TEAM 12

ROADS TO THE FUTURE

Project Preliminary Feasibility Study

2/6/2007

Justin Pipe  Marcus Byker
Cliff Matthews  Nate Maack  Jordan DeRooy
EXECUTIVE SUMMARY

Calvin College has multiple traffic related problems on the Calvin College campus. Some of these include insufficient parking for vehicles and bicycles, problematic intersections and poor entrances and exits from of the East Beltline. The goal of project is to try to alleviate these problems. The Team 12: Roads to the Future project consists of four major components:

- Parking Structure
- Intersection redesign
- East Beltline Entrances and Exits
- Bicycle Barns

These components can be broken down into two major goals:

- To provide sufficient parking for vehicles and bicycles
- To provide a safe and transparent road system

The proposed solution to the insufficient number of parking spaces on campus for vehicles is to design a parking structure. The parking structure will be located in the Kelsbeek-Huizinga Parking Lot which is located on the northern end of the Calvin College Campus. The parking structure will have a parking surface area of roughly 396,000 square feet and have a capacity of 1500 vehicles. The cost per parking space in this parking structure is roughly $7,700.

The design of the parking structure uses Pre-Cast concrete as the material of choice. This was chosen over a post-tension concrete or steel frame with post-tension slab concrete structure.

The parking structure is justifiable for multiple reasons. Calvin College just approved the construction of the new Spoelhof Fieldhouse Complex. This new complex will have an increased seating capacity of 800 people and will also reduce the existing parking which is currently used for events in the Fieldhouse. Also, Calvin College is considering making it mandatory for students to live on campus three years living rather than two. This increases the parking demand in that there are more vehicles that are remaining on campus 24 hours a day. Calvin College is expected to continue to grow and as it becomes more and more common for students to have vehicles, the number of spaces that will be needed on campus will increase. Finally, with the current quantity of parking spaces on campus, many of the parking lots are operating at or above capacity.

Currently there are not sufficient bicycle racks on campus for the number of bicycles which are ridden to campus by on and off campus students. This is both a discouragement to students to ride their bicycles and is a security problem for the bicycles parked because many of them are not securely locked to a bicycle rack. This shortage encourages students to drive their cars rather than ride their bikes. Another deterrent of riding bikes to campus is the chance of rain and snow.

By installing “Bicycle Barns” on campus, this would alleviate all of these inhibitions to using a bicycle on campus. They will provide increased volume capacity for parking bicycles and a covered area to protect bicycles from the elements.

The proposed design for the “Bicycle Barns” includes a more efficient bicycle rack and a curved roof mounted off of columns on each end of the bicycle rack. These columns are set in concrete footings covered in “Calvin Brick” to match the aesthetics of the Calvin College campus.
The existing entrances and exits from the East Beltline are problematic and need to be updated. One of the problematic entrance/exits is directly west of the Knollerest Dining Hall. This intersection is problematic because of the very short queue length coming off of the East Beltline which is a safety hazard. It is also not aesthetically appealing and is not designed to handle the dominant direction of traffic flow. The proposed modification will move the Calvin Loop East, provide more of a free-flow route for the dominant traffic flow and increase the available space for the queue on the exit from the East Beltline.

The other problematic entrance and exit off of the East Beltline is immediately North of the Calvin Seminary. This intersection is problematic in that the entrance to the East Beltline does not line up with the existing intersection. This causes uncertainty about right of way for vehicles exiting the Calvin College campus which creates a safety hazard. The proposed modification moves the Calvin intersection to line up with the existing intersection on the East Beltline. This way a traffic light could be added for the Calvin entrance onto the East Beltline thus making the intersection safer and more convenient. It will also allow for vehicles to exit the East Beltline at this intersection while heading north which is not currently possible.

The last component of the project is to redesign problematic geometries of current intersections on the Calvin College campus, specific modifications are being proposed for three heavily used intersections:

- Burton St. Entrance to campus
- Lake Dr. Entrance to campus
- East Beltline Underpass Triangle

The suggested modification for the Burton St. Entrance intersection is to remodel the intersection with a roundabout. This would alleviate most points of conflict between vehicles as well as provide a transparent flow to traffic through the intersection. It will provide safer paths for pedestrians who are crossing the intersection by adding refuge islands. There are also benefits from the aesthetic improvements that could be added on the center of the roundabout, such as landscaping, signs, or statues.

The Lake Dr. Entrance will be modified to a standard “T” intersection. This will allow free flow of traffic around the campus loop and will also decrease the angle needed to turn for vehicles entering the campus from Lake Drive and going to the Fieldhouse, which is the predominant traffic movement. This will increase the safety of the intersection as well as encourage vehicles to take the northerly route around the campus loop.

The current East Beltline Underpass Triangle has three free flow movements and three stop signs, and is an unusual intersection which can confuse visitors. The proposed modification would give the three highest traffic volume movements the free flow movements and add exclusive turn lanes for other movements. This would increase safety, efficiency, and the transparency of the intersection. Pedestrians would also only have to cross the road once instead of twice as with the existing intersection.
Table of Contents

A. INTRODUCTION ............................................................................... 12
   1.1 Project Goal/Objective........................................................................ 12
   1.2 Client.................................................................................................. 12
   1.3 Team Members and Project Roles.......................................................... 13
      1.3.1 Marcus Byker.............................................................................. 13
      1.3.2 Nathan Maack............................................................................. 13
      1.3.3 Jordan DeRooy........................................................................... 13
      1.3.4 Justin Pipe.................................................................................. 13
      1.3.5 Cliff Matthews........................................................................... 13
   1.4 Other Contributors............................................................................... 13
      1.4.1 Phil Beezhold.............................................................................. 13
      1.4.2 David Wunder............................................................................ 13
      1.4.3 Frank Gorman............................................................................ 13
   1.5 Industrial Consultant........................................................................... 13
   1.6 Preliminary Project Feasibility Study Outline......................................... 13

B. PARKING STRUCTURE INTRODUCTION................................. 15
   1 OBJECTIVE ................................................................................. 15
      1.1 Problem.......................................................................................... 15
      1.1.1 Existing Conditions....................................................................... 15
      1.1.2 Parking Lot Information................................................................. 16
         1.1.2.1 Knollcrest East Lower Parking Lot (Small) (1).......................... 16
         1.1.2.2 Knollcrest East Lower Parking Lot (Large) (2)....................... 17
         1.1.2.3 Knollcrest East Upper Parking (3).......................................... 17
         1.1.2.4 East Beltline Parking Lot (4)................................................. 17
         1.1.2.5 Kelsbeek-Huizinga Parking Lot (5)........................................ 17
         1.1.2.6 Fine Arts Center Parking Lot (6).......................................... 17
         1.1.2.7 Science Building/Spoelhof Parking Lot (7)............................ 17
         1.1.2.8 Field House Parking Lot (8)................................................. 18
         1.1.2.9 DeVos/Prince Conference Center Parking Lot (9)............... 18
         1.1.2.10 Seminary Parking Lot (10).................................................. 18
      1.1.3 Future Conditions......................................................................... 18
         1.1.3.1 Spoelhof Fieldhouse Complex............................................. 18
         1.1.3.2 Three Year Policy.................................................................. 19
         1.1.3.3 Growth................................................................................ 19
      1.2 Goal.............................................................................................. 20
      1.3 Justification.................................................................................... 20
         1.3.1 Environmental Advantages....................................................... 20
         1.3.2 Visitor Advantages.................................................................... 20
         1.3.3 Parking Consolidation Advantages.......................................... 20
      1.4 Design Norms................................................................................ 20
         1.4.1 Stewardship............................................................................. 20
2 DESIGN OPTIONS ................................................................. 21

2.1 Location Decision Matrix Criteria ...................................................... 21
  2.1.1 East Beltline Parking Lot ................................................................. 21
  2.1.2 Seminary Parking Lot ................................................................. 21
  2.1.3 Field House Parking Lot .............................................................. 23
  2.1.4 Kalsbeek-Huizinga Parking Lot .................................................... 23

2.2 Material Selection ........................................................................... 25
  2.2.1 Decision Matrix Criteria ............................................................. 26
    2.2.1.1 Quality Control ........................................................................ 26
    2.2.1.2 Surfacing .................................................................................. 26
    2.2.1.3 Construction Weather Limitations ........................................ 26
    2.2.1.4 Curing ..................................................................................... 26
    2.2.1.5 Erection Speed ......................................................................... 26
    2.2.1.6 Fire Protection ......................................................................... 26
    2.2.1.7 Corrosion Resistance .............................................................. 26
    2.2.1.8 Longevity ............................................................................... 27
    2.2.1.9 Slab Depth ............................................................................ 27
    2.2.1.10 Load Deflection .................................................................... 27
    2.2.1.11 Joints .................................................................................. 27
    2.2.1.12 Cost .................................................................................... 27
  2.2.2 Pre-Cast Concrete Elements ......................................................... 28
    2.2.2.1 Double Tee ............................................................................ 28
    2.2.2.2 Beam/Spandrel ........................................................................ 30
    2.2.2.3 Spandrel Supporting Column ................................................ 30
    2.2.2.4 Double Column (Supporting Double-Tee) ......................... 33

2.3 Layout ............................................................................................ 33
  2.3.1 Choice Criteria ........................................................................... 35
    2.3.1.1 No Helical Ramps .................................................................. 35
    2.3.1.2 Road View Aesthetics ............................................................. 35
    2.3.1.3 Efficient Use of Structure Space ......................................... 35
    2.3.1.4 Functionality ........................................................................ 35
    2.3.1.5 Cost ..................................................................................... 35
    2.3.1.6 Efficient Use of Land ........................................................... 35
  2.3.2 Decision Matrix .......................................................................... 36
  2.3.3 Hybrid Layout ............................................................................. 36

3 DESIGN CONSIDERATIONS ......................................................... 38

3.1 Zoning ........................................................................................... 38
3.2 Soil ................................................................................................. 38
3.3 Foundations .................................................................................... 38
3.4 Stairway / Elevator .......................................................................... 38
3.5 Lane Separation Barriers ................................................................. 39
3.6 Drainage ........................................................................................ 39
3.7 Lighting .......................................................................................... 39
3.8 Architectural Additions......................................................................................... 39
3.9 Sidewalks............................................................................................................. 39
3.10 Handicap Accommodation.................................................................................. 39

4 PROJECT COST ........................................................................................................... 39
4.1 Source of Information............................................................................................ 39
4.2 Cost Information..................................................................................................... 39
4.3 Total Cost................................................................................................................ 40

5 PROJECT SCHEDULE ................................................................................................ 40

6 SUMMARY ................................................................................................................... 40

C. BIKE STRUCTURE INTRODUCTION ..................................................................... 42

1 OBJECTIVE ................................................................................................................ 42
1.1 Problem................................................................................................................... 42
1.1.1 Existing Conditions............................................................................................. 42
1.1.2 Future Conditions.............................................................................................. 45
1.2 Goal......................................................................................................................... 45
1.3 Justification............................................................................................................. 45
1.3.1 Environmental Advantages............................................................................... 45
1.3.2 Visitor Advantages.............................................................................................. 45
1.4 Design Norms........................................................................................................ 45
1.4.1 Stewardship........................................................................................................ 45
1.4.2 Integrity............................................................................................................... 46
1.4.3 Transparency...................................................................................................... 46

2 DESIGN OPTION ....................................................................................................... 46
2.1 Location................................................................................................................... 46
2.2 Rack......................................................................................................................... 49
2.2.1 Decision Matrix Criteria..................................................................................... 50
  2.2.1.1 Space required............................................................................................... 50
  2.2.1.2 Usability......................................................................................................... 50
  2.2.1.3 Aesthetics..................................................................................................... 50
  2.2.1.4 Cost............................................................................................................... 50
  2.2.1.5 Storage Capability......................................................................................... 50
2.3 Structure................................................................................................................... 51
  2.3.1 Choice Criteria.................................................................................................. 53
  2.3.1.1 Space Required............................................................................................. 53
  2.3.1.2 Aesthetics.................................................................................................... 53
  2.3.1.3 Cost.............................................................................................................. 53
2.3.2 Decision Matrix.................................................................................................. 54

3 DESIGN CONSIDERATIONS ..................................................................................... 54
3.1 Soil......................................................................................................................... 54
3.2 Drainage................................................................................................................. 56
3.3 Lighting................................................................................................................... 56
3.4 Architectural.......................................................................................................... 56
3.5 Sidewalks.............................................................................................................. 56
4 PROJECT SCHEDULE ................................................... 56
5 SUMMARY........................................................................ 57
D. ENTRANCES AND EXITS INTRODUCTION .............. 58

1 OBJECTIVE ................................................................. 59
   1.1 Problem......................................................................................................................... 59
   1.1.1 Existing Conditions............................................................................................... 59
   1.1.2 Future Conditions ................................................................................................. 60
      1.1.2.1 Spoelhof Fieldhouse Complex ................................................................. 60
      1.1.2.2 Growth .............................................................................................................. 60
      1.1.2.3 New Commons Building ........................................................................... 60
   1.2 Goal............................................................................................................................... 60
   1.3 Justification................................................................................................................... 60
      1.3.1 Visitor Advantages................................................................................................ 60
      1.3.2 Safety Advantages ............................................................................................... 60
   1.4 Design Norms ............................................................................................................... 61
      1.4.1 Stewardship........................................................................................................... 61
      1.4.2 Integrity................................................................................................................. 61
      1.4.3 Transparency......................................................................................................... 61
      1.4.4 Cultural Appropriateness ...................................................................................... 61
      1.4.5 Humility ................................................................................................................ 61

2 DESIGN OPTIONS............................................................................. 61
   2.1 Seminary Entrance and Exit.......................................................................................... 61
      2.1.1 Right of Way Issues .............................................................................................. 62
      2.1.2 Free Flow Entrance ............................................................................................. 62
      2.1.3 Mall Style Entrance ............................................................................................. 63
   2.2 Knollcrest Entrance and Exit ........................................................................................ 63
      2.2.1 Traffic Study ......................................................................................................... 63
      2.2.2 Right of Way Issues ............................................................................................. 64
      2.2.3 Free Flow Entrance ............................................................................................. 64
      2.2.4 Mall Style Entrance ............................................................................................. 66

3 FINAL DESIGN ................................................................................. 66
   3.1 Seminary Entrance and Exit.......................................................................................... 66
      3.1.1 Decision Matrix ..................................................................................................... 66
         3.1.1.1 Aesthetics ........................................................................................................ 67
         3.1.1.2 Ease of Use ..................................................................................................... 67
         3.1.1.3 Efficiency ....................................................................................................... 67
         3.1.1.4 Safety ............................................................................................................. 67
      3.1.2 Final Design .......................................................................................................... 67
   3.2 Knollcrest Entrance and Exit ........................................................................................ 67
      3.2.1 Decision Matrix ..................................................................................................... 67
         3.2.1.1 Aesthetics ........................................................................................................ 68
         3.2.1.2 Ease of Use ..................................................................................................... 68
         3.2.1.3 Efficiency ....................................................................................................... 68
3.2.1.4 Safety ................................................................................................................ 68
3.2.2 Final Design ........................................................................................................... 68

4 PROJECT COST ......................................................................................................... 68
4.1 Source of Information .............................................................................................. 68
4.2 Cost Information ....................................................................................................... 68
4.3 Total Cost .................................................................................................................. 68

5 PROJECT SCHEDULE ............................................................................................... 69

6 SUMMARY .................................................................................................................... 69

E. INTERSECTION INTRODUCTION ................................................................................. 70

1 OBJECTIVE ................................................................................................................. 70
1.1 Problem ...................................................................................................................... 70
1.1.1 Existing Conditions and Utilities .......................................................................... 70
1.1.1.1 Burton St. Intersection ...................................................................................... 70
1.1.1.2 East Beltline Underpass ................................................................................... 71
1.1.1.3 Lake Drive Intersection ................................................................................... 71
1.1.2 Future Conditions .................................................................................................. 72
1.1.2.1 Knight Way Closing ....................................................................................... 72
1.1.2.2 Spoelhof Fieldhouse Complex ...................................................................... 72
1.1.2.3 Overall Growth .............................................................................................. 72
1.2 Goal ............................................................................................................................. 72
1.3 Justification ............................................................................................................... 73
1.3.1 Safety ...................................................................................................................... 73
1.3.1.1 Burton St. Intersection ..................................................................................... 73
1.3.1.2 East Beltline Underpass ................................................................................... 73
1.3.1.3 Lake Dr. Intersection ...................................................................................... 73
1.3.2 Efficiency .............................................................................................................. 73
1.3.3 Aesthetics .............................................................................................................. 73
1.4 Design Norms ........................................................................................................... 74
1.4.1 Stewardship ........................................................................................................... 74
1.4.2 Integrity ................................................................................................................. 74
1.4.3 Transparency ........................................................................................................ 74

2 DESIGN OPTIONS ..................................................................................................... 74
2.1 Type of Intersection ................................................................................................ 74
2.1.1 Decision Matrix Alternatives .............................................................................. 74
2.1.1.1 Roundabout ................................................................................................... 74
2.1.1.2 Standard Intersection .................................................................................... 75
2.1.1.3 One Approach has Right-of-Way ................................................................... 75
2.1.1.4 Replace the Signage ...................................................................................... 75
2.1.1.5 No Action ....................................................................................................... 75
2.1.2 Choice Criteria ..................................................................................................... 75
2.1.2.1 Safety .............................................................................................................. 75
2.1.2.2 Uniformity ...................................................................................................... 75
2.1.2.3 Efficiency ...................................................................................................... 76
2.1.2.4 Cost ................................................................................................................... 76
2.1.2.5 Aesthetics........................................................................................................... 76

3 Final Design ................................................................................................................ 76
3.1 Burton St. .................................................................................................................... 76
3.2 East Beltline .............................................................................................................. 77
3.3 Lake Dr. ..................................................................................................................... 78

4 DESIGN CONSIDERATIONS ........................................................................ 79
4.1 Existing Layouts and Utilities ................................................................................... 79
4.2 Space ......................................................................................................................... 79
4.3 Drainage ..................................................................................................................... 79
4.4 Sidewalks ................................................................................................................... 79
4.5 Additional Lanes/Widening Road ............................................................................. 80
4.6 Design Vehicle ......................................................................................................... 80

5 PROJECT COST .......................................................................................... 80
5.1 Cost Information ....................................................................................................... 80
5.2 Total Cost ................................................................................................................... 80
5.2.1 Burton St. Intersection ........................................................................................ 80
5.2.2 East Beltline Underpass ....................................................................................... 80
5.2.3 Lake Dr. Intersection ............................................................................................ 81

6 PROJECT SCHEDULE ........................................................................... 81

7 SUMMARY ............................................................................................... 81

F. REFERENCES .......................................................................................... 82

Table of Figures
Figure 1: Image of Calvin College Campus ................................................................. 12
Figure 2: Parking Lot Layout Key .................................................................................. 16
Figure 3: Calvin College Enrollment .......................................................................... 19
Figure 4: East Beltline Parking Lot Utility Lines ......................................................... 21
Figure 5: Seminary Parking Lot Utility Lines ............................................................... 22
Figure 6: Field House Parking Lot Utility Lines ......................................................... 23
Figure 7: Kalsbeek-Huizinga Parking Lot ................................................................. 24
Figure 8: Parking Structure Proposed Location ......................................................... 25
Figure 9: Sample Pre-Cast Parking Structure Interior Photo .................................. 28
Figure 10: Double-Tee to Girder Joint ....................................................................... 29
Figure 11: Double-Tee to Double-Tee Joint ............................................................... 29
Figure 12: Pre-cast Concrete Spandrel Section ......................................................... 30
Figure 13: Double-Tee to Spandrel Joint ................................................................. 30
Figure 14: Pre-Cast Concrete Column Construction ............................................... 31
Figure 15: Beam to Column Joint Detail .................................................................... 32
Figure 16: Spandrel to Column Joint Detail ............................................................... 32
Figure 17: Hybrid Front Elevation ........................................................................... 36
Figure 18: Hybrid Bottom Floor Plan .......................................................... 37
Table of Tables

Table 1: Parking Lot Capacities.......................................................................................... 15
Table 2: Location Decision Matrix..................................................................................... 24
Table 3: Material Decision Matrix...................................................................................... 25
Table 4: Parking Structure Type Decision Matrix................................................................. 36
Table 6: Decision Matrix for Bicycle Structure................................................................. 54
Table 7: Soil Descriptions For Calvin College.................................................................... 56
Table 8: Seminary Layout Decision Matrix......................................................................... 67
Table 9: Knollcrest Layout Decision Matrix......................................................................... 67
Table 10: Seminary Cost Breakdown.................................................................................. 69
Table 11: Knollcrest Cost Breakdown................................................................................ 69
Table 12: Burton St. Intersection Decision Matrix.............................................................. 76
Table 13: East Beltline Underpass Decision Matrix............................................................ 77
Table 14: Lake Dr. Intersection Decision Matrix................................................................. 78
Table 15: Burton St. Intersection Cost Breakdown.............................................................. 80
Table 16: East Beltline Underpass Cost Breakdown............................................................ 81
Table 17: Lake Dr. Intersection Cost Breakdown.............................................................. 81
A. INTRODUCTION

1.1 Project Goal/Objective
The goal of our projects is to fix traffic related problems on the campus of Calvin College. These improvements are as follows:

- Add a parking garage on campus to alleviate existing parking shortages.
- Replace problematic intersections with modern roundabouts or more feasible layouts to improve traffic movement and safety.
- Install improved bicycle parking on campus to provide sufficient space for parking bicycles as well as protection from the elements.
- Modify layouts of East Beltline entrances and exits to the Calvin College campus to improve efficiency, safety and transparency.

For all of the designs that will be created, our focus will be on the benefit of the students, visitors, neighbors and faculty of Calvin, as well as being good stewards of God’s creation.

1.2 Client
Our client for this project is Calvin College. All of the components of the project involve modifications to the infrastructure of the Calvin College Campus. An aerial view of the campus can be seen in the figure 1.

Our contact with Calvin College is the director of the Calvin College Physical Plant, Phil Beezhold.

![Figure 1: Image of Calvin College Campus](image-url)
1.3 Team Members and Project Roles

1.3.1 Marcus Byker
- Parking Structure
- East Beltline Entrances and Exits

1.3.2 Nathan Maack
- East Beltline Entrances and Exits

1.3.3 Jordan DeRooy
- Bicycle Barns
- Media

1.3.4 Justin Pipe
- Campus Intersections

1.3.5 Cliff Matthews
- Parking Structure

1.4 Other Contributors

1.4.1 Phil Beezhold
Phil Beezhold is the director of the Physical Plant on the Calvin College Campus. He has provided Team 12 with advice as well as documentation resources for the project. Phil is Team 12’s main client.

1.4.2 David Wunder
David Wunder is the Calvin College professor who is responsible for the oversight of the Team 12 design project.

1.4.3 Frank Gorman
Frank Gorman is the Calvin College Campus Architect. Frank has provided us with recommendations on parking structure locations as well as preferred aesthetic for the designs in the project.

1.5 Industrial Consultant
Mike DeVries is an employee of URS and is Team 12’s industrial consultant. He has provided the team with advice on the management of the project as well as layouts of intersections, and entrances/exits. Mike has helped direct Team 12 in the elements of the project that need to be focused on and provided us with useful information from his experience.

1.6 Preliminary Project Feasibility Study Outline
Because of the multiple elements in the project, the Preliminary Project Feasibility Study (PPFS) has been broken down into four sub-projects. These are arranged in the following order in the report:
• Parking Structure
• Bicycle Barns
• East Beltline Entrances and Exits
• Intersections

The information and feasibility analysis which is relevant to each of these sub-projects will be included in each individual section.
B. PARKING STRUCTURE INTRODUCTION

Calvin College has an existing need for an increase in parking spaces. The goal of this project is to select the location and design of a parking structure for the Calvin College Campus which will meet the existing and future parking needs of the campus.

1 OBJECTIVE

1.1 Problem

1.1.1 Existing Conditions

Currently the Calvin College Campus has five parking lots used by campus residents and for parking lots used by Calvin’s commuting students. An additional parking lot is allotted for the Calvin Seminary Students. The DeVos Communications Building and the Prince Conference Center share one large parking lot. The capacities and percent use of these parking lots are shown below in the Table 1.

<table>
<thead>
<tr>
<th>Map Key</th>
<th>Parking Lot</th>
<th>Capacity</th>
<th>Peak Hour % of Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Knollcrest East Lower Parking Lot (Small)</td>
<td>15</td>
<td>100%</td>
</tr>
<tr>
<td>2</td>
<td>Knollcrest East Lower Parking Lot (Large)</td>
<td>195</td>
<td>84%</td>
</tr>
<tr>
<td>3</td>
<td>Knollcrest East Upper Parking Lot</td>
<td>137</td>
<td>97%</td>
</tr>
<tr>
<td>4</td>
<td>East Beltline Parking Lot</td>
<td>305</td>
<td>99%</td>
</tr>
<tr>
<td>5</td>
<td>Kalsbeek-Huizinga Parking Lot</td>
<td>524</td>
<td>83%</td>
</tr>
<tr>
<td>6</td>
<td>Fine Arts Center Parking Lot</td>
<td>333</td>
<td>98%</td>
</tr>
<tr>
<td>7</td>
<td>Science Building/Spoelhof Parking Lot</td>
<td>879</td>
<td>91%</td>
</tr>
<tr>
<td>8</td>
<td>Field House Parking Lot</td>
<td>176</td>
<td>98%</td>
</tr>
<tr>
<td>9</td>
<td>DeVos/Prince Conference Center Parking Lot</td>
<td>552</td>
<td>(January Series)</td>
</tr>
<tr>
<td>10</td>
<td>Seminary Parking Lot</td>
<td>147</td>
<td>+100%</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>3263</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parking Lot Capacities
Team 12 has performed a parking capacity study of these parking lots during the peak hour for each location. This parking study showed that both the resident and commuter parking lots frequently operate at 90% capacity. The East Beltline Parking Lot is operating at 99% capacity and overflows into the DeVos/Prince Conference Center Parking Lot on a regular basis. During peak class hours (Monday, Wednesday, and Friday at 11:30) most commuter parking lots (Fine Arts Center parking lot, Science Building/Spoelhof parking lot, Field House parking lot) they are filled to capacity and are overflowing into the DeVos/Prince Conference Center parking lot. During a Calvin vs. Hope game, the Calvin Loop Rd. between the Lake Dr. entrance and the Field House had 44 cars parked along side which is a no parking zone. Having these parking lots filled to capacity on a routine basis makes it very difficult for visitors to find parking spaces and it has a potential to cause students to be late to class on a routine basis. Also, the routine cycling of vehicle through the parking lots looking for spaces is a safety hazard for students waking through the parking lots to go to class.

1.1.2 Parking Lot Information

1.1.2.1 Knollcrest East Lower Parking Lot (Small) (1)

This parking lot is located West of the courtyard apartment buildings and is accessed from Burton Street. This lot is full most of the time due to the prime location for those living in the courtyard apartments. There are no handicap spaces in this parking lot and all spaces are designated for Knollcrest East Residents.
1.1.2.2 Knollcrest East Lower Parking Lot (Large) (2)
This parking lot is located between the courtyard apartments and the Calvin Seminary apartments. This lot is divided into two different parking zones, a Knollcrest East zone and a Seminary Apartments zone. The Knollcrest East zone occupies roughly 2/3 of the parking lot, while the Seminary Apartments zone occupies the remaining 1/3. All of the spaces that are zoned for Knollcrest East are full on a consistent basis and thus the 84% capacity is due to the open spaces that exist for the Seminary Apartments.

1.1.2.3 Knollcrest East Upper Parking (3)
This parking lot is located between the DeVos Communications Building and Theta Epsilon Residence Hall. This lot is designated for Knollcrest East residents and is full on a regular basis. There are three handicap spaces in this parking lot.

1.1.2.4 East Beltline Parking Lot (4)
This parking lot is located across the East Beltline from the southern dormitories and is designated for students living in the dormitories. This lot does not meet the current parking demands and many students are forced to park in the DeVos/Prince Conference Center Parking Lot. There are no handicap spaces in this parking lot.

1.1.2.5 Kelsbeek-Huizinga Parking Lot (5)
This parking lot is located north of the dormitories and provides parking for the northern dormitories on campus. This lot is also being used for parking by the physical plant for their equipment, rental vehicles, Calvin vans, and storage of sand and salt during the winter. This lot has five handicap spaces and has some extra capacity however only specific dormitory residents are allowed to park here.

1.1.2.6 Fine Arts Center Parking Lot (6)
The Fine Arts Center parking lot encircles two thirds of the Fine Arts Center. This lot is used heavily by commuter students as well as visitors for events that take place in the Fine Arts Center. This lot is one of the first lots to fill in the morning and remains full for most of the day. During a count during a Jars of Clay concert, it is full too 98% of capacity and was overflowing into the DeVos/Prince Conference Center Parking Lot. The parking lot has nine handicap parking spaces.

1.1.2.7 Science Building/Spoelhof Parking Lot (7)
This parking lot extends from Burton Street to the North side of the Engineering Building. This lot is used by commuter students and facility. This lot fills during peak class hours and major sporting events (such as Calvin College vs. Hope College basketball games).
1.1.2.8 Field House Parking Lot (8)
This parking lot is located just west of the existing Field House. This lot is used by commuter students and is used for bus and vehicles parking during large Field House events.

1.1.2.9 DeVos/Prince Conference Center Parking Lot (9)
The parking lot is located on the south side of the DeVos Communications Building and the Prince Conference Center. This parking lot is seen and used by many visitors to Calvin’s Campus because of the hotel in the Prince Conference Center. This lot is also used during large events such as “The Panel of Faiths” and January Series when people are shuttled from this lot to their destinations. This parking lot is also largely used as the overflow for other parking lots on campus. This lot should always operate below capacity so there is space for visitors of the Prince Conference Center.

1.1.2.10 Seminary Parking Lot (10)
This parking lot is located between the Calvin Seminary and the East Beltline. This lot is use exclusively by Calvin Seminary Students. This lot often exceeds its current capacity. There are four handicap spaces along the exterior of the Calvin Seminary Building.

1.1.3 Future Conditions
There are going to be multiple causes for increase in demand for Calvin College campus parking in the near and distant future. These increases will be caused by:

- The loss of parking spaces due to the construction of the new Spoelhof Fieldhouse Complex
- The increase in demand for parking during game events because of increased gym capacities
- A change in Calvin College’s policy to students being required to spend three years as a campus resident
- Overall growth of Calvin College

These changes on the Calvin College campus could greatly increase the demand for parking spaces on campus and thus be some justification for the installation of a Calvin College parking structure.

1.1.3.1 Spoelhof Fieldhouse Complex
Calvin College recently approved the construction of a new $35 million Spoelhof Fieldhouse Complex. This new facility will have a seating capacity of 5000 people, an 800 person increase from the current Field House. The new building will extend partially into what is currently the Field House Parking Lot thus reducing the capacity of that parking lot. Because of the more modern facility, the regularity of games that will take place in the facility will increase significantly and therefore there will be a more regular demand for parking spaces. This change in parking space demand will occur in the very near future and currently there are no plans to resolve the shortage of parking that will occur at the new Spoelhof Fieldhouse Complex.
1.1.3.2 Three Year Policy
Calvin College has been considering changing the requirement for students to spend two years living on campus to three years. Although this may reduce the number of students that commute to campus on a routine basis, it will increase the number of vehicles that are parked on campus. This will in the end cause a shortage of parking on campus in the evenings when events such as concerts and games are happening because more parking spaces on campus will be filled on a 24 hour basis. Therefore the increase in demand that will occur during events on campus will no longer be as effectively met by filling the commuter parking spaces on campus because there will not be as many.

1.1.3.3 Growth
The population of Calvin College has continued to grow. The schools population has increase by as much as 114 students since 1997 and has had an enrollment that is 133 students higher than its current population of 4,133. One of the effects of this increase in faculty and students on campus is that there will be a greater demand for parking. This will need to be met by the college and this is another reason that a parking structure on the Calvin College campus would be justified.

Calvin Enrollment

![Calvin Enrollment Graph]

Figure 3: Calvin College Enrollment
1.2 Goal
The goal of this project is to assess the feasibility of building a parking structure on the campus of Calvin College. This assessment will include a study of current parking capacity at Calvin, a selection of the ideal location for a proposed parking structure, the suggested method and materials to build a proposed parking structure, and an ideal layout for a proposed parking structure.

1.3 Justification

1.3.1 Environmental Advantages
The Calvin College community highly values the preservation of the green spaces on the campus. One of the reasons for building a parking structure rather than adding another ground level parking lot is that this avoids the need to eliminate more green space on campus. The proposed parking structure would be built on an existing parking lot and therefore no green space would be lost. There are also environmental benefits to a parking structure in that the 66% of the parking structure surface area would not be exposed to the weather. Therefore, only 33% of the parking structure surface area will be exposed to rain and snow. By reducing the surface area for storm water runoff, the quantity of pollutants from runoff will be greatly reduced.

1.3.2 Visitor Advantages
One of the advantages of building a parking structure on Calvin’s campus would be the easier time visitors would have in finding a parking space. The proposed parking structure would also make it easier to consolidate the Calvin College Campus parking in one location thus making it more difficult to get lost on campus and easier to figure out where visitors are supposed to go to park. The appeal of the Calvin College Campus is an essential part of the college and the use of a parking structure would increase convenience for incoming visitors.

1.3.3 Parking Consolidation Advantages
By consolidating the parking for large events on the Calvin College Campus, there is a greater level of feasibility in using a shuttle bus to transport people from the parking lot to the event. When large events such as the January Series occur on campus, people parked all over campus thus making the shuttle busses from the DeVos/Prince Conference Center only shuttle a portion of the people that are going to the event. However with the use of a parking structure, all of the parking for these large events could be consolidated to one location thus making the shuttle busses more effective.

1.4 Design Norms

1.4.1 Stewardship
The proposed parking structure should be designed to minimize the negative effects on the surrounding area. The proposed design must limit tree removal, as well as possible pollutant runoff. The proposed structure must also be economically designed.

1.4.2 Integrity
The proposed parking structure must be pleasing and intuitive to use. Parking structures are often confusing and difficult to navigate. The proposed parking structure will be
designed for easy use by the end user. Also, the proposed parking structure must meet the necessary form verses function balance. A good design will maintain Calvin College’s architectural style, as well as a functional parking structure.

1.4.3 Transparency
The design of the proposed parking structure must be transparent the user. Signs should be posted direction traffic, and visitor should also find the structure easy to navigate.

2 DESIGN OPTIONS

2.1 Location Decision Matrix Criteria
The Calvin College Master Plan has two locations which are allotted as possible future locations for parking structures on the Calvin College campus. These locations are the East-Beltline Parking Lot and the Seminary Parking Lot. Team 12 also is considering however the feasibility of placing the parking structure in the Field House Parking Lot or the Kalsbeek-Huizinga Parking Lot. There are multiple advantages and disadvantages to each alternative.

2.1.1 East Beltline Parking Lot
The East Beltline Parking Lot is currently operating at 100% of capacity and overflowing into the DeVos/Prince Conference Center Parking Lot. A disadvantage of this location is that it is a significant distance from the location of the future Spoelhof Fieldhouse Complex. It is also near the Calvin Nature Preserve which could have negative impacts on the quality of the storm water runoff in the area. There is also one 16” water main which runs through the Southwest corner of the parking lot which may have to be moved to allow for the foundations of the parking structure. The existing utility lines under the East Beltline Parking Lot can be seen in Figure 4.

2.1.2 Seminary Parking Lot
Some advantages to the Seminary Parking Lot location are that it is closer to the Fine Arts Center and there are no utility lines running under the parking lot. The proximity to
the Fine Arts Center would make it more feasible for commuter traffic to use the structure on a regular basis. The lack of utility lines would have some cost advantages in that no lines would have to be moved.

The most significant disadvantage of the Seminary Parking Lot location is that unless the parking structure were placed under ground it would block the view of the Calvin Seminary from the East Beltline. Currently the land between the seminary and the East Beltline has a couple of trees but is mostly clear. This clear view gives the Seminary an aesthetic appeal to people traveling on the East Beltline. There is also a more significant size restriction on the Seminary Parking Lot location which would reduce the capacity of the parking structure. The existing utility lines under the Seminary Parking Lot can be seen in Figure 5.

Figure 5: Seminary Parking Lot Utility Lines
2.1.3 Field House Parking Lot

The greatest advantage to locating the parking structure in the Field House Parking Lot would be that it would be very convenient to traffic for large game events and also student commuter traffic.

The largest disadvantage of the Field House Parking Lot location is that it would place a large parking structure immediately behind the back yards of Calvin College’s neighbors. There are also more utility lines that run through the Field House Parking Lot which would make the excavations for foundations more difficult. The existing utility lines under the Field House Parking Lot can be seen in Figure 6.

2.1.4 Kalsbeek-Huizinga Parking Lot

There are multiple advantages to this location. The greatest advantage is that it is the largest location of the four. It is also very close to the new Spoelhof Fieldhouse Complex which would make it ideal for large sporting events that will be happening at that facility. This location is also convenient for Calvin College campus residents, as well as visiting spectators of Calvin sporting events. There are not utility lines which run under the current parking lot which would need to be moved. This will make it easy to excavate for the foundations. The lot is not located near the Calvin Nature Reserve which reduces the effect which it could have on the environment.

Figure 6: Field House Parking Lot Utility Lines
A decision matrix was used to make the decision on which of the four locations to design the parking structure for. The decision matrix was weighted the most heavily on the cost per parking space which is based on the amount of money that would be required to install a parking structure at that location.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Per Unit</td>
<td>11</td>
<td>3</td>
<td>33</td>
<td>1</td>
<td>11</td>
<td>2</td>
<td>22</td>
<td>4</td>
<td>44</td>
<td>149</td>
</tr>
<tr>
<td>Security</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>2</td>
<td>18</td>
<td>4</td>
<td>36</td>
<td>3</td>
<td>27</td>
<td>127</td>
</tr>
<tr>
<td>Existing Utilities</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>12</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>16</td>
<td>153</td>
</tr>
<tr>
<td>Demand</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>4</td>
<td>40</td>
<td>3</td>
<td>30</td>
<td>1</td>
<td>10</td>
<td>174</td>
</tr>
<tr>
<td>Foundation</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>1</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>2</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>1</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>2</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Water Table Conflicts</td>
<td>6</td>
<td>3</td>
<td>18</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>2</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Stewardship</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Transparency</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>2</td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Integrity</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Neighbor Conflict</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>2</td>
<td>10</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Location Decision Matrix

The Kalsbeek-Huizinga Parking Lot scored the highest on the decision matrix. This location makes also makes the most practical sense. Building the proposed parking structure on this lot will eliminate conflicts with the neighboring residents, as well as provide the most additional parking for the smallest per spot cost. A satellite image of the Kalsbeek-Huizinga parking lot can be seen in Figure 8. The red area 142,000 sq ft box which represents the general floor size of the proposed parking structure.
2.2 Material Selection

There are three different materials that can be used to construct the parking structure. These three materials are:

1. Pre-Cast Concrete
2. Post-Tension Concrete
3. Steel Supported Post Tension Concrete

A decision matrix was used to determine which material choice would be the most feasible and effective for the Calvin College Campus parking structure.

![Figure 8: Parking Structure Proposed Location](image)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Steel Frame + Post Tension Deck</th>
<th>Post Tension Frame + Deck</th>
<th>Pre-Cast Frame + Deck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Control</td>
<td>11</td>
<td>2</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Surfacing</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Construction Weather Limitations</td>
<td>8</td>
<td>2</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>Curing</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Erecting Speed</td>
<td>12</td>
<td>2</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Corrosion Resistance</td>
<td>10</td>
<td>1</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Longevity</td>
<td>13</td>
<td>2</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Seismic Loading</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Slab Depth</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Load Deflection</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Joints</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Cost</td>
<td>14</td>
<td>2</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>169</strong></td>
<td><strong>205</strong></td>
<td><strong>232</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Material Decision Matrix
2.2.1 Decision Matrix Criteria

2.2.1.1 Quality Control
There are different levels of quality control depending on where the parking structure is fabricated. For the pre-cast concrete, the pieces are all cast indoors and are heat treated. They also are cast in a standardized manner. This gives it higher quality control than the post-tension options where the concrete is being cast in the field where it is more difficult to maintain quality.

2.2.1.2 Surfacing
The pre-cast concrete has an option of pre-topped double-tees which would eliminate the need for on site surfacing of the concrete. The post-tension concrete options would not require surfacing once the concrete is poured however the pouring process requires significant work to get a smooth enough surface. This would have already been done with the pre-topped, pre-cast concrete.

2.2.1.3 Construction Weather Limitations
One of the disadvantages to the post-tension concrete is that it cannot be poured in the snow or rain. The pre-cast pieces however can be cast and installed in any weather because the casting is done indoors and the pieces can be installed even when the weather is bad. For the steel option the steel could be installed in bad weather however the concrete slabs would not be able to be poured.

2.2.1.4 Curing
The curing process for the pre-cast concrete is done by the fabricator and involves heating the concrete during the curing process so that it becomes much less penetrable and more resistant to corrosion. The curing process for the post-tension concrete must be done in the field and therefore can be affected by adverse weather conditions.

2.2.1.5 Erection Speed
Pre-cast concrete has a much faster erection speed because all that has to be done is to pour the footings and use a crane to place the pieces and perform the joint connections. For the post-tension concrete, the speed is slower because you have to wait for the lower levels of the structure to cure before the next levels can be added. The steel erects quickly however the post concrete that would be placed on it would not installation quickly.

2.2.1.6 Fire Protection
Both concrete options do not require any fire protection. The post-tension concrete with the steel frame however would require fire proofing because the steel could be weakened by fire.

2.2.1.7 Corrosion Resistance
The pre-cast concrete is the most resistant to corrosion. Because the concrete is heat treated when it is cast, it penetrability is much lower than the post tension concrete. This protects the internal rebar in the concrete more effectively than
the post-tension concrete. The steel frame would be the most susceptible to corrosion from salt and the elements because of the exposed steel frame.

2.2.1.8 Longevity
The post-tension concrete has the longest lifespan of the three different material choices. It also has the greatest structural integrity for seismic loads. Because the State of Michigan has very minimal seismic loading, the necessity for the post-tension concrete for seismic loading is somewhat lost. Pre-Tension concrete has also been shown according to the Mid-Atlantic Pre-cast Association (MAPA) to last as long as post-tension concrete or even longer if it is well maintained. The maintenance costs are also much less for the pre-cast parking structure according to MAPA.

2.2.1.9 Slab Depth
The thickness of the slab between different floors of the parking structure has some affect on the needed height for the parking structure. The post-tension concrete with the steel faming has the thinnest concrete slab however; the thinnest overall slab would be the post-tension concrete slab. The pre-cast concrete double-tees tend to have a deep web which would add to the amount of space needed for the slab thickness. However, there is an advantage in that all utility lines can be enclosed in the slab area and no extra height would need to be added to account for them.

2.2.1.10 Load Deflection
The deflection of the slabs of the parking structure is a design aspect that needs to be considered. All of the materials would allow for minimal deflections however the steel frame would probably deflect to a larger extent than both pure concrete options. The post-tension concrete would also be more rigid than the pre-cast double-tees which are designed to flex some.

2.2.1.11 Joints
The joints of the post-tension concrete design and the pre-cast design are completely different. The post-tension joint allows for very little movement and is attached together by tying the rebar and then pouring the concrete over it. This method is much more time consuming and allows for very little expansion and contraction that would occur with changes in temperature of the concrete. The pre-cast concrete joints involve bolts and nylon spacers to connect the different pieces. The advantage to the pre-cast joint is that there is very little motion restriction which reduces the buckling and cracking that would normally occur from expansion-contraction cycles.

2.2.1.12 Cost
The overall cost of construction for the pre-cast concrete is the lowest. This is because the pre-cast concrete can be erected much more quickly and it can be erected in all weather conditions. The labor that goes into constructing the parking structure is much less since all of the casting is done by a standardized method in a fabrication shop and the only field work that is done is joints and crane work. The other two post-tension concrete options are more expensive because of the amount of labor that has to be done in the field.
2.2.2 Pre-Cast Concrete Elements

There are four different pre-cast pieces which will be needed for the construction of the parking structure. These are as follows:

- Double-Tee
- Spandrel
- Spandrel Supporting Column
- Double Column (Supporting Double-Tee)

2.2.2.1 Double Tee

The general layout of a Double-Tee pre-member can be seen in Figure 9. The Double-Tees would be 50 ft long and 12ft wide. The depth would be approximately 32 inches. The depth of the Double-Tee will be determined depending on the load demands. The Double-Tee comes with an option of being pre-topped which will be used on the parking structure. The justification for using pre-topped Double-Tees are that the surface is then heat treated when the Double-Tee is cast which makes it more resistant to infiltration of corrosives and other chemicals which will corrode the steel in the Double-Tee. For the sake of minimized maintenance and the life time of the building, pre-topped Double-Tees will be used. Figure 9 shows an example of a pre-cast parking structure using double tees members.

![Figure 9: Sample Pre-Cast Parking Structure Interior Photo](From: Mid-Atlantic Precast Association)
Figure 10: Double-Tee to Girder Joint
From: Mid-Atlantic Precast Association

Figure 11: Double-Tee to Double-Tee Joint
From: Mid-Atlantic Precast Association
2.2.2.2 Beam/Spandrel

There will be spandrels installed only for the areas where there is a road that passes under the support location for the Double-Tees. These Spandrels will have to be sized appropriately to handle the span and loads from supporting the Double Tees. The connection between the Double-Tee and the Spandrel can be seen in Figure 12.

![Figure 12: Pre-cast Concrete Spandrel Section](image)

2.2.2.3 Spandrel Supporting Column

Spandrel Supporting Columns will be used to support the ends of the Spandrels which are supporting the Double-Tees over the roadways. These columns will be sized to handle the load requirements of the structure and will span the entire height of the building. Foundations will be designed for these columns. These columns can be designed to handle higher loading to allow for more floors to be
added to the parking structure at a later date. Figure 14 shows a parking structure where pre-cast doubles supporting Double-Tee members.

Figure 14: Pre-Cast Concrete Column Construction
From Mid-Atlantic Precast Association
Figure 15: Beam to Column Joint Detail
From: Mid-Atlantic Precast Association

Figure 16: Spandrel to Column Joint Detail
From: Mid-Atlantic Precast Association
2.2.2.4 Double Column (Supporting Double-Tee)
In between parking space sections there will be Double Columns used which will directly support the Double-Tees without the use of the spandrel. These will only be used on the interior sections of the buildings so as to not restrict light and airflow into the building. Cables will then be placed along these columns rather than a concrete wall as a safety measure to prevent vehicles from striking the columns or passing between spaces.

2.3 Layout
When considering what general layout to use for our parking structure, we found a company called Polar Inertia which had a chart of general parking structure layouts. These were as follows.

- Staggered Floor One-Way Circulation

- Staggered Floor Two-Way Center Ramp

- Flat Floor Straight One-Way Ramps
- Slopping Floors Two-Way Circulation

- Slopping Floors One-Way Circulation

- Slopping Floors Cross Connected One-Way Circulation

- Slopping Floors With Express Helical Down Ramp

- Concentric Opposed Plane Helical Ramps
2.3.1 Choice Criteria

2.3.1.1 No Helical Ramps
The decision was made not to use layouts that involve helical ramps because of the material choice for pre-cast concrete. It is not a standard shape for the pre-cast concrete fabricators and thus would be an added expense. The helical ramp also does not efficiently use space therefore that design would reduce the size of the parking structure given the land restrictions that exist. This criterion eliminates the Slopping Floors with Express Helical down Ramp and the Concentric Opposed Plane Helical Ramps layout possibilities.

2.3.1.2 Road View Aesthetics
It is important to have an aesthetic appeal to the side of the building that is facing the Campus Loop Road. One way to make the building aesthetically appealing is to maintain level floors along that side of the building. A tower can also be added for the stairs and elevator which will add aesthetic appeal to the structure.

2.3.1.3 Efficient Use of Structure Space
The most efficient use of the square footage of the parking structure is important in the design process of the parking structure. Some of the parking structure layouts are more efficient in the use of space in the parking structure. These designs are more favorable than those which do not use the space efficiently. The more efficient the use of space in the parking structure, the less the cost per space in the structure.

2.3.1.4 Functionality
The parking structure’s traffic flow needs to be efficient and understandable to the average user. It is important to make sure that layout and signage on the parking structure are self-explanatory enough that no user has difficulty getting in and out and around the inside of the parking structure.

2.3.1.5 Cost
The cost of the parking structure is a very high priority. Calvin College values good stewardship and therefore, excessive spending on a structure where no quality is gained would not be efficient use of our world’s resources. It is also important for the approval of this project to minimize costs as much as is reasonable.

2.3.1.6 Efficient Use of Land
Because for this project we are already aware of the land limitations that we have, it is important to determine which parking structure layout will allow for the most efficient fill of the land space that we are able to use.
2.3.2 Decision Matrix

A decision matrix was created to determine which of the possible layouts of the parking structure. A hybrid design was then created to incorporate all of the positive aspects of the different layouts. This hybrid model is what will be used for the layout of the parking structure for the Calvin College campus.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural Appeal</td>
<td>6</td>
<td>3</td>
<td>18</td>
<td>4</td>
<td>24</td>
<td>9</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Efficiency of Parking Spaces</td>
<td>5</td>
<td>4</td>
<td>20</td>
<td>2</td>
<td>35</td>
<td>6</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>Functionality</td>
<td>4</td>
<td>6</td>
<td>24</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Ramp Feasibility</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>4</td>
<td>16</td>
<td>1</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Cost Considerations</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>3</td>
<td>31</td>
<td>5</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Efficient use of land</td>
<td>3</td>
<td>5</td>
<td>15</td>
<td>2</td>
<td>6</td>
<td>2</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Structural Design Needs</td>
<td>2</td>
<td>6</td>
<td>12</td>
<td>6</td>
<td>36</td>
<td>4</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>91</td>
<td></td>
<td>91</td>
<td></td>
<td>101</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Parking Structure Type Decision Matrix

2.3.3 Hybrid Layout

The decision matrix showed which designs were most favorable, however none of these designs met all of our requirements. A hybrid layout was designed using the most favorable aspects of each generic parking structure layout. The hybrid uses the general ramp layout of the sloping floor models in that it utilizes the ramps for more parking space. It also has a large amount of square flat space for each floor which uses the space the most efficiently. There is one way parking in the parking structure to increase the efficiency of the parking structure both in traffic flow and in the number of spaces that are in the structure.

Figure 17: Hybrid Front Elevation
Figure 18: Hybrid Bottom Floor Plan

Figure 19: Hybrid Middle Floor Plan

Figure 20: Hybrid Top Floor Plan
3 DESIGN CONSIDERATIONS

3.1 Zoning
The Kelsbeek-Huizinga Parking Lot is located within the City of Grand Rapids, Michigan city limits, and is zoned as R-1 Residential. This residential zoning requires easements for any building over 35ft tall. For this project to be built, a variance form must be approved by the Grand Rapids Planning Department. The form that is required can be found at the website http://www.municode.com/resources/gateway.asp?pid=12116&sid=22.

3.2 Soil
The soil at the location of the parking structure according to the Natural Resource Conservation Service (NRCS) is Glynwood Loam. Glynwood loam is very deep, moderately well drained, and formed in glacial tills. It has a slow permeability and slopes range from 0 to 12 percent.

3.3 Foundations
Foundations for the parking structure will have to be installed to support the columns of the parking structure. For the Double Column (Supporting Double-Tee) will have to be shaped in a long and narrow fashion however the required load bearing capabilities will be minimal due to the limited load on each column. Foundations will also have to be installed for each Spandrel Supporting Column and the required load bearing ability of these foundations will be determined based on the loads carried by the structure and the self-weight of the structure.

3.4 Stairway / Elevator
One stairway and elevator towers will be added to the building, for the southwest corner of the structure. This will consist of a central core elevator shaft and a stair case that orbits the exterior of the elevator shaft. The stairway and the elevator shaft will be enclosed with an aluminum and
red brick frame and Plexiglas windows. The location will allow for easy access to the Field House for sporting events.

3.5 Lane Separation Barriers
Curbs will be installed between lanes in some locations so as to prevent head on collisions between vehicles. These locations will be places such as the central entrance roads and corners where there is no parking.

3.6 Drainage
The top floor of the parking structure will be graded in order to drain rain water and snow melt from the top of the parking structure. The storm water will be carried in covered gutters to the sides of the parking structure where it will be carried by pipes to the ground. Catch basins will then be installed on the ground level to catch the water from the top level of the parking structure.

3.7 Lighting
Pole lighting will be installed on the uncovered top of the parking structure. They will be spaced according to code so as to provide sufficient lighting for visibility and safety. Lighting will also be installed on the ceilings of both other levels of the parking structure and in the stair/elevator tower.

3.8 Architectural Additions
The parking structure will have an exterior that is covered in “Calvin Brick” so that it matches the Calvin Architectural Master Plan. The design of the parking structure also focuses on maintaining an open feel to the structure by maintaining open space and low railings, etc.

3.9 Sidewalks
Sidewalks will be placed on either side of the road that enters the parking structure and between the parking structure and the Field House. These will lead to the stair/elevator tower which will allow people to get to their vehicles.

3.10 Handicap Accommodation
Handicap spaces will be placed on the ground floor of the parking structure. These will have easy access to sidewalks that are outside the parking structure. The number of spaces will be determined based on the capacity of the parking structure.

4 PROJECT COST

4.1 Source of Information
The general cost information for the parking structure was taken from a catalogue published by Saylor Publications. This provided a cost per linear foot for pre-cast panels, reinforced frame parking structure.

4.2 Cost Information
- The cost of the parking garage per square foot is $35.70
- The scale factor for Grand Rapids, Michigan in 0.82
- The parking structure is 396,000 square feet
4.3 Total Cost
The estimated cost for the parking structure is $11,592,500 total cost. The cost per parking space is roughly $7,700.

5 PROJECT SCHEDULE
The schedule for the completion of the parking structure design process can be seen in the Gantt Chart in Figure 22. This schedule was determined based on the creation of a Work Break Down Structure to determine tasks and then approximating how much time will be needed in order to complete those tasks.

<table>
<thead>
<tr>
<th>ID</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
<th>Resource Names</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>4 hrs</td>
<td>Thu 2/6</td>
<td>Thu 2/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>7 hrs</td>
<td>Thu 2/6</td>
<td>Thu 2/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>15 hrs</td>
<td>Thu 2/6</td>
<td>Fri 2/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>4 hrs</td>
<td>Thu 2/6</td>
<td>Thu 2/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>15 hrs</td>
<td>Thu 2/6</td>
<td>Fri 2/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>6 hrs</td>
<td>Thu 2/6</td>
<td>Thu 2/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>15 hrs</td>
<td>Thu 2/6</td>
<td>Fri 2/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>12 hrs</td>
<td>Fri 2/6</td>
<td>Mon 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>10 hrs</td>
<td>Thu 2/6</td>
<td>Fri 2/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>8 hrs</td>
<td>Fri 2/6</td>
<td>Mon 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>4 hrs</td>
<td>Tue 3/6</td>
<td>Tue 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>24 hrs</td>
<td>Thu 3/6</td>
<td>Mon 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>24 hrs</td>
<td>Thu 3/6</td>
<td>Mon 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>32 hrs</td>
<td>Tue 3/6</td>
<td>Fri 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>24 hrs</td>
<td>Mon 3/6</td>
<td>Wed 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>32 hrs</td>
<td>Wed 3/6</td>
<td>Mon 3/6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>48 hrs</td>
<td>Thu 3/6</td>
<td>Thu 3/6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 22: Project Design Completion Schedule and Gantt Chart

6 SUMMARY
Team 12 is proposing a three story parking structure to be built on the existing East Beltline Resident Parking Lot. The proposed parking structure will be designed using pre-cast concrete components. The proposed parking structure will be faced in Calvin brick, and keep with the architectural style of the campus. This proposed parking structure will have the ability to service Calvin College for both on campus residents and large even visitors.
Prestressed Concrete
34"x12' Double Tee
(PRETOPPED)

PHYSICAL PROPERTIES
Precast
A = 951 in²  Sₚ = 3200 in³
I = 85,053 in⁴  Sₙ = 10,335 in³
Wₖ = 25.77 lb  Wₖ = 991 psf
Wₙ = 8.23 in  Wₙ = 83 psf

DESIGN DATA
1. Precast strength @ RELEASE = 3000 PSI (min.)
2. Precast strength @ 28 days = 6000 PSI.
3. Precast Density = 150 PSI
4. Strand = 0.67" 0.270k LS-relaxation
5. Maximum bottom tensile stress is 12/70 = 430 PSI
6. All superimposed load is treated as live load in the structural strength analysis.
7. Flexural capacity is based on stress/strain strand relationships.
8. Maximum moment capacity is critical at midspan for parallel strands and is critical near 0.4 span for draped strands.

<table>
<thead>
<tr>
<th>Table of Safe Superimposed Loads (lbs. per sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
</tr>
<tr>
<td>34-8.5 P</td>
</tr>
<tr>
<td>34-8.6 P</td>
</tr>
<tr>
<td>34-10.6 P</td>
</tr>
<tr>
<td>34-12.6 P</td>
</tr>
<tr>
<td>34-14.6 D</td>
</tr>
<tr>
<td>34-16.6 D</td>
</tr>
<tr>
<td>34-18.6 D</td>
</tr>
</tbody>
</table>

This table is for simple spans and uniform loads. Design data for any of these span-load conditions is available on request. Individual designs may be furnished to satisfy unusual conditions of heavy loads, concentrated loads, cantilevers, flange or stem openings and narrow widths.

Figure 23: Double-Tee Specification Sheet from Nitterhouse Concrete Products

2655 MOLLY PITCHER HWY. SOUTH, IAD K
CHAMBERSBURG, PA 17201-0813
717-267-4505 • FAX 717-267-4518

Team 12: Roads to the Future  Page 41
C. BIKE STRUCTURE INTRODUCTION

Need for bicycle parking has increased on the campus of Calvin College. The goal of this project is to design a standard bicycle storage system to meet the future and current demands of bicycle storage on the campus of Calvin College. This system will be comprised of a rack system as well as a structure to cover the rack and bicycles from weather conditions.

1 OBJECTIVE

1.1 Problem

1.1.1 Existing Conditions
Currently the Calvin College Campus has a total of 414 parking spaces for bicycles. There are 243 resident bicycle parking spaces, and 171 campus building spaces. These bicycle spaces are used by students, faculty, and staff. The bicycle locations typically have a standard bicycle rack that is unique to Calvin College made by DERO. The DERO RR4H is designed to hold up to 9 bicycles, but is often cluttered with many more. When the capacity of the RR4H is met, finding a place to lock the extra bicycles becomes difficult and frustrating.
Figure 24: Campus Map with Bicycle Locations and Current Bicycle Capacity
Bicycle Locations in Red with Number Describing Capacity
Figure 25: Old bicycle rack in front of BHT

Figure 26: New bicycle rack in front of Science Building
The bicycle racks are in continuous use and are usually running near or over capacity. Furthermore, in weather conditions where the cyclist’s seat could be wet, cyclists are more inclined to bring the bicycle into the campus buildings; which is against Calvin College rules, and usually bring in mud and dirt.

1.1.2 Future Conditions
There will be a greater need for enclosed bicycle structures in the near and distant future on Calvin Colleges campus. This increase in bicycle parking may be caused by the new Fieldhouse as described in 1.1.3.1. Also Calvin College is proposing a three year living on campus policy as detailed in 1.1.3.2, which adds to the demand of bicycle parking. Furthermore, Calvin College is slowly growing as outlined in 1.1.3.3. These general trends on campus, plus the rise in price of gasoline and diesel may increase the demand for bicycle parking on campus.

1.2 Goal
The goal of this project is to asses the feasibility of building parking structures for bicycles at key locations on the campus of Calvin College. This assessment will include a study of current bicycle parking capacity at Calvin College and a selection of an ideal rack and structure system. The final design will be a standard bicycle structure to meet the increasing parking demands of the school.

1.3 Justification

1.3.1 Environmental Advantages
Calvin College greatly values the preservation of green spaces and the environment. Adding bicycle structures will encourage the use of bicycles on campus and will reduce harmful pollutants created from driving cars. Furthermore, addition of bicycle structures will reduce the amount of automobile parking and thus reduce the space needed for parking on campus. The addition of bicycle structures will be in locations that already have a bicycle rack or in a location where there is a great demand for the structure, thus reducing the environmental impact.

1.3.2 Visitor Advantages
Adding bicycle structures to the campus of Calvin College will be beneficial to visitors. The bicycle structures will encourage the use of cycling and thus open free automobile parking spaces for visitors. The addition of a standardized structure is easily identifiable and visitors on bicycles will be able to locate bicycle parking structures. The appeal of the Calvin College campus is an essential part of the college and the use of bicycle structures will increase the convenience for incoming visitors.

1.4 Design Norms

1.4.1 Stewardship
The proposed bicycle parking structures should be designed to minimize the negative effects on the surrounding areas. The proposed structure must be economically designed.
1.4.2 Integrity
The proposed bicycle parking structures must be pleasing and intuitive to use. Bicycle racks can be confusing and difficult to navigate. The proposed parking structure will be designed for easy use by the end user. Also, the proposed parking structure must meet the necessary form verses function balance. A good design will maintain Calvin College’s architectural style, as well as being a functional bicycle parking structure.

1.4.3 Transparency
The design of the proposed parking structure must be transparent the user. It should be second nature to use, and visible to all as a place to park their bicycles.

2 DESIGN OPTION

2.1 Location
There are various locations on campus that currently have bicycle racks. The locations where the bicycle structures are to be built are based off current demand, and existing conditions. Therefore, the dormitories on campus will not need bicycle structures because there are existing locations to store the bicycles outdoors as well as indoors with minimal maintenance or cleaning required. Furthermore, structures built should not be in locations where a significant amount of rerouting utilities is required.

Figure 27: Inside location at RVD
The bicycle structures are then determined to be placed in locations shown on the campus map in Figure 30.
Figure 30: Campus Map of Purposed Bicycle Structures
Bicycle Locations in Red with Number Describing Capacity
2.2 Rack
There are three main types of rack configuration that are proposed for the bicycle parking structure. These types are shown in the figures below:

1. Hanger

![Figure 31: Hanger Rack](image1)

2. Conventional Stand

![Figure 32: Conventional Stand](image2)

3. Round Tube (current style)

![Figure 33: Round Tube Parking Currently Used on Campus](image3)
2.2.1 Decision Matrix Criteria

2.2.1.1 Space required
The bicycle rack system must be able to fit in the required space. Where there are bicycle systems already the rack must be able to adapt to that spacing. Also, the rack should not require excessive heights or large widths. The existing rack system is approximately 111” long, and with bicycle in place on each side it has a width of approximately 95”.

2.2.1.2 Usability
The rack that will be chosen must be user friendly. It must be intuitive to use and as well as accessible to all users. Typically lifting a whole bicycle off the ground to hang it is difficult. Furthermore, when there are more bicycles than capacity, which may occur, the rack must be able to have more bicycles placed on it rather than restricting the usage to specific bicycle parking locations.

2.2.1.3 Aesthetics
Calvin College has specific constraints for what the architecture on campus may look like. The rack must be aesthetically pleasing as well as have some consistency with the campus architecture.

2.2.1.4 Cost
The bicycle structure must be cost effective but of high quality.

2.2.1.5 Storage Capability
The new bicycle rack must be able to store more bicycles than the current bicycle storage system. Multiple racks can be used, but using one rack would be beneficial for limiting the space required to be covered by the bicycle structure.

Table 6 shows the decision matrix used to determine which rack choice would be the most feasible and effective for the Calvin College Campus bicycle parking structure.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Hanger</th>
<th>Conventional Stand</th>
<th>Round Tube (Current Option)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weight</strong></td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
</tr>
<tr>
<td>Space Required</td>
<td>20</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Usability</td>
<td>20</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>15</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cost</td>
<td>15</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Storage Capacity</td>
<td>30</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
<td></td>
<td>750</td>
</tr>
</tbody>
</table>

Table 5: Decision Matrix for Rack Method

The decision matrix determined that the conventional stand would be most appropriate for campus, because it is one of the easier racks to use as well as having the highest storage capacity.
2.3 Structure
There are a few different types of bicycle rack roof structures that can be used for the bicycle structure. All structures will have a headspace of approximately 2ft, as well as being approximately 20ft long to fit the rack choice underneath. These structures and variations of them are as follows:

Figure 34: Brick wall with curved roofing
Figure 35: Brick wall with peak roofing
Figure 36: Brick wall with slant roofing
Figure 37: Four poles with curve roofing
Figure 38: Four poles with brick foundation, curved roofing
Figure 39: Four poles with peak roofing
Figure 40: Four poles with brick foundation, peak roofing

Figure 41: Four poles with slant roofing

Figure 42: Four poles with brick foundation, slant roofing

Figure 43: Two poles with curve roofing

Figure 44: Two poles with brick foundation, curve roofing

Figure 45: Two poles with peak roofing
2.3.1 Choice Criteria

2.3.1.1 Space Required
All structures must have a sufficient size to fit the bicycles, rack and room to move. The height of the structure should also accommodate a large head space and possible lighting within the structure. The structure must be efficient with the space of the footing.

2.3.1.2 Aesthetics
These bicycle structures will be transparent and fit within the campus architecture. The structures should create a feeling of security because patrons will be using the structure to lock their bikes.

2.3.1.3 Cost
The structure should be cost effective. Structures with large curves and extravagant materials will cost more than a simple design.
2.3.2 Decision Matrix

A decision matrix was used to determine which structure choice would be the most feasible and effective for the Calvin College Campus bicycle parking structure.

<table>
<thead>
<tr>
<th>Decision Matrix - Structure</th>
<th>Space Required</th>
<th>Aesthetics</th>
<th>Cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank</td>
<td>20</td>
<td>60</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Brick wall with curved roofing</td>
<td>15</td>
<td>33</td>
<td>15</td>
<td>2580</td>
</tr>
<tr>
<td>Brick wall with peak roofing</td>
<td>15</td>
<td>32</td>
<td>16</td>
<td>2540</td>
</tr>
<tr>
<td>Brick wall with slant roofing</td>
<td>15</td>
<td>31</td>
<td>17</td>
<td>2500</td>
</tr>
<tr>
<td>Four poles with curve roofing</td>
<td>17</td>
<td>43</td>
<td>15</td>
<td>3220</td>
</tr>
<tr>
<td>Four poles with brick foundation, curved roofing</td>
<td>13</td>
<td>45</td>
<td>10</td>
<td>3160</td>
</tr>
<tr>
<td>Four poles with peak roofing</td>
<td>17</td>
<td>42</td>
<td>16</td>
<td>3180</td>
</tr>
<tr>
<td>Four poles with brick foundation, peak roofing</td>
<td>13</td>
<td>44</td>
<td>11</td>
<td>3120</td>
</tr>
<tr>
<td>Four poles with slant roofing</td>
<td>17</td>
<td>41</td>
<td>17</td>
<td>3140</td>
</tr>
<tr>
<td>Four poles with brick foundation, slant roofing</td>
<td>13</td>
<td>43</td>
<td>12</td>
<td>3080</td>
</tr>
<tr>
<td>Two poles with curve roofing</td>
<td>19</td>
<td>53</td>
<td>18</td>
<td>3920</td>
</tr>
<tr>
<td>Two poles with brick foundation, curve roofing</td>
<td>15</td>
<td>55</td>
<td>16</td>
<td>3920</td>
</tr>
<tr>
<td>Two poles with peak roofing</td>
<td>19</td>
<td>52</td>
<td>16</td>
<td>3820</td>
</tr>
<tr>
<td>Two poles with brick foundation, peak roofing</td>
<td>15</td>
<td>53</td>
<td>19</td>
<td>3860</td>
</tr>
<tr>
<td>Two poles with slant roofing</td>
<td>19</td>
<td>51</td>
<td>20</td>
<td>3840</td>
</tr>
<tr>
<td>Two poles with brick foundation, slant roofing</td>
<td>15</td>
<td>53</td>
<td>17</td>
<td>3820</td>
</tr>
</tbody>
</table>

Table 6: Decision Matrix for Bicycle Structure

It was determined that the “curve structure” is best fit for the campus of Calvin College. Both two pole curve structures are the same, and an emphasis on the design consideration below are what determine the final structure. Therefore, the Two Poles with Brick Foundation will be the best choice for the Calvin College campus.

3 DESIGN CONSIDERATIONS

3.1 Soil

Each structure design must take into account what the soil types in the location are. Furthermore, where a location is determined to be urban land a regression of surrounding areas is needed to determine the actual soil type in the area. Figure 49 shows the Natural Resource Conservation Service (NRCS) the soil map and Table 7 describes the soils found on Calvin’s campus.
### Soil Map for Calvin College

<table>
<thead>
<tr>
<th>Map Unit Symbol</th>
<th>Map Unit Name</th>
<th>Acres in AOI</th>
<th>Percent of AOI</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Cohoctah loam</td>
<td>3.3</td>
<td>0.2</td>
</tr>
<tr>
<td>12B</td>
<td>Tustin loamy fine sand, 2 to 6 percent slopes</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>12C</td>
<td>Tustin loamy fine sand, 6 to 12 percent slopes</td>
<td>1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>15</td>
<td>Sloan loam</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>17C</td>
<td>Chelsea loamy fine sand, 6 to 12 percent slopes</td>
<td>1.2</td>
<td>0.1</td>
</tr>
<tr>
<td>18B</td>
<td>Glynwood loam, 2 to 6 percent slopes</td>
<td>134.2</td>
<td>9.9</td>
</tr>
<tr>
<td>18C</td>
<td>Glynwood loam, 6 to 12 percent slopes</td>
<td>32.4</td>
<td>2.4</td>
</tr>
<tr>
<td>19B</td>
<td>Blount loam, 2 to 6 percent slopes</td>
<td>84.4</td>
<td>6.3</td>
</tr>
<tr>
<td>20</td>
<td>Houghton muck</td>
<td>14.3</td>
<td>1.1</td>
</tr>
<tr>
<td>24A</td>
<td>Abscota loamy sand, 0 to 3 percent slopes</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>31</td>
<td>Wallkill silt loam</td>
<td>16</td>
<td>1.2</td>
</tr>
<tr>
<td>32</td>
<td>Palms muck</td>
<td>8.1</td>
<td>0.6</td>
</tr>
<tr>
<td>36B</td>
<td>Marlette loam, 2 to 6 percent slopes</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>36E</td>
<td>Marlette loam, 18 to 25 percent slopes</td>
<td>3.8</td>
<td>0.3</td>
</tr>
<tr>
<td>39C</td>
<td>Arkport loamy very fine sand, 6 to 12 percent slopes</td>
<td>3.8</td>
<td>0.3</td>
</tr>
<tr>
<td>45B</td>
<td>Perrinton loam, 2 to 6 percent slopes</td>
<td>223.2</td>
<td>16.5</td>
</tr>
<tr>
<td>45C</td>
<td>Perrinton loam, 6 to 12 percent slopes</td>
<td>54.3</td>
<td>4</td>
</tr>
<tr>
<td>45D</td>
<td>Perrinton loam, 12 to 18 percent slopes</td>
<td>35.6</td>
<td>2.6</td>
</tr>
<tr>
<td>45E</td>
<td>Perrinton loam, 18 to 25 percent slopes</td>
<td>79.9</td>
<td>5.9</td>
</tr>
<tr>
<td>47</td>
<td>Pewamo loam</td>
<td>21.4</td>
<td>1.6</td>
</tr>
<tr>
<td>51B</td>
<td>Oakville fine sand, loamy substratum, 0 to 6 percent slopes</td>
<td>5.5</td>
<td>0.4</td>
</tr>
<tr>
<td>68C</td>
<td>Saylesville silt loam, 6 to 12 percent slopes</td>
<td>4.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Soil Type</td>
<td>Description</td>
<td>R</td>
<td>%W</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------</td>
<td>---</td>
<td>----</td>
</tr>
<tr>
<td>74 Dumps</td>
<td>Dumps</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>75 Udorthents, loamy</td>
<td>90.6</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>76 Udipsamments, nearly level to steep</td>
<td>3</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>78 Urban land</td>
<td>59</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>79 Houghton muck, ponded</td>
<td>11.8</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>82B Urban land-Perrinton complex, 0 to 8 percent slopes</td>
<td>422.4</td>
<td>31.3</td>
<td></td>
</tr>
<tr>
<td>82C Urban land-Perrinton complex, 8 to 15 percent slopes</td>
<td>20.4</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>W Water</td>
<td>8.8</td>
<td>0.6</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Soil Descriptions For Calvin College

3.2 Drainage

The bicycle structure must be designed such that there is proper drainage for rain water and snow melt. The structures will be designed so that there is no need for gutters on the roof, thus reducing the annual maintenance of leaves and other items dropped from trees that may build on the roof. The actual drainage from the roof must also be dealt with ensuring that there is no standing water near the structure.

3.3 Lighting

Some lighting should be in place near the structure. If there is no lighting near the structure pole lighting or inside lighting may be installed. Proper lighting to the structures will increase visibility and safety as well as deter the theft of bicycles.

3.4 Architectural

The bicycle parking structure will use the Calvin College Architectural Plan. Brick used will be the standard “Calvin Brick”. The structure should not distract from other buildings it is near.

3.5 Sidewalks

Sidewalks should be placed on both sides of the structure to ensure that patrons are using both sides of the bicycle rack. The addition of sidewalks on both sides will also ensure that erosion caused by cyclists is reduced to a minimum.

4 PROJECT SCHEDULE

The schedule for the completion of the bike parking structure design process can be seen in the Gantt Chart in Figure 50. This schedule was determined based on the creation of a Work Break Down Structure to determine tasks and then approximating how much time will be needed in order to complete those tasks.
Team 12: Roads to the Future

Figure 50: Gantt Chart for Bicycle Parking Structure

5 SUMMARY

Team 12 is proposing to build standardized structures on the campus at key locations. The structure will be composed of a curved roof with a two pole columns. These poles will be placed into brick footings covered in “Calvin Brick”. These bicycle structures will be beneficial to the environment as well as visitors. The bicycle structures will enable the continual improvement to the kind of campus that Calvin College is committed to.
D. ENTRANCES AND EXITS INTRODUCTION

Team 12 is redesigning the entrance/exit located behind Knollcrest Dining Hall and the entrance/exit located next to Calvin Seminary. These must be designed to meet Michigan Department of Transportation (MDOT) requirements and codes, City of Grand Rapids codes, and Calvin College Physical Plant requirements.

Currently the Knollcrest Entrance has a queue length of two cars which can cause cars to back up into the deceleration lane on the East Beltline. MDOT prefers that cars not stack onto highways. Figure 51 shows the current alignment of the Knollcrest Entrance.

![Figure 51: Existing Knollcrest Entrance](image)

Currently the Seminary entrance is just to the north of the Michigan left turn for Burton Street. The stop-bar for the East Beltline is located north of the exit and creates confusion about when is the appropriate time to turn. Figure 52 shows the current alignment of the Seminary Entrance.
1 OBJECTIVE

1.1 Problem

1.1.1 Existing Conditions
The Knollcrest Entrance currently has a queue length of two cars and intersects the Calvin Loop behind the Knollcrest Dining Hall. The short queue length can cause backups onto the East Beltline during high traffic events. The driver entering Calvin sees the back of the Knollcrest Dining Hall which is not an aesthetically pleasing sight. This does not create a good impression with visitors to the campus and prospective and new students. The straightness of the campus loop at this location allows for drivers to speed if they desire which reduces the safety of the road.

The Calvin Seminary Entrance is currently accessible from southbound on the East Beltline. The Entrance allows access to the Seminary and Campus Loop. The exit currently is aligned slightly to the north of the existing Michigan left turn. The light for the southbound East Beltline is partially visible to the driver sitting at the exit but the driver is past the stop bar. This creates confusion for the drivers exiting Calvin College. It is unclear when a right turn is permitted.
1.1.2 Future Conditions

There are going to be multiple causes for an increase in traffic into and out of Calvin College in the future. The increase will be caused by:

- The addition of the new Spoelhof Fieldhouse Complex
- The overall growth of Calvin College

1.1.2.1 Spoelhof Fieldhouse Complex

See section B.1.1.3.1 for a description of the Spoelhof Fieldhouse Complex. With the addition of this complex Knight Way will be closed and replaced with a pedestrian walkway. Because of the more modern facility, the regularity of games that will take place in the facility will increase significantly and therefore there will be an increase in traffic in and out of Calvin College.

1.1.2.2 Growth

See section B.1.1.3.2 for a description of student growth. One of the effects of this increase in faculty and students on campus is an increase in the overall traffic into and out of Calvin College. The current traffic has a difficult time navigating these entrances, and the increased growth will only enhance this problem.

1.1.2.3 New Commons Building

See section B.1.1.3.3 for a description of the New Commons Building. With the addition of the New Commons Building, the Knollcrest Dining Hall will be demolished and replaced with open space.

1.2 Goal

The East Beltline entrances and exits will be redesigned to meet MDOT codes, City of Grand Rapids codes, and Calvin College Physical Plant requirements. Driver confusion at the Calvin Seminary Exit should be decreased. The flow of the Knollcrest entrance and exit will be improved. The safety of each intersection will be increased by improving sight distance, traffic flow and increase car queue lengths. The Knollcrest entrance is the primary entrance for students and visitors coming south on the East Beltline and should have a more aesthetically pleasing look.

1.3 Justification

1.3.1 Visitor Advantages

Having more aesthetically pleasing entrances will improve visitor’s impression of Calvin College. This can lead to an increase in enrollment should more students decide to come to Calvin College. Visitors to events such as the January Series or sporting events in the new fieldhouse will have a better impression of Calvin College if the entrances are better looking. Better looking intersections, better signage and a better layout will make the campus easier to navigate leaving a good impression on any visitor.

1.3.2 Safety Advantages

The number one priority for any project is safety. By redesigning the entrances and exits to eliminate driver confusion and increase traffic flow safety will be increased.
1.4 Design Norms

1.4.1 Stewardship
The entrances and exits will be designed to effectively use materials and resources. The materials and resources used should not cause harm to the environment and the design should try to minimize the removal of trees and green areas.

1.4.2 Integrity
The entrances and exits will be a complete design. They will be designed to provide easy use to the drivers, bicyclists, and pedestrians. The design will be kept simple so that it remains intuitive to the user.

1.4.3 Transparency
Any design needs to be understandable and clear. The drawings should be comprehensible by the client, and by the contractor building the entrance/exit. The final constructed product should be easy to understand for any user.

1.4.4 Cultural Appropriateness
The entrances and exits will be designed to match exiting Calvin entrances and exits. This will be done by designing the entrances and exits out of the same materials and adding the same features. The designs will be easy to use and be designed for easy storm water and snow removal.

1.4.5 Humility
The design of the entrances and exits will focus on safety. Humans are imperfect which is what leads to accidents. This is why safety is the most important aspect in any roadway design.

2 DESIGN OPTIONS

2.1 Seminary Entrance and Exit
The Seminary entrance and exit redesign includes added features. The entrance and exit will be realigned with the Michigan left turn on the East Beltline and traffic will be allowed to enter Calvin from this movement. This adds an additional entrance to Calvin and will serve to improve traffic flow through campus by allowing drivers a shorter route to the Seminary, Library, and Science Building and Spoelhof parking lots. This will be important since Knight Way is being closed as part of the new Spoelhof Fieldhouse. Both designs move the exit from Calvin south of the Michigan left turn which eliminates the confusion of who has right of way and when the exit movement is allowed to turn. Significant changes in grade will be made to eliminate the steep drive from the Seminary to the entrance.
2.1.1 Right of Way Issues

Since the entrances and exits come from the East Beltline any change in location will require MDOT approval since the East Beltline is a limited access highway. MDOT generally approves projects that increase safety. The exit must be a certain distance from the intersection of Burton Street and the East Beltline. Addition of the left turn into Calvin College will have to done by MDOT since it is within their right of way.

2.1.2 Free Flow Entrance

The first redesign to the Calvin Seminary entrance and exit is with a free flow entrance to help ease traffic flow into and out of campus. Each entering movement will have no stop sign until it reaches the campus loop or a yield sign to yield to the other incoming movement. All intersecting geometry intersects at right angles which provide the best sight distance. Figure 53 shows the Free Flow Entrance option.

Figure 53: Seminary Free Flow Style Entrance
2.1.3 Mall Style Entrance

The second option is a mall style entrance where all entering and exiting traffic come to one point like a normal intersection and the entering traffic is free flow with all other movements yielding to it. The benefits of this are that traffic entering can enter the Calvin Seminary or Calvin College without have to worry about oncoming traffic. This layout can be seen in Figure 54.

![Figure 54: Seminary Mall Style Entrance](image)

2.2 Knollcrest Entrance and Exit

The Knollcrest entrance and exit will be redesigned to free flow the major traffic movement into and out of Calvin College to remove the existing two car queue length and prevent traffic from backing up onto the East Beltline. The design will also decrease the speed of drivers along the Calvin Loop since drivers continuing around will be forced to stop. This project will remove most of the parking located behind the Knollcrest Dining Hall. It should be done at the same time the dining hall is removed.

2.2.1 Traffic Study

A traffic study was done at the Knollcrest Entrance on Monday, December 4 to aid in the redesign of this entrance/exit. The peak hour flows can be seen in Figure 55.
Figure 55: Knollcrest Entrance Peak Hour Movements

As can be seen in the above figure, the majority of the traffic entering from the East Beltline continues South on the Campus Loop road.

2.2.2 Right of Way Issues

Since the entrances and exits come from the East Beltline any change in location will require MDOT approval since the East Beltline is a limited access highway. MDOT generally approves projects that increase safety and because the entrance and exit are being moved. The deceleration lane will need to be relocated to the new entrance and MDOT should be willing to do this since it will stop cars from backing up onto the East Beltline.

2.2.3 Free Flow Entrance

The first option to fix the Knollcrest entrance and exit is with a free flow entrance to help ease traffic flow into and out of campus for the primary turning movement. The entering movement will not have to stop. All geometry intersects at right angles which provide the best sight distance. Figure 56 shows the Free Flow Entrance option.
Figure 56: Knollcrest Free Flow Style Entrance
2.2.4 Mall Style Entrance

The second option is a mall style entrance where all entering and exiting traffic come to one point like a normal intersection and the entering traffic is free flow with all other movements yielding to it. This will allow for the intersection to stay in the arrangement it is now but still allows for traffic entering to continue to move and keeps cars from backing up onto the beltline. This layout can be seen in Figure 57.

Figure 57: Knollerest Mall Style Entrance

3 FINAL DESIGN

3.1 Seminary Entrance and Exit

3.1.1 Decision Matrix

In order to decide which layout to use a decision matrix was created. The decision matrix can be seen in Table 8.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Alternatives</th>
<th>Free Flow Entrance/Exit</th>
<th>Mall-Style Entrance/Exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>3</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Efficiency</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Safety</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 8: Seminary Layout Decision Matrix

3.1.1.1 Aesthetics

The aesthetics of any entrance to Calvin College are important to the school and so the aesthetics of the design are important. It is weighted low since it is a minor consideration in any roadway design since it has no affect on safety.

3.1.1.2 Ease of Use

The ease of use is important in any roadway design. The easier any road is to use the less confusion for the driver. The goal is eliminate driver confusion which results in a safer road and improved traffic flow. It is weighted higher because of the high affect on safety and traffic movement.

3.1.1.3 Efficiency

Movement and flow through an intersection are important. Cars should continue to flow through the entrance and exit to prevent back ups onto other roads. It is weighted in the middle because it affects the safety of the intersection.

3.1.1.4 Safety

Safety is the primary concern in any roadway design. A safer roadway will result in fewer accidents. It is weighted the greatest for this reason.

3.1.2 Final Design

The design for the Seminary Entrance and Exit will be the free flow style entrance seen in Figure 53. This entrance was chosen because it provides the safest and easiest use for everyone.

3.2 Knollcrest Entrance and Exit

3.2.1 Decision Matrix

In order to decide which layout to use a decision matrix was created. The decision matrix can be seen in Table 9.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Rating</th>
<th>Score</th>
<th>Rating</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetics</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Efficiency</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Safety</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>10</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 9: Knollcrest Layout Decision Matrix
3.2.1.1 Aesthetics

The aesthetics of any entrance to Calvin College are important to the school and so the aesthetics of the design are important. It is weighted low since it is a minor consideration in any roadway design since it has no affect on safety.

3.2.1.2 Ease of Use

The ease of use is important in any roadway design. The easier any road is to use the less confusion for the driver. The goal is eliminate driver confusion which results in a safer road and improved traffic flow. It is weighted higher because of the high affect on safety and traffic movement.

3.2.1.3 Efficiency

Movement and flow through an intersection are important. Cars should continue to flow through the entrance/exit to prevent back ups onto other roads. It is weighted in the middle because it affects the safety of the intersection.

3.2.1.4 Safety

Safety is the primary concern in any roadway design. A safer roadway will result in fewer accidents. It is weighted the greatest for this reason.

3.2.2 Final Design

The final design for the design for the Knollcrest Entrance and Exit will be the free flow style entrance as seen in Figure 56. It provides the greatest safety and ease of use for everyone. It will prevent cars from backing up onto the East Beltline and will slow traffic on the Campus Loop.

4 PROJECT COST

4.1 Source of Information

MERL Project Estimator and the City of Wyoming Engineering Department is the source of cost information.

4.2 Cost Information

- The cost of pavement is currently $60.00 per ton
- The cost to remove existing pavement is about $3.00 per square yard
- Landscaping, tree removal, tree movement, tree planting and grading can be paid in one sum since Calvin College Physical Plant will do most of that work
- Movement of existing storm sewer

4.3 Total Cost

The estimated total cost for the Seminary Entrance is $77,600. The cost breakdown can be seen in Table 10. The estimated total cost for the Knollcrest Entrance and Exit is $60,000. The cost breakdown can be seen in Table 11. The total cost of the project is $138,000.
## Table 10: Seminary Cost Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>$60.00</td>
<td>$19,800.00</td>
</tr>
<tr>
<td>Remove Pavement</td>
<td>$3.00</td>
<td>$7,354.00</td>
</tr>
<tr>
<td>Grading/Other</td>
<td>$50,000.00</td>
<td>$50,000.00</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>$500.00</td>
<td>$500.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$77,654.00</strong></td>
</tr>
</tbody>
</table>

## Table 11: Knollcrest Cost Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>$60.00</td>
<td>$14,400.00</td>
</tr>
<tr>
<td>Remove Pavement</td>
<td>$3.00</td>
<td>$5,456.67</td>
</tr>
<tr>
<td>Grading/Other</td>
<td>$40,000.00</td>
<td>$40,000.00</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>$500.00</td>
<td>$500.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$60,356.67</strong></td>
</tr>
</tbody>
</table>

### 5 PROJECT SCHEDULE

The schedule for the completion of the entrance and exit design process can be seen in the Gantt Chart in Figure 58. This schedule was determined based on the creation of a Work Break Down Structure to determine tasks and then approximating how much time will be needed in order to complete those tasks.

![Figure 58: Entrances and Exits Project Schedule](image)

### 6 SUMMARY

Team 12 is proposing to redesign the two southbound East Beltline entrances and exits. They are being redesigned to improve traffic flow into and out of campus, to increase safety and eliminate driver confusion. Both Entrances will be redesigned with a free flow entrance for the greatest turning movement.
E. INTERSECTION INTRODUCTION

Due to safety issues, there is a need to redesign three intersections on the Calvin College campus. These three intersections are the Burton Street intersection, the East Beltline underpass, and the Lake Drive intersection. With the closing of Knight Way, the problems at these intersections will only get worse with greater traffic volumes. The goal of this project is to redesign these intersections to create safer, more efficient intersections.

1 OBJECTIVE

1.1 Problem

1.1.1 Existing Conditions and Utilities

1.1.1.1 Burton St. Intersection

The Burton St. intersection has grown too large over the past few years. The stop signs have been moved around to try and figure out the best setup, leading to uncertainty for drivers. There are many points of conflict and unusual movements. Drivers do not know who has the right-of-way or who has to stop for whom. This entrance is a main entrance to Calvin College, and has high traffic volumes. The predominant movement is the approach coming from Burton St. turning left onto the campus loop. The current layout and peak hourly flows from the traffic study done can be found in Figure 59.

![Figure 59: Burton St. Intersection Peak Hourly Flows](image)

The utilities that will need to be dealt with at this intersection are storm sewers, a sanitary sewer, electrical lines, and a communication line.
1.1.1.2 East Beltline Underpass

The East Beltline underpass is an awkward intersection. It forms a triangle with three free flow movements and three stop signs. This can create confusion among drivers because it is unlike most intersections. The predominant movement is the approach coming from the East Beltline exit and going underneath the overpass. The current layout and peak hourly flows from the traffic study can be found in Figure 60.

![East Beltline Underpass Peak Hourly Flows](image)

The utilities that will need to be dealt with at this intersection are electrical lines and a 16 in. water main west of the intersection. This water main will be avoided as much as possible.

1.1.1.3 Lake Drive Intersection

The Lake Drive entrance is the least problematic of the three intersections. The drive that intersects the through movement is not exactly perpendicular, therefore creating less than ideal sight distance issues for cars coming from the Fieldhouse. The predominant movement is the approach coming from Lake Dr. and turning to go to the Fieldhouse. This movement currently must make a turn greater than 90°. The current layout and peak hourly flows from the traffic study can be found in Figure 61.
The utilities that need to be dealt with are storm sewers and electrical lines.

1.1.2 Future Conditions
There are going to be multiple causes for an increase in traffic volumes at these three intersections in the near and distant future on the Calvin College Campus. These increases will be caused by:

- The closing of Knight Way
- The construction of the Spoelhof Fieldhouse Complex
- Overall growth of Calvin College

1.1.2.1 Knight Way Closing
The closing of Knight Way will increase traffic at the Burton St. intersection as well as the Lake Dr. intersection. The traffic that currently uses this road will be forced to get to the other side of campus by going north through the Lake Dr. intersection, or south through the Burton St. intersection.

1.1.2.2 Spoelhof Fieldhouse Complex
See section B.1.1.3.1 for a description of the Spoelhof Fieldhouse Complex. The updated Fieldhouse is expected to increase trips made to and from the complex. This will attract more people to campus, and these intersections will face increased traffic volumes.

1.1.2.3 Overall Growth
See section B.1.1.3.2 for a description of the growth of Calvin College. This growth is going to exacerbate the current problems at these intersections.

1.2 Goal
The goal of this project is to assess the feasibility of the redesigning these three intersections on the campus of Calvin College. This will include traffic studies of these intersections, determining the affects of the future needs, and choosing the proper redesign for each intersection.
1.3 Justification

1.3.1 Safety

1.3.1.1 Burton St. Intersection
The Burton St. intersection faces problems of safety. Pedestrians must constantly be watching the cars entering the intersection to make sure they are noticed by the drivers. The cars going west on the campus loop must look through a few small trees too see the cars that they must stop for. They must also watch for cars coming from the parking lot and Burton St., as well as pedestrians. Cars coming from Burton St. must watch for cars from their far left and immediate right, as well as watch for pedestrians. This intersection is not as safe as it needs to be.

1.3.1.2 East Beltline Underpass
There are no other intersections that are like this one. Cars coming from the underpass must choose to go north and stop or go south. Cars coming from the East Beltline exit may go underneath the underpass without stopping, or continue south and stop. Cars coming from DeVos/Prince Center may continue north or stop before going underneath the East Beltline. This is unusual and some drivers do not understand exactly what they should do and end up making u-turns around the ends of the triangle.

1.3.1.3 Lake Dr. Intersection
The Lake Dr. intersection is the least problematic. Cars coming from the Fieldhouse must stop and wait for an opening, while cars coming from the Lake Dr. entrance and those driving west have the right of way. The drive coming from the Fieldhouse isn’t exactly perpendicular with the other road. The predominant movement is from the Lake Dr. entrance going to the Fieldhouse. This turn currently is greater than 90°, which should be addressed.

1.3.2 Efficiency
These intersections are not as efficient as they could be. There are many times when a car must stop and wait, even though there are no other cars around. Calvin as a Christian College must be aware of these issues and ways to correct them. Roundabouts, standard intersections, or even just redoing the signage may increase efficiency. Also, with a college, there are times when many people are leaving at the same time, and the intersections must be able to handle the high traffic quickly and efficiently.

1.3.3 Aesthetics
As a college, Calvin must be able to attract students in order to continue providing high quality education. One aspect that may help the process is for prospective students to see the pleasing sights on Calvin’s campus. New intersections could be part of these sights. Roundabouts and standard intersections provide space for statues, trees, signs, flowers, and many more things to appeal to prospective and current students, and alumni.
1.4 Design Norms

1.4.1 Stewardship
These intersections will improve stewardship at Calvin. Safety will be improved for drivers and pedestrians. The intersections will improve efficiency, thus reducing fuel consumption, air pollution, and delay.

1.4.2 Integrity
The proposed design of these intersections must be pleasing to look at. Calvin looks to impress visitors, prospective and current students, and alumni. The intersections must be easily understood by all drivers, while addressing the issues of safety and efficiency. Good design will incorporate Calvin’s signs and landscaping.

1.4.3 Transparency
The intersections must be easily understood by all drivers. Drivers must not have to stop and figure out what to do and where to go. This would defeat the purpose of redesigning these intersections. The intersections must be intuitive and flow well. They must be common enough for any driver to figure out without consciously thinking about it.

2 DESIGN OPTIONS

2.1 Type of Intersection

2.1.1 Decision Matrix Alternatives

2.1.1.1 Roundabout
The option of roundabout would be expensive, due to the removal of the existing asphalt, concrete, and possible trees. The cost of grading and reconfiguring existing utilities is also considered. A roundabout is considered more efficient than most standard intersections, because entering traffic is not required to come to a full stop, but yield to traffic already in the roundabout. Roundabouts reduce delay, fuel consumption, and air pollution. This will be safer for some intersections than others. A roundabout reduces the number of points of conflict in the intersection because the drivers entering the intersection only have to look left to check for traffic. A roundabout will provide an open area in the middle for landscaping and increased aesthetics. Roundabouts also slow traffic down, but keeps it moving. Figure 62 shows a typical roundabout.

![Figure 62: Typical Roundabout](image)
2.1.1.2 Standard Intersection

The standard intersection is something all drivers understand. A standard intersection is understood to be a perpendicular intersection with three or four approaches. This could be quite expensive at these intersections because some of the approaches might have to be realigned. This will also involve removing asphalt, concrete, and trees. A standard intersection is very well understood by drivers, and is still efficient, though not as efficient as the roundabout. Figure 63 shows an example of a standard intersection.

![Figure 63: Standard Intersection](image)

2.1.1.3 One Approach has Right-of-Way

A standard intersection consists of keeping the intersection mostly the same, but slight changes may be necessary. Traffic studies done to find the predominant movement will affect which approach has the right-of-way. Safety would be improved at most intersections. Since only slight changes would be necessary, cost is less expensive than roundabouts or standard intersections. The efficiency may be improved, as well as safety. Aesthetics will be improved, although not as much as a roundabout or standard intersection.

2.1.1.4 Replace the Signage

This would be the least expensive of the options, but safety and efficiency would increase minimally. This wouldn’t solve any real problems of safety and efficiency.

2.1.1.5 No Action

No redesign at all would be the worst action to take. The problems laid out for each intersection will only get worse with the growth of Calvin. It would be the least safe action, and would cost nothing financially for the college to keep these intersections the way they are.

2.1.2 Choice Criteria

2.1.2.1 Safety

Safety was the most important of the criteria, and appropriately weighted in the decision matrix. Safety for drivers, but also for bikes and pedestrians was considered. The main goal of this project is to improve safety for the students and staff at Calvin College.

2.1.2.2 Uniformity

For intersections, an important consideration is uniformity for the sake of the drivers. A driver who doesn’t know what to do at an intersection is more likely
to make a mistake which could lead to a serious accident. Drivers who know what to do and what to look for are safer drivers. This was given consideration.

2.1.2.3 Efficiency
Another goal of this project is to improve efficiency at the intersections. Increased efficiency reduces traffic delay, fuel consumption, and air pollution. This factor was weighted appropriately in the decision matrix.

2.1.2.4 Cost
Cost will be a factor in this decision, but keeping safety first and foremost is the concern. Cost is important in many decisions but was weighted so as to not be the deciding factor. The main goal of this project is to improve safety, and so cost will be minded, but not decide the final design.

2.1.2.5 Aesthetics
Aesthetics is something that is pleasing. Calvin has some beautiful scenery. These intersections should add to this. Roundabouts and standard intersections will provide the highest aesthetics and improve Calvin’s overall appearance.

3 Final Design

3.1 Burton St.
The Burton St. intersection was evaluated and a decision matrix was constructed to discover the best option for redesign. A roundabout has been chosen as the optimum redesign alternative. Safety would be greatly improved, as well as efficiency. As the main entrance to Calvin, a roundabout would allow a great place for landscaping or for an art piece. Table 12 shows the decision matrix for the Burton St. intersection.

<table>
<thead>
<tr>
<th>Burton St.</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Roundabout</td>
</tr>
<tr>
<td>Criteria</td>
<td>Weight</td>
</tr>
<tr>
<td>Safety</td>
<td>10</td>
</tr>
<tr>
<td>Uniformity</td>
<td>7</td>
</tr>
<tr>
<td>Efficiency</td>
<td>8</td>
</tr>
<tr>
<td>Cost</td>
<td>5</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>309</strong></td>
</tr>
</tbody>
</table>

Table 12: Burton St. Intersection Decision Matrix

The roundabout would be two lanes, connecting to the intersection at existing points. This design also closes the parking lot entrance/exit to reduce points of conflict and prevent the roundabout from becoming too large. The parking lot entrance/exit was too close to the intersection. Figure 64 shows the layout of a roundabout at the Burton St. Intersection.
3.2 East Beltline

The best option for the East Beltline underpass is for an approach to have the right of way. The intersection allows for minimal changes to existing pavement and concrete, while efficiency will be improved. The decision matrix can be found below in Table 13.

<table>
<thead>
<tr>
<th>E. Beltline Underpass</th>
<th>Alternatives</th>
<th>Roundabout</th>
<th>Standard Intersection</th>
<th>One Approach - R.O.W.</th>
<th>Redo Signage</th>
<th>No Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Weight</td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
</tr>
<tr>
<td>Safety</td>
<td>10</td>
<td>9</td>
<td>90</td>
<td>9</td>
<td>90</td>
<td>8</td>
</tr>
<tr>
<td>Uniformity</td>
<td>7</td>
<td>6</td>
<td>42</td>
<td>10</td>
<td>70</td>
<td>8</td>
</tr>
<tr>
<td>Efficiency</td>
<td>8</td>
<td>7</td>
<td>56</td>
<td>7</td>
<td>56</td>
<td>10</td>
</tr>
<tr>
<td>Cost</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>7</td>
<td>8</td>
<td>56</td>
<td>6</td>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>249</strong></td>
<td><strong>263</strong></td>
<td><strong>296</strong></td>
<td><strong>93</strong></td>
<td><strong>8</strong></td>
<td><strong>93</strong></td>
</tr>
</tbody>
</table>

Table 13: East Beltline Underpass Decision Matrix

The proposed intersection would include a left-turn lane for the approach from the East Beltline exit, as well as a right- and left-turn lane from the DeVos Communications/Prince Conference Center. This layout would give the three highest volume approaches free flow. Figure 65 shows what the reconstructed East Beltline underpass would look like.
### 3.3 Lake Dr.

The best option for the Lake Dr. intersection is for one approach to have the right of way. With the closing of Knight Way, this intersection will have greater traffic volumes, most of which will be the campus loop. As it stands right now, the approach coming from the Fieldhouse must stop in order to continue on the campus loop. The redesign will make the campus loop the right of way, with the Lake Dr. entrance coming perpendicular into it, and stopping. The decision matrix can be found below in Table 14.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Weight</th>
<th>Roundabout</th>
<th>Standard Intersection</th>
<th>One Approach - R.O.W.</th>
<th>Redo Signage</th>
<th>No Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
<td>Rating</td>
</tr>
<tr>
<td>Safety</td>
<td>10</td>
<td>8</td>
<td>80</td>
<td>8</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Uniformity</td>
<td>7</td>
<td>6</td>
<td>42</td>
<td>10</td>
<td>70</td>
<td>1</td>
</tr>
<tr>
<td>Efficiency</td>
<td>8</td>
<td>4</td>
<td>32</td>
<td>4</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>Cost</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Aesthetics</td>
<td>7</td>
<td>7</td>
<td>49</td>
<td>6</td>
<td>42</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 14: Lake Dr. Intersection Decision Matrix**

The proposed reconstructed Lake Dr. intersection would make the Lake Dr. entrance intersect the campus loop at a right angle, increasing sight distance. The highest volume of traffic must make a turn greater than 90° at the existing intersection. The Lake Dr. entrance would have a stop sign to allow the campus loop to flow freely, and have two turn lanes to accommodate high volumes to the Fieldhouse. Also, an exclusive right-turn lane on the campus loop further keeps traffic flowing freely. Figure 66 shows the proposed Lake Dr. Intersection.
4 DESIGN CONSIDERATIONS

4.1 Existing Layouts and Utilities

One important factor in the design process is the existing layout and utilities. The existing layout may dictate what will be the final designed intersection. Using the existing layout and space will save trees and green space around each intersection. While this will be taken into consideration, safety of the users will be first and foremost. Utilities will also play a factor in the layout. There are some utilities that will be minded around each intersection, most notably the 16 in. water main near the East Beltline underpass.

4.2 Space

Space is an important issue. Many of the intersections around Calvin’s campus are the way they are due to the space limitations. Calvin’s campus is a small campus, with nearly all the buildings within walking distance. This can create some problems at intersections. Around the Burton St. intersection, there are many trees that limit the available space. Some of these trees will need to be cut down or removed in order to have a roundabout. The East Beltline underpass must deal a steep hill on one side, and a 16 in. water main on the other side. The Lake Dr. intersection must deal with the new mail building and trees and bushes that surround the intersection.

4.3 Drainage

Drainage is always a consideration when designing roads and intersections. The intersections will be designed so as to use the existing storm sewers as much as possible, and install as few new storm sewers as needed.

4.4 Sidewalks

These intersections are being designed for the students and staff of Calvin College, and the safety of these students is the first priority. This includes pedestrians and bicyclists. When designing these intersections, sidewalks will need to be rearranged, removed, and installed. The roundabout at the Burton St. intersection will have pedestrian islands, which allow them to cross one lane of traffic, and wait for another. The Lake Dr. intersection’s sidewalks will be redesigned according to the intersection. The East Beltline underpass has only one sidewalk serving pedestrians, and
with the redesign pedestrians will only have to cross one road, thus improving safety. Adding another sidewalk on the other side of the road will be considered.

### 4.5 Additional Lanes/Widening Road

With this redesign, the widening of the road will have to be considered. The Burton St. intersection will have a two-lane roundabout. This will be necessary to handle the high traffic volume in a short time span. The East Beltline underpass and Lake Dr. intersection will be slightly widened to add the proposed turn lanes.

### 4.6 Design Vehicle

The design vehicle for each intersection will be a BUS-45. This is a motor coach. This vehicle was chose for the teams that come to Calvin on the chartered motor coaches. Also influencing this decision are bands’ busses that play at the Fine Arts Center and trucks that bring supplies to Calvin.

## 5 PROJECT COST

### 5.1 Cost Information

The cost of this project is divided into each intersection. Calvin will be able to choose to update one or all the intersections. The total cost includes the cost of removing the existing asphalt, concrete, and sidewalk, the cost of removing/installing or moving utilities, the cost of grading, and the cost of the asphalt, concrete, and sidewalks.

### 5.2 Total Cost

The cost of this entire project is $181,000. The cost of the Burton St. intersection is $63,500. The cost of the East Beltline underpass is $58,750. The Lake Dr. intersection will cost $58,850. See section 4.1 and 4.2 for detailed cost information.

#### 5.2.1 Burton St. Intersection

The cost of reconstructing the Burton St. intersection is $63,500. This was due to the cost of installing a roundabout, which involves more asphalt and concrete than the other intersections. The cost breakdown of the Burton St. intersection can be found in Table 15.

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>$60.00</td>
<td>$16,620.00</td>
</tr>
<tr>
<td>Remove Pavement</td>
<td>$3.00</td>
<td>$4,843.15</td>
</tr>
<tr>
<td>Grading/Other</td>
<td>$40,000.00</td>
<td>$40,000.00</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>$2,000.00</td>
<td>$2,000.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$63,463.15</td>
</tr>
</tbody>
</table>

*Table 15: Burton St. Intersection Cost Breakdown*

#### 5.2.2 East Beltline Underpass

The cost of reconstructing the East Beltline underpass is $58,750. Not as much pavement will be needed as the redesign reduces the amount of pavement necessary. There will be a substantial amount of pavement needed to be removed, however. The breakdown of the total cost can be found in Table 16.
### Table 16: East Beltline Underpass Cost Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>$60.00</td>
<td>$12,600.00</td>
</tr>
<tr>
<td>Remove Pavement</td>
<td>$3.00</td>
<td>$5,908.92</td>
</tr>
<tr>
<td>Grading/Other</td>
<td>$40,000.00</td>
<td>$40,000.00</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>$250.00</td>
<td>$250.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$58,758.92</strong></td>
<td></td>
</tr>
</tbody>
</table>

5.2.3 Lake Dr. Intersection

The cost of reconstructing the Lake Dr. intersection was $58,850. This is due to the cost of removing the existing asphalt and concrete and moving the drive over. The breakdown of the total cost of can be found in Table 17.

### Table 17: Lake Dr. Intersection Cost Breakdown

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement</td>
<td>$60.00</td>
<td>$13,200.00</td>
</tr>
<tr>
<td>Remove Pavement</td>
<td>$3.00</td>
<td>$4,146.64</td>
</tr>
<tr>
<td>Grading/Other</td>
<td>$40,000.00</td>
<td>$40,000.00</td>
</tr>
<tr>
<td>Storm Sewer</td>
<td>$1,500.00</td>
<td>$1,500.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$58,846.64</strong></td>
<td></td>
</tr>
</tbody>
</table>

### 6 PROJECT SCHEDULE

The schedule for the completion of the bike parking structure design process can be seen in the Gantt Chart in Figure 67. This schedule was determined based on the creation of a Work Break Down Structure to determine tasks and then approximating how much time will be needed in order to complete those tasks.

![Figure 67: Intersections Project Schedule](image)

### 7 SUMMARY

Team 12 is proposing redesigning the three intersections at the Burton St. intersection, the East Beltline underpass, and the Lake Dr. intersection. The Burton St. intersection will be designed as a roundabout and the East Beltline underpass and Lake Dr. intersection will be designed with one approach having the right of way. This will be done to increase the safety and efficiency at these intersections, for drivers and pedestrians.
F. REFERENCES


"Code of the City of Grand Rapids, Michigan." Municode. CITY OF GRAND RAPIDS,


Michigan Department of Transportation. 2 Nov. 2006 <http://www.michigan.gov/mdot/>

Mid-Atlantic Pre-cast Association Website. 19 Nov. 2006 <http://www.mapaprecast.org/>
National Pre-Cast Concrete Association Website  5 Nov. 2006.

National Resource Conservation Service’s Website.  16 Nov. 2006

Nitterhouse Drawings and Specs.  10 Nov. 2006

Oonk, Jeff. "Pavement Calculations." E-mail to the author. 21 Nov. 2006.

"ParkABike." Bike Parking Racks, Bicycle Storage, Bicyle Storage, Bike Lockers. 2005. 7 Dec. 2006

Parking Structure Type  Polar Inertia.  November / December 2004

   1997 Chicago, IL

Regis IMS Parcel Finder Service Website.


RoundaboutsUSA.  26 Oct. 2006
   <http://www.roundaboutsusa.com/>

Saylor Square Foot Building Costs.  16 Nov. 2006.