissioned based on calculations

- HEAT ISLAND INDEX
  - Heat is reflected
  - Temperature is reduced by 15 degrees; Trees and Planting Areas provide additional cooling and shading

- MATERIAL COST
  (Material cost does not include labor)
  - Impervious: 8,053 SF (33%)
  - Pervious: 15,947 SF (67%)
  - Cost: $425,642.29
  - Cost decreased by $604,397.63 (41%)

- PROGRAMS
  Pedestrian Crosswalk
  Autonomous Vehicle Tracks
  Dedicated Bicycle/Small Vehicle Lane
  Dedicated Pedestrian Sidewalk
  Pick-up/Drop-off Zone
  Shared Communal Space/ Front Yard
  Vegetative Swale and Infiltration Trench
  Bioretention and Wetland

- Street Boundary
**SHARED GREEN STREET**

**LOCAL STREET (FUTURE)**

- **PLANTING**
  - Area: 15,947 SF
  - Tree: 44
  - Carbon Sequestration: 28,058 LB/YR

- **STORMWATER**
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 34,652.8 CF
  - Reserve: 43,365 CF
  - Difference: +6,707.48 CF
  - Runoff is captured on site
  - Permeable Pavement and Infiltration Trenches can accommodate for 100% of the runoff
  - Vegetative swale and Bioretention can accommodate for additional runoff
  - Stormwater Drainage System can be capped and/or decommissioned based on calculations

- **HEAT ISLAND INDEX**
  - Heat is reflected
  - Temperature is reduced by 15 degrees; Trees and Planting Areas provide additional cooling and shading

- **MATERIAL COST**
  (Material cost does not include labor)
  - Impervious: 8,053 SF (33%)
  - Pervious: 15,947 SF (67%)
  - Cost: $425,642.29
  - Cost decreased by $604,397.63 (41%)

- **PROGRAMS**
  - Smart Street Technology
  - Autonomous Vehicle Tracks
  - Dedicated Bicycle/ Small Vehicle Lane
  - Dedicated Pedestrian Sidewalk
  - Pick-up/ Drop-off Zone
  - Shared Communal Space/ Front Yard
  - Vegetative Swale and Infiltration Trench
  - Bioretention and Wetland
  - Single Family Residential
  - Detached Garage
  - Street Boundary
COLLECTOR STREET

EXISTING
Collector streets often have multiple passing lanes and parking lanes on one or both sides of the street, taking up most of the right-of-way and making it difficult for other modes of transportation - bikes, scooters, pedestrians - to use or cross the street. Because collector streets typically have commercial uses along them, most have extensive amounts of parking in lots or ramps on adjacent private property. The amount of pavement along collector streets greatly increases the heat island effect, and the amount of impervious surface increases runoff and water pollution.

SHARED GREEN STREET (FUTURE)
AV’s will substantially alter collector streets. The number of lanes will decrease, since AV’s can operate safely when much closer together than driven vehicles, and so they can move the same number of people in much less space. As part of mobility services, AV’s also will not need parking, since they will drop off passengers and move on to their next call, much as taxis and ride sharing vehicles do now. That allows former on-street parking spaces to be used for dropping off and picking up passengers or for other, pedestrian-oriented uses. The additional space in the right-of-way also allows for dedicated bike lanes, a denser tree canopy, rain gardens, and other sidewalk-oriented activities in place of parked vehicles. Surface parking lots can also be used for urban agriculture, solar and wind farms, or new infill development, whose green roofs can further decrease heat islands and increase animal habitat.
COLLECTOR STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 0 CF
- Difference: -56,738.5 CF
- Runoff is captured on site and redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 36,000 SF (100%)
- Cost: $1,208,065.32

PROGRAMS
- Existing Collector Street
- Pedestrian Sidewalk
- Collector Street Parking
- Surface Parking Lot
- Street Boundary
COLLECTOR STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 0 CF
- Difference: -56,738.5 CF
- Runoff is captured on site and redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 36,000 SF (100%)
- Cost: $1,208,065.32

PROGRAMS
Existing Collector Street
Pedestrian Sidewalk
Collector/ Street Parking
Surface Parking Lot
Street Boundary
SHARED GREEN STREET
COLLECTOR STREET (FUTURE)

**PLANTING**
- Area: 26,326 SF
- Tree: 35
- Carbon Sequestration: 22,420 LB/YR

**STORMWATER**
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 56,738.5 CF
- Reserve: 47,960.3 CF
- Difference: -8,778.22 CF
- Runoff is captured on site
- Permeable pavement and infiltration trenches can accommodate for 84% of the runoff, Green roof helps with rainfall
- Vegetative swale and bioretention can accommodate for the remaining runoff

**HEAT ISLAND INDEX**
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and planting areas provide additional cooling and shading
- Sun’s rays can be collected, stored, and use

**MATERIAL COST**
(Material cost does not include labor)
- Impervious: 9,674 SF (27%)
- Pervious: 26,326 SF (73%)
- Cost: $697,764.84
- Cost decreased by $510,300.48 (58%)
- Saving can be used to fund neighborhood’s projects and initiatives to create a more resilient community

**PROGRAMS**
- Pedestrian Crosswalk
- Autonomous Vehicle Tracks
- Dedicated Bicycle/Small Vehicle Lane
- Dedicated Pedestrian Sidewalk
- Pick-up/Drop-off Zone
- Shared Communal Space
- Vegetative Swale and Infiltration Trench
- Bioretention and Wetland
- Agricultural Farm
- Wind and Solar Farm
- Smart Street Technology
- Street Boundary
**SHARED GREEN STREET**
**COLLECTOR STREET (FUTURE)**

**PLANTING**
- Area: 26,326 SF
- Tree: 35
- Carbon Sequestration: 22,420 LB/yr

**STORMWATER**
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 36,738.5 CF
- Reserve: 47,963.2 CF
- Difference: -8,722.2 CF
- Runoff is captured on site
- Permeable Pavement and Infiltration Trenches can accommodate for 84% of the runoff; Green Roof helps with rainfall
- Vegetative swale and Bioretention can accommodate for the remaining runoff

**HEAT ISLAND INDEX**
- Heat is reflected
- Temperature is reduced by 8 degrees; Trees and Planting Areas provide additional cooling and shading
- Sun’s ray can be collected, stored, and use

**MATERIAL COST**
(Material cost does not include labor)
- Impervious: 9,674 SF (27%)
- Pervious: 26,326 SF (73%)
- Cost: $697,744.84
- Cost decreased by $510,300.48 (58%)
- Saving can be used to fund neighborhood’s projects and initiatives to create a more resilient community

**PROGRAMS**
- Autonomous Vehicle Tracks
- Dedicated Bicycle/ Small Vehicle Lane
- Dedicated Pedestrian Sidewalk
- Pickup/ Drop-off Zone
- Shared Communal Space
- Vegetative Swale and Infiltration Trench
- Bioretention and Wetland
- Agricultural Farm
- Wind and Solar Farm
- Smart Street Technology

Street Boundary
ARTERIAL STREET

EXISTING
Arterial streets gather the traffic from local and collector streets and concentrate vehicles in what are often very wide roadways, with more than one travel lane in each direction and often with turn lanes and on-street parking as well. As arterial streets move through downtowns or dense commercial corridors, surface parking and structured parking ramps also abound. Although street trees often exist along arterial streets, the heat radiating off of the impervious surfaces – as well as the heat from building air-conditioning units – makes these streets among the warmest in any municipality.

SHARED GREEN STREET (FUTURE)
The changes that AVs and mobility services will bring to arterial streets will be among the most striking. The number of lanes will decrease significantly, given the efficiency with which AVs move large numbers of people, and turn lanes will largely disappear, since AVs sense the movement of everything around them and respond without the need of signals. Indeed, traffic signals will only be needed to control pedestrian crossings, which can occur at various points along a block, not just at intersections. In a mobility service future, parking ramps will no longer be needed for the storage of vehicles and will likely get converted to uses, such as housing or hydroponic food production. Meanwhile, surface parking lots will offer space for infill development, increasing density and while improving the efficiency of mobility services and growing a city’s tax base, which will, in turn, help pay for the AV infrastructure that makes all of this possible.
ARTERIAL STREET

PLANTING
- Area: 0 SF
- Tree: 0
- Carbon Sequestration: 0 LB/ YR

STORMWATER
(Stormwater calculations are based on a 10-year rainfall event in Minnesota)
- Volume: 77,160.3 CF
- Reserve: 0 CF
- Difference: 77,160.3 CF
- Runoff is captured on site; Redirected to the Stormwater Drainage System below and discharged and/or stored off site

HEAT ISLAND INDEX
- Heat is absorbed
- Temperature increased

MATERIAL COST
(Material cost does not include labor)
- Impervious: 46,000 SF (100%)
- Cost: $1,386,090.72

PROGRAMS
Existing Arterial Street
Pedestrian Sidewalk
Arterial Street Parking
Dedicated Bicycle Lane
Surface Parking Lot
Parking Ramp

-- Street Boundary
**ARTERIAL STREET**

- **PLANTING**
  - Area: 0 SF
  - Tree: 0
  - Carbon Sequestration: 0 LB/ YR

- **STORMWATER**
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 77,160.3 CF
  - Reserve: 0 CF
  - Runoff is captured on site; redirected to the Stormwater Drainage System below and discharged and/or stored off site

- **HEAT ISLAND INDEX**
  - Heat is absorbed
  - Temperature increased

- **MATERIAL COST**
  (Material cost does not include labor)
  - Impervious: 48,000 SF (100%)
  - Cost: $1,386,090.72

- **PROGRAMS**
  - Existing Arterial Street
  - Pedestrian Sidewalk
  - Arterial/Street Parking
  - Dedicated Bicycle Lane
  - Surface Parking Lot
  - Parking Ramp
  - Street Boundary

---

Arterial Street (80' - 0")

Right-Of-Way (100' - 0")
**SHARED GREEN STREET**

**ARTERIAL STREET (FUTURE)**

- **PLANTING**
  - Area: 34,945 SF
  - Tree: 50
  - Carbon Sequestration: 32,788.8 LB

- **STORMWATER**
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 77,160.3 CF
  - Reserve: 69,960.3 CF
  - Difference: -7,200 CF
  - Runoff is captured on site
  - Permeable Pavement and Infiltration Trenches can accommodate for 90% of the runoff, Green Roof helps with runoff
  - Vegetative swale and Bioretention can accommodate for the remaining runoff

- **HEAT ISLAND INDEX**
  - Heat is reflected
  - Temperature is reduced by 9 degrees; Trees and Planting Areas provide additional cooling and shading
  - Sun’s ray can be collected, stored, and use

- **MATERIAL COST**
  (Material cost does not include labor)
  - Impervious: 13,055 SF (27%)
  - Pervious: 34,945 SF (73%)
  - Cost: $911,286.67
  - Cost decreased by $474,804.05
  - Saving can be used to fund neighborhood’s projects and initiatives to create a more resilient community

**PROGRAMS**

- Pedestrian Block Crossing
- Autonomous Vehicle Tracks
- Dedicated Bicycle/ Small Vehicle Lane
- Dedicated Pedestrian Sidewalk
- Pick-up/ Drop-off Zone
- Shared Communal Space
- Vegetative Swale and Infiltration Trench
- Bioretention and Wetland
- Agricultural Farm
- Wind and Solar Farm
- Smart Street Technology
- Street Boundary
**Shared Green Street**

**Arterial Street (Future)**

- **Planting**
  - Area: 34,945 SF
  - Tree: 50
  - Carbon Sequestration: 32,788.8 LB

- **Stormwater**
  (Stormwater calculations are based on a 10-year rainfall event in Minnesota)
  - Volume: 77,160.3 CF
  - Reserve: 69,960.3 CF
  - Difference: 7,200 CF
  - Runoff is captured on site
  - Permeable Pavement and Infiltration Trenches can accommodate for 90% of the runoff; Green Roof helps with runoff.
  - Vegetative swale and Bioretention can accommodate for the remaining runoff.

- **Heat Island Index**
  - Heat is reflected
  - Temperature is reduced by 9 degrees; Trees and Planting Areas provide additional cooling and shading
  - Sun's ray can be collected, stored, and use

- **Material Cost**
  (Material cost does not include labor)
  - Impervious: 13,055 SF (27%)
  - Pervious: 34,945 SF (73%)
  - Cost: $911,286.67
  - Cost decreased by $474,804.05 (66%)
  - Saving can be used to fund neighborhood's projects and initiatives to create a more resilient community.

- **Programs**
  - Adaptive Reuse Structure
  - Autonomous Vehicle Tracks
  - Dedicated Bicycle/ Small Vehicle Lane
  - Dedicated Pedestrian Sidewalk
  - Pickup/ Drop-off Zone
  - Shared Communal Space
  - Vegetative Swale and Infiltration Trench
  - Bioretention and Wetland
  - Agricultural Farm
  - Wind and Solar Farm
  - Smart Street Technology
  - Street Boundary
Arterial Street

Right-of-Way
### ALLEY CALCULATIONS

**Alley Surfaces Calc**

<table>
<thead>
<tr>
<th>Block Type</th>
<th>% Impervious</th>
<th>Block Width (ft)</th>
<th>Block Length (ft)</th>
<th>Block Area (sq ft)</th>
<th>Block Area (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>45.00%</td>
<td>50.00</td>
<td>150.00</td>
<td>7500.00</td>
<td>0.17</td>
</tr>
<tr>
<td>Residential</td>
<td>45.00%</td>
<td>75.00</td>
<td>105.00</td>
<td>7,875.00</td>
<td>0.18</td>
</tr>
<tr>
<td>Residential</td>
<td>45.00%</td>
<td>10.00</td>
<td>120.00</td>
<td>1200.00</td>
<td>0.03</td>
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</tbody>
</table>

**Cost Calc**

<table>
<thead>
<tr>
<th>Cost</th>
<th>2000 per ft (220 RO)</th>
<th>Typical value</th>
<th>Typical block = 10,000 ft</th>
<th>Cost Block = 10,000 ft Block Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paving Concrete 6&quot; slab</td>
<td>$ 33.00</td>
<td>0</td>
<td>$ 330.00</td>
<td>$ 33,000.00</td>
</tr>
<tr>
<td>Paving asphalt</td>
<td>$ 7.00</td>
<td>1,000.00</td>
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<td>$ 70,000.00</td>
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<tr>
<td>3.00</td>
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<td>$ 3,000.00</td>
<td>$ 30,000.00</td>
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<td>3.00</td>
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</tr>
<tr>
<td>3.00</td>
<td>0</td>
<td>$ 3,000.00</td>
<td>$ 30,000.00</td>
<td></td>
</tr>
<tr>
<td>Storm drain 18&quot; Concrete</td>
<td>$ 27,000.00</td>
<td>$ 270,000.00</td>
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<tr>
<td>Landscaping</td>
<td>$ 30.00</td>
<td>0</td>
<td>$ 300.00</td>
<td>$ 3,000.00</td>
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<tr>
<td>Sidewalk &amp; Lightening Wash Cost</td>
<td>$ 1,030,000.92</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### LOCAL CALCULATIONS

**Surface Calc**

<table>
<thead>
<tr>
<th>Total Area</th>
<th>Impervious Area</th>
<th>Rainfall (inches/24hr)</th>
<th>Stormwater Calc</th>
<th>Storm Drainage Calc</th>
<th>Stormwater Calc</th>
<th>Cost Calc</th>
<th>Cost Calc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000.00</td>
<td>45.00%</td>
<td>0.455</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
</tr>
</tbody>
</table>

**Side-Walk and Lighting Wash Cost**

<table>
<thead>
<tr>
<th>Total Area</th>
<th>Surface Type</th>
<th>Impervious Area</th>
<th>Stormwater</th>
<th>Storm Drainage</th>
<th>Stormwater</th>
<th>Cost Calc</th>
<th>Cost Calc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000.00</td>
<td>45.00%</td>
<td>0.455</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
</tr>
</tbody>
</table>

**Local Heat Effect (estimate)**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Impervious Area</th>
<th>Stormwater</th>
<th>Storm Drainage</th>
<th>Stormwater</th>
<th>Cost Calc</th>
<th>Cost Calc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000.00</td>
<td>45.00%</td>
<td>0.455</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
<td>76440</td>
</tr>
</tbody>
</table>

**Gutter Relief Lighting Wash Cost**

<table>
<thead>
<tr>
<th>Area (sq ft)</th>
<th>Wash Cost</th>
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</thead>
<tbody>
<tr>
<td>1,000.00</td>
<td>$ 1,030,000.92</td>
</tr>
</tbody>
</table>

**Urban Heat Effect**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Impervious Area</th>
<th>Stormwater</th>
<th>Storm Drainage</th>
<th>Stormwater</th>
<th>Cost Calc</th>
<th>Cost Calc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000.00</td>
<td>45.00%</td>
<td>0.455</td>
<td>10.5</td>
<td>76440</td>
<td>10.5</td>
<td>76440</td>
</tr>
</tbody>
</table>

**Annual Temperature Reduction**

Annual temperature reduction = $ 7,200,000 (140°F - 10°F)
### COLLECTOR CALCULATIONS

**Surface Calc:**

<table>
<thead>
<tr>
<th>Total Area</th>
<th>Impervious Area</th>
<th>Plant Area (Front)</th>
<th>Plant Area (Back)</th>
<th>Stormwater Area</th>
<th>Stormwater Impervious Area</th>
<th>Stormwater Plant Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Urban Heat (optional):**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Heat Index Reduction</th>
<th>Air Temperature Reduction</th>
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</thead>
<tbody>
<tr>
<td>Urban heat</td>
<td>0</td>
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</tr>
</tbody>
</table>

### ARTERIAL CALCULATIONS

**Surface Calc:**

<table>
<thead>
<tr>
<th>Total Area</th>
<th>Impervious Area</th>
<th>Plant Area (Front)</th>
<th>Plant Area (Back)</th>
<th>Stormwater Area</th>
<th>Stormwater Impervious Area</th>
<th>Stormwater Plant Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

**Urban Heat (optional):**

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Heat Index Reduction</th>
<th>Air Temperature Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban heat</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>
PROJECT DEVELOPMENT
PROJECT DEVELOPMENT
PROJECT DEVELOPMENT
PROJECT DEVELOPMENT

Existing (Ty 2018)

Proposed (Ty 2050)
PROJECT DEVELOPMENT

Existing (Ty 2018)

Proposed (Ty 2050)
PROJECT DEVELOPMENT

Existing (Ty 2018)

Proposed (Ty 2030)
PROJECT DEVELOPMENT

Existing (Ty 2016)

Proposed (Ty 2050)
PROJECT DEVELOPMENT

Existing (Tyr 2016)

Proposed (Tyr 2050)