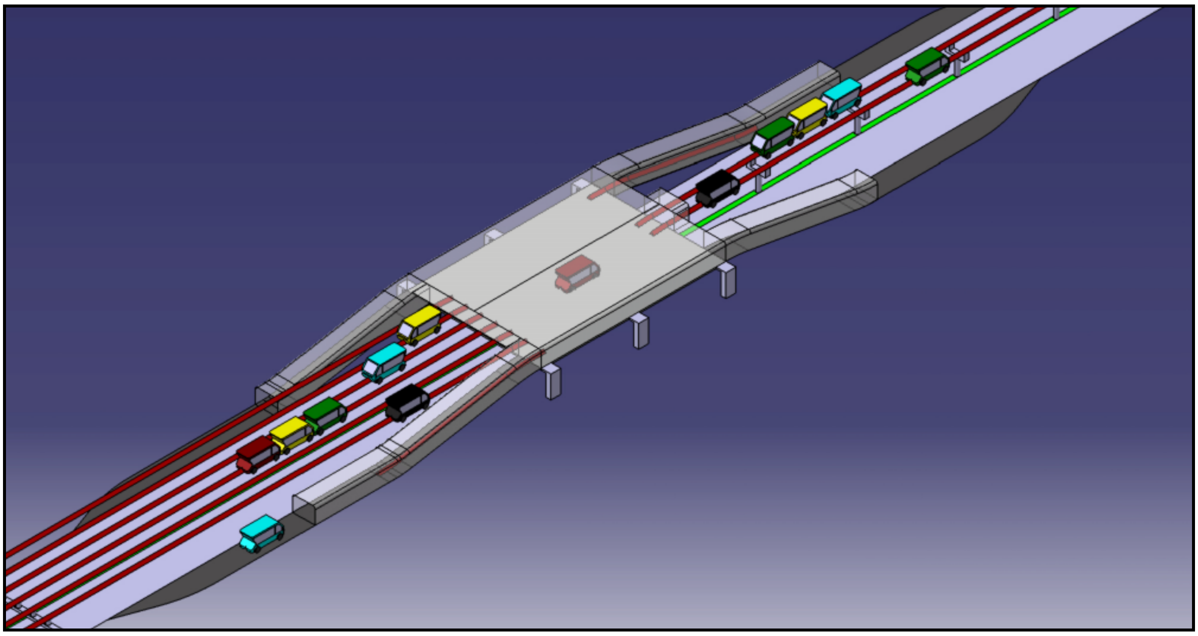
Final Report

European Project Semester

Autumn 2007

Group 4: Dimension of a RUF Junction



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ABSTRACT:

Since the beginning of time, man has needed to move. With this need to move came different modes of transportation. This transportation brought about problems with congestion, pollution and accidental death common with many of today's major cities.

The RUF system provides an answer to these problems if the idea of transportation is rethought. RUF combines the best of man's transportation techniques into one dual-mode transportation system. The goal of this group is to design and dimension the junctions needed for the RUF system. There are three basic elements described in this report; The rail configuration for the crossing junction, the switch that will be used for the crossing junction and the switch that will be used for getting on and off the RUF system.

These elements must be safe and comfortable for the user, be realistic to construct and allow for travel quickly and easily in each direction. Each elements design will be described and dimensions will be suggested. Because there are still questions surrounding some aspects of the junction, these questions will be noted and commented on when an answer cannot be reached. The documented questions and the work done in this report could provide the foundation for future progress and modifications of the RUF junction. Sound engineering principles from a multitude of engineering fields will be considered when making professional suggestions about a RUF junction. Ideas will be filtered through a series of decision making tools and techniques to obtain the best solution. It will then be shown that this final solution is able to be implemented on Jarmers Plads street intersection in Copenhagen, Denmark.

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The members of Group 4 “Dimension of a RUF Junction” would like to extend thanks to the following people and institutions.

Firstly we would like to thank Mr. Palle Jensen, founder of RUF and company representative of our project. Also, we would like to extent our gratitude to our IHK supervisor Mr. David Ashworth. Without their expertise and constant encouragement our project would not have been possible. We would like to thank Mr. Jørgen Hansen for his passion in putting together and organizing EPS.

The team would like to show appreciation to our individual home Universities for their efforts to encourage and allow students to experience studies abroad.

- University of Applied Sciences Rosenheim: Rosenheim, Germany
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- University of Applied Sciences Kempten: Kempten, Germany
- Institution Superior of Technology and Management: Paris, France
- Michigan Technological University: Houghton, Michigan, U.S.A.

Thanks again to all those involved in this project, for their help and guidance.

GLOSSARY OF TERMS:

EPS: European Project Semester

maxi-ruf: The name for the bus-like public transport vehicle used on the RUF system

RUF: Rapid Urban Flexible

ruf: The name for a personal transport vehicle used on the dual-mode RUF system

LCD: Liquid Crystal Diode

GPS: Global Positioning System

PRT: Personal Rapid Transport

RT: Rapid Transportation

ULTra: Urban Light Transport

MAGLEV: Magnetic Levitation

TGV: Train à Grande Vitesse

CHAPTER 1: Background Information

Introduction

The group working on dimensioning a RUF junction and is composed of five international students coming from around the world. Students in the group have different educations and skills, which help to see the project through in all areas. These skills include backgrounds in economics, civil and mechanical engineering, electronics and informatics. This group is put together within the framework of the Erasmus exchange program for the EPS at Copenhagen University College of Engineering (IHK). This project will be doing work for the RUF International company. This is the final report for the design and dimension of a RUF system junction. The concept of a junction will be explained in more detail in the following chapter.

The RUF system was originally the idea of Mr. Palle Jensen, the founder of RUF International. The RUF International logo can be seen below in FIGURE 1.1. RUF International is in collaboration with IHK and has its test laboratory in the same building.

FIGURE 1.1: RUF Logo

RUF International

The RUF system is a new kind of dual-mode transportation system. The ruf vehicles, know as rufs, are electrically powered vehicles that can drive on both normal road and special RUF system triangular monorail. Vehicles are equipped with both normal road wheels and special rail wheels. FIGURE 1.2 shows both the rail wheels and normal drive wheels.

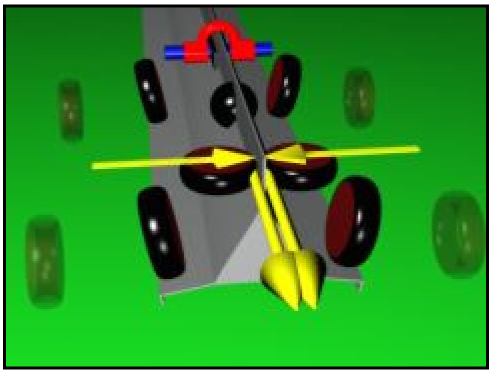


FIGURE 1.2: Ruf Wheel System

RUF International

The rufs can draw charge from the rail as it is moving to charge its batteries that it can then use to drive on a normal road surface. Below an example of a ruf vehicle can be seen in FIGURE 1.3.

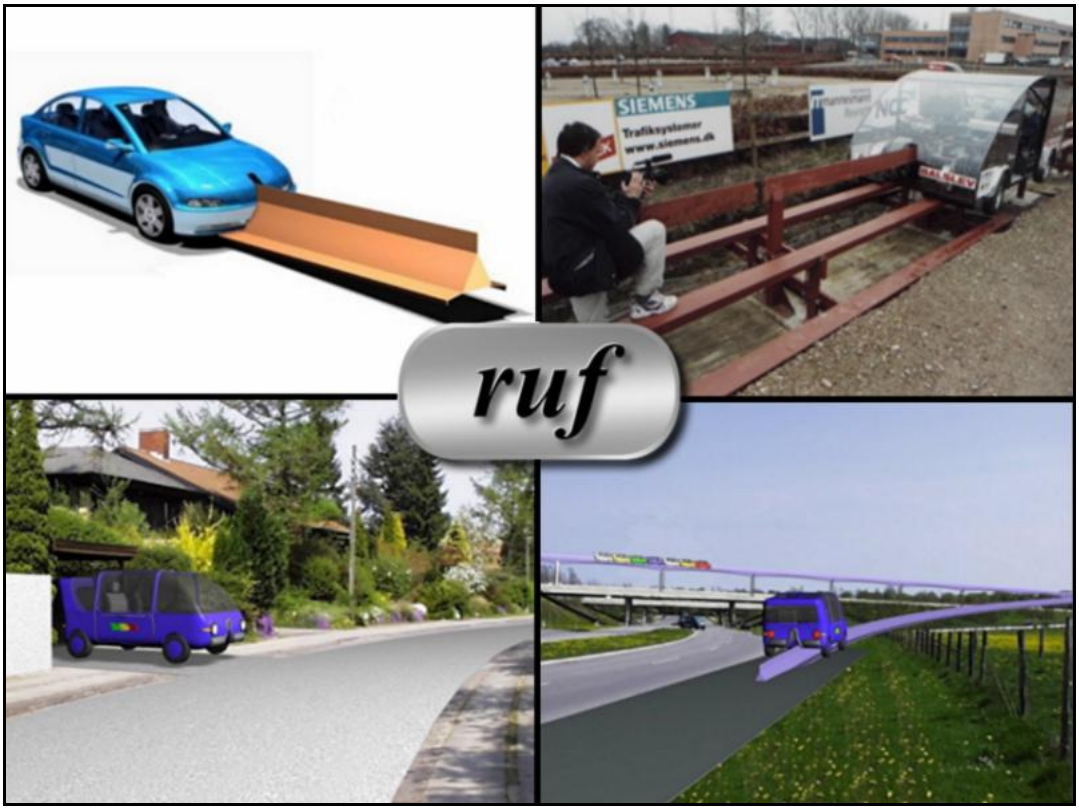


FIGURE 1.3: Ruf Vehicle on RUF Monorail System

RUF International

There are also bus-like rufs known as maxi-rufs. The main use of the maxi-ruf is for public transportation, and can hold up to 10 passengers. They can transport passengers with higher frequency, and are more economic and smaller than conventional buses. The length is about 6.75 meters and is approximately half the length of a normal bus. FIGURE 1.4 shows a comparison between maxi-ruf size and normal Copenhagen buses.

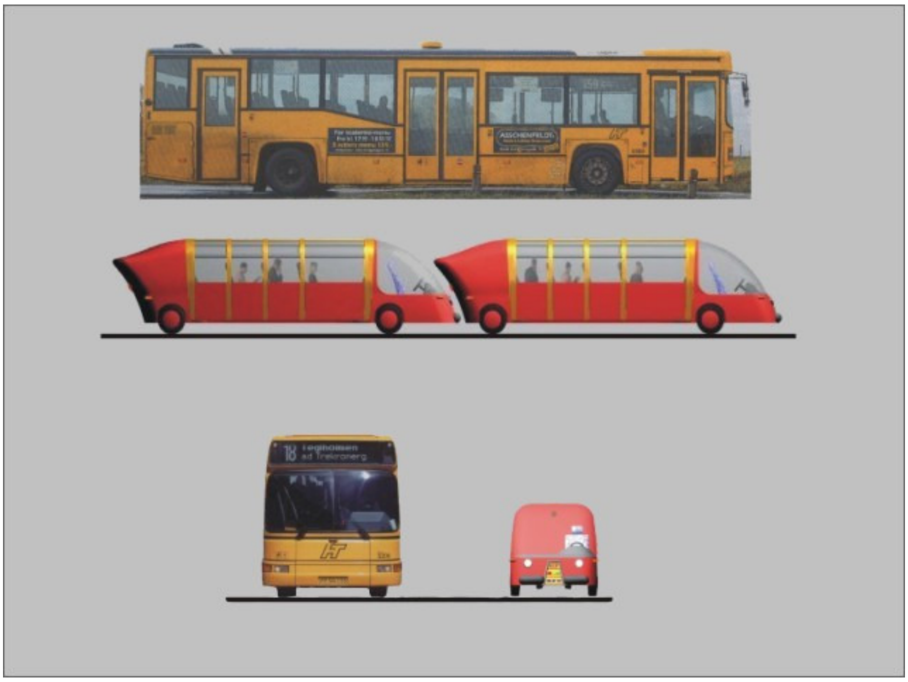


FIGURE 1.4: Maxi-ruf Comparison to Copenhagen Buses

RUF International

Unlike classic buses, the maxi-ruf could go to a specific place according to the passengers' desires. Plus, there could be different kinds of seats in the vehicle, similar to first and second class, so it could be possible to book a place in advance the place you would like to sit. A new type of payment and communication could appear with the RUF system based on an electronic way to transfer information. This new payment and communication way could possibly use some type of chip that can store information about financial, geographic and user identity information. An example of these payment and communication device is shown in FIGURE 1.5 below.

FIGURE 1.5: RUF Handheld Device

RUF International

With the maxi-rufs and rufs, it could be possible to include such things as cameras, LCD screens and access to the internet inside to attract more riders. An example of the maxi-ruf in action can be seen in the picture below in FIGURE 1.6.

FIGURE 1.6: Maxi-ruf

RUF International

The RUF concept was born to combat the various faults of current modes of transportation including traffic jams, air pollution, and the consumption natural resources. The RUF system will first be implemented as public transportation and then later for personal vehicle use.

To show that the RUF system has the possibility of being more efficient than current transportation systems, it can be seen in FIGURE 1.7 that during times of less dense capacity one maxi-ruf could be used. During times of need for increased capacity maxi-rufs could be coupled together to form an articulated bus. This articulated bus could increase capacity without increasing the need for drivers. Also shown in FIGURE 1.7 is the possibility that the RUF system could consumer less energy than a normal car.

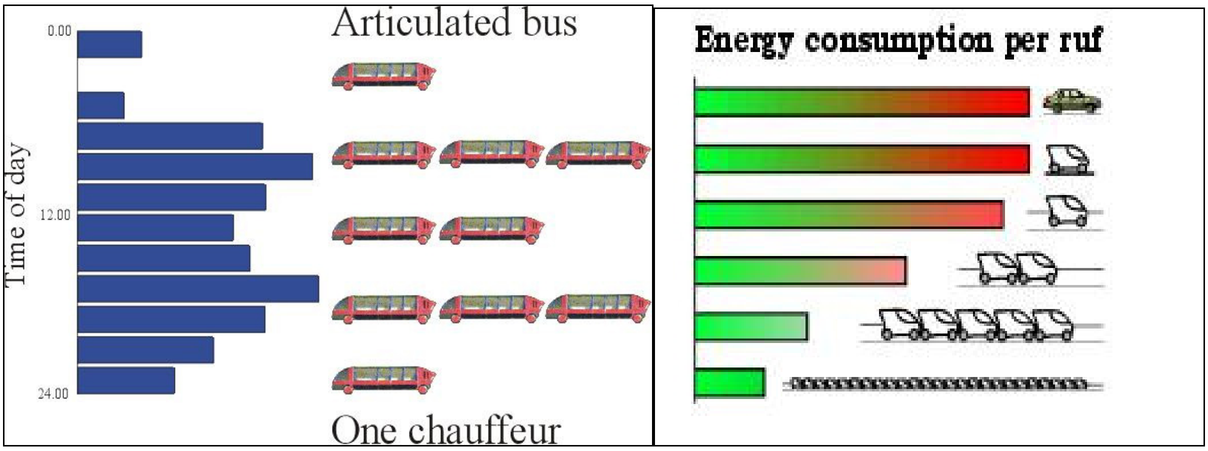


FIGURE 1.7: RUF Efficiency

RUF International

This project is to design and dimension a junction for the RUF system that is safe and comfortable for the user, and allows the user to go quickly and easily in every direction. It also must be realistic to construct and implement. The main implementation of this design will be to fit into the Jarmers Plads junction in Copenhagen. This junction can be seen in FIGURE 1.8 below. This project generates a lot of questions, some of which will not be answered. This project is quite general and is meant to provide a foundation of information and ideas for future groups to try and understand more completely and precisely. The questions that are not answered will be noted in the chapter regarding future progress that needs to be made for completion of the RUF system design.

Each chapter of this report will exhibit a structure that is composed of an introduction, a main body, and a conclusion. The reader of this report should have a basic understanding of the RUF concept.

FIGURE 1.8: Jarmers Plads Location in Copenhagen

http://www.googleearth.com

CHAPTER 2: RUF Junction Concept

2.1 Introduction

The concept of the RUF junction is a fairly complex one, but when broken down into separate parts, it becomes manageable. It involves the need to take many variables into consideration. As stated in the introduction chapter it is the goal of this project to create an intersection for the RUF rails that allows safe and efficient travel, and is affordable and reasonable to construct, modify and implement into an already existing infrastructure of transportation. Throughout this chapter the concept of the RUF junction will be described as detailed as possible. The problems that are discovered throughout the process of this project will be answered as completely as possible. If the question is in need of further research it will be noted and recorded in Chapter 6 designated for currently unanswered questions titled Future Progress.

2.2 Concept

RUF is a dual-mode system that uses both road wheels and ability to drive on a raised rail. The rufs need to be able to enter and exit the rail, as well as change from one rail to another. The rufs that are travelling in one direction on the rail, and want to change directions at a point where two rails intersect, can do so by means of a rail change. To complete a rail change, the rufs need to get off the rail and use the road wheels to be guided automatically by the magnetic field to another rail corresponding to the desired direction. This is done within the confines of a switch. It can be seen in FIGURE 2.1 that a switch that allows rufs to access and exit the rail, as well as switch from one rail to another.

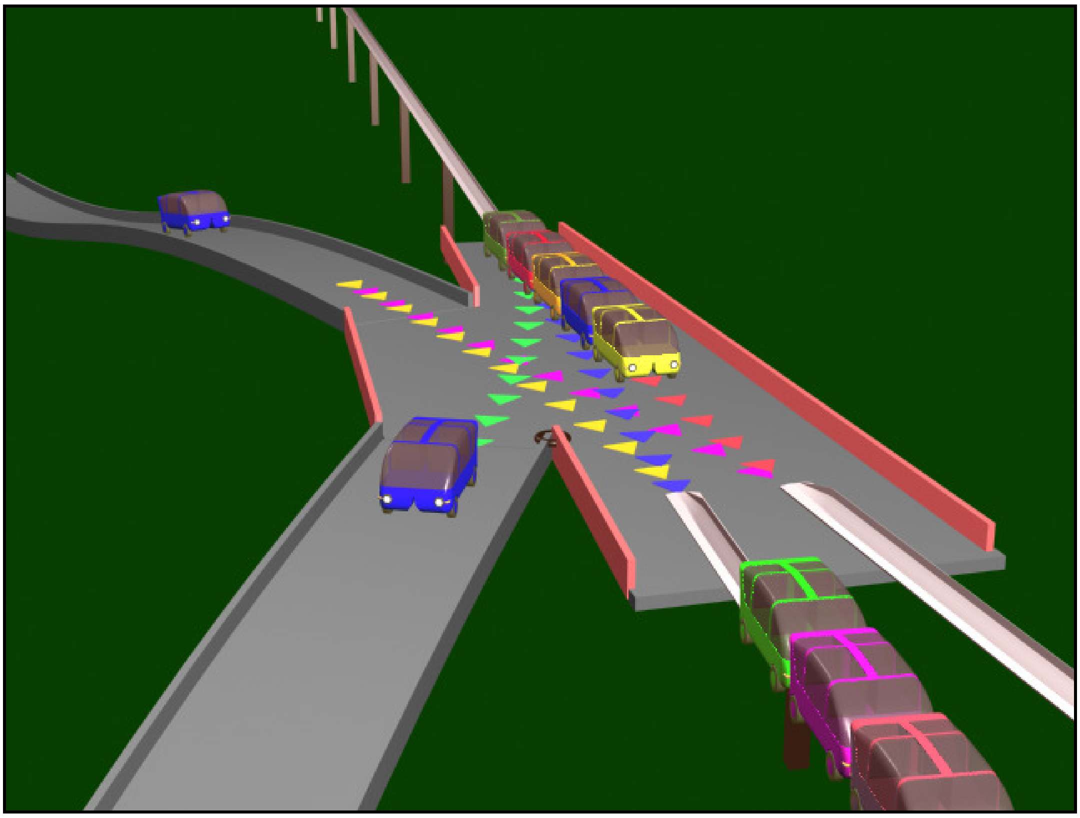


FIGURE 2.1: RUF Switch Concept

RUF International

These switches are usually placed around an intersection of two rails. This layout can be seen in FIGURE 2.2. After a switch, the rufs enter the crossing junction and are driven in the direction they want to go. Rufs that are coming from other switches around the intersection and going in the same direction are merged together onto one rail via another switch. Another function of the switch is that rufs can enter and exit the system. If the switch is not in front of an intersection, its function is to allow rufs to enter and exit the RUF system, it is called an on/off switch.

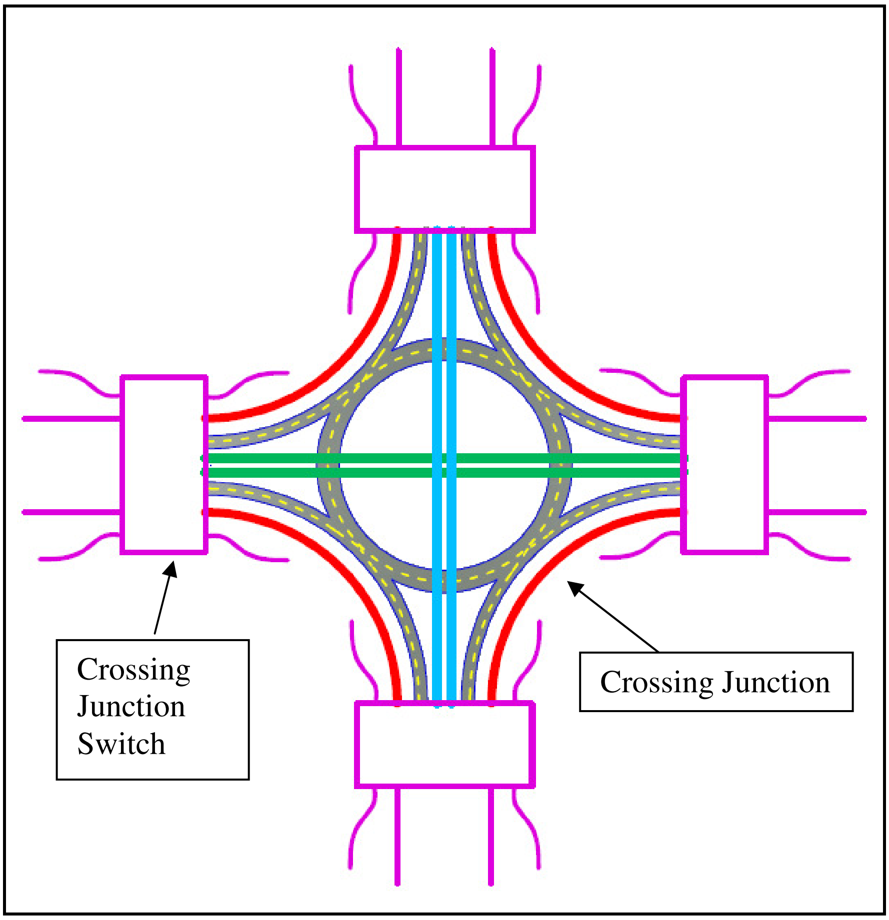


FIGURE 2.2: RUF Junction Layout

2.3 Magnetic Guidance

When the RUF system is in control of the rufs, the system will use magnetic fields to guide the rufs while on road surface. Each direction that can be taken will be set at a different frequency in accordance with turning at right, left, going straight ahead, or exiting the system. Cables will be laid underneath the road surface that will emit the magnetic field. There will be a magnetic sensor in the rufs which can select the right frequency according to the user's desires. An example of the magnetic field guidance can be seen previously in FIGURE 2.1, they are represented by colored triangles.

The use of magnetic field is totally safe for the rufs as well as the user. The wires that emit the magnetic field are buried beneath the road surface, protecting any user from electrification. Magnetic field technology has been proven safe and reliable in a couple of different currently used systems. MAGLEV is a Japanese train that can reach speeds of 581 km/h by using a magnetic field between the train and the rail, providing nearly zero friction. Also, service vehicles in the Eurotunnel between Paris and London are guided by a similar guidance system to ensure accident free travel. Both of these systems can be seen and described in more details in Chapter 3 of this report.

When the rufs are not driving on the normal road they will be riding on a triangular monorail. The rail that will be used in real-life can be seen in box 1 of FIGURE 2.3. For simplicity sake, the triangle in box 2 was used to represent the largest outer dimensions of the monorail. These rails can be seen compared together in FIGURE 2.3.

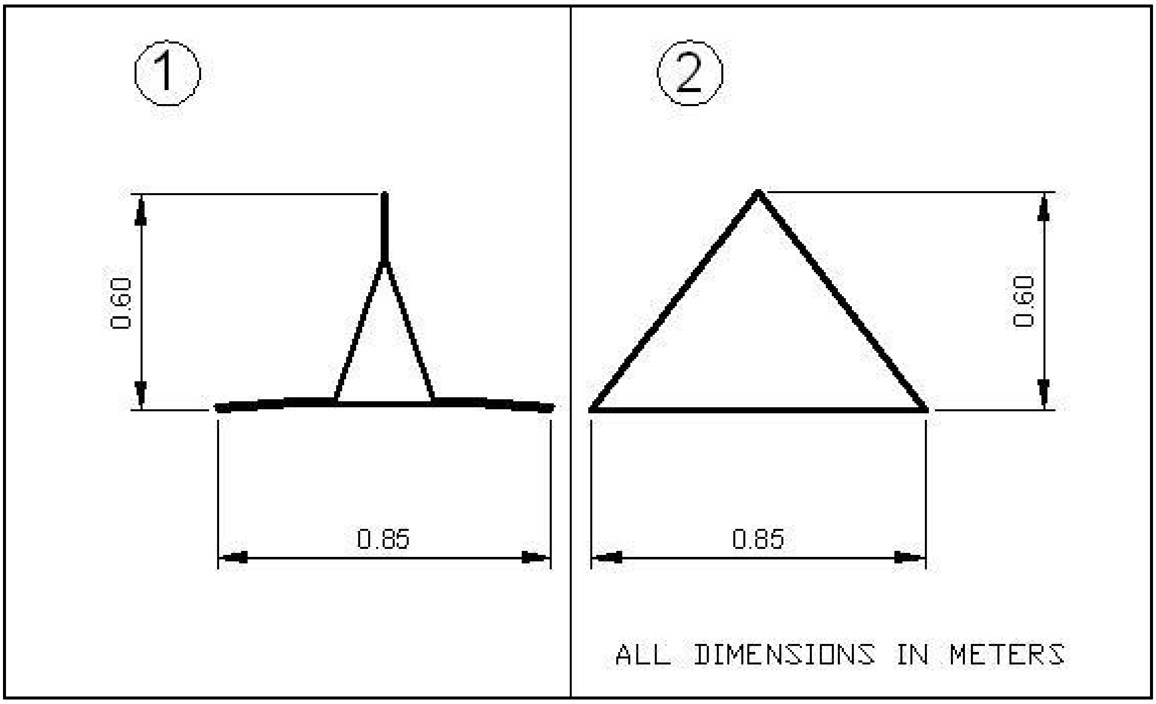


FIGURE 2.3: RUF Rail

2.4 Crossing Junction

As stated earlier there is a goal to show that a crossing junction and necessary switches can be implemented at the Jarmers Plads intersection in Copenhagen. There is a dimensioned photo below in FIGURE 2.3 showing the measurement that will constrain the overall size and placement of the designed crossing junction and switches.

It was determined to be important that no building was to be destroyed in the construction of the RUF junction and switches. Also, disruption of normal everyday traffic on the road was to be kept to a minimum. When implementing the actual design and configuration of the crossing junction and switches, there are specific needs for each unique intersection. One junction will be described, but the different configurations can be seen and will be discussed further in Chapter 4.

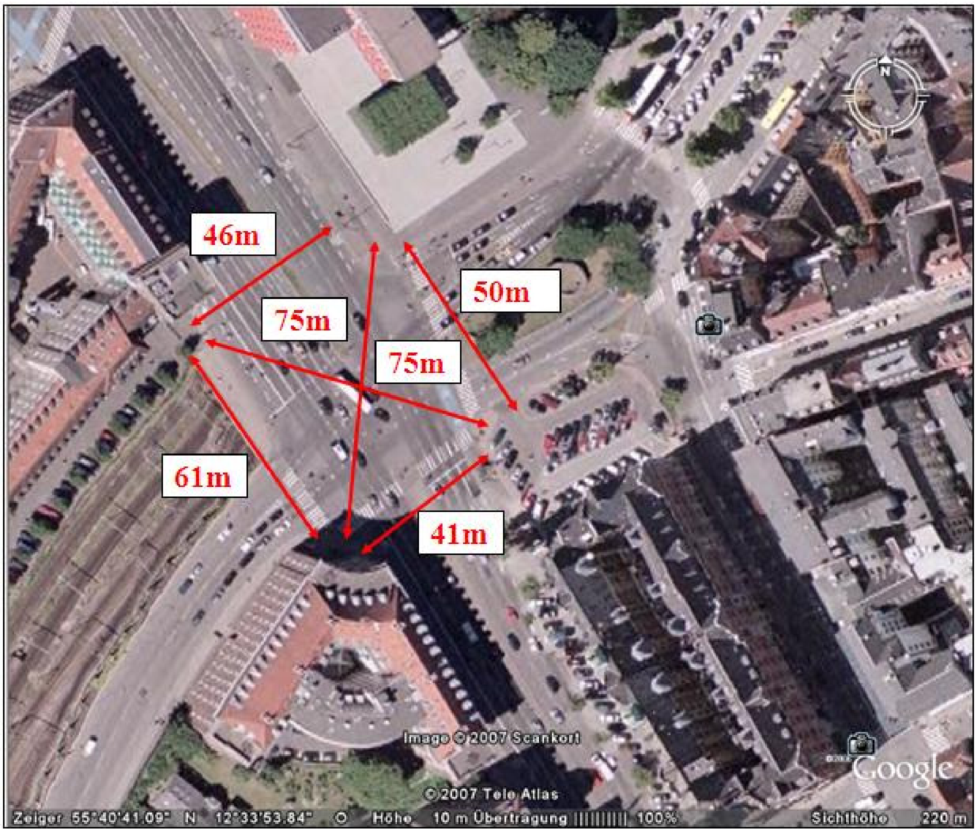


FIGURE 2.4: Physical Dimensions of Jarmers Plads Intersection

http://www.googleearth.com

2.5 Naming Convention

To ensure understanding of the naming convention used to describe the different parts of a switch, FIGURE 2.5 is provided to show how things are named. There will be an entering building that will be covered and be the point where the RUF system automatically takes control of the ruf vehicle and slow down or speeds up the ruf to prepare for accessing the rail. From the entering building the ruf will be guided with the magnetic field onto the access rail where the rufs rail drive system will be tested. This area will consist of both road and rail to ensure the ability of the vehicle to move if the rail drive system were to fail. This part of the switch will also be covered to protect the system from the environment. The ruf will then enter the actual switch platform structure. Here the system will automatically guide the ruf to the desired direction and rail. With this switch there is also an egress road that allows users to exit the RUF system back to the normal road.

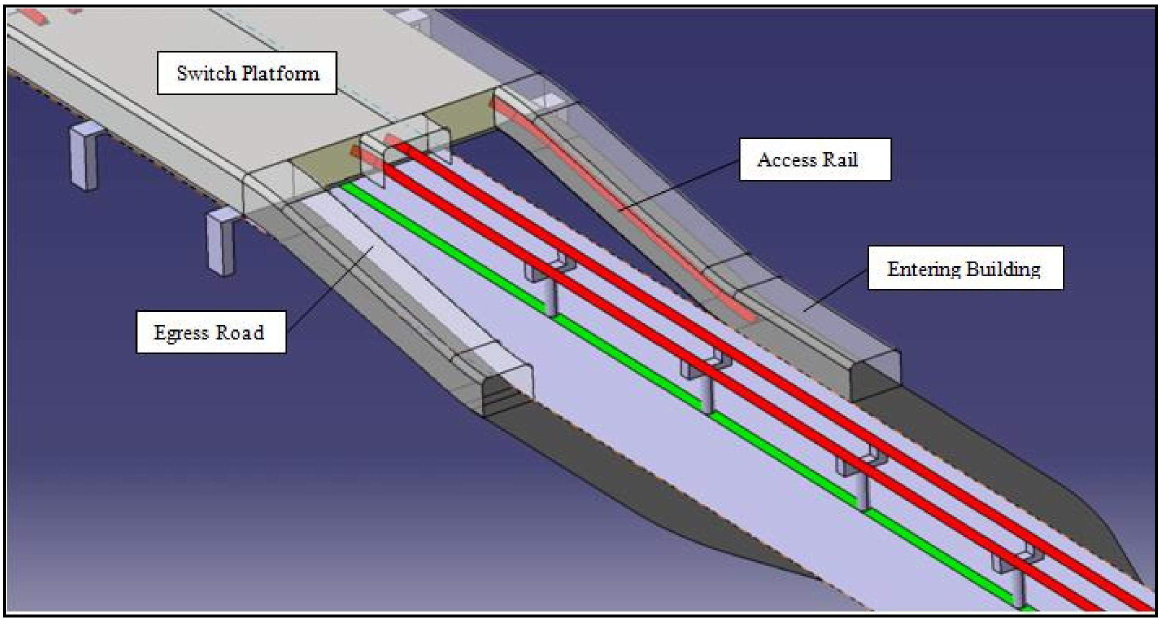


FIGURE 2.5: RUF Switch Naming Convention

2.6 Conclusion

This chapter has provided a basic understanding of how a RUF junction could operate. The ideas presented are not necessarily the best or most effective solutions for every junction needed in the RUF system. There are many variables that can be changed, or modified to provide each unique road intersection with a RUF junction that both meets the traffic need of the area, and can physically fit into the space provided. Ideas for different variables that can be tuned to change different characteristics of the junction will be discussed further in Chapter 4 of this publication. There are also some unanswered questions surrounding the RUF junction that will not be discussed or solved in this publication. However, they will be recorded in Chapter 6 where the issues can be presented to future RUF engineers for discussion.

CHAPTER 3: Project Plan

3.1 Introduction

As with every project, a plan is necessary to ensure correct direction and achievement of project goals. EPS is as much about how to go about solving the problem as it is about solving the actual problem. To ensure the success of this project some organizational and decision making techniques have been implemented and described in this chapter.

3.2 Group Structure

To ensure the goals and objective are accomplished there were certain ideals and techniques implemented. Some of these included weekly meetings with supervisors and daily group meetings to ensure completion and correct direction of the project. Some organizational techniques were also used such as templates for formal meeting agendas and minutes that can be seen in APPENDIX A1 and APPENDIX A2 respectively. The agenda has fields for date, time, those invited, chairman and secretary. The agenda provided the structure to allow for an organized and smooth running meeting. The document for the meeting minutes also has much of the same information fields to ensure proper documentation. Each decision was recorded, and the general happenings of the meeting were kept track of. To make sure each group member participates evenly and has the opportunity to experience the different roles, secretary and chairman positions were rotated each meeting. Each week a to-do list was filled out and names were assigned to each task to ensure team member responsibility. Also, a date for completion was noted to allow for proper budgeting of time. All the documents, research, and useful information has been kept in a team folder for future reference.

As information was gathered a technical givens document was produced to ensure accuracy of previously determined RUF characteristics. This document is viewable in APPENDIX A3. This document is also useful for future groups to use as a quick reference guide to getting RUF facts.

3.3 Brainstorming

To help get started with understanding the project surrounding a RUF junction, a brainstorming diagram was created. The diagram consisted of thoughts both radical and reasonable to start mapping out the ideas each of the members had about a RUF junction. It incorporated thoughts and ideas that were incorporated into the design of the junction. It also provided a good starting point for determining questions that needed to be answer for project work to continue. When these questions were then captured, brainstorming on how to answer those questions could begin. The beauty of brainstorming is the ideation that goes along with it. It maximizes the benefit of a team's knowledge by encouraging and spurring on ideas in each other as the brainstorming is carried out. An example of the team's brainstorming can be seen in APPENDIX A4**.** The interesting aspect of brainstorming is that the ideas emerge from the minds of each member. Half of the suggestions are similar because they are centered around the main characteristics of the project. The other suggestions represent some ideas which are in accordance with the education of each member. This means every student does not have the same vision of same project.

3.4 Flowchart

A flowchart was created in attempt to dissect the possibilities of the RUF system. It attempted to capture the choices a RUF user would be faced with along the journey from beginning to end while using the RUF system. The process of creating the flowchart is similar to that of brainstorming because each member gives their ideas to describe the flowchart. This flowchart is important to understand the big picture idea of the RUF system. As the team attempts to design and dimension the RUF junctions it is important to keep in mind that the work being done is just one piece of the puzzle that is the RUF system. If the junctions are designed without the function of the rest of the RUF system being kept in mind then the junctions may not fulfill exactly what the junctions need to do.

To start to use the RUF system the user must first decide to use the ruf for transportation. The user can use the ruf to drive normally as a car, or can choose to enter the RUF system with the ruf. If the user chooses to use the ruf on the RUF system, the user can input the destination at any time before the access switch is reached. The ruf would have a RUF guidance system similar to a GPS navigational system that would calculate a route to the nearest RUF system access switch. If the user chooses to take a route alternate to the route suggested by the RUF guidance system a new route will continually be updated for the user to follow. If no destination is entered, the RUF guidance system will not give any suggestions and the user can go about driving wherever. As the ruf driver nears the access switch, they will need to navigate into the entering building. Once the ruf driver has safely navigated into the entering building at the recommended 30 km/hr the RUF system will take control of the ruf by means of some magnetic field radiating from the roadway. The RUF system will than brake or accelerate accordingly to achieve proper road to rail transition speed. The RUF system will also make corrective steering adjustments to ensure proper alignment onto the rail, and to avoid contact with the entering building and other rufs.

If not done up to this point, the user must then input the desired final destination. This must be done by a certain point on the access rail to allow the RUF system to adjust incoming and exchanging traffic flow to ensure smooth and fast transition onto the RUF rail system. Once the final destination is entered and the ruf has successfully transitioned onto the access rail, the RUF rail drive system will be checked. The ruf will also have to be able to use the road wheels for propulsion in case the RUF rail drive system is faulty. Testing of the RUF rail drive system can be done using a pressure and propulsion test between the transition from normal road to raised RUF rail system. If the RUF rail drive system is functioning correctly the ruf will continue to be guided and integrated into the correct flow of traffic via the switch. If either the user has not inputted the final destination or the RUF rail drive system is faulty the ruf will be guided onto and off the switch by the RUF system.

After the ruf is guided off of the switch the user will be given a signal to answer to ensure ability to regain control of ruf. If the user fails to answer the signal then the RUF system could guide the ruf into a safety turn off parking area. If user continues to ignore signal then authorities could be contacted to check on user. If the user responds to the signal to regain control, the RUF system will allow function back to the user controls. The ruf is then ready for normal road use. If the user has successfully entered the RUF rail system the RUF system will determine the most efficient route to achieve the final destination. If during the course of the travel the RUF user decides to change the final destination, the RUF system will recalculate best route and guide the ruf accordingly. When the ruf reaches the junction closest to final destination exit procedure is the same as mentioned before. An example of the flowchart created can be found in APPENDIX A5.

3.5 Responsibility Matrix

The purpose of the responsibility matrix is to ensure division of work among the team members, and is another organizational tool used to ensure group success. Along the left vertical axis there are descriptions of the work needed to be done. Along the top horizontal axis is each of the group member's names. This type of document in important because it allows the team to know what is expected of each member can put effort forth to make a contribution to the success of the project. Responsibility is given to one or all of the group members, and designation with the letter "R" for responsible. Those members that will support the responsible person or persons are designated with the letter "S" for supporting. Below in TABLE 3.1 is the example of the responsibility matrix used. It can be noted that as the project develops this matrix is a living document and can be modified to show the different needs of the group as well as the changing desires of each group member.

Team Members	Katie	Christian	Hendrik	Beau	Hubert
Work Breakdown Structure					
Planning / Organization			S		R
Documentation				R	S
Literature/Internet/ Expert Research	S	S	S	R	S
Measurements (Jarmers Plads)	S	S	S	S	S
Civil Engineering Research	R	S			
Economics Research		S	R		
Define Junction and Details	R	R	R	R	R
Dimension of the Junction	R	R	R	R	R
Create 3D Model	S			S	R
Create Physical Model	S	R	S	S	S
Calculations / Budget	S	S	R		S
Final Report	R	R	R	R	R

TABLE 3.1: Responsibility Matrix

R = Responsible **S** = Supporter

3.6 Gantt Chart

The Gantt chart was created to show as accurately as possible the timeline for the project that the team will attempt to follow. This schedule of the project is broken into many different parts. After each part of the project a milestone was set. Milestones are bigger check points that allow for easier and better supervision of the progress of the project. Furthermore all resources of the team are visible in the Gantt chart.

The project has been divided into these different parts:

- Literature / Internet / Experts research and Measurements of Jarmers Plads
- Brainstorming / Ideas / Solutions
- Define junction:
    - Define entering building
    - Define the access rail
    - Define on/off and crossing junction switch
    - Define the crossing junction
- Rank the solutions
- Dimension of the best solution
- Create 3D model
- Create physical model

The Gantt chart can be found in APPENDIX A6. This is a living document and has been modified through the duration of this project. The version shown is the latest version that most accurately describes the timeline the team followed.

3.7 Research

3.7.1 Rapid Transportation

Research was carried out on different transportation systems and technologies. This research was used to fuel ideas as well as confirm idea possibilities. There was a wide range of research carried out to help the team understand which direction transportation is heading. Some research was useful and others confirmed the team's questions. This following section will go through the different research done and how it contributed to the project.

Research on rapid transportation was done to better understand the direction that transportation is heading. "Rapid transport is a bus-based system that will enhance the public transport network to cater for increasing travel demand around the city. Rapid Transport will work alongside other modes of public transport including buses, rail and taxis to give residents and visitors more environmentally friendly, fast and safe travel options. By increasing the alternative options to private vehicles, and utilising environmentally friendly vehicles, it also offers environmental benefits. " (Palle Jensen, RUF International)

"Personal Rapid Transit-PRT is a system of small vehicles under independent or semi-independent automatic control, running on fixed guide ways. The idea attempts to address a number of perceived weaknesses of public mass transit including fixed timetabling, limited routes, and sharing travel space with unrelated travelers." (http://www.brighton-hove.gov.uk/index.cfm?request=c1146307)

PRT has some of the following characteristics:

- Fully automated vehicles capable of operation without human drivers
- Vehicles captive to a reserved guide way
- Small guide ways that can be located aboveground, at ground level or underground
- Vehicles able to use all guide ways and stations on a fully coupled PRT network
- Direct origin to destination service, without a necessity to transfer or stop at intervening stations

An example of a PRT system is ULTra. Although there are no commercial productions of ULTra a project is under construction at London's Heathrow Airport with an opening date of 2008. It was the hope that by researching ULTra it would provide insight into how a junction was implemented into the system. Unfortunately, ULTra uses small rubber tires on a road-like guide way and intersections are very similar to normal vehicle intersections. This did not help in figuring out how a railed vehicle junction would look. One beneficial idea conceived from this research was to use for the most part off-the-shelf items and technologies to reduce the research and development costs. This ideal will be used wherever possible. An example of an ULTra vehicle on its track can be seen below in FIGURE 3.1.

FIGURE 3.1: ULTra Transportation System

http://www.atsltd.co.uk/images/pics/13.jpg

3.7.2 Eurotunnel

As the idea to use a magnetic field to control rufs is being integrated into the junction design, a real-life application of this technology was thought to be good to find. Similar electronic guidance systems were found to be used in the Eurotunnel that connect Paris and London. There are service vehicles used in the service tunnel that can be manually controlled or electronically controlled. Because of the close quarters in the tunnel, service vehicles go under automated guidance as they pass by each other to ensure safety. The technology has been proven to be successfully used. FIGURE 3.2 shows these service vehicles in operation.

FIGURE 3.2: Eurotunnel Service Vehicles

http://des-srl.net/ukc.pdf

3.7.3 Tri Track

Another Dual-Mode system researched was called Tri Track from Austin, Texas in the USA. It has some similarities to RUF because it primarily uses a raised monorail guide way system to travel as well as road wheels, but provided little guidance for how to solve the problem of rails intersecting and changing directions. As seen in the quote below, this system has decided to avoid an intersection all together and have the vehicles leave the rail and drive with normal traffic to another rail going in the desired direction.

"A computer advises the driver of the best path to take, and the driver then decides whether to follow that route or not. The only merging is on the ground, and you have to come down to the ground to make turns." (http://www.tritrack.net/grid.html)

With the RUF system, an attempt will be made to allow directional changes without leaving the rail. You can see below in FIGURE 3.3 that as Tri Track rails intersect they do not have the ability to change directions.

FIGURE 3.3: Tri Track Dual-Mode System

http://www.tritrack.net/gallery.pdf

3.7.4 MAGLEV

MAGLEV is a system that stands for magnetic levitation. This new technology suspends, guides and propels the train. Unlike classic trains, the MAGLEV does not have contact with rails. This method minimizes frictions so this train can reach higher speeds than a wheeled one. It allowed a railed train in Japan to reach 581 km/h, that is to say 6 km/h higher than the conventional TGV speed record. Although this project is not using magnetic levitation technology, it was still beneficial to see that the use of magnetic technologies is advancing, and the possibility of a magnetic guidance system seems more realistic. Seen below in FIGURE 3.4 is an example of the MAGLEV train.

FIGURE 3.4: MAGLEV Train

http://en.wikipedia.org/wiki/Image:JR-Maglev-MLX01-2.jpg

3.7.5 Other Crossing Junctions

In order to ensure the success of the project, the decision was made to improve and enhance the groups' knowledge of currently implemented intersections from around the world. Transportation and traffic junctions in USA and Europe were researched. Each member researched how intersection problems were solved in their home countries of Latvia, Germany, France, and the USA. Also, traffic accounts and traffic statistics, road and bridge construction standards in Denmark were studied.

In Latvia, the Dienvidu tilts (Southern bridge) that is being built over river Daugava at the moment, has one of the most sophisticated traffic junction systems in the country. Dienvidu tilts is expected to relieve Riga's traffic problems. A complex multi-level traffic junction system made of reinforced concrete will be installed on both ends of the bridge to ensure better traffic flow. An example of this junction can be seen below in FIGURE 3.5.

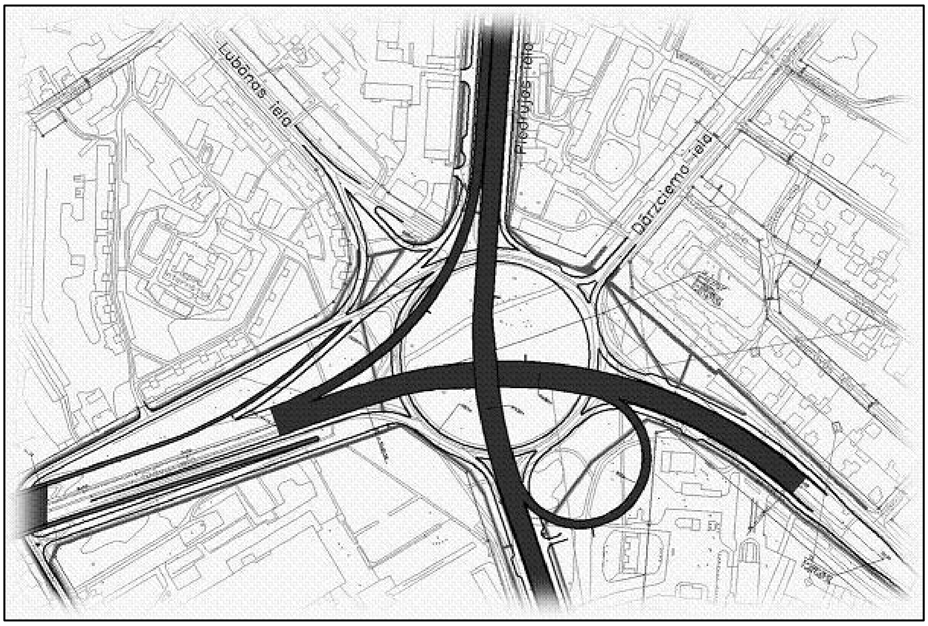


FIGURE 3.5: Riga, Latvia Southern Bridge Plan

http://www.rdpad.lv/uploads/dienvidu%20tilts/pic%20(5).jpg

The USA has some of the worst traffic congestion in the world and thus is forced to design and use various traffic junction systems such as cloverleaf, partial cloverleaf, collector/distributor roads, semi-directional ramps, 'braiding' loop ramps and many others. It makes USA one of the leading countries of the world in this field. There are plenty of possible solutions to traffic junction systems and each of them has its own pros and cons. Below is an example of a cloverleaf junction found in the USA in FIGURE 3.6. This picture is useful to get an idea of how the roads are packaged together, and how the question of going from one direction to all directions is answered.

FIGURE 3.6: Cloverleaf Junction, Raleigh, North Carolina, USA

http://www.googleearth.com

In Germany a roundabout interchange is the most used frequently used traffic junction system. It is relatively cheap to build and has proven to be able to handle large volumes of traffic. It has the ability to be modified easily and with a little practice becomes simple to navigate. An example of this type of roundabout junction can be seen below in FIGURE 3.7. The roundabout idea is a good idea that is explained more in depth in the next chapter.

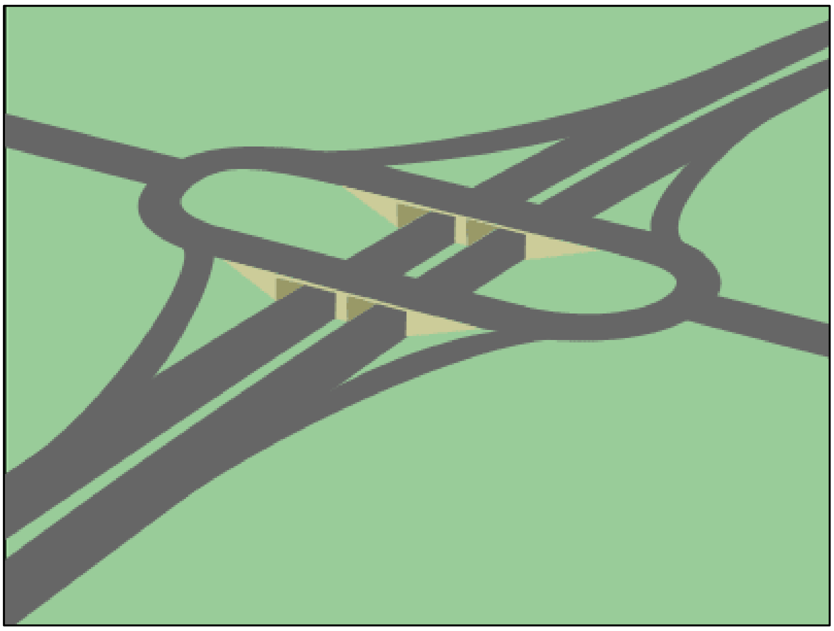


FIGURE 3.7: Roundabout Interchange Model

http://www.cbrd.co.uk/reference/interchanges/roundabout.shtml

Paris is a town with very special traffic flow. It has 26 million cars a day on its roads and has a high potential of traffic congestion. To minimize this phenomenon, a lot of junctions with red light signalization are installed. In this way, each branch of the junction can across in turn. Plus, the crossing period can be adapted to the junction flow to account for rush hours. The most common junctions have a cross form but are easily adaptable with a road's configuration. An example of a classic junction with red light can be seen in the FIGURE 3.8 with its different turning possibilities.

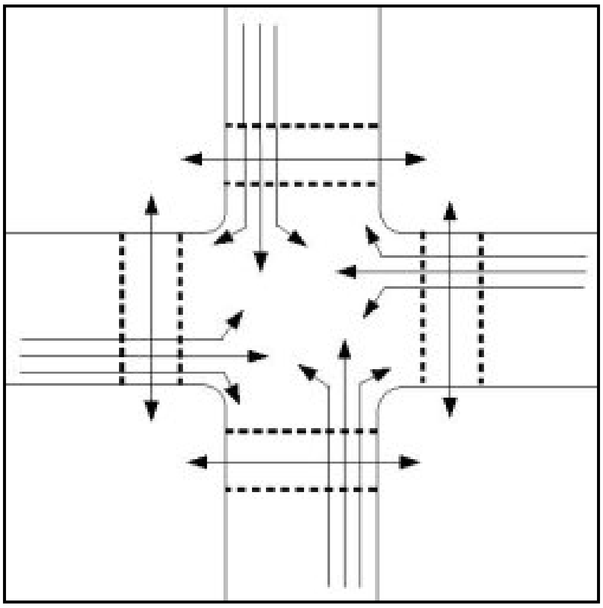


FIGURE 3.8: Crossing Junction with Red Lights

http://fr.wikipedia.org/wiki/Image:Carrefour_16_mouvements.jpg

3.8 Conclusion

As previously mentioned the project planning has helped the team to maximize its final results by getting a jumpstart with other existing ideas. Although the research has not answered all questions, it has provided a foundation for the work done in this publication. Some of this research has been very helpful and will be used as guidance for development of the RUF junction. Other research has confirmed some doubts and left questioned still to be answered.

CHAPTER 4: RUF Junction Ideas

4.1 Introduction

In this chapter, different types and design ideas of the RUF junctions are presented. Sketches are shown and described to relate advantages and disadvantages about each design. After initial ideas were ranked, a final solution was pursued. This choice was made using a decision matrix weighting technique to understand the strengths and weaknesses of each idea. A brief description of each of the ideas and their sketches will be presented. These ideas will naturally progress from the simplest idea to more complicated ideas. Factors such as number of levels, rail to road and road to rail transitions, capacity and size will be noted and taken into consideration when choosing a final design. It should also be mentioned that designs that include rufs driving on rail are considered safer, and designs with the least amount of transitions from road to rail and rail to road are more desirable. The number of levels that a RUF junction has is also important. This is because the fewer levels needed the more visually acceptable it would be.

It should also be noted that the crossing junction sketches do not include the placement of switches. It can be assumed that switches will be placed in a similar fashion as those in Chapter 2. Colors and lines will be used to describe different levels and directions the rufs will travel to help the reader better understand the 3D nature of the 2D sketches. These colors and what they represent are shown below in TABLE 4.1.

→	RUF Travel Direction
(grey)	Road Surface on 1st Level
- - - - - - (yellow on grey)	Magnetic Guidance Field
(orange)	Ground Level of RUF Rail
(red)	1st Level of RUF Rail
(green)	2nd Level of RUF Rail
(light blue)	3rd Level of RUF Rail

TABLE 4.1: Sketch Key

4.2 Description of Junction Sketches

4.2.1 Crossing Junction #1

Crossing junction #1, in FIGURE 4.1, shows the most basic form of intersection for rufs. This junction resembles a normal street crossing. It would be a raised platform that covers a normal road intersection. However, the rufs that entered this junction would be under complete automation. The capacity of this style of junction could be greater than that of a normal stop and go street junction because of the automatic control. Rufs would be able to pass very closely to one another under complete safety and control of the RUF system. With a constant motion and no stopping, this could increase capacity. There would be only two changes from rail to road, and back again. This is good because it is thought that the changing from rail to road and road to rail would be slightly agitating. Its overall small size is also desirable for easy implementation into already existing street intersections.

On the other hand, the close passing of rufs could cause the users to be scared when they are driving through a junction where other cars are passing nearby. One way to help users feel safer would be to create trains. Trains are rufs that are linked together and traveling in the same direction. Being part of a whole train would increase efficiency and could give the user a sense of safety. Due to the possibility of bad weather, the road part of this junction would have to be covered to ensure the RUF systems ability to control the rufs safely.

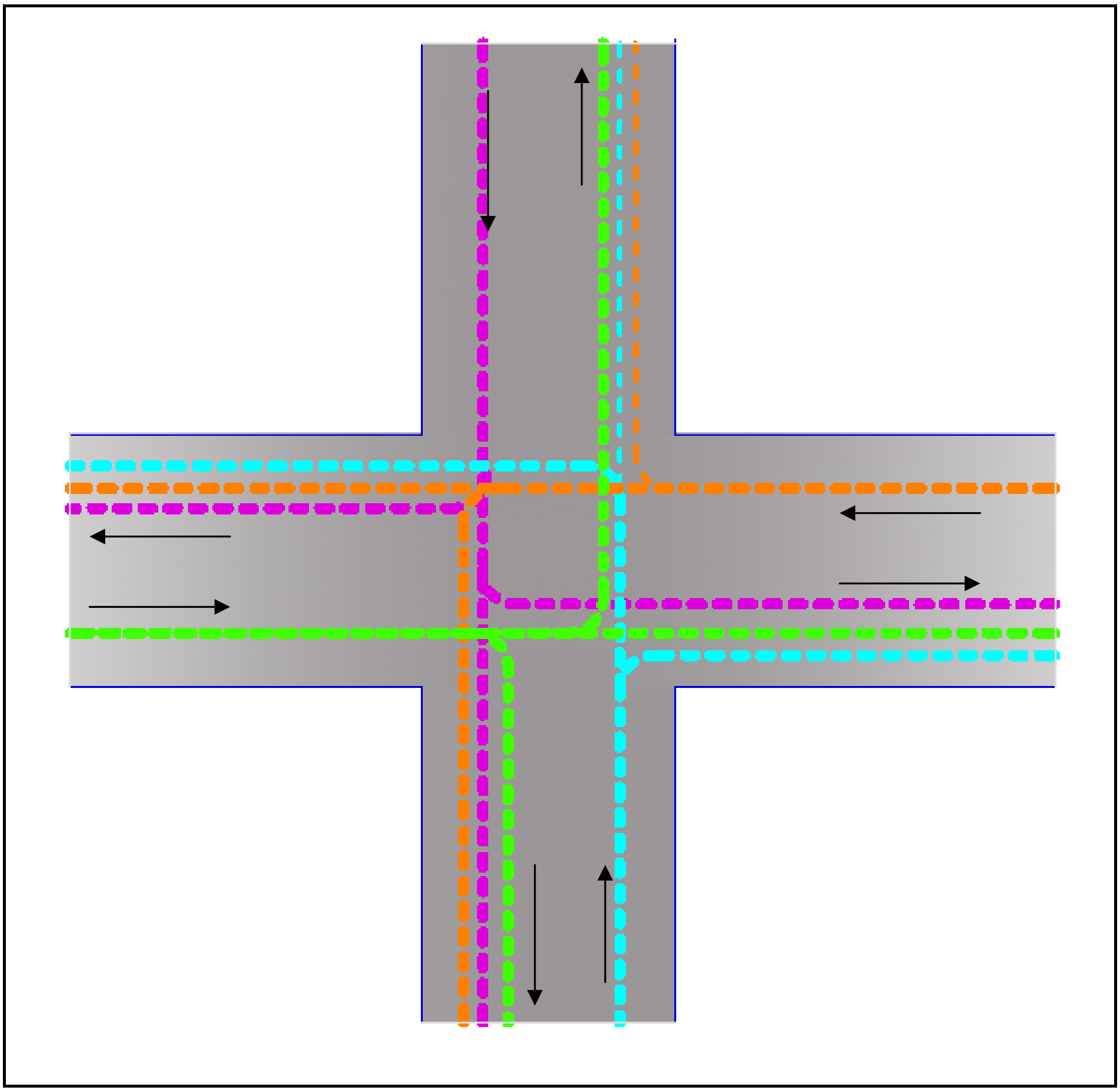


FIGURE 4.1: Crossing Junction #1

4.2.2 Crossing Junction #2

This junction represents another very simple road junction. Same as the previous it would be placed above the normal road intersection, and would need to be covered to ensure safe operation. Instead of two streets perpendicularly intersecting, a roundabout junction is created. All the rufs that enter the junction from their respective switches would enter the roundabout. After entering the roundabout the ruf would continue on in a circular path till it reached the direction that it wanted to go and would be guided in that direction.

This design is advantageous because it is fairly small in size and could easily fit above an existing normal road intersection. It is also only on one level which is desirable. The switches that surround the junction would be of a smaller size also because there is only need for switching to either the roundabout or the egress road. Unfortunately, the capacity of this style of junction is thought to be lower than what would be ideal. FIGURE 4.2 shows the roundabout design with arrows to signify direction of traffic flow.

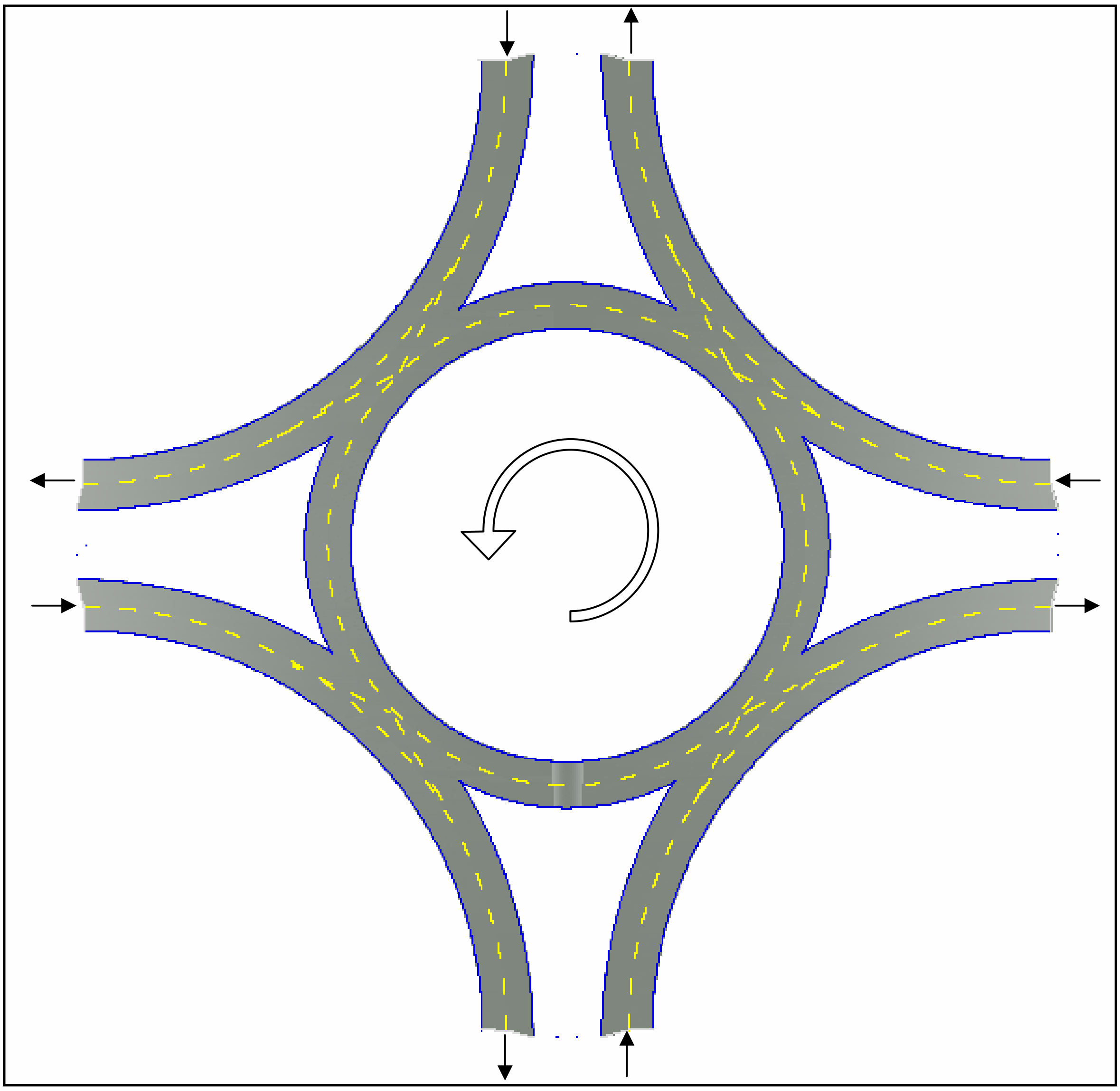


FIGURE 4.2: Crossing Junction #2

4.2.3 Crossing Junction #3

This junction is similar to crossing junction #2 in that its design is based around a roundabout. The difference is that the rufs that want to travel straight use an entirely separate rail from the roundabout. This is better than crossing junction #2 because RUF users that want to continue on straight through the junction can now do so without having to deal with going through a roundabout. It should be noted that the two directions of straight going rails would cross at different levels. If the roundabout is considered level 1, then the two straight going rails would cross at levels 2 and 3. However, if there were room below the roundabout platform, say in the middle of a roundabout on the ground, then the 3rd level of rail could drop down below the 2nd level of rail and decrease the overall height. The lower the overall height the better the design is considered.

This design allows rufs from different directions to merge together at two points if they are going to be traveling in the same direction. The first is on the switch and the second is on the roundabout. The roundabout would be used by rufs that want to travel left from their original direction. If a right turn is wanted, then the rufs would just follow the road going to the right with no need to enter the roundabout. This seems better because each direction has its own road or rail to travel, seemingly increasing capacity.

A big advantage of this junction is the size. It is not bigger than crossing junction #2 but may be able to handle more rufs more efficiently because it takes the straight going traffic out of the roundabout. It should be mentioned that if a ruf is going to turn while on rail that it needs a minimum radius of 26 meters to allow for the current design of rufs to be able to navigate it. By using road to do the turning, the size is reduced because a ruf can turn with a smaller turning radius when using road wheels. Also, the rufs that are going right or left only have to get of and back on a rail only once which is considered good.

Similar to the previous two crossing junction ideas, the road section of crossing junction #3 would have to be covered to protect it from weather. Also, the switch needed for this type of junction would be a little larger because of the need to navigate to the straight going rail, the roundabout and the egress road. FIGURE 4.3 shows crossing junction #3 with three levels, and arrows signifying ruf travel direction.

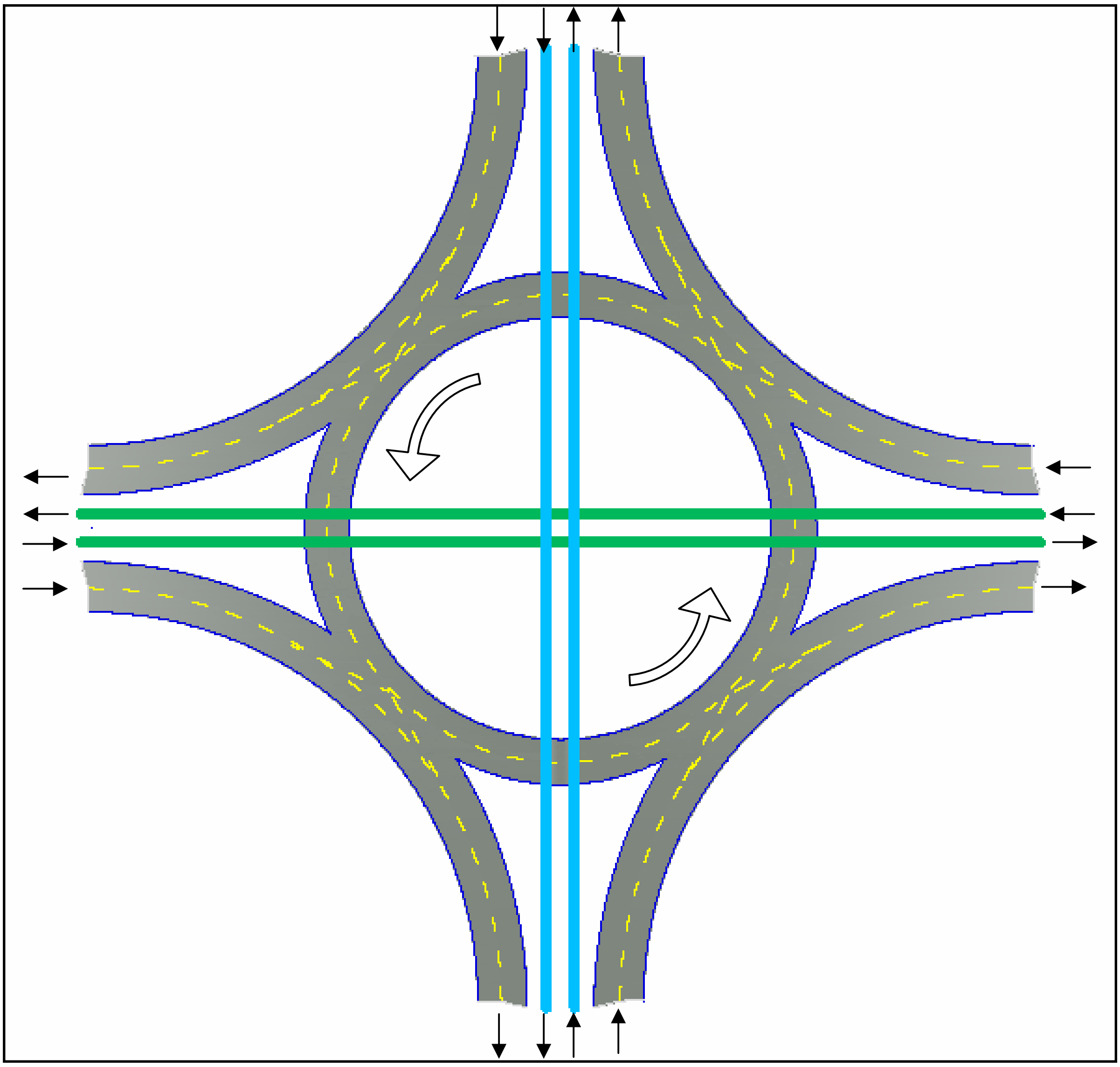


FIGURE 4.3: Crossing Junction #3

4.2.4 Crossing Junction #4

Crossing junction #4 is really just a slightly modified version of crossing junction #3. It has a mix of road and rail. The main difference between this junction and the previous is the addition of a completely separate rail for the right going rufs. This leaves only the left going rufs to use the roundabout. This addition of rail, on the same level as the roundabout, would seem to also increase the capacity of the junction which is good. However it also increases the size of the switch because of the need to get to the straight going rail, the left going roundabout, the right going rail, and the egress road. There is a drawback to adding another rail. This means that only the left going rufs are subject to just one off and on rail experience. Both straight and right going rufs must get off the rail and back on the rail at least twice to navigate this junction.

The sketch of crossing junction #4 as seen in FIGURE 4.4 may be a little deceiving. Because it is not dimensioned, it is unsure if the right going rail and the roundabout would have the same radiuses. As mentioned before any turning that is done on the rail has to have a minimum turning radius of 26 meters. The addition of the right going rail means that this rail has to have a minimum radius of 26 meters. This constraint could possibly make the size of this junction bigger than previously described junctions. This becomes the tradeoff that needs to be taken into consideration. As with previously described junctions, the road would have to be covered. With the addition of more rail though, the need for covering is gone. Rufs traveling on the rail could be considered 100% safe from colliding with another ruf. There may be another advantage to this design, because the rufs have separate paths for each direction, traffic flow could be sped up or slowed down more precisely to allow the RUF system to organize rufs in a more efficient way. This organization of rufs may be good because all traffic eventually has to be collected onto a single switch which, if not designed and controlled correctly, could lead to inefficient traffic flow and backups.

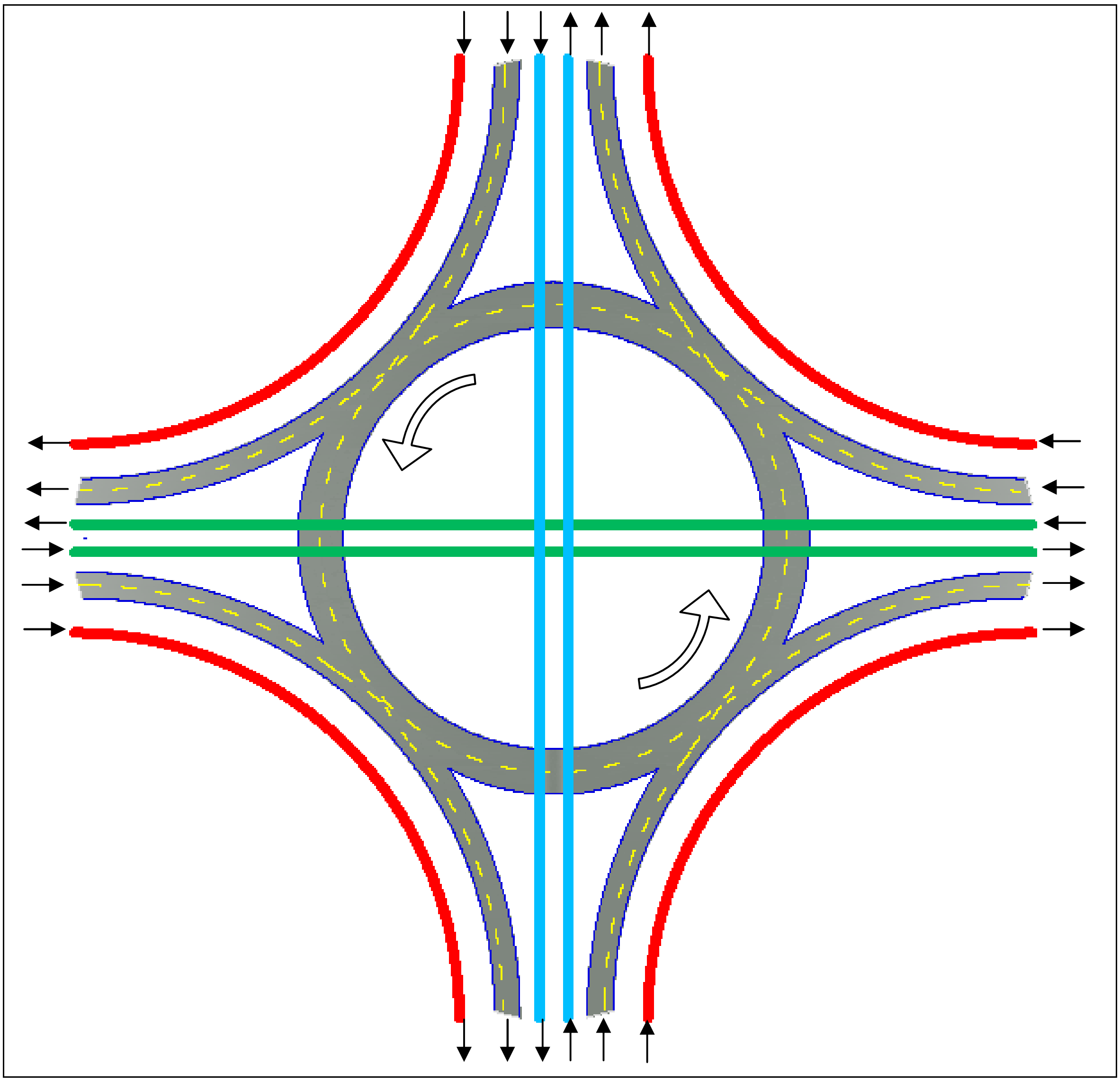


FIGURE 4.4: Crossing Junction #4

4.2.5 Crossing Junction #5

This junction is completely different from previously described junctions because it consists only of rails. This eliminates the need to cover anything in the junction, and means rufs are 100% safe. This also means there are two road and rail transitions for rufs traveling in any direction. This could be considered a drawback.

To implement this, a big roundabout for the existing ground traffic is needed. This is a disadvantage right away because one of the goals was to not disturb normal traffic. One line which goes straight ahead goes down to the bottom of the roundabout, the other rails cross these rails on level 2. All the lines for going right are on level 2. Also two lanes for going left are on the level 1 the other two are on level 2. This can be seen below in FIGURE 4.5 by following the direction arrows.

There are some disadvantages with this design. The biggest is the size. This junction is bigger than the previously described junctions. It would be more of a challenge to implement into an already existing junction. Its size comes from the minimum radius requirements needed to turn on rail, and the length needed to comfortably transition from one level to another

With all these rails, the design has to be careful not to send the user on a rollercoaster-like ride through the junction. Once again, because each directions uses a separate rail, a larger switch would be needed to allow rufs access to left, straight, right directions, as well as access to the egress road.

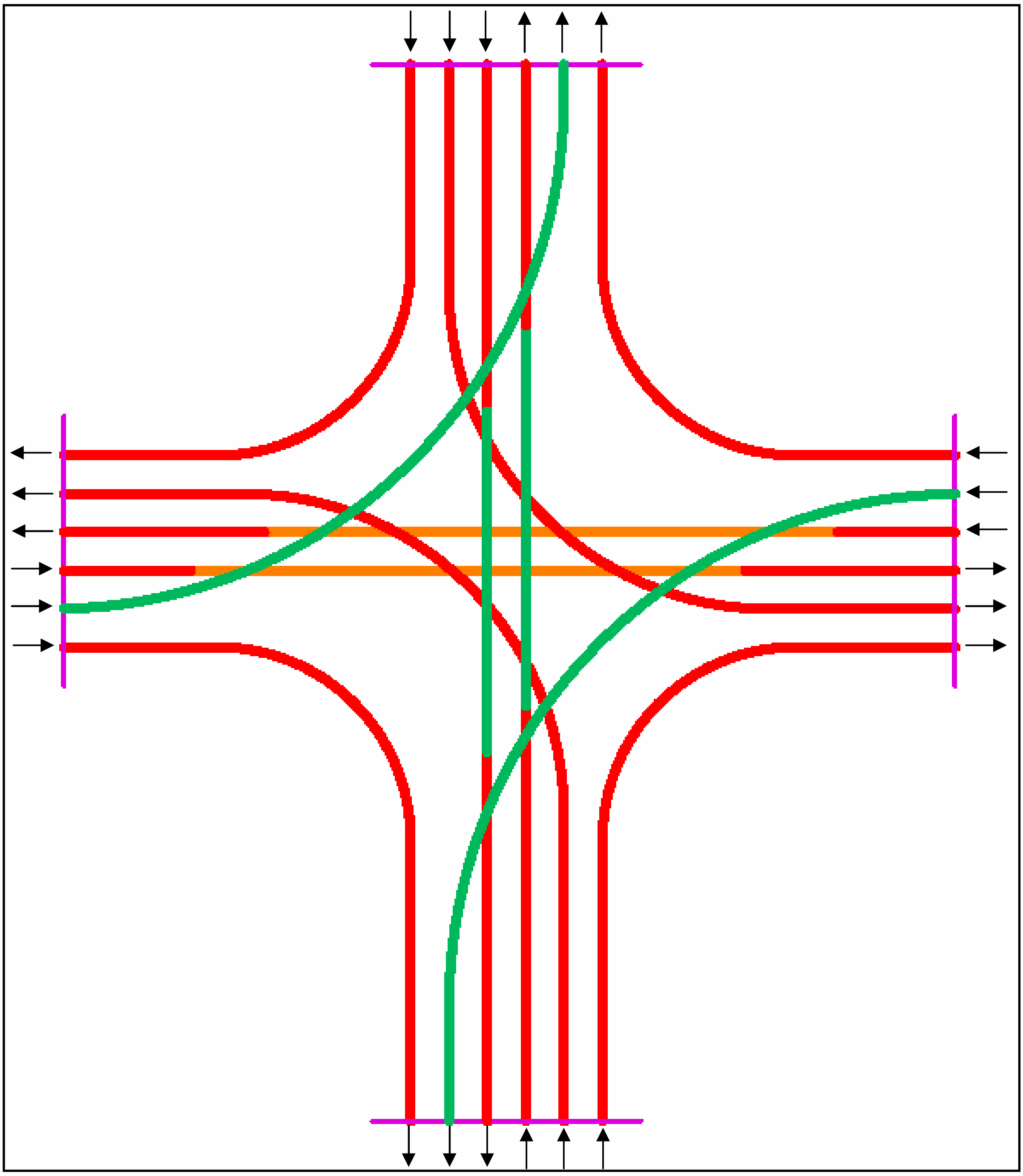


FIGURE 4.5: Crossing Junction #5

4.2.6 Crossing Junction #6

This junction is similar to crossing junction #5. The different from crossing junction #5 is that one straight going rail crosses the other straight going rail on the outside in a curve. Check out FIGURE 4.6 for a better idea. Because of this there is more space in the middle of the junction. So the lanes for going left could be pulled in closer together which makes the whole junction a bit smaller. A disadvantage could be that you have to go up and down while making a turn to the left. This may cause a rollercoaster like feeling talked about earlier.

This junction has the same advantages and disadvantages as crossing junction #5, but in a smaller package. The rufs are completely safe while traveling on the rail, and there is no need for any type of covering. There are however more road to rail transitions than the first three crossing junction designs. There is also increased capacity because each direction has its own traveling path, but there is also the risk of the switch being cluttered if not designed and operated correctly. The switch would be the same size as crossing junction #5 to allow access to the straight going, left going, right going rails and the egress road.

Level 1 would consist of the right going rails and two left going rails. Level 2 would consist of the other two left going rails and one set of straight going rails. The last set of straight going rails is shown to go down to a ground level and would keep the junction at a more desirable two levels. But, this last set of straight going rails could also be put on level 3 if a roundabout for normal traffic is not available.

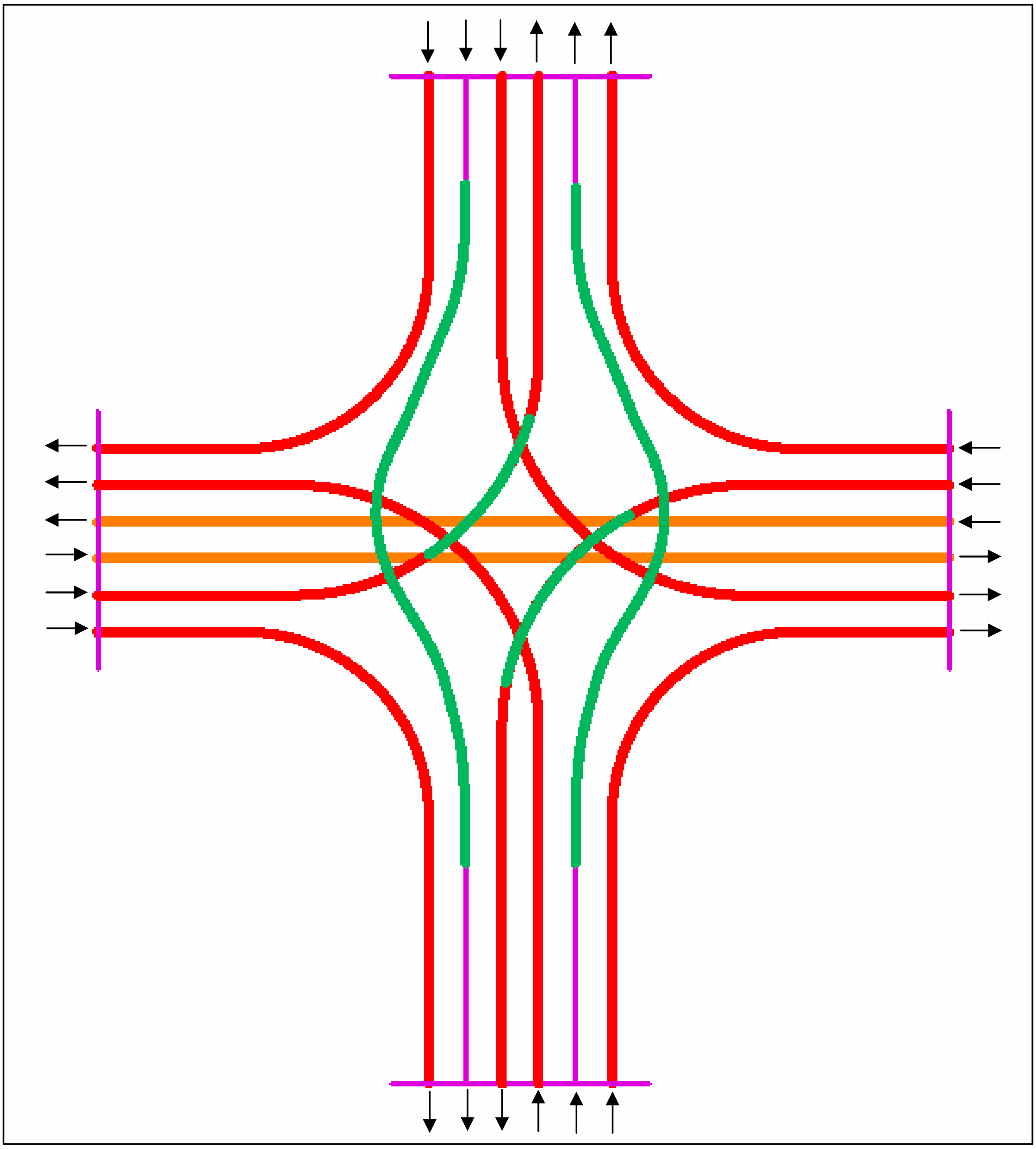


FIGURE 4.6: Crossing Junction #6

4.3 Decision Matrix

To realize which of the previously described crossing junctions would be the best solution, a ranking was made. The junctions were ranked in four categories. The first and most important point was safety for the user. The second point was how realizable the design is. This means how possible would it be to create this junction to fit on Jarmers Plads. The third is the size of the junction. The last category was the amount of levels needed for the junction. These four points come from the goals which were defined in the beginning of the project. Also, a weighting of the different categories was done, and can been seen in the last column of TABLE 4.2.

For the ranking an approximate calculation of the junctions was done. The best solution got received a "5" and the worst would receive a "1". The ranking can be seen in TABLE 4.2.

	Junction 1	Junction 2	Junction 3	Junction 4	Junction 5	Junction 6	Weighting
Safety	1	1	2	3	5	5	0.4
Realizable	5	5	5	5	1	5	0.3
Size	5	4	4	3	1	3	0.15
Level	5	5	2	2	2	2	0.15
Result	**3.4**	**3.25**	**3.2**	**3.45**	**2.75**	**4.25**	1

TABLE 4.2: Decision Matrix

4.4 Conclusion

This chapter has explored some of the ideas for a crossing junction design. The pros and cons of each junction have been described, the good and bad characteristics have been mapped out for any future junction ideas that may come up. In conclusion, a modified version of crossing junction #6 will be explained in detail and dimensioned in the following chapters. The switches and the completed design will also be covered.

CHAPTER 5: Design of a RUF Junction

5.1 Introduction

This chapter is dedicated to providing the basic dimensions of specific switch and junction ideas. The crossing junction that will be pursued is a modified version of crossing junction #6 in Chapter 4. The visual and verbal descriptions will provide the basis for future work. They will also provide an idea of the size of the switches and junctions, as well as providing an idea of the size of the components that make up each. There is also an explanation of why each decision was made as far as the physical dimensions and make up of both the switches and the junctions. The final junction suggestion will be shown in its actual environment on Jarmers Plads intersection in Copenhagen. Also, the flow of this chapter will allow the reader to see the junction be constructed layer by layer, and then show the addition of switches to complete the RUF junction. If there were other questions surrounding a decision being made that were unanswerable, they were noted and discussed in Chapter 6.

5.2 Crossing Junction

To get a good first impression and to be able to visualize how the rails are arranged, the figures on the following two pages were created. Colors with similar consistency to Chapter 4 were used. The color convention is used to help improve the reader's ability see the different levels of rail. FIGURE 5.1 shows the three combined levels from the isometric view. FIGURE 5.2 shows the three combined levels of rail from a top view. FIGURE 5.3 and FIGURE 5.4 show the two different side views of the three levels of rail.

→	RUF Travel Direction
(red line on grey)	Magnetic Guidance Field
(red)	1st Level of RUF Rail
(green)	2nd Level of RUF Rail
(blue)	3rd Level of RUF Rail

TABLE 5.1: Drawing Key

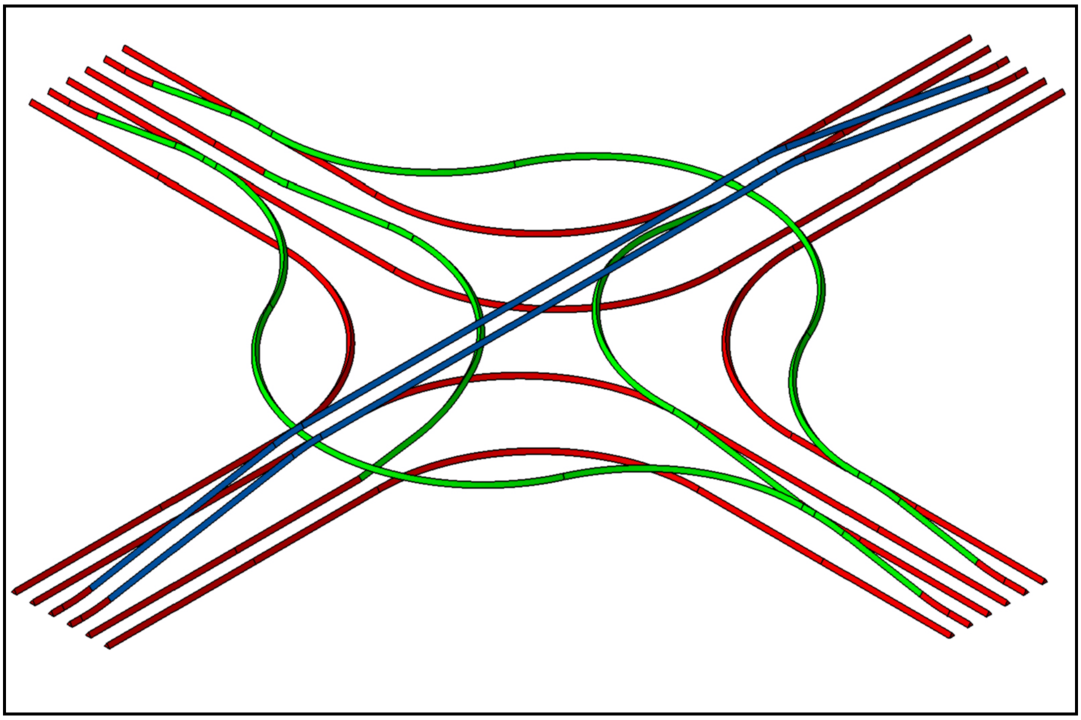


FIGURE 5.1: Isometric View Crossing Junction all Levels

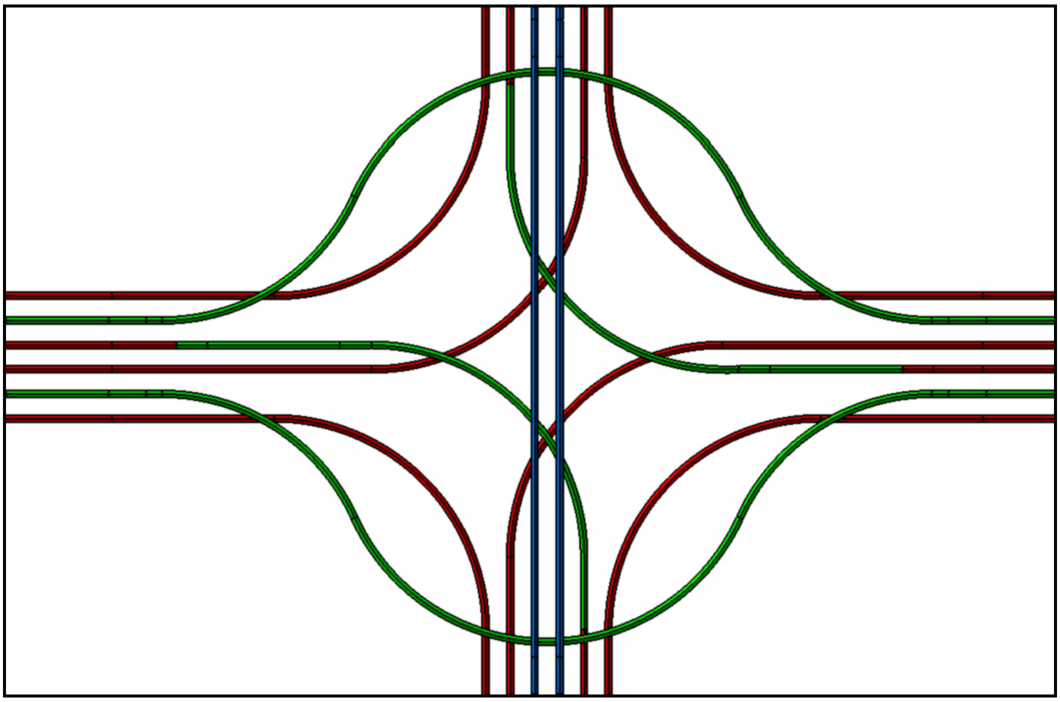


FIGURE 5.2: Top View Crossing Junction all Levels

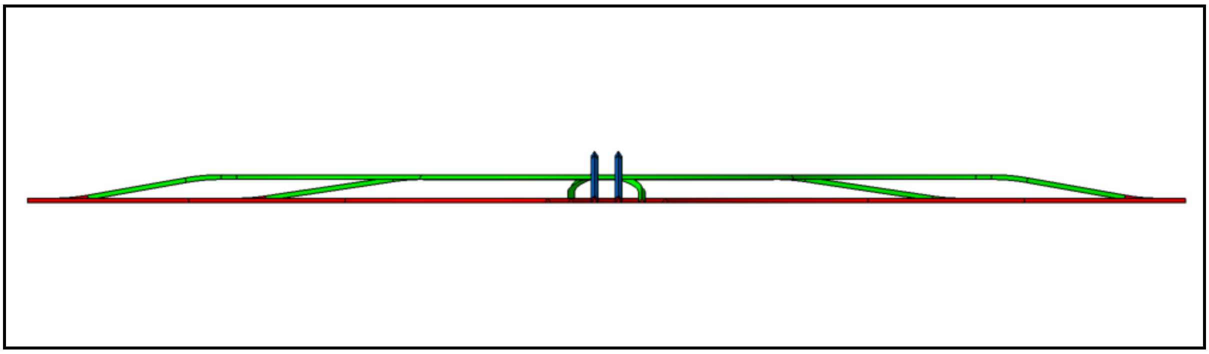
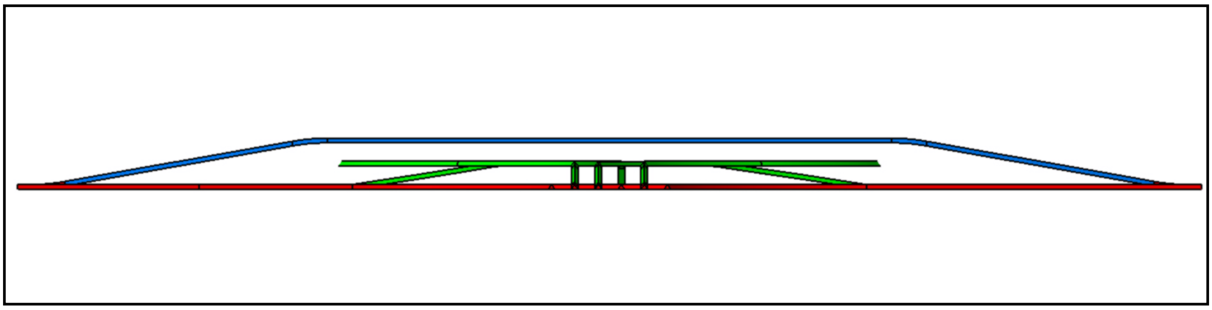


FIGURE 5.3: Side View #1 Crossing Junction all Levels



FIGURES 5.4: Side View #2 Crossing Junction all Levels

5.2.1 Design of Level 1

Level 1 consists of six rails. It has all four rails for turning to the right, and two left going rails. This layout was chosen because it could incorporate the greatest number of rails on the first level. This is advantageous for a couple reasons, including the lower cost associated with building lower levels, smaller overall junction design, and better visual appeal. They are arranged to allow clearance and provide room for the other levels that will be shown and explained in more detail later when the complete junction is put together. The right going rails are designated with a letter "R", while left going rails are designated with a letter "L". Arrows also show directional travel of the rufs on this level. An isometric view of level 1 can be seen in FIGURE 5.5. A radius of 26 meters is used for any turn on the rail. This is the minimum radius that maxi-rufs will be able to navigate. This was a constraining factor throughout the construction of the crossing junction. To minimize the size of the junction this 26 meter radius was used everywhere. Size of the junction could be made smaller if the maxi-rufs were designed to be able to turn on a smaller radius on rail. There may be a drawback with a tighter turning radius though. With the smaller turning radius the speed on the rails may have to be decreased to ensure user comfort. This decision would have to be weighed to best fit the needs of the specific junction. Dimensions of level 1 can be seen in APPENDIX A7.1.

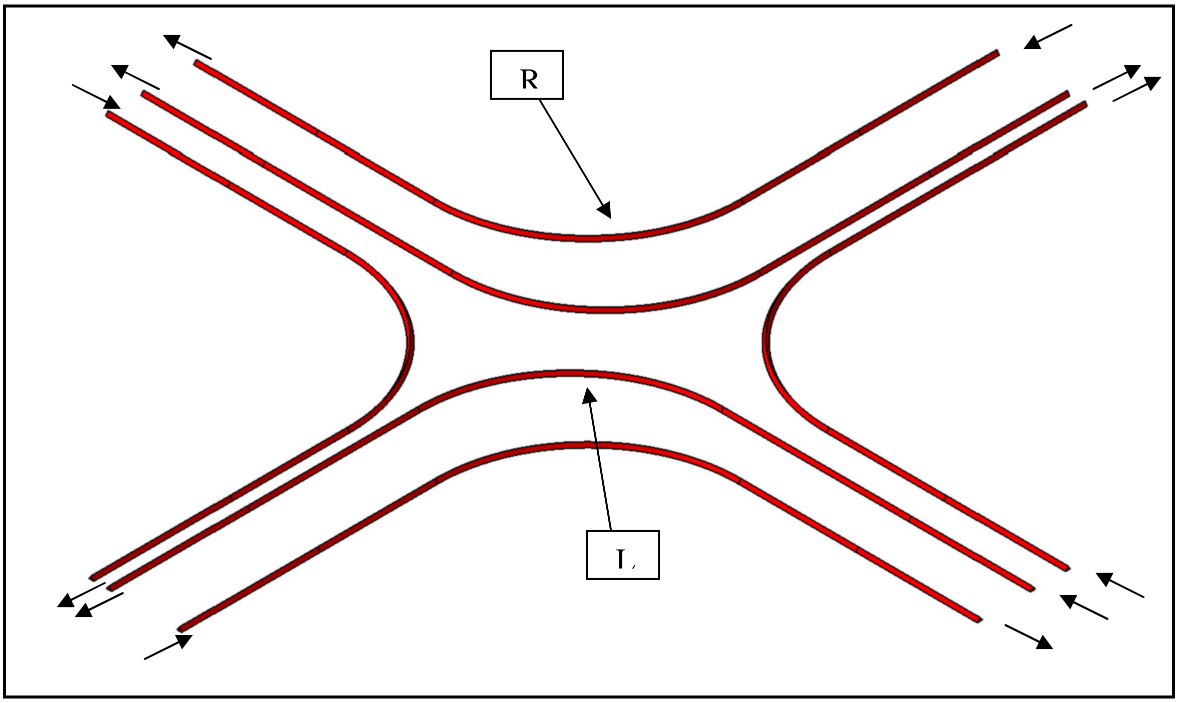


FIGURE 5.5: Isometric View Level #1

5.2.2 Design of Level 2

Level 2 consists of four rails. The remaining two left turning rails marked with the letter “L”, and two of the four straight going rails marked with the letter “S”. An isometric view of level 2 can be seen in FIGURE 5.6. Directions can also be seen. Arrows go to and from the crossing junction switches. These switches will be shown later. To allow for the junction to provide enough clearance for the rufs to travel, the second level is designed to be three meters above level 1. This number was determined to allow a maxi-ruf, if stranded under another rail, to fully open their doors and allow passengers to exit. It should be noted that that distance of three meters is also needed between rails on the same level. If there is a need to exit on the crossing junction it is still undetermined where the passengers will go. The height between the rails could be made smaller if the maxi-rufs door opening design was altered or a complete opening of the door is not necessary.

It can be seen in FIGURE 5.6 that with level 2 there is also a red section where the second level returns to the first level to allow access to the crossing junction switches. The transition from level 1 to level 2 has some constraints. The elevation change was restricted to 10°. This is to ensure comfort for the RUF user. This is a compromise between size of the junction and comfort for the users. A transition radius of 26 meters was used, this however is not a set-in-stone constraint and could be modified. It was determined to be an acceptable radius by the members of this group and its supervisors.

Speed in the junction could possibly be increased if the rails were banked during turning. However, there may be a drawback because it could cause the ride through the junction to be roller coaster like. Speed is beneficial because it allows the rufs to go through the junction faster which is more desirable for the RUF user. The straight going rails in level 2 can be seen bowing out. This is both favorable and unfavorable. It is favorable because this arrangement allows for a crossing junction to be created with three levels. It is unfavorable because the straight going rufs have to experience a non straight travel if they want to go through the junction. If height concern is not a factor then these straight going rails could be moved to level 4 that would allow them to travel straight on their passage through the junction. To better understand the two levels together, FIGURE 5.7 shows the combination of level 1 and level 2 each with their respective colors. Dimensions for level 2 can be seen in APPENDIX A7.2.

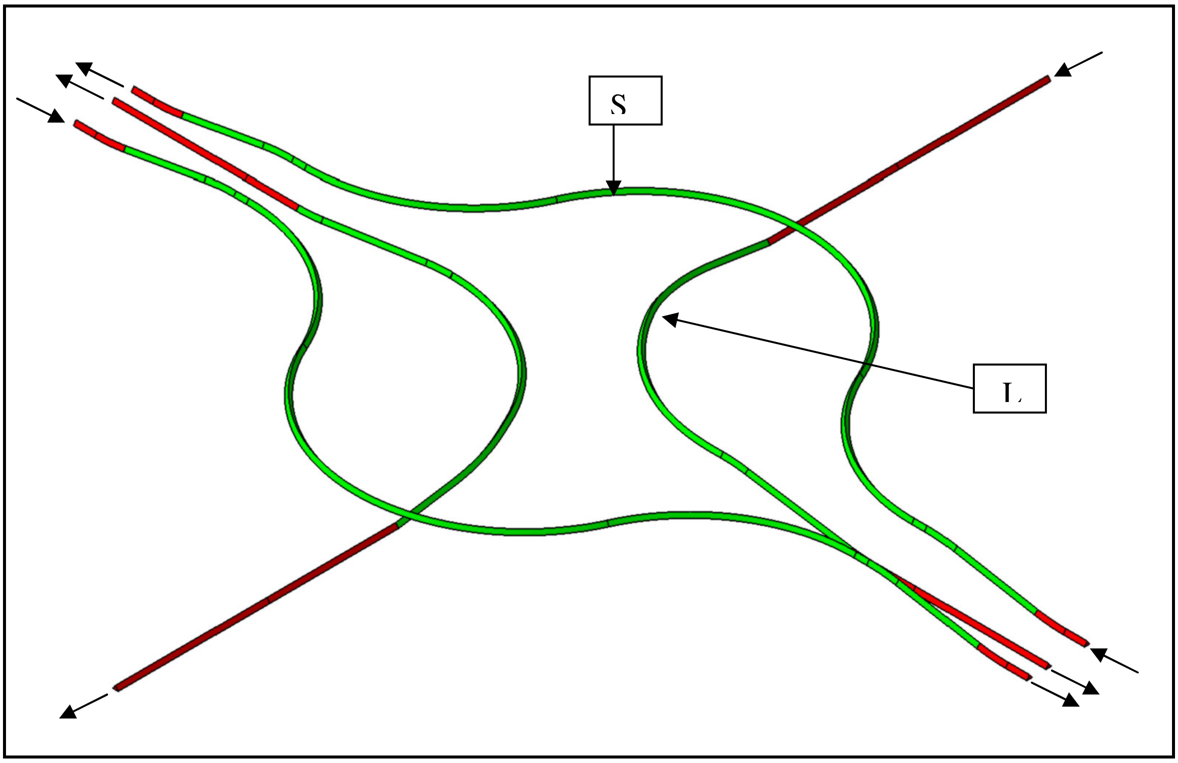


FIGURE 5.6: Isometric View Level #2

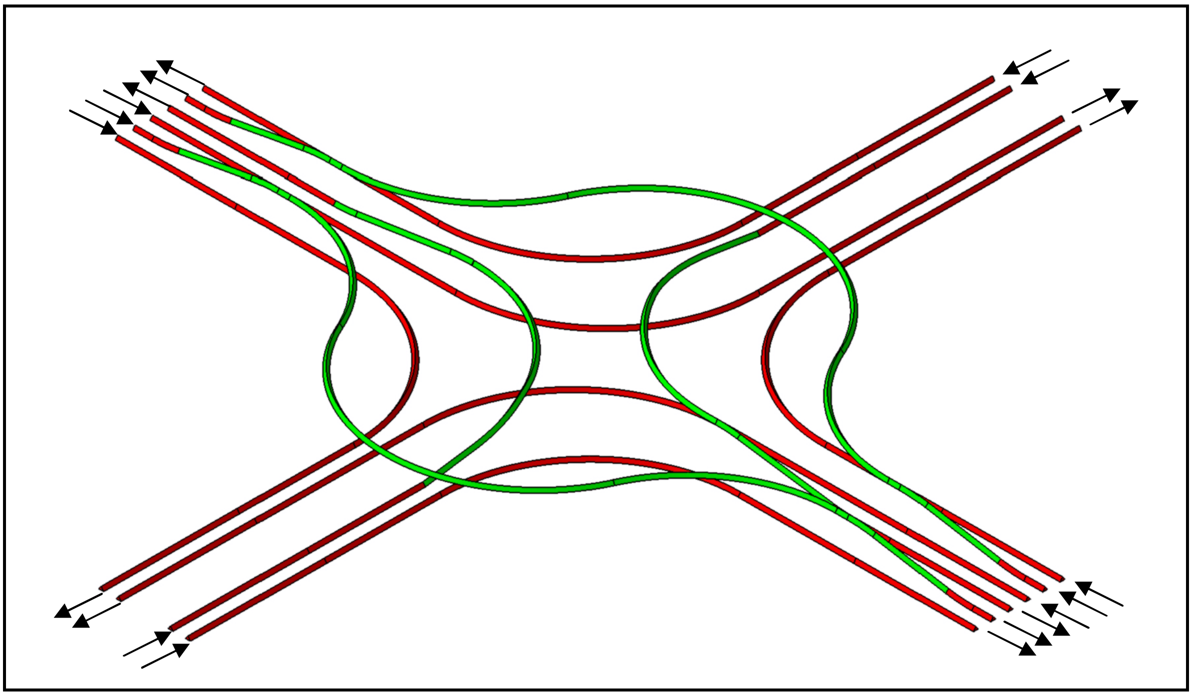


FIGURE 5.7: Isometric View Levels #1 and #2

5.2.3 Design of Level 3

The third level of the RUF junction is the simplest level. The rails just go straight forward and allow the rufs to do the same. It has the same constraints as level 1 and 2 in that it is three meters above level 2, changes elevation at a 10° slope, and has a 26 meter radius change to make elevation changes smooth. These dimensions of level 3 can be found in APPENDIX A7.3. These rails are located three meters apart to allow again for the doors of a maxi-ruf to be useful in the event of an emergency. With these rails an emergency walkway could be suspended between the rails to allow stranded passengers an exit route. This method is not available for the rest of the junction where spacing between the rails is not as uniform. You can also see the change of colors in FIGURE 5.8 from blue to red to signify the change from level 3 back down to level 1 to allow access to the switch. The decision to have this set of straight going rails on a third level instead of going down to the ground level, was made because to go down to the ground level a roundabout for normal road traffic would need to be created. This situation wanted to be avoided. These straight going rails are a better design than the straight going rails in level 2 because the rufs that desire to go straight can simply continue on in a straight path. In level 2 they must make turns to achieve a straight destination. A combination of all levels can be seen in the next section.

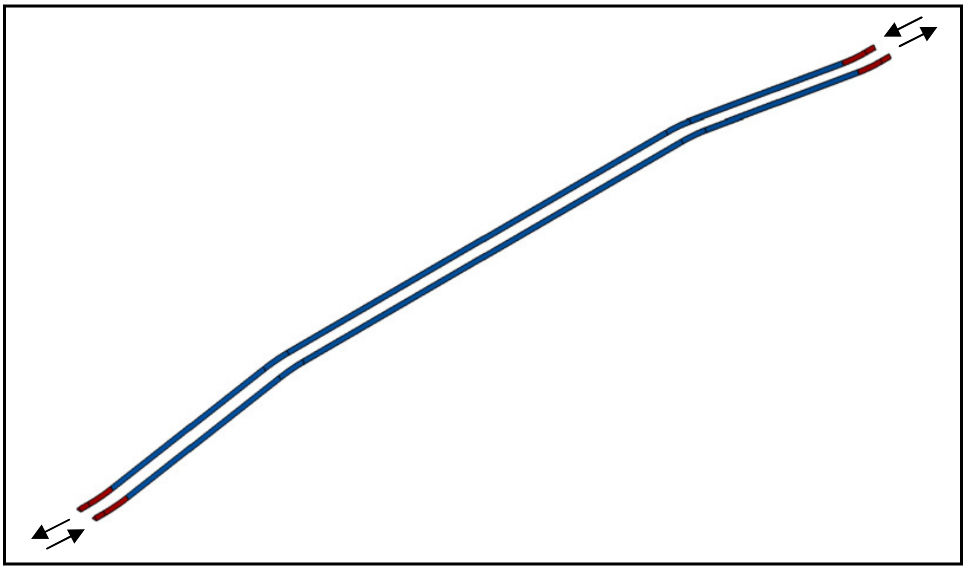


FIGURE 5.8: Isometric View Level #3

5.2.4 Design of Combined Levels

The combined levels of the crossing junction were seen at the beginning of this chapter. A more detailed picture showing the directions of travel for each rail can be seen below in FIGURE 5.9.

For a description of the advantages and disadvantages of this crossing junction please refer to Chapter 4. Because each level has been described in detail, the combination of levels should be fairly clear. When the levels are combined, the greatest diameter of the crossing junction is created by the straight going rails that go to the outsides.

It should be noted that because of the 26 meter turning radius that was used to minimize the size, a speed of 30 km/h is being recommended to keep the lateral G-forces to a minimum when traveling in the junction. The idea of banking the rails came up, but was not officially included in the design or calculated to see if it was even feasible. But if it were, this may allow for the rufs to travel faster between the switches thus cutting down travel time in the junction. If the rufs were to create trains, it would be more efficient. These trains could possibly be built on the rails between the switches.

Throughout the design of this junction, there has been one part that has purposely been left out. That is the placement of the support masts. There were no calculations done on the amount of support needed for the crossing junction designed. It is known that for every 20 meters of straight going rail there would be a need for support. It has been noted in Chapter 6 as to the work that still needs to be carried out and some suggestions for mast designs can also be seen there. With the effort that was put into determining where the mast would go, it can be said that it is a fairly involved process to figure it out.

The crossing junction that was designed is the most ideal junction. It can be seen that it is symmetrical. However, it is known that not every crossing junction is a perfect perpendicular intersection. So there are known limitations to this design because of this. It would be impossible to say that one design of a junction is universal and can be used on every junction. Each real life intersection has characteristics, terrain, buildings and traffic flow that must individually be taken into consideration when a RUF junction is designed.

As mentioned before, FIGURE 5.9 shows a combination of levels 1, 2 and 3 with arrows that show travel direction.

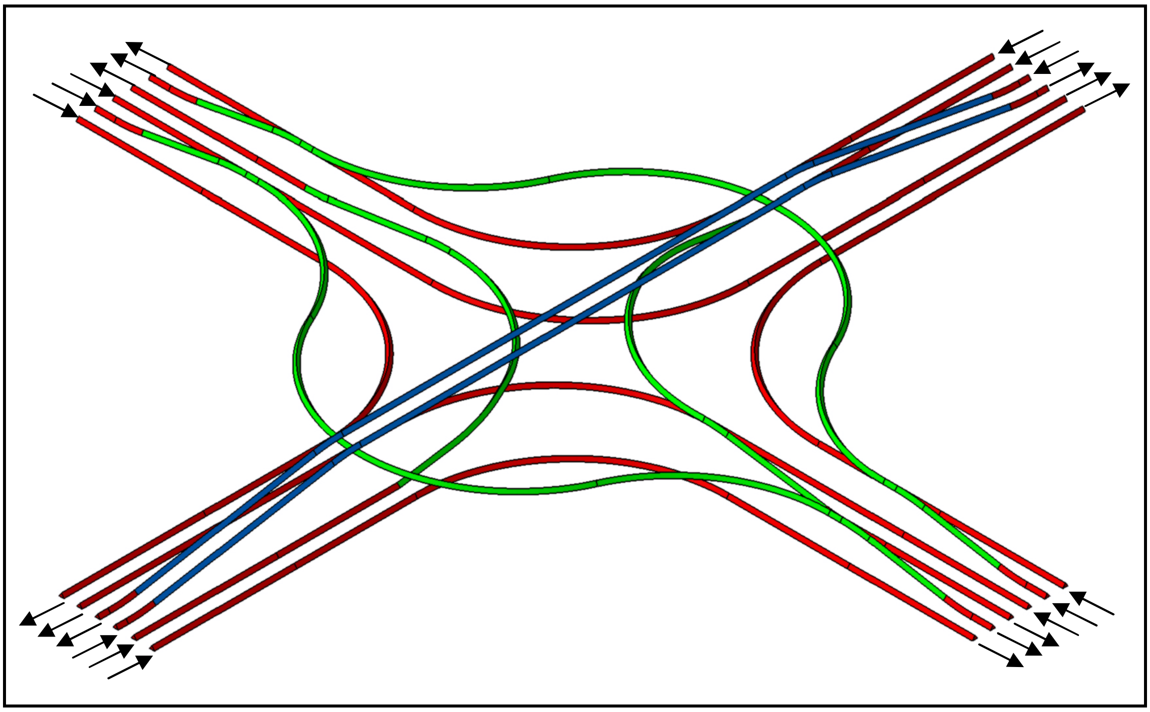


FIGURE 5.9: Isometric View Levels #1, #2 and #3 Combined

5.3 Crossing Junction Switches

This section will build off of Chapter 2 and the switch concept. It will go into the detail as to what needs to be considered when a switch for the crossing junction is build and designed. This section is designated only to the switches that are directly surrounding the crossing junction. An example of the crossing junction switch that was designed can be seen below in FIGURE 5.10. There are a couple of different switch designs for the crossing junction that will be described later, but this specific switch that will be dimensioned is considered a full crossing junction switch, with access rails and egress roads on both sides of the switch.

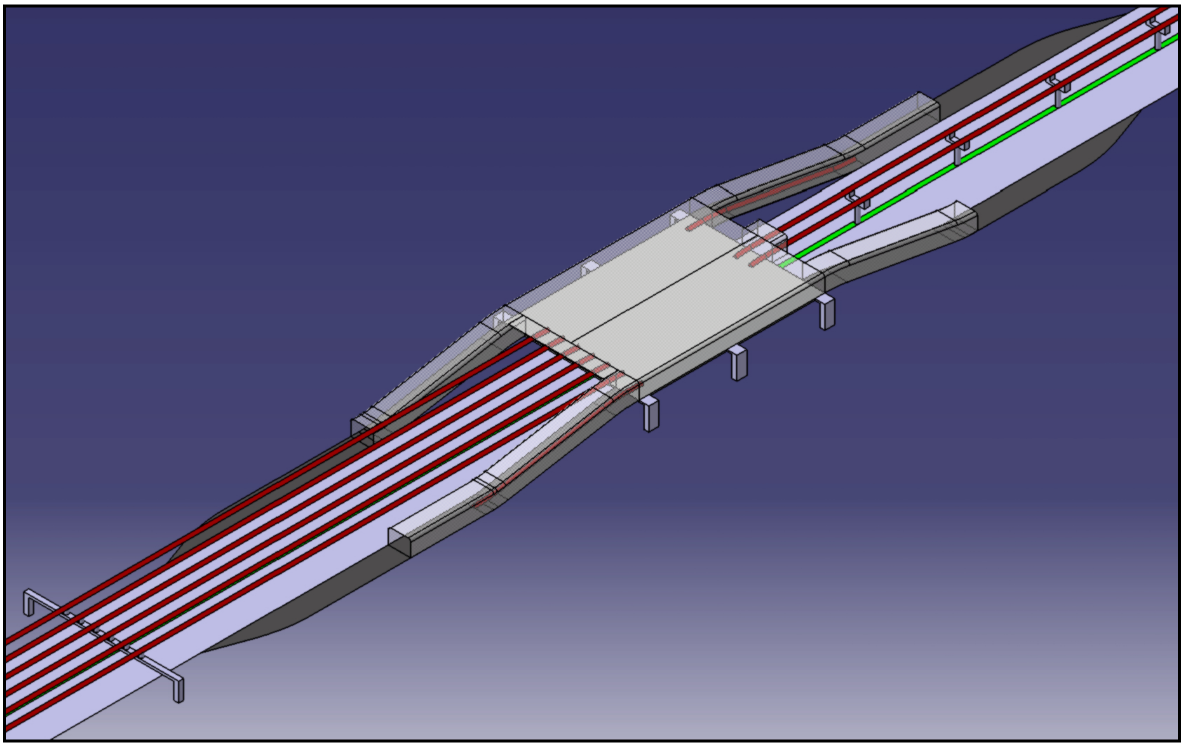


FIGURE 5.10: Isometric View Crossing Junction Full Switch

It was determined that the best place for rufs driving in normal traffic to enter the switch was on the right. This is consistent with the norm for exiting on normal highways and wanted to be used as much as possible. Individual junctions and compromises may not make this possible in all situations. First the rufs would have to leave the normal road and begin to align their approach to the entering building. This is done via the entering road that is represented by the dark gray colored road that goes into the entering building. Sizes of this may vary due to availability of space and nature of the switch. In the city, there is limited space and speeds that are slower than on the highway so this entering road can have a shorter distance. Outside the confines of city driving this road could be longer to accompany the greater speeds and the greater abundance of space. This principle can be applied to the exit road also. The distance needed to achieve proper speed for reentry into normal traffic depends on the settings surrounding the switch, and the distances can be altered accordingly. These distances also depend on the technical given of the rufs and how fast they are able to accelerate. Real life lanes for merging traffic were used as the basis for these dimensions. The actual dimensions of this component can be seen in APPENDIX A8.1.

From the entering road the rufs would then come to the entering building. There were a couple main dimensions that needed to be determined. These included length, width and height. Because the RUF system will be taking over at this point a covering is needed to ensure safe operation even in bad weather. All of these dimensions were kept to as minimal size as possible to allow for easiest implementation. The height of the covering was constrained by the maximum height of the maxi-ruf with its doors open. The doors of the maxi-ruf would only be opened in the event of a stopped emergency, but to ensure that passengers would be able to exit properly complete door function is needed.

It should be noted that all coverings on the switches are shown in the pictures to be transparent and are only 1mm thick. It is understood that an actual covering may not be of these dimensions and is just put there as a representative possibility. Actual covers will need structure and possible lighting to be implemented into their design. These things were taken into consideration when the suggestions for a height are given.

The height that would allow for complete use of maxi-ruf doors and allow for structure and lighting was determined to be 3.2 meters. This height will be consistently used throughout the coverings of all the switches.

Next, the length of the entering building needed to be determined. In this length, as stated previously in the description of the flowchart, rufs have to be able to obtain a speed of 30 km/h when entering the access rail. This means that the entering building has to have enough distance to allow rufs traveling at high rates of speed to be slowed down, and rufs traveling at a low rate of speed to be sped up. After a couple of quick tests to see the slowing and speeding up distances of a normal vehicle, it was settled that the entering building would need a length of 15 meters to allow for rufs to accelerate from 0 to 30 km/h and to slow down comfortably from 50 to 30 km/h. The actual acceleration and deceleration characteristics of the rufs are unknown, so future work needs to be done to figure these out exactly. Once they are specifically known the length of the entering building can be modified.

The width of the entering building is the last constraining dimension needed. Because there are no emergency exit stairs leaving the switch there was enough room designed into the entering buildings width to allow for passengers on foot to exit even when the maxi-rufs doors are completely open. Also, for RUF users to feel comfortable, the width of the entering building needs to be big enough to allow for safe and easy access to the system. A width of 4.5 meters was used when all these criteria are taken into consideration. This width was used to accommodate room for an emergency exit on one side of the rail. Passengers on the side opposite to the extra room for emergency exit still have enough room to exit the ruf and make their way out of the access rail. To get a better look at the height and width of the entering building look at FIGURE 5.11 below. Dimensions of the switch cover can be seen in APPENDIX A8.2.

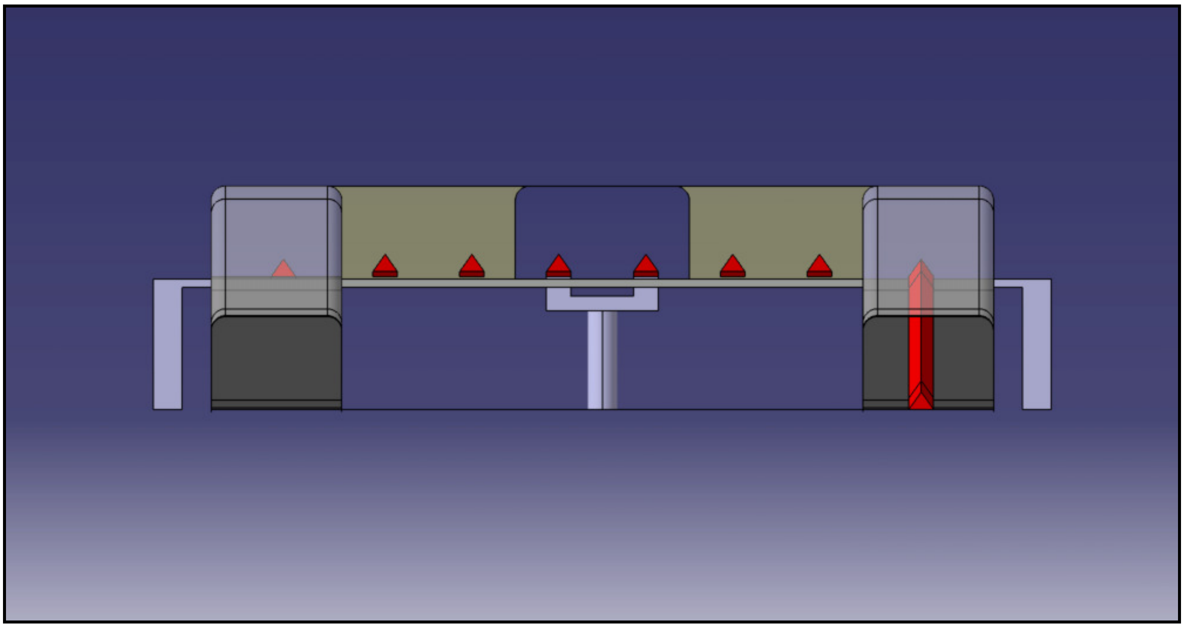


FIGURE 5.11: Front View Crossing Junction Full Switch

The next decision that had to be made was how the access rail would actually be designed to allow for smooth transition from road to rail and allow for both drive systems to be used. This is done in case the rail drive systems function is tested and does not work. Then the normal road wheels would still be functional for propulsion onto the switch platform and off of the junction via the egress road.

The interaction of the access rail with the road will be described next. It was important to design this transition to be as smooth as possible. The rail starts right from the ground to give the approaching user a feel that the transition will be smooth. From the ground, the rail rises above the road 8 cm with a radius of 26 meters to allow for use of both road wheels and rail drive system. When the rail terminates on the switch it just stops at 8 cm about the switch platform.

This 8 cm was measured from the current ruf vehicle model but may be subject to change because there may be differences between the actual production ruf and the one that was measured. The rail and road rise at 10°. The total length of the RUF junction would be greater or lesser if this angle was altered. If the rufs were able to comfortably use a steeper angle than the total length of the RUF junction would decrease. If they needed a less steep angle than the total length would increase. As the incoming rail reaches the switch platform it begins to descend to the surface of the switch platform to allow for full weight to be transferred back to the road wheels. It is important that the rail does not begin its descent until it is already on the switch platform. If the rail were to begin to get closer to the switch platform surface before the wheels of the ruf had cleared the edge of the switch platform then the wheels may hit causing an undesirable impact.

As mentioned earlier there is a need to test the rail drive system. Because this test procedure is undefined the actual distance needed to conduct this test is unknown. It is assumed that the access rail will provide enough distance for this test. All switches are designed that if the rail drive system does not work, the ruf has a straight path from the access rail to the egress road to ensure minimal traffic interruption. To get a better idea of how long the access rail is, look at FIGURE 5.12. Dimensions can be seen in APPENDIX A8.3.

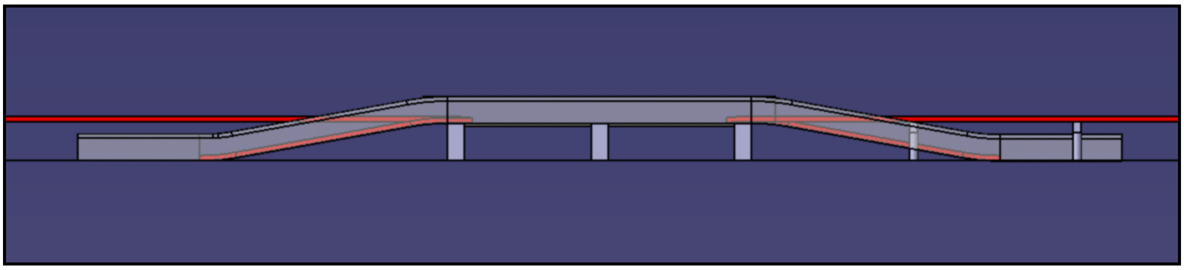


FIGURE 5.12: Side View Crossing Junction Full Switch

If everything goes well the ruf would then enter the switch platform. Here the ruf would be automatically guided to its needed rail. The size of the switch platform was determined based on the following factors.

The length of the platform is a function of comfortable turning ability of the ruf vehicle, if it had to go from one side of the platform to the other. Comfort is determined by the speed and turning radius used. So the slower a ruf travels through a switch the sharper the angle it can comfortably drive.

A magnetic field will guide the rufs as they are on the platform. An example of this magnetic field can be seen in FIGURE 5.13. Two 26 meter radiuses were used to reach the correct rail. Turning begins as soon as the ruf leaves the rail. The length was designed to allow for a small section of straight going travel to ensure proper mounting of the rail by the ruf.

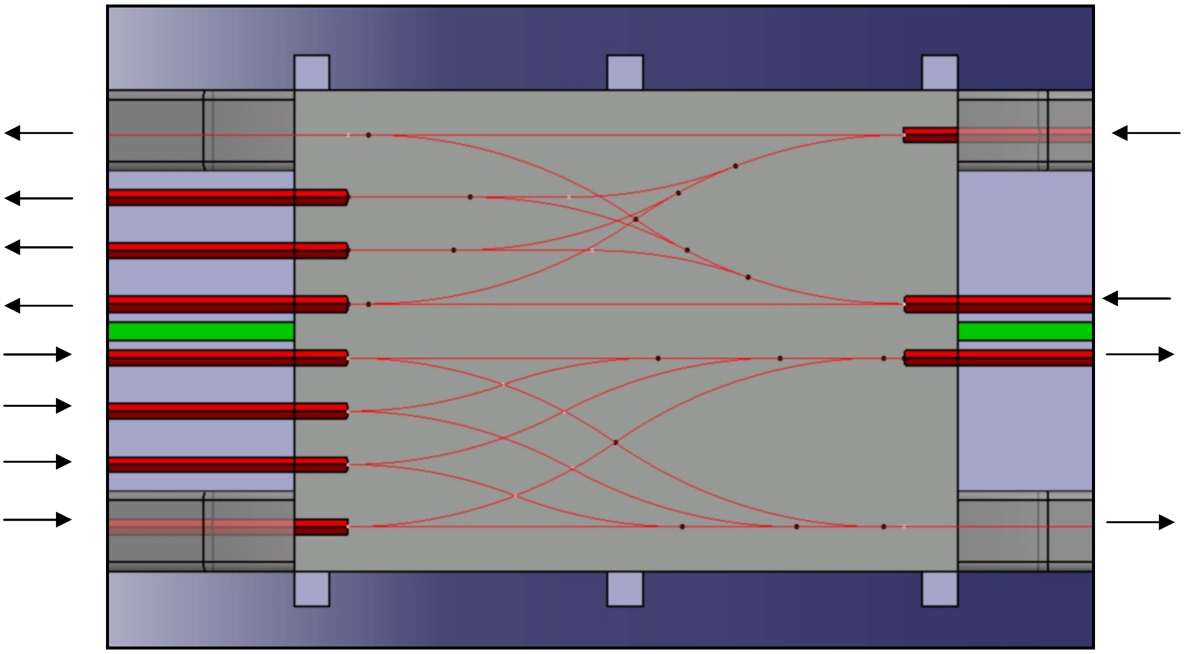


FIGURE 5.13: Top View of Magnetic Field for Crossing Junction Full Switch

Length could also be shortened if the two middle rails on the right side of FIGURE 5.13 were moved outwards. This decreases the needed turning radius which allows for the switch to be shorter. However, if the rails are moved outwards this means that at some point they would have to come back closer together to allow for uniform masts to be used. This also moves the rails from a position that allows the straight going rails to be in line from one side of the switch to another. This is unfavorable.

Width of the platform is determined by the distance needed between the rails. The fewer number of rails the smaller the width will be. It should also be known that the rail on the egress road was deleted to save cost and because it is not completely necessary. The ruf can navigate with the magnetic field and use the normal road wheels for control. If the rail was added to the egress road then that would add two road to rail transitions, and extra cost. Because of Copenhagen's extensive use of bikes, it is recommended but not shown that the bikes should be routed to the complete outside of the switch and both access rail and egress road.

In cases where a smaller switch width is needed, brainstorming has been done to come up with possible alternatives to the full switch to save width. There would be the possibility to only have one access rail and egress road on the switch. If there were four of these switches placed around the crossing junction it would still allow the junction to be functional. Also, it would be less convenient for the user, because there are less places to get on and off. An example of a half switch can be seen below in FIGURE 5.14.

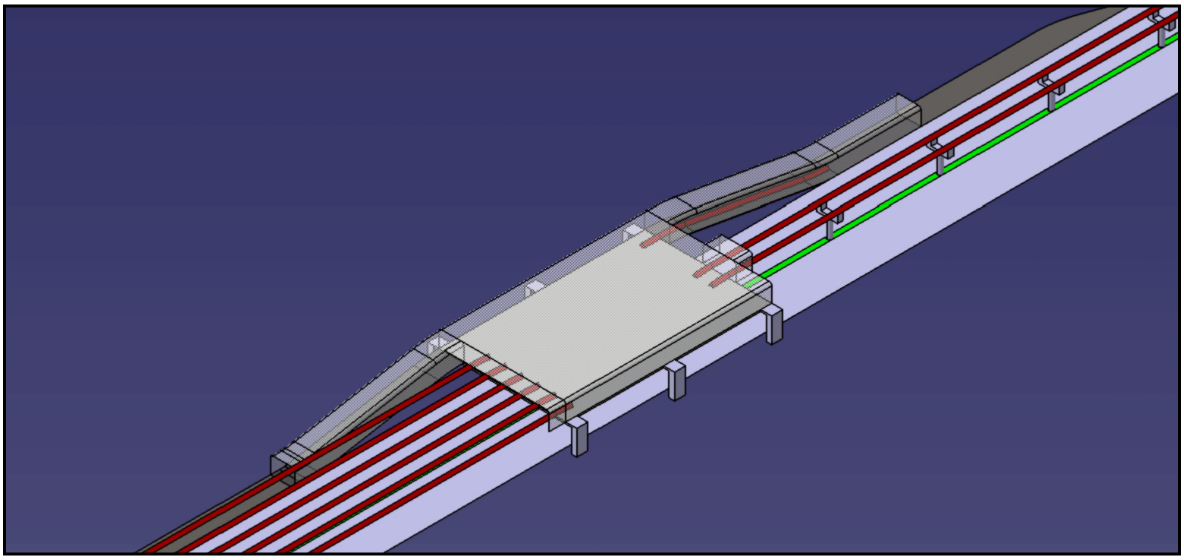


FIGURE 5.14: Isometric View Crossing Junction Half Switch

In some special cases, there may be no need to get on and off directly on the crossing junction switch. The RUF user could get on and off at a separate on/off junction and then proceed to a small simple switch as seen in FIGURE 5.15. This obviously puts limits on some things, but would allow the rufs to switch between the necessary right, left or straight directions of the crossing junction.

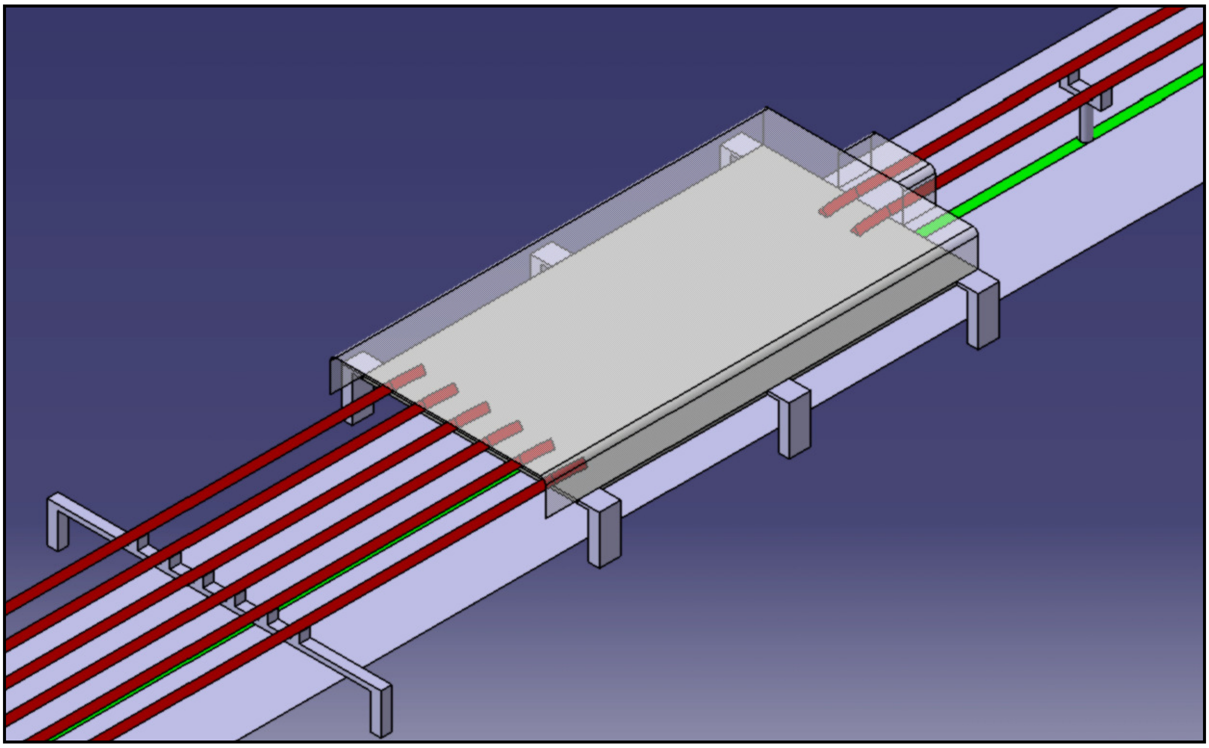


FIGURE 5.15: Isometric View Crossing Junction Small Switch

On every switch there would be a covering as mentioned earlier. This covering could possibly be made of a transparent material that would allow for sunlight to light the junction during the day, and would only necessitate the need to light during evening hours which would cut down on costs. This covering extends three meters beyond the switch platform. It covers the rails to allow for extra covering in the case of bad weather. This is only a recommended distance but the idea to cover beyond the switch is presented clearly.

The idea to make a parking area at the end of each egress road was considered. Thisidea was not used because of the extra space needed. If there were to be extra space, it may be beneficial to have such a parking area. This area would be used for disabled rufs, or passengers that are unable to regain control of the ruf when the automatic control is done. Rufs would be parked here automatically if the driver does not respond to the systems signal to regain control. Also rufs that are not functional could be parked here. The disabled rufs may be helped to this parking area by other rufs connected to it, or by the speed created by gravity and coming down the egress road. After some time, the system could recognize this disabled ruf and automatically contact a towing service, or ambulance if needed.

5.4 On/off Switches

The on/off switch has very much the same concept as the crossing junction switch. The on/off construction and concept is very similar to the crossing junction switch with only a couple of differences that will be discussed in this section. The biggest difference between the on/off switch and the crossing junction switch is that the on/off switch only allows the user to continue in their straight on path, and enter or exit the rail. These on/off switches will usually be placed above existing roads. This switch was designed to be placed above a four lane highway with two lanes of traffic in each direction. Users will exit the normal road on the right and into the entering building, and if in good working order will be guided onto the straight going rail. An example of this type of switch can be seen below in FIGURE 5.16. Dimensions of the on/off switch are found in APPENDIX A9.1.

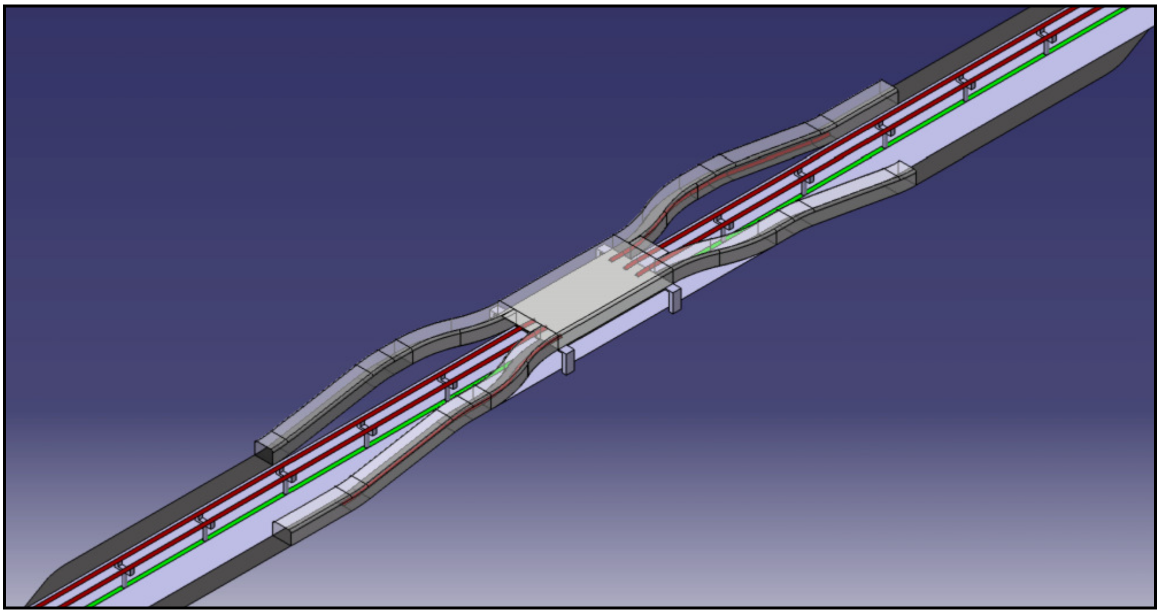


FIGURE 5.16: Isometric View On/off Switch over Existing Road

The on/off switch only has two rails going in and out along with the access rail and egress road, it has a smaller width than the crossing junction switch that needs room to accommodate each directional rail. Because of this the on/off switch platform is not as wide as the crossing junction switch platform so the access rail and egress road must first get wider to get to the edges of the road before descending down to the road surface. It is important to make sure that the access rail and egress road are still high enough to allow traffic to pass underneath. FIGURE 5.17 shows a front view and allows a view of how traffic could travel underneath the switch.

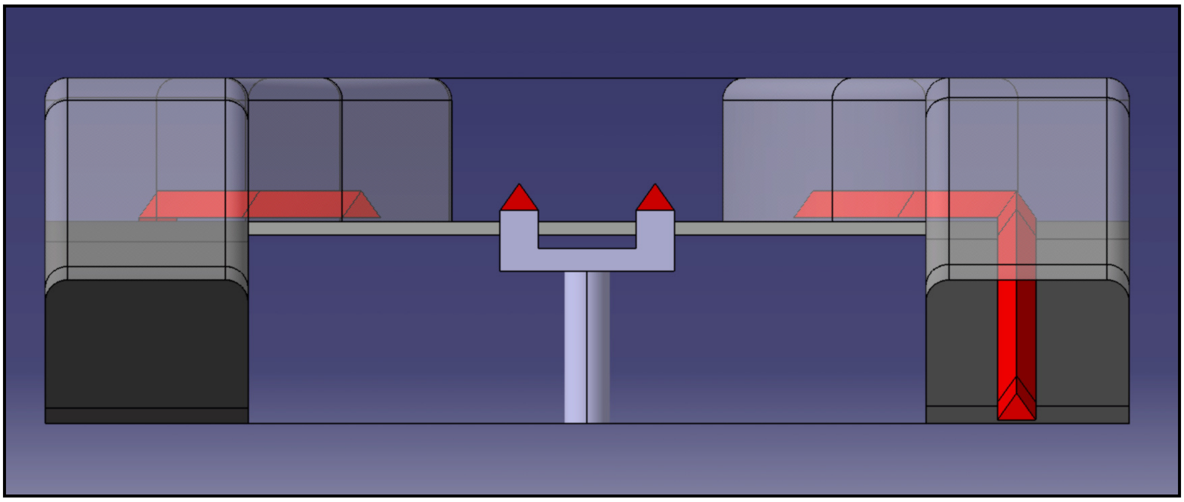


FIGURE 5.17: Front View On/off Switch over Existing Road

Because the access rail and egress road must first get wide enough to clear the road beneath, the on/off switch becomes a little longer in overall length. This does not seem to be a problem because of the rural place where these junctions will be put. FIGURE 5.18 shows the side view of the on/off junction.

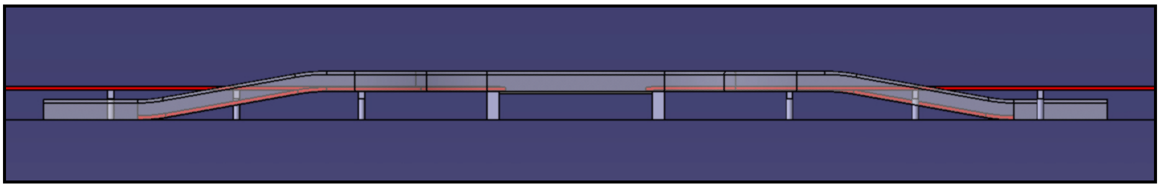


FIGURE 5.18: Side View On/off Switch over Existing Road

The on/off switches are controlled using the same magnetic guidance as the crossing junction switches. This magnetic field is present beginning at the entering building and is present until the end of the egress road. Below in FIGURE 5.19 is the suggested magnetic field for the on/off switch. As soon as the ruf leaves a rail onto the switch platform it will begin its turn to its desired direction. The turning radiuses are designed to allow a portion of straight travel to allow the ruf to straighten before reentering the rail. It is unsure if this straight travel section is needed or not. If future research shows it not to be necessary, then the switch could become a little shorter in length.

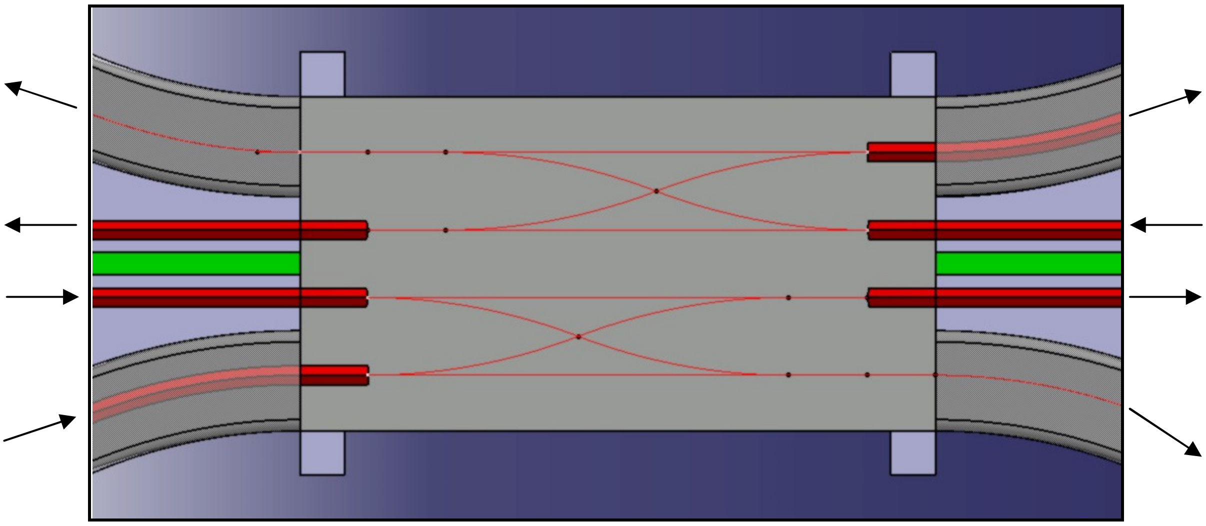


FIGURE 5.19: Top View of Magnetic Field for On/off Switch over Existing Road

As with the crossing junction switch there may be circumstances where a different design of on/off switch will suite the situation better. Below in FIGURE 5.20 and FIGURE 5.21 are two different variations of on/off switches. FIGURE 5.20 shows an on/off switch that could be used in the middle of a field. Only vehicles that can use the RUF system would be able to access the roads that lead to the on/off switch. This type of on/off switch is smaller than the previously mentions on/off switch, because it does not allow for vehicles to pass below it.

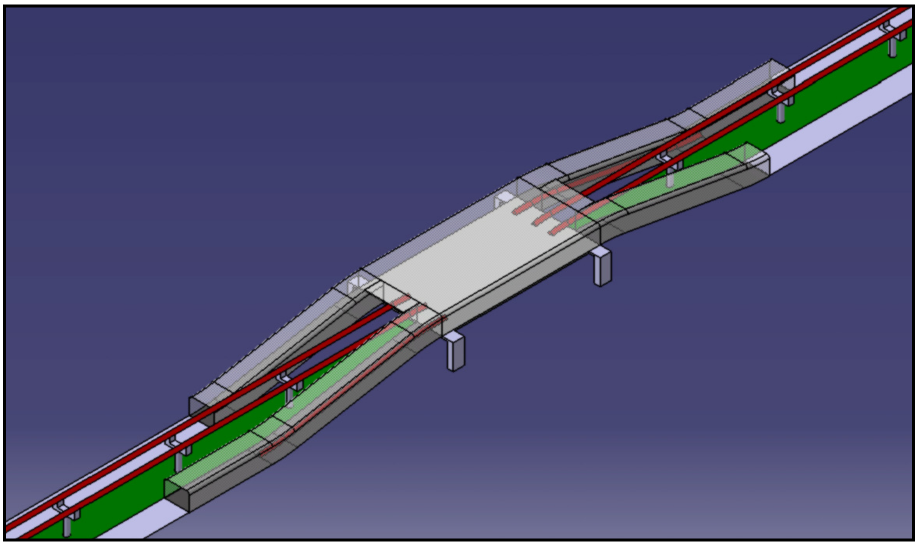


FIGURE 5.20: Isometric View On/off Switch Isolated

FIGURE 5.21 shows a modification to one side of the access rail and egress road. Sometimes if the switch is in a highly populated area, there may not be enough room for an on/off switch to be placed completely in the correct orientation. One proposal would be to turn one of the access rails and one of the egress roads 90° and have them on a road perpendicular to the normal travel. This is illustrated in the figure.

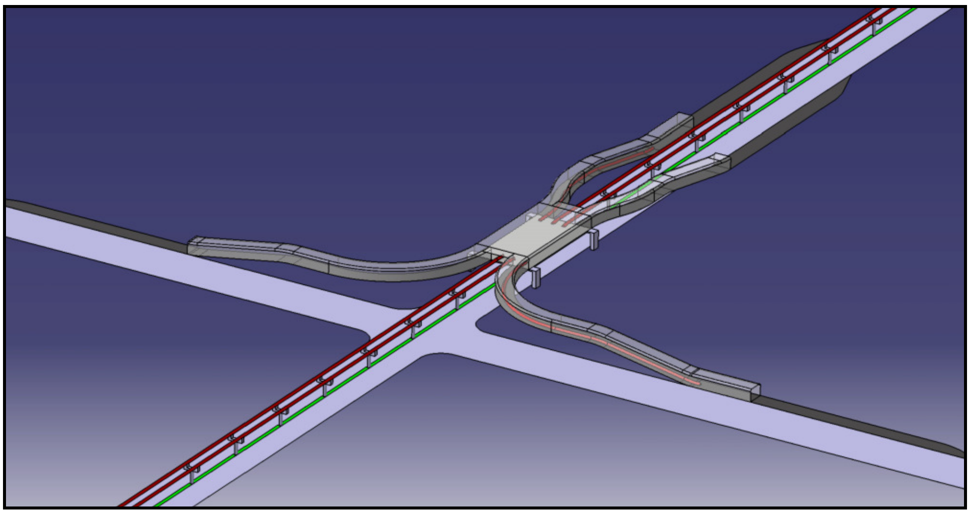


FIGURE 5.21: Isometric View of 90° Access and Egress to On/off Switch

5.5 Jarmers Plads Junction

In this section the two previous sections will be combined to show the complete crossing junction with four switches. In an ideal situation the crossing junction switches would be positioned directly around the crossing junction as seen previously in FIGURE 2.2. Unfortunately, this is not the case for the Jarmers Plads intersection. A number of compromises needed to be made to fit a junction onto this intersection. These compromises will be discussed and explained in the following section. FIGURE 5.22 shows a suggested position of the crossing junction and its switches.

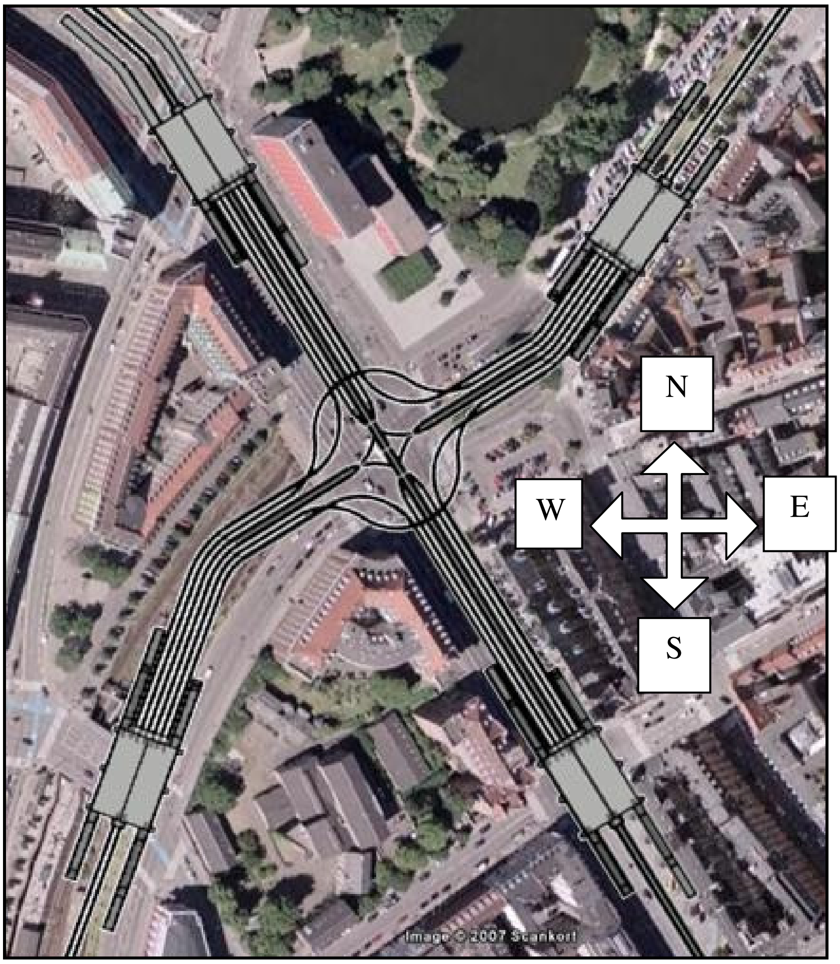


FIGURE 5.22: Overlay of RUF Junction on Jarmers Plads

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The first thing that needs to be mentioned a symmetric crossing junction was used. However, this will not be the best solution for Jarmers Plads. To make things simpler a symmetric crossing junction was designed and shown to fit. A crossing junction that is skewed a little bit would better fit this non-perpendicular intersection and would make a more comfortable crossing. At first the smallest solution was thought to be the best because it would take up less space in a crowded city area. That would mean switches placed directly around the crossing junction. This proved to be a bad design because rufs would exit directly at the existing intersection. It also would be bad because if a red light were to appear and exiting rufs were stopped, a traffic jam could occur that would back up into the switch itself and stop ruf travel altogether. So another place for the switches had to be determined.

As previously mentioned it was a goal to disturb existing traffic as little as possible. For this it was decided to place the switches over the surround ground intersections. This had some negative effects also. It increased the size needed for the junction and switches to be implemented, and there was a need for the six rails that are exiting and entering the switch would have to travel parallel a long ways to reach the actual crossing junction. Also, the roads that make up the intersection of Jarmers Plads are not straight. This means that two of the switches had to be placed at an angle. In FIGURE 5.22 the northeast and southwest switches needed to be turned.

The ground road leading to the southwest switch is surrounded on one side with S-Train rails. There was an assumption made that this area could be considered useable area. It is unsure how the placement of the switch in this area will affect existing traffic and were the final placement of the switch could be.

Current traffic levels were assumed to be highest on the road going from southeast to northwest. Some decisions were made based upon this assumption. In the design of the crossing junction there were two different designs for straight going traffic. One had the straight on traffic rise to the third level and travel straight on. The other bowed out to the sides on the second level to allow for rufs to go straight. The third level straight on design was orientated according to the road with the highest traffic flow. This will be the most comfortable and fastest solution for the users, because they do not have to make a curve while going straight. An idea that was shown in the previous section that had an access rail and egress road in an orientation that was 90° from the switch was not used. This was because the access rail and egress road should be on the road with most traffic if possible. It was possible if the southeast switch was positioned directly over the existing road intersection.

The northeast switch, after a small turn between the switch and crossing junction, seemed to fit well because of a parking area and a large boulevard which can be used. Also, no buildings or ground intersections were disturbed by the placement of this switch.

The northwest switch seemed to be a little more difficult to place because of a large angle between the two crossing ground roads. The switches that were designed best fit on perpendicular intersections. It would have been impossible to design a switch that can universally be used on every street intersection. Because of this, compromises were made in the placement of the switches. The access rail and egress road had to be designed to allow traffic to travel underneath them before descending to the road surface. To make sure that this will work the access rail and egress road have to stay on level 1 for a distance before making a curve and traveling down to the road surface. This is best illustrated in FIGURE 5.22.

Figure 5.23 shows a 3D view of the junction from of the northeast. The buildings shown in this figure are just representative. They are similar but not exact. Here it is also possible to see that no existent ground intersection is disturbed by the designed RUF junction. There is the possibility to decrease the time needed to cross the junction if more of the room available was used. If this area was used, the radiuses could be made larger, allowing for a faster speed to be used. This does make the junction bigger which is unfavorable. Now the junction is designed for 30 km/h but this could be increased when the users feel comfortable with the system and the crossing junction is bigger.

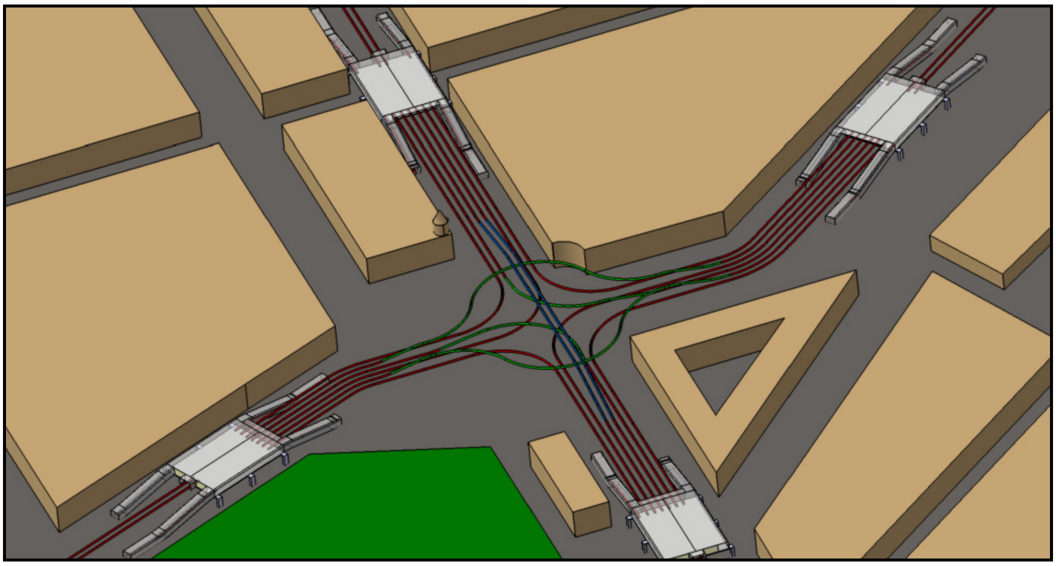

FIGURE 5.23: 3D Model of RUF Junction on Jarmers Plads

FIGURE 5.24 compares the whole solution of the junction with a normal highway junction. In this way it is possible to see that the RUF junction size is nearly half of the highway junction size. The scale of the figure of the RUF junction to the highway junction is 1:1.

FIGURE 5.24: Overlay of RUF Junction on Highway Intersection

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5.6 Physical Model

The creation of a physical model is the last step to make this project complete. Indeed, the model will help people to understand how the crossing junction works and to see the complexity and constraint of this assignment. In the same way, the presenter can show the different possibilities, benefits and functional aspects of the selected solution.

The approach of the modelling is used to simplify the work and to eliminate the very small details. So the result is neater because only the important details are shown. Plus, this physical model will be made to look like Jarmers Plads to be more realistic. However, this place has been adapted a little bit to better explain the final idea. To obtain a correct aspect, it's important to respect the dimensions and find a suitable scale. The dimensions used to describe the rails, switch, and buildings are located in APPENDIX A10. The scale for the model was set to 1:200, for example 10 meters is equal to 5 centimetres.

Now, to obtain a clean model that could be shown to the public, it's important to find the suitable materials:

- polystyrene for making the buildings (to keep them smooth)
- a wood board to support the model
- aluminium board for the satellite's floor (metal flexible enough)
- flexible transparent plastic for satellite's roof
- small metal sticks (about 2cm) to make the masses and bridges
- flexible wires of different colors to differentiate the three levels
- spray paint, glue, adhesives and tape

A top view and isometric view of the resulting physical can be seen below in FIGURE 5.25 and FIGURE 5.26.

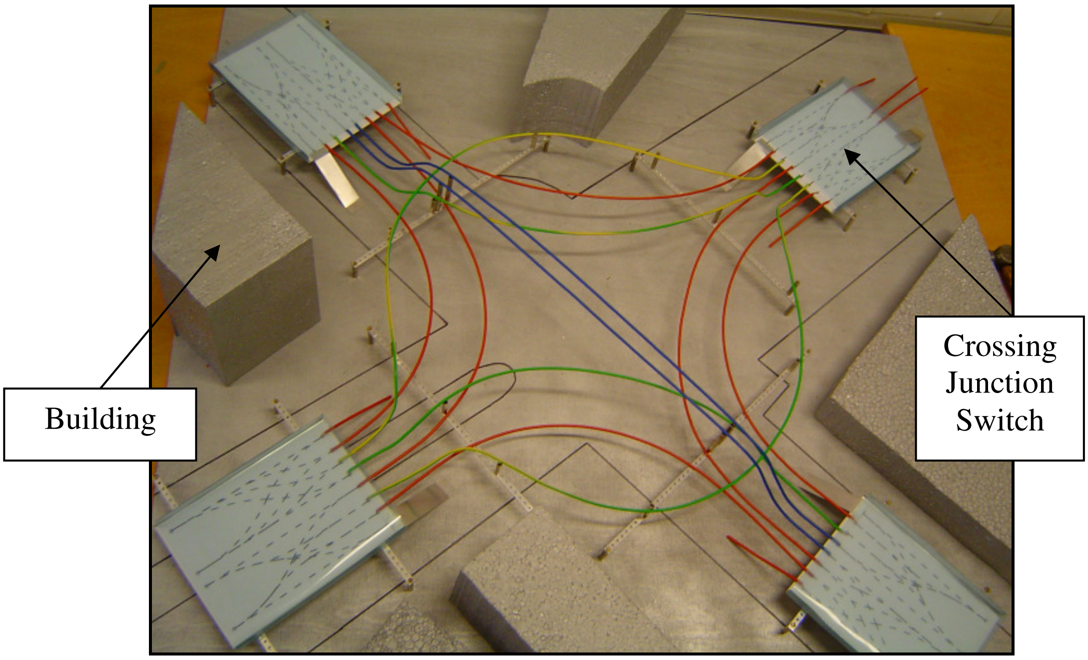


FIGURE 5.25: Top View Physical Model

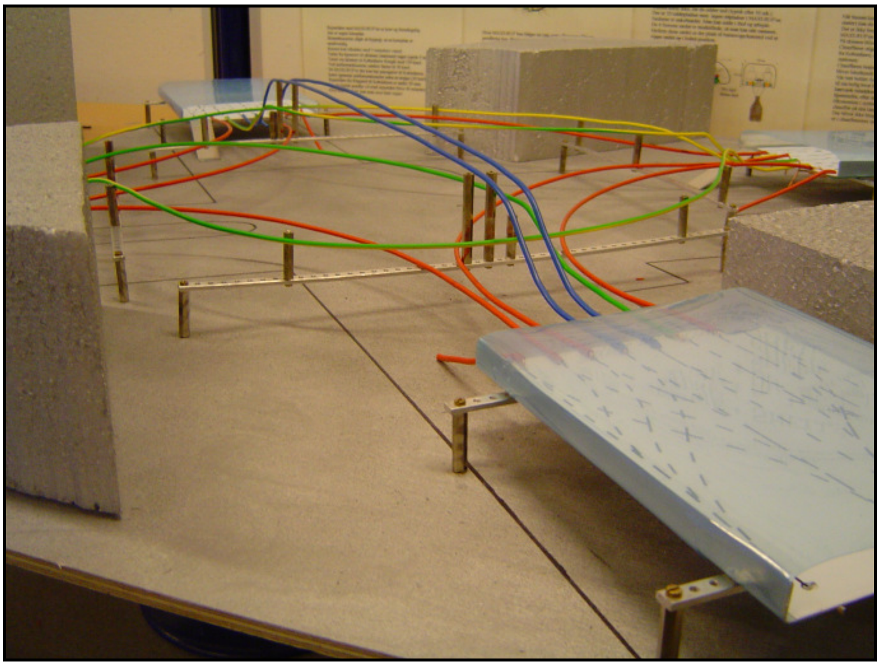


FIGURE 5.26: Isometric View of Physical Model

The complexity of the three levels of rails can be seen in FIGURE 5.27.

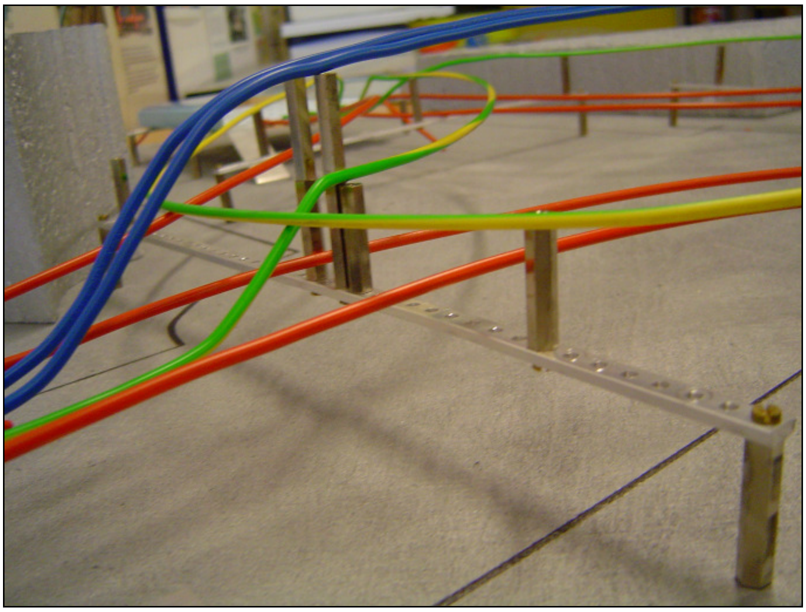


FIGURE 5.27: Physical Model Rails

Below the crossing junction that is represented by the physical model can be seen in FIGURE 5.28.

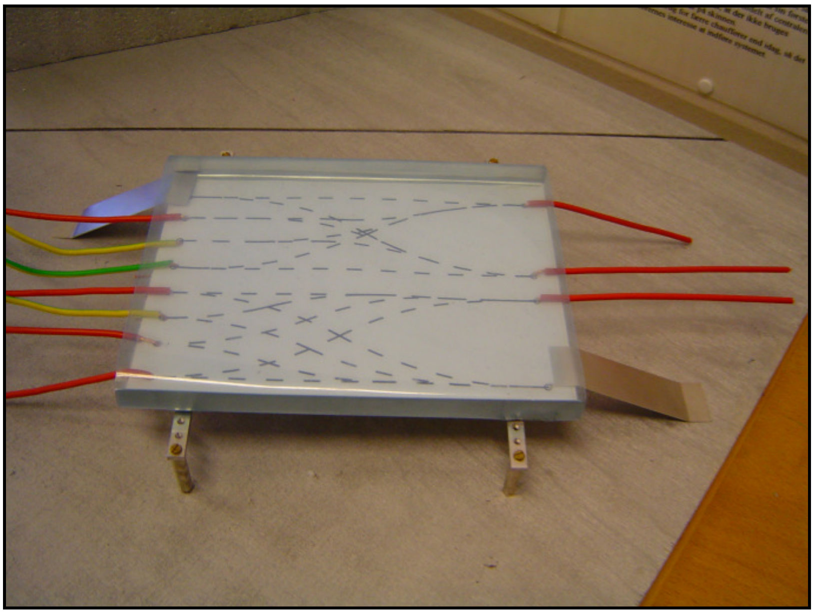


FIGURE 5.28: Physical Model Crossing Junction Switch

Difficulties encountered when constructing the physical model are listed below:

1. First, the buildings have been made with cardboard but the result was not totally satisfactory because of the adhesive tape's visibility and the imperfection of the cardboard so it was decided to make them with the handy material like the polystyrene that could be cut with a specific machine (which was a fine wire that was heated). With this construction the buildings can have a smooth texture.
2. The buildings were painted with different colors but the problem was that some spray paints attack the polystyrene. So the buildings have been made a second time and painted with a non-aggressive color which was in accordance with the color of the wood board support.
3. The wires have to keep a specific radius of 13cm. This was resolved by finding a circular object with exactly the same radius.
4. Also a difficult aspect was to straighten the wires.

5.7 Conclusion

In conclusion the design shown can be made to fit on Jarmers Plads. This means that the RUF system can be implemented into a city. However, to say that the proposed junction is the best design for every street intersection would be incorrect. There are a number of variations that are shown that would more easily allow the junction to fit on other intersections with different characteristics. Variables such as existing buildings, angle of road intersection, and the width available on the road all need to be taken into consideration when putting a junction in the city. Although the junction proposed is a possible solution, there are even improvements to this design to better fit Jarmers Plads. The work done and ideas presented in this chapter will provide the foundation for future designs of a RUF junction. It is certain that improvements can and will be made to this design but the knowledge gained will be forever useful.

CHAPTER 6: Future Progress

6.1 Introduction

The different questions that still need to be answered for the successful completion of the RUF system are presented in the following chapter. These unanswered questions will be possibly starting points for future projects, and allow the readers to understand what assumptions were made in this publication when designing and dimensioning the RUF junction. This projects main purpose, as stated before, was to show a proposal for a crossing junction that fits on the Jarmers Plads intersection in Copenhagen. That means, that not all questions could be answered. These questions could not be answered because of a lack of time or because of unknown factors that have yet to be determined. These questions are important to mention to show all things have been taken into consideration with the design, knowing that deeper research and design is needed, and modifications need to be made to the proposed RUF junction to accommodate and apply knowledge learned from answering these questions.

6.2 Questions to be Answered

6.2.1 Crossing Junction Switches and On/off Switches

How long should the entering building be?

For the entering building there are some questions that have yet to be answered. A lot of these questions depend on obtaining further technical givens of the rufs. The distance which the rufs and maxi-rufs need to slow down safely and comfortably is not known now. It is not clear if the estimated distance used for the entering building is long enough to slow down the rufs from 50 km/h or 70 km/h to the safe entering speed of 30 km/h. For safety reasons it had to be discussed if a user who goes into the entering building with a very excessive speed can be slowed down by the system safely. To prevent entering at very high speeds, an idea such as speed bumps could be implemented in front of the entering building. All these factors have an influence on the length of the entering building. Another factor is the snow and environment. The entering building is roofed, but it is not clear how it could be prevented that snow is pushed inside the entering building while clearing the connection between the entering building and the normal street.

What distance is needed on the access rail to successfully check the rail drive system? How will the drive system be checked?

At this point it is not clear if the rail drive system needs a rail to check the functionality of the rail drive system before entering the RUF system. If the rail drive system does need a rail to check its functionality then it is unsure if the designed about of access rail is enough for that test to take place. There is currently an idea that the rail drive system will be checked by powering the ruf up the access rail onto the switch platform. If the rail drive system is not functioning correctly then the road wheels would power the ruf up the access rail where the ruf would then be guided off of the switch under the power of the normal road wheels. It is impossible for the ruf to enter the RUF rail system if the rail drive system is not working. A traffic jam would ensure, thus defeating the efficiency of the RUF system.

What is the best distance for the rail to be placed above the street to allow both rail drive system and normal road wheels to be used?

There has to be a standard which defines the distance between the rail wheels and road wheels when each ruf or maxi-ruf is built. This is important to know this distance so that the access rail can be placed at the optimal height for functional use of both rail drive system and normal road wheels. This is an important function to allow use of the normal road wheels in case there is a malfunction of the rail drive system.

How accurate can the magnetic guidance work?

It was not known how accurate the magnetic guidance system could work. Designs were made under the assumption that the guidance system was accurate to $\pm$ 5 cm. The switch was created out of two circles with a radius of 26 meter and at the end a small part which goes straight. If this straight line is not long enough another possibility would be that the magnetic guidance of the switch consists of a 26 meters and 10 meters radius. But this would mean that the rufs have to slow down in the 10 meters radius what would decrease the capacity.

Which security measures have to be implemented?

If a ruf has a problem or if it wants to leave the system and the user don't react to the signal the system will guide it from the rails and park it on a special parking area. This project hasn't handled with the signal on which the user has to react or with the parking area. This means that it isn't clear if there has to be a parking area at each satellite or if one for a junction is enough. Also the place is not sure. It shouldn't be far away from the satellite but it also shouldn't disturb the normal traffic. Also security exits are not implemented.

Do the rufs have to be traveling straight when entering and exiting a rail?

Turning at 26 meters right now, will the ruf bind if they exit or enter at a slight off of straight angle, if they need to go straight this will increase the length of the switch to allow for a straight going section of travel

How will the switch coverings be supported and what they will be made of?

The current drawings show a one mm thick representation of the covering for the switches. Extra space was left between the top of the rufs and the covering to allow for future structuring to be designed in and space for extras such as lighting. It is unsure what material the covering would be made of but could possibly made of a transparent plastic that would allow for light to come in during the day. This transparent matieral would also allow exiting RUF users to see existing traffic and be prepared to make necessary actions when control is regained.

How to make sure traffic jams on road don't back up into the ruf junction?

Because the rufs exit into existing traffic there is the possibility that if there is a traffic jam on the normal ground road it would not allow rufs to leave the rail. This would cause the rufs to start backing up into the switch. If this were to happen it could cause a traffic jam on the RUF system. It is unsure how to avoid this situation.

Is using the access rail and egress road for safety exiting of passengers on foot ok?

There may be safety regulations surrounding the exit of passengers from a structure like a RUF switch. The switches were designed to allow for emergency exit, but maybe in the future an escape staircase may have to be added.

6.2.2 Crossing Junction

How will the junction rails be supported?

The whole topic of masts was not touched in detail in this project. It is not calculated where the masts have to be, what they will have to carry or how they will influence the ground traffic. The pictures show some possibilities how the mast problem could be solve.

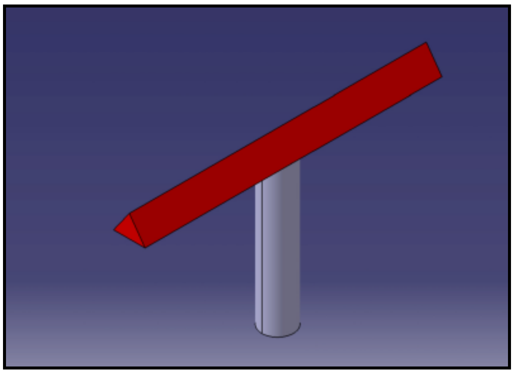


FIGURE 6.1: Isometric View Single Mast

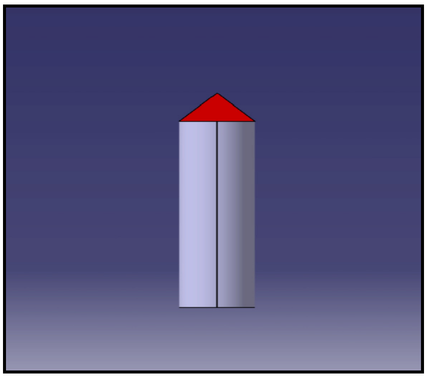


FIGURE 6.2: Front View Single Mast

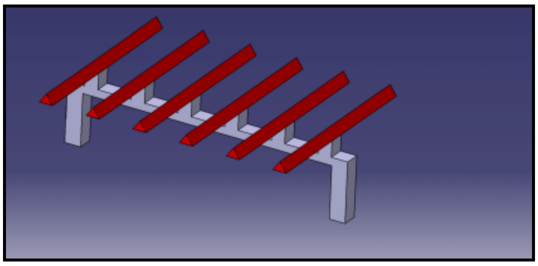


FIGURE 6.3: Isometric View Bridge Mast

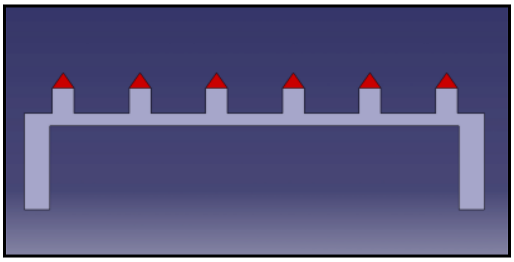


FIGURE 6.4: Front View Bridge Mast

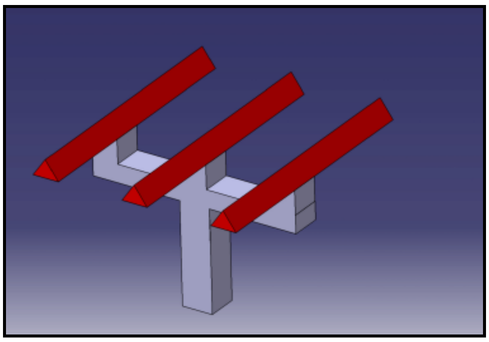


FIGURE 6.5: Isometric View T-Mast

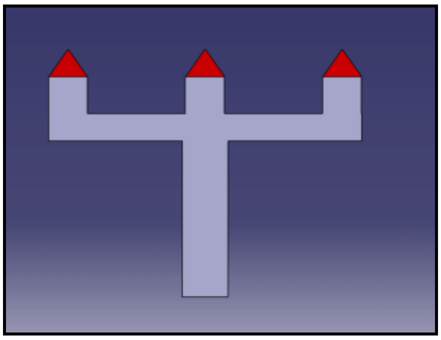


FIGURE 6.6: Front View T-Mast

Each mast has advantages and disadvantages. The bridge allows traffic to flow underneath it when there is need to support a lot of rails. The single mast is the simplest design but can only be used for one rail. The T-mast design is possibly the most universal. It could be used for supporting two rails or more when needed.

Could be the junction rails be covered?

The junction could also be implemented in a building. This could be used like a mast which carries some rails or safety systems could be installed in it. But it also could help to make it more beautiful and because of this it could be more accepted by the public.

Which safety measures have to be implemented?

At this status it is not clear what safety possibilities have to be implemented. There are different possibilities that include stairs so that passengers can leave the system at certain points, or suspended walkways between two rails. Because of the complexity of the rail design for the crossing junction it is unsure how users would safely exit the system in case of an emergency. Maybe a crane like apparatus could be used to lift disabled rufs off of the crossing junction. This has to be discussed at a later time.

What capacity will the junction have?

Another topic which was not discussed in detail is the capacity of the junction. No calculations had been made to see where the problems of capacity could be. It is also not clear if the capacity could be enlarged with making the radius of the curves bigger so that the rufs could drive faster because it is no use when the rufs can cross the junction in a shorter time, but than have to wait in front of the switch. Perhaps the capacity could increase if the switch is bigger and the rufs can merge at different points. But all these point has to be calculated in another project.

What is the cost of the RUF junctions?

Because of inaccurate cost comparisons a cost for the RUF junction was not estimated. Listed below in TABLE 7.1 are the meters of rail, and square meters for each switch to allow for future cost analysis.

Description	Total	Units
Crossing Junction Rails	2710	m
Crossing Junction Switch	1692	m^2
Crossing Junction Switch Rail	92	m
On/off Switch	1581	m^2
On/off Switch Rail	132	m

TABLE 6.1: RUF Junction Number Analysis

6.3 Conclusion

There are still many questions at this point that need to be answered, and still many questions that need to be documented for others to research and answer. These questions will provide a good starting point for future RUF engineers.

CHAPTER 7: Remarks and Suggestions

Conclusion

In conclusion, it is clear that there is still work to be done before the best RUF junction is designed and dimensioned. This report can be used as a starting point and foundation of knowledge for future work on the RUF junction. That being said, it should be known that the goals of this project were successfully achieved. A crossing junction and switches for the RUF junction were developed and their dimensions were determined. This final RUF junction was successfully placed on Jarmers Plads street intersection in Copenhagen, Denmark.

To say that the designs and dimensions suggested in this publication provide the universal solution for every street intersection would be incorrect. It has become clear that because of the great amount of variation from one existing street intersection to another, specific attention and specific designs would have to be made to effectively execute a RUF junction.

It has been shown that the RUF junction is smaller than conventional highway intersections. Although there were not any specific cost calculations made, it is the hope that the RUF system would be less expensive to build and operate than conventional roads. The many benefits of the RUF system seem to be very desirable to ending the current problems with transportation. Whether or not the rail system and junctions will be visually accepted by the public is yet to be determined. Also, the legal aspects such as safety regulations and building regulations are still obstacles that need to be overcome.

It is the hope that this project has shed some light on the idea of a RUF junction and what things need to be done and considerations that need to be made so that in the future the RUF system can become reality.

APPENDICES:

A1: Agenda Template

Group 4 Meeting Agenda

- **Meeting Date**:
- **Meeting Time**:
- **Those Invited**:
- **Chairman**:
- **Secretary**:

- **Approval of Agenda:**
- **Approval of last meeting Minutes:**
- **Summary of Previous Minutes:**

- **New Business:**
  1.
  2.
  3.

- **Other Business:**
- **Set Date for Next Meeting:**
- **Set People and Dates to To-Do List:**

A2: Minutes Template

Group 4 Meeting Minutes

Meeting Date:
Meeting Time:
Those Present:
Chairman:
Secretary:

Issues Discussed:

1.
2.
3.

To-Do List:

Things to do	Persons Responsible	Complete By	Completed

Decisions Made:

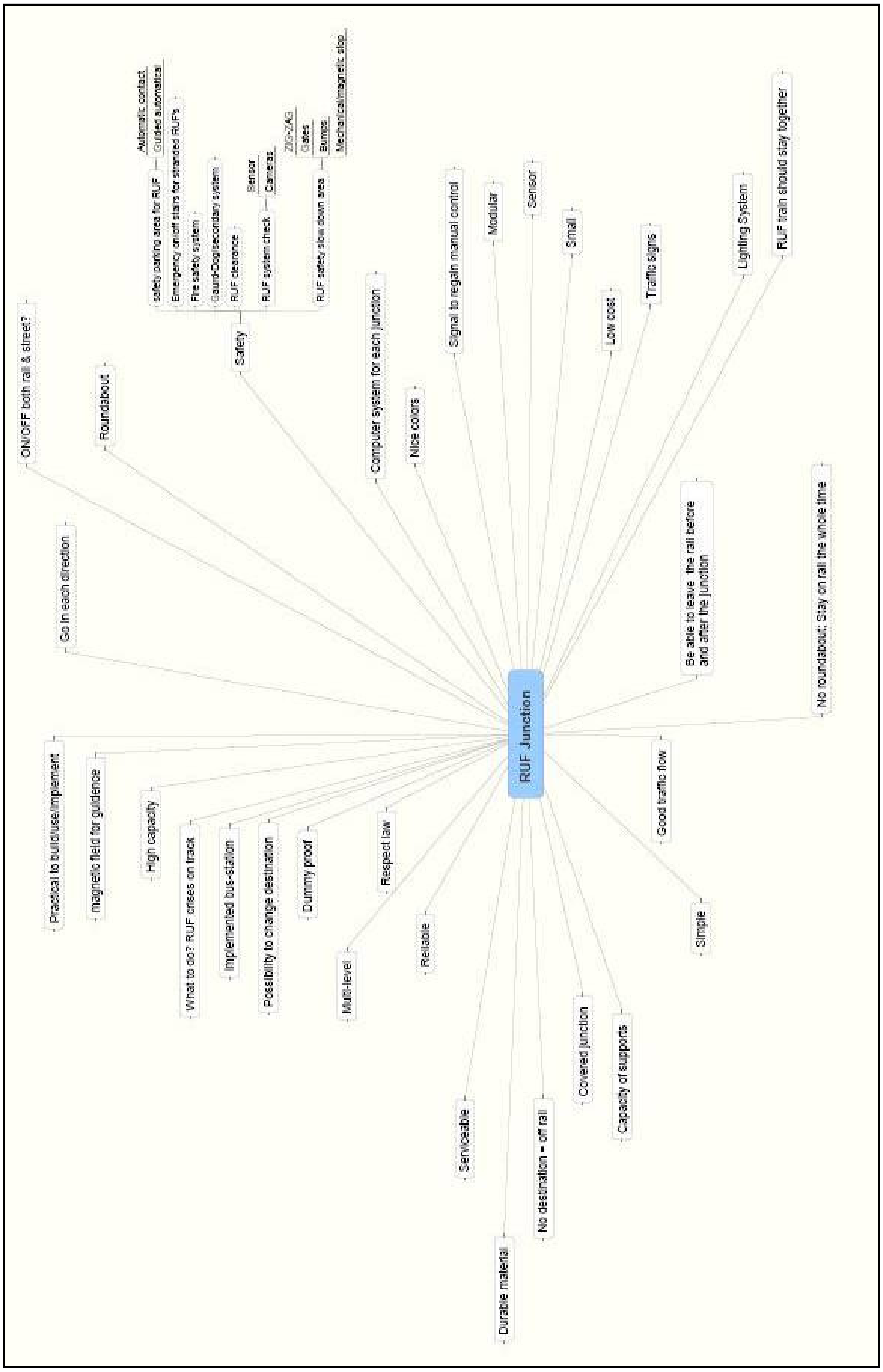
1.
2.
3.

A3: Technical Givens

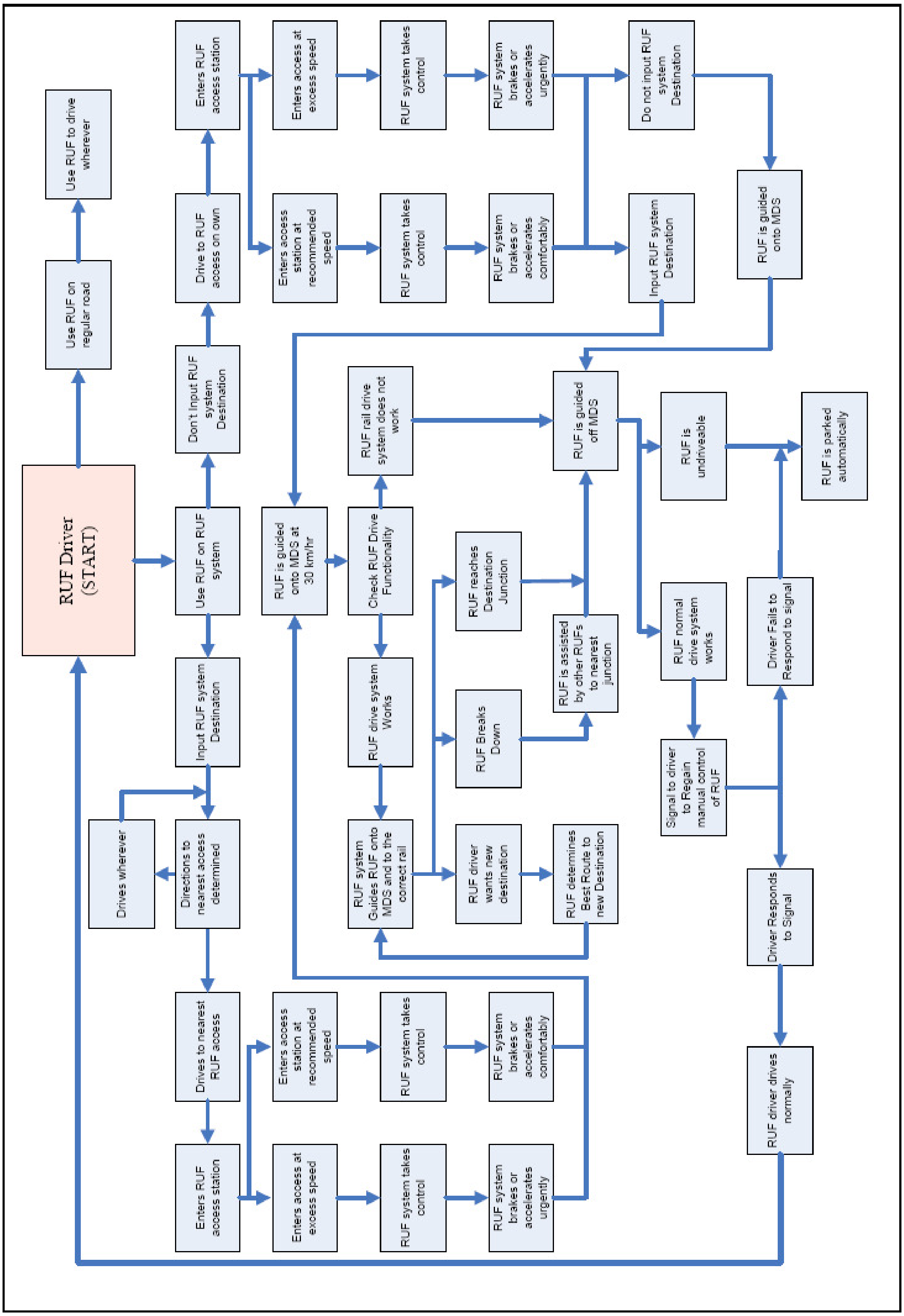
Technical Givens

Given	Units
Radius of minimum Turning ability on Rail	26 meters
Minimum Turning Radius on Ground	10 meters
Comfortable Angle of Elevation	10 degrees
Comfortable lateral turning G-force	0.2 g
Distance between rails	3 meters
Max ruf width door closed	2 meters
Maxi ruf width door open	3 meters
Maxi ruf height door closed	2 meters
Maxi ruf height door open	3 meters
Maxi ruf length	6.75 meters
Maxi ruf weight full	3,500 kg
Mono Rail Overall width	0.85 meters
Mono Rail Overall height	0.60 meters
support of rail per meter	500 kg
distance between masts	20 meters
magnetic field wire distance apart	0.30 meters
Comfortable breaking from 50 km/hr to 30km/hr	20 meters
Emergency braking from 70km/hr to 0	10 meters

A4: Brainstorming



A5: Flowchart



A6: Gantt Chart

Nr.		Vorgangsname	Dauer	Anfang	Ende
1	✓	Team-building / Organisation	15 Tage?	Mon 27.08.07	Fre 14.09.07
2	✓	Project review #1	3 Tage?	Mon 17.09.07	Don 20.09.07
3	✓	Create presentation	3 Tage?	Mon 17.09.07	Mit 19.09.07
4	✓	Finished presentation	0 Tage	Mit 19.09.07	Mit 19.09.07
5	✓	Finished project review #1	0 Tage	Don 20.09.07	Don 20.09.07
6	✓	Submission for David	9 Tage?	Mon 17.09.07	Fre 28.09.07
7	✓	Create submission	9 Tage?	Mon 17.09.07	Don 27.09.07
8	✓	Finished submission and sent to David	0 Tage	Fre 28.09.07	Fre 28.09.07
9	✓	Project work _ RUF international # 1	27 Tage?	Mon 17.09.07	Die 23.10.07
10	✓	research / solutions	25 Tage?	Mon 17.09.07	Fre 19.10.07
11	✓	Measurements (see the place)	10 Tage?	Mon 17.09.07	Fre 28.09.07
12	✓	Literature / Internet / Experts research	10 Tage	Mon 17.09.07	Fre 28.09.07
13	✓	Define the entrance modul	15 Tage	Mon 01.10.07	Fre 19.10.07
14	✓	Define the access rail	15 Tage	Mon 01.10.07	Fre 19.10.07
15	✓	Define the sattelite / switch	15 Tage	Mon 01.10.07	Fre 19.10.07
16	✓	Define the crossing junction	15 Tage	Mon 01.10.07	Fre 19.10.07
17	✓	Brainstorming / Ideas / Solutions	15 Tage	Mon 01.10.07	Fre 19.10.07
18	✓	Ranking of the solutions	2 Tage?	Mon 22.10.07	Die 23.10.07
19	✓	Finished ranking	0 Tage	Die 23.10.07	Die 23.10.07
20	✓	Interim report	10 Tage?	Mon 08.10.07	Fre 19.10.07
21	✓	Write interim report	10 Tage?	Mon 08.10.07	Fre 19.10.07
22	✓	Finished interim report	0 Tage	Fre 19.10.07	Fre 19.10.07
23		Project review # 2	6 Tage	Don 18.10.07	Fre 26.10.07
24	✓	Create presentation	6 Tage	Don 18.10.07	Don 25.10.07
25		Finished presentation	0 Tage	Don 25.10.07	Don 25.10.07
26	✓	Finished project review # 2	0 Tage	Fre 26.10.07	Fre 26.10.07
27	✓	Project work _ RUF international # 2	28 Tage?	Mit 24.10.07	Fre 30.11.07
28	✓	Dimension of the 1. solution	23 Tage?	Mit 24.10.07	Fre 23.11.07
29	✓	CAD 3D model	23 Tage?	Mit 24.10.07	Fre 23.11.07
30	✓	Create 3D model	23 Tage?	Mit 24.10.07	Fre 23.11.07
31	✓	Finished 3D model	0 Tage	Fre 23.11.07	Fre 23.11.07
32	✓	Physical model	10 Tage?	Mon 19.11.07	Fre 30.11.07
33	✓	Create physical model	10 Tage?	Mon 19.11.07	Fre 30.11.07
34	✓	Finished physical model	0 Tage	Fre 30.11.07	Fre 30.11.07
35	✓	Calculation / Budget	5 Tage	Mon 26.11.07	Fre 30.11.07
36	✓	Finished calculation	0 Tage	Fre 30.11.07	Fre 30.11.07
37	✓	Final report	57 Tage?	Mon 17.09.07	Mit 05.12.07
38	✓	Final report	57 Tage?	Mon 17.09.07	Die 04.12.07
39	✓	Finished final report and sent to David	0 Tage	Mit 05.12.07	Mit 05.12.07
40	✓	Final exam	8 Tage?	Mit 05.12.07	Fre 14.12.07
41	✓	Create presentation	8 Tage?	Mit 05.12.07	Fre 14.12.07
42	✓	Finished final exam	0 Tage	Fre 14.12.07	Fre 14.12.07

27. Aug '0
S M D M

Projekt: 070918_timeplan_Gr4 fir
Datum: Die 04.12.07

Vorgang
Unterbrechung
In Arbeit
Meilenstein
Sammelvorgang
Projektsammelvorgang
Externe Vorgänge
Externer Meilenstein
Stichtag

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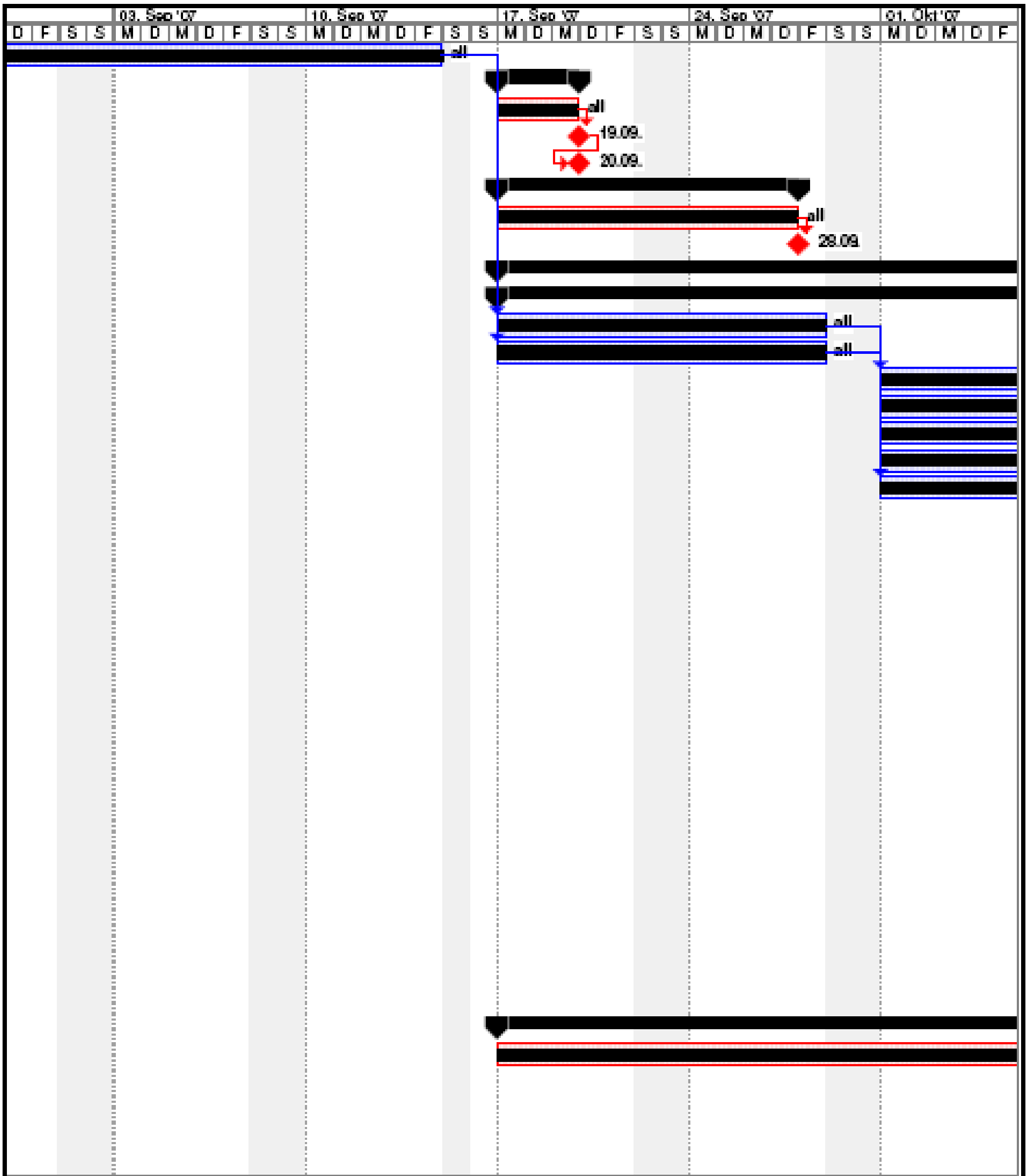

Projekt: 070918_timeplan_Gr4 für
Datum: Die 04.12.07

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In Arbeit		Externer Meilenstein	
Meilenstein		Stichtag	
Sammelvorgang			

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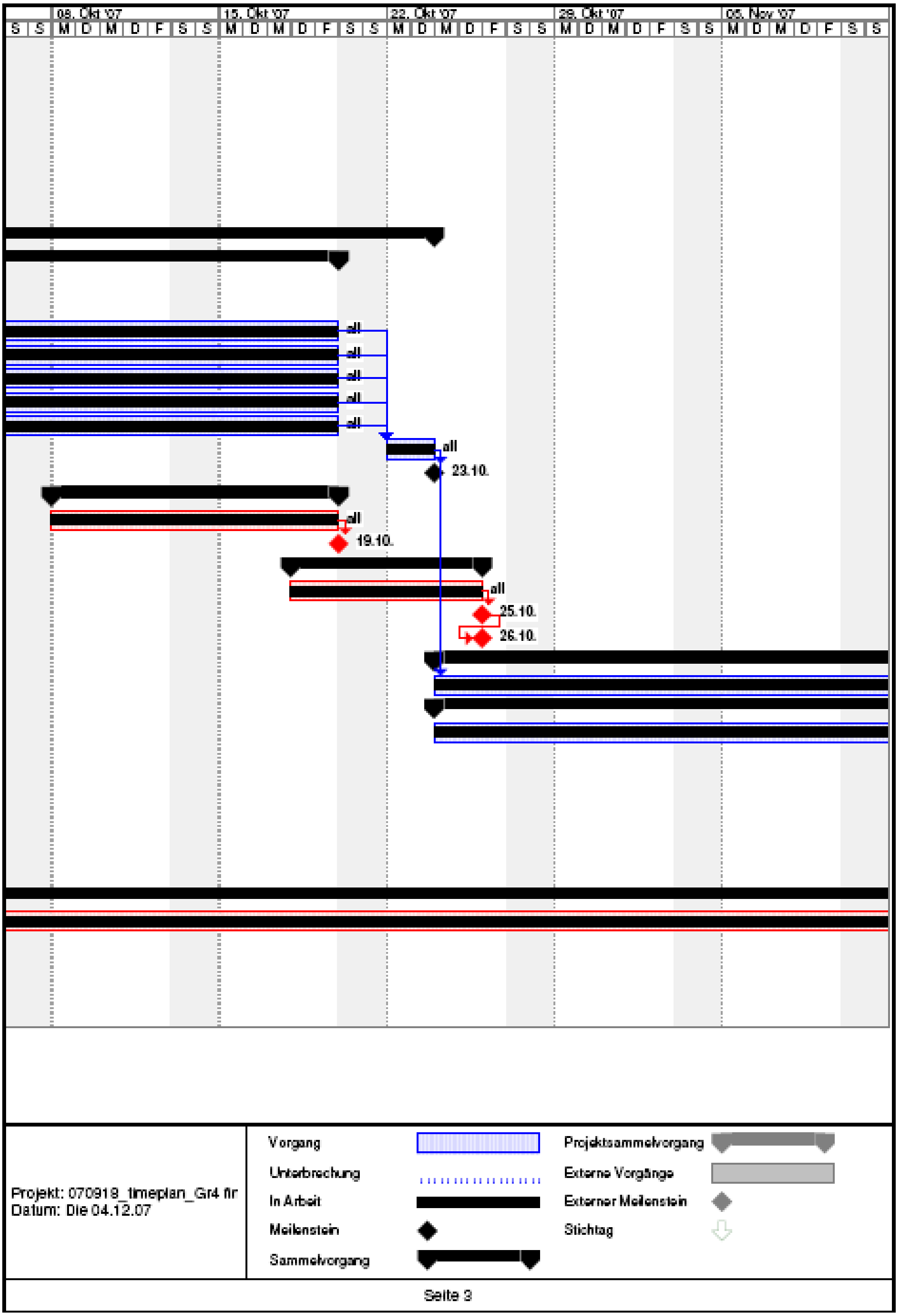

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15. Okt '07
22. Okt '07
29. Okt '07
05. Nov '07
all
23.10.
19.10.
25.10.
26.10.
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Datum: Die 04.12.07
Vorgang
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Sammelvorgang
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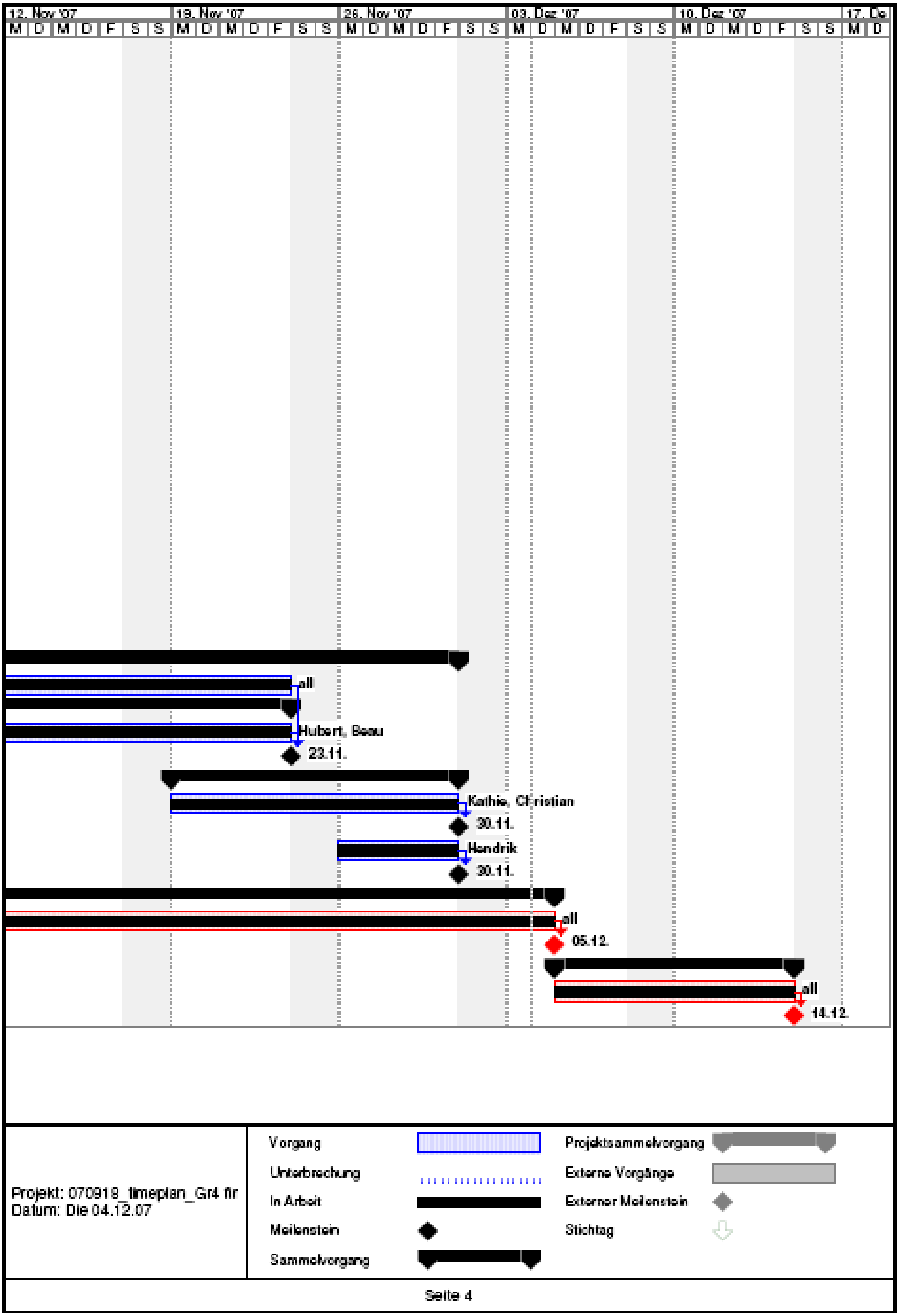
12. Nov '07
19. Nov '07
26. Nov '07
03. Dez '07
10. Dez '07
17. De
M D M D F S S M D M D F S S M D M D F S S M D M D F S S M D M D F S S M D
all
Hubert, Beau
23.11.
Kathie, Christian
30.11.
Hendrik
30.11.
all
05.12.
all
14.12.
Projekt: 070919_timeplan_Gr4 fir
Datum: Die 04.12.07
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Projektsammelvorgang
Externe Vorgänge
Externer Meilenstein
Stichtag
Seite 4

A7: Crossing Junction Dimensions

A7.1: Dimensions of Level 1

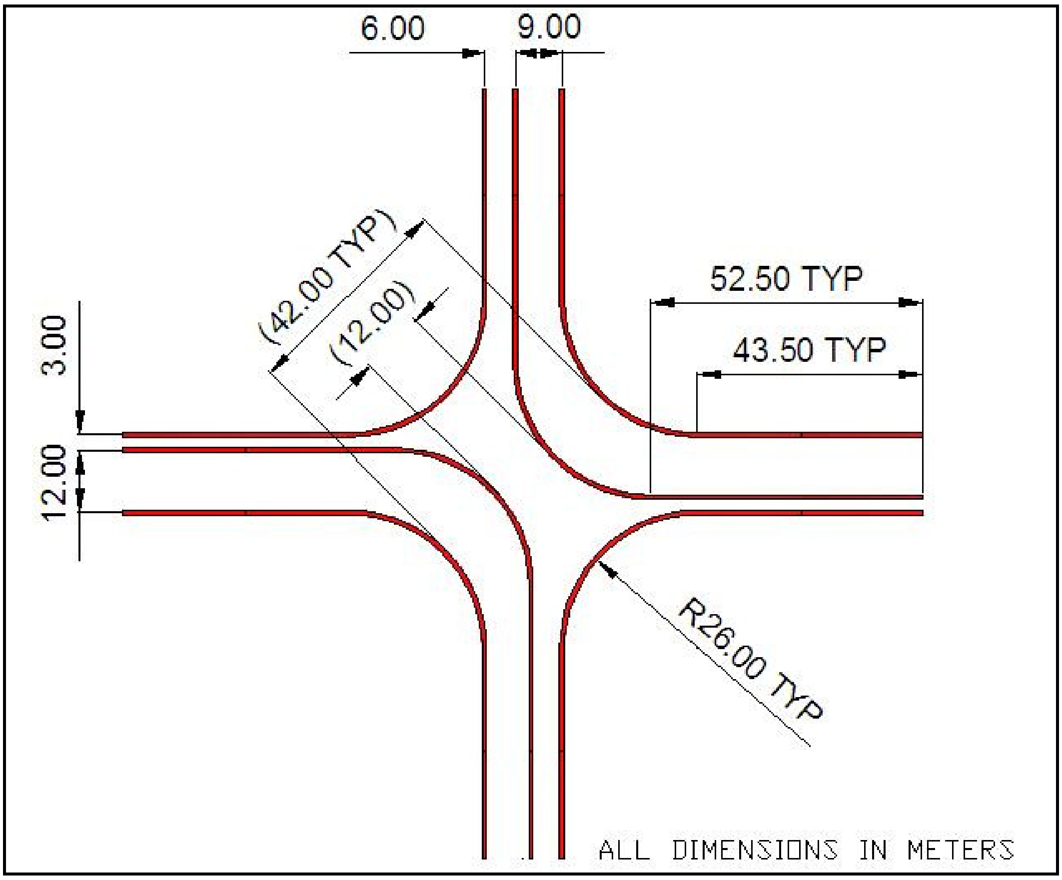

FIGURE A7.1.1: Top View Level 1 Dimensions

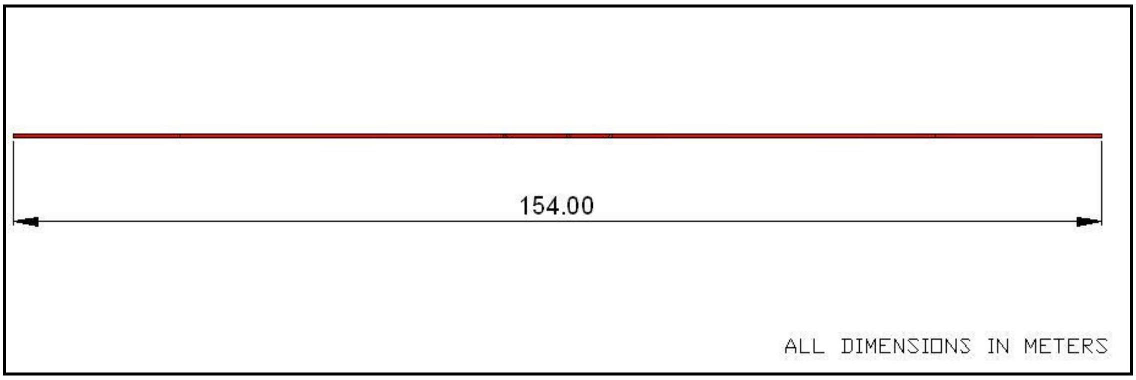

FIGURE A7.1.2: Side View Level 1 Dimensions

A7.2: Dimensions of Level 2

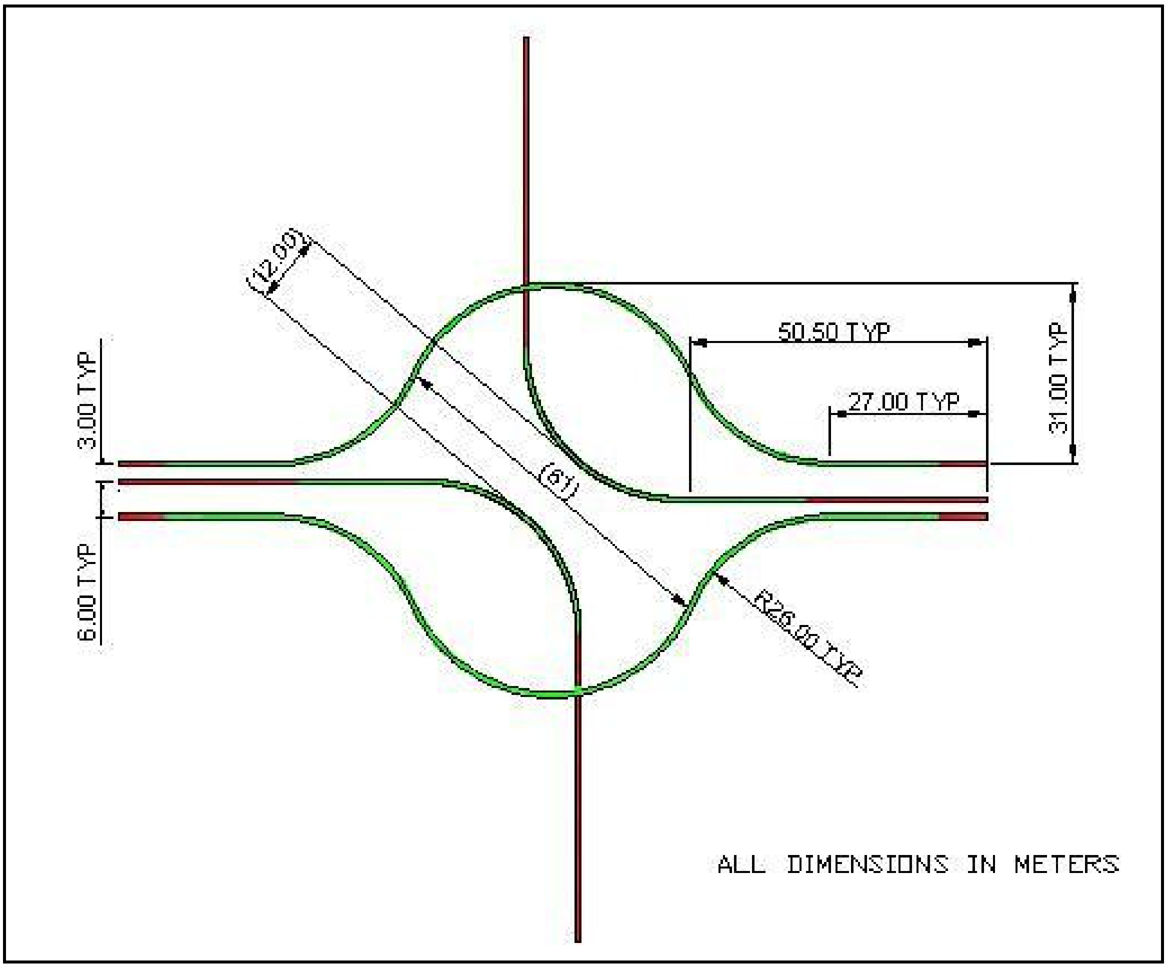

FIGURE A7.2.1: Top View Level 2 Dimensions

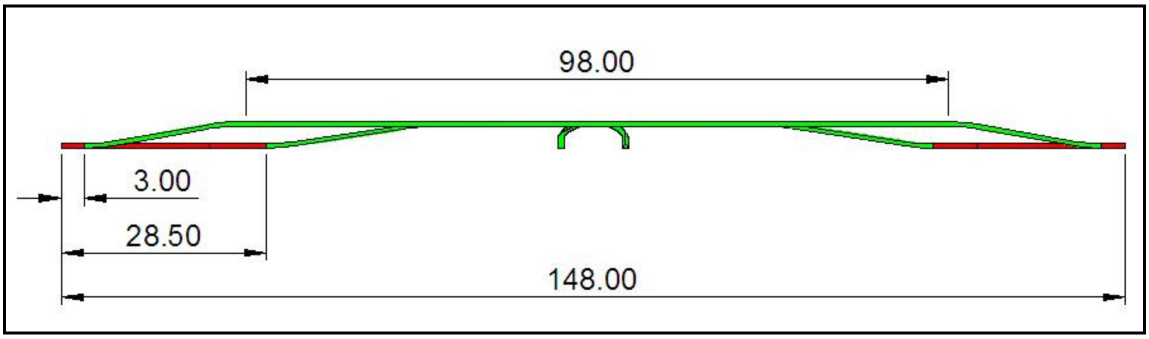

FIGURE A7.2.2: Side View Level 2 Dimensions #1

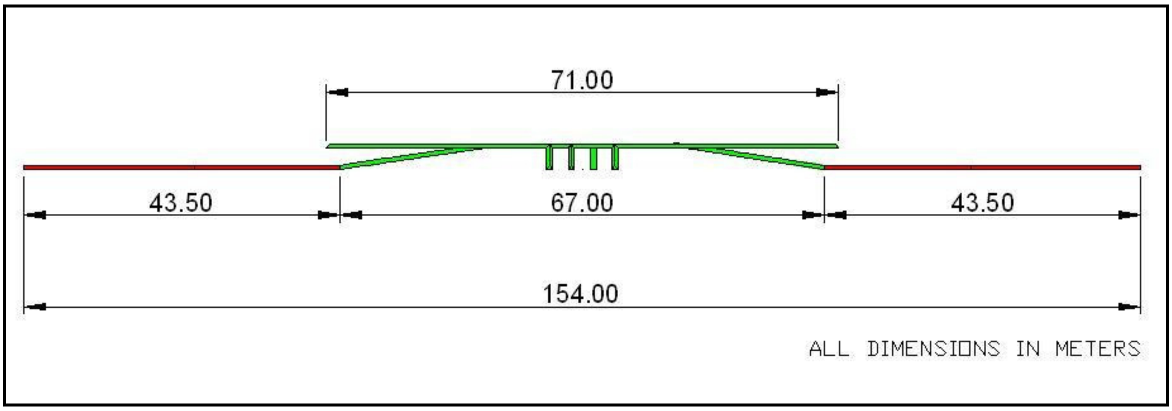

FIGURE A7.2.3: Side View Level 2 Dimensions #2

A7.3: Dimensions of Level 3

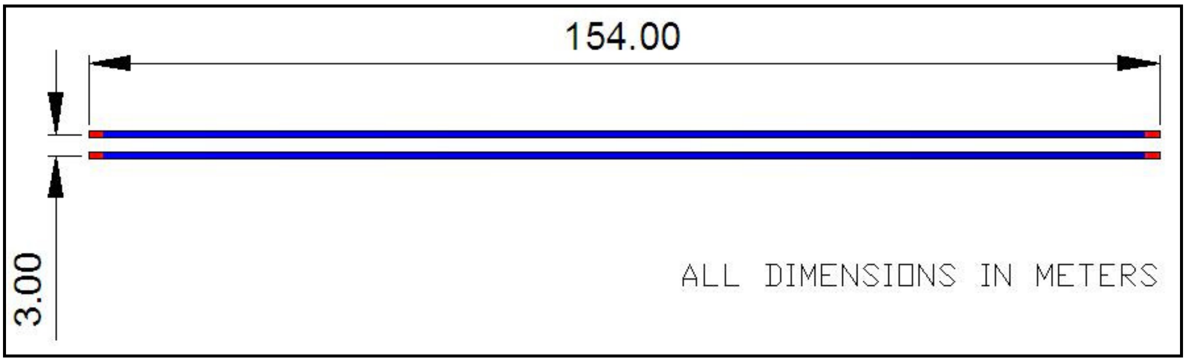

FIGURE A7.3.1: Top View Level 3 Dimensions

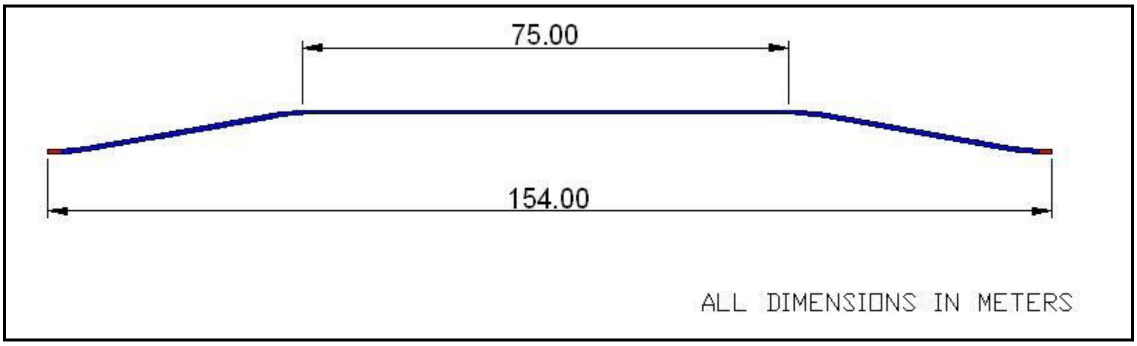

FIGURE A7.3.2: Side View Level 3 Dimensions

A8: Crossing Junction Full Switch Dimensions

A8.1: Crossing Junction Switch

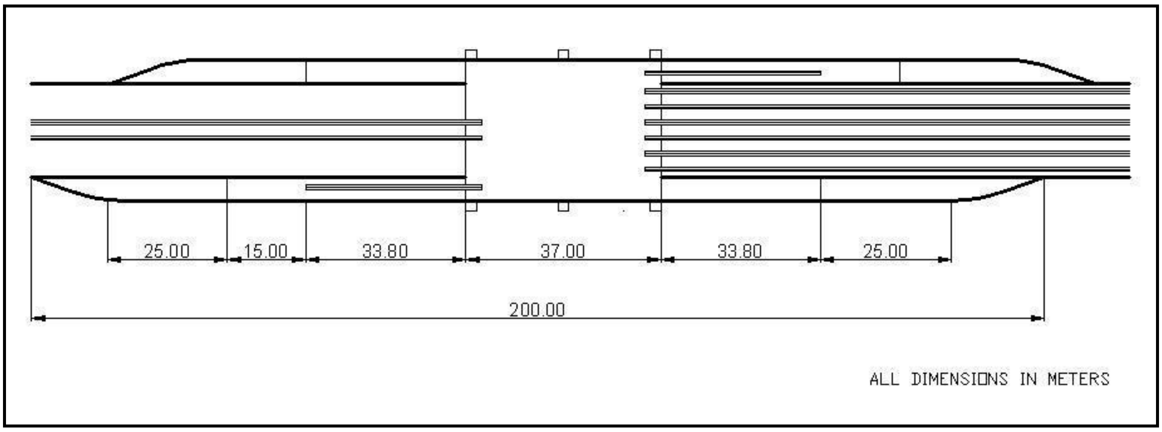

FIGURE A8.1.1: Top View Crossing Junction Switch Dimensions

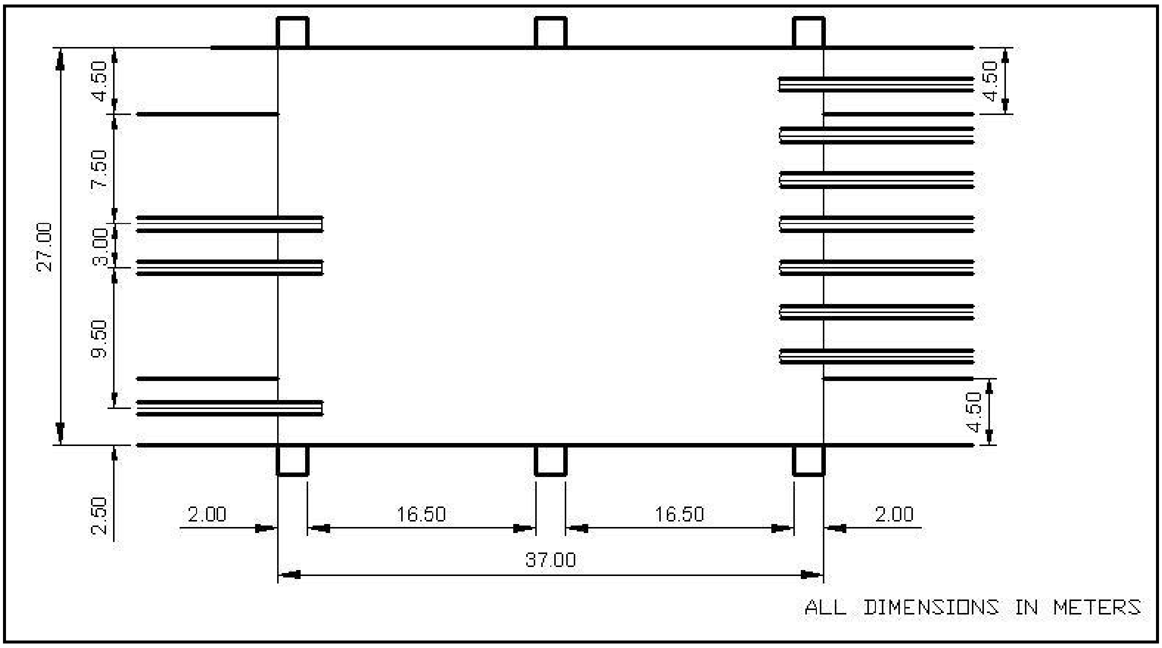

FIGURE A8.1.2: Top View Crossing Junction Switch Platform Dimensions

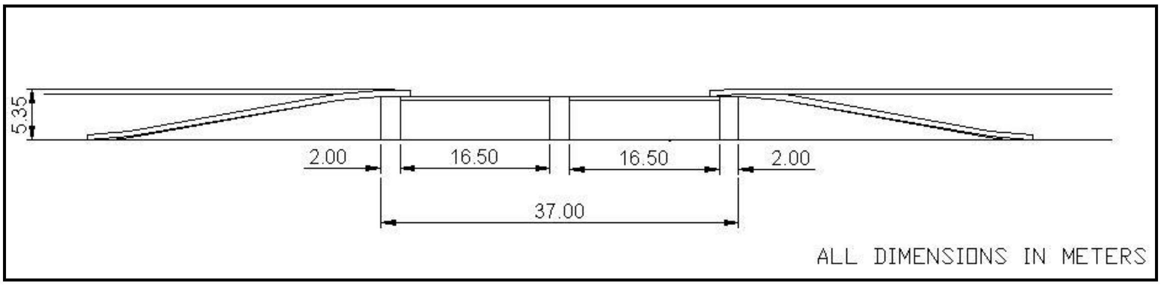

FIGURE A8.1.3: Side View Crossing Junction Switch Dimensions

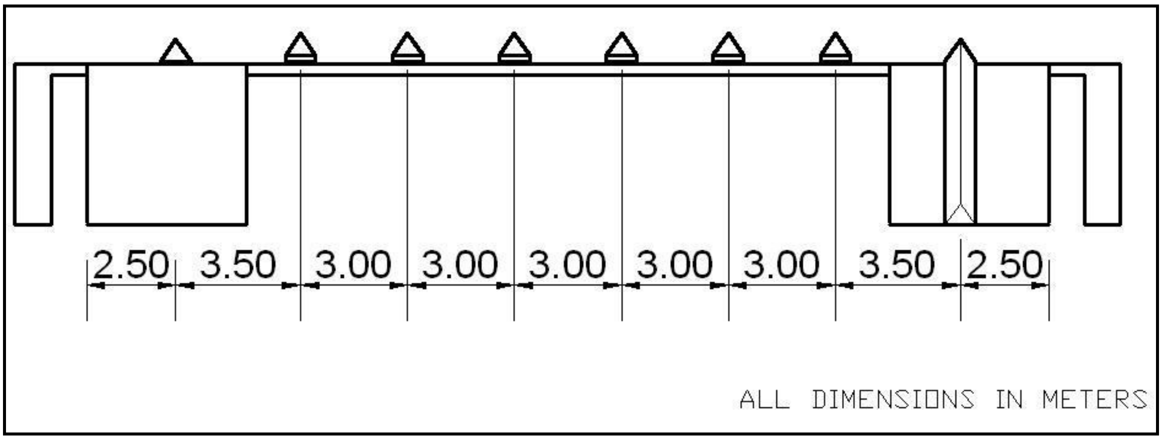

FIGURE A8.1.4: Front View Crossing Junction Switch Dimensions

A8.2: Crossing Junction Switch Cover

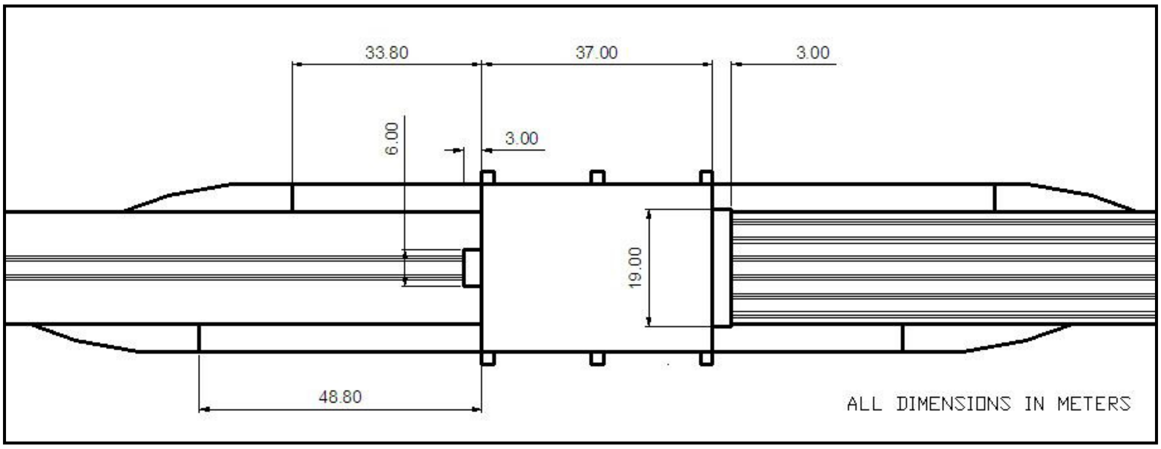

FIGURE A8.2.1: Top View Crossing Junction Switch Cover Dimensions

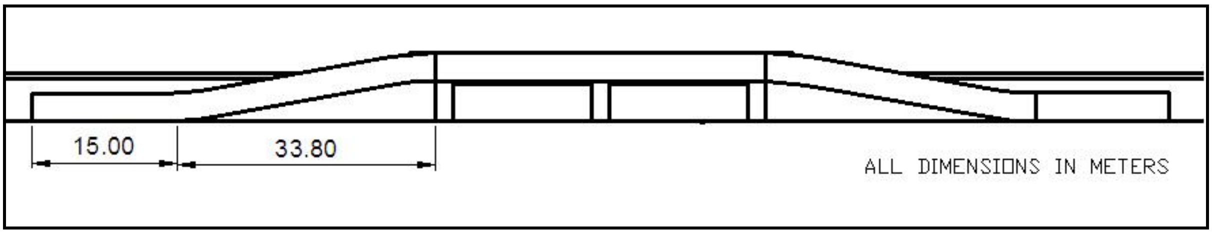

FIGURE A8.2.2: Side View Crossing Junction Switch Cover Dimensions

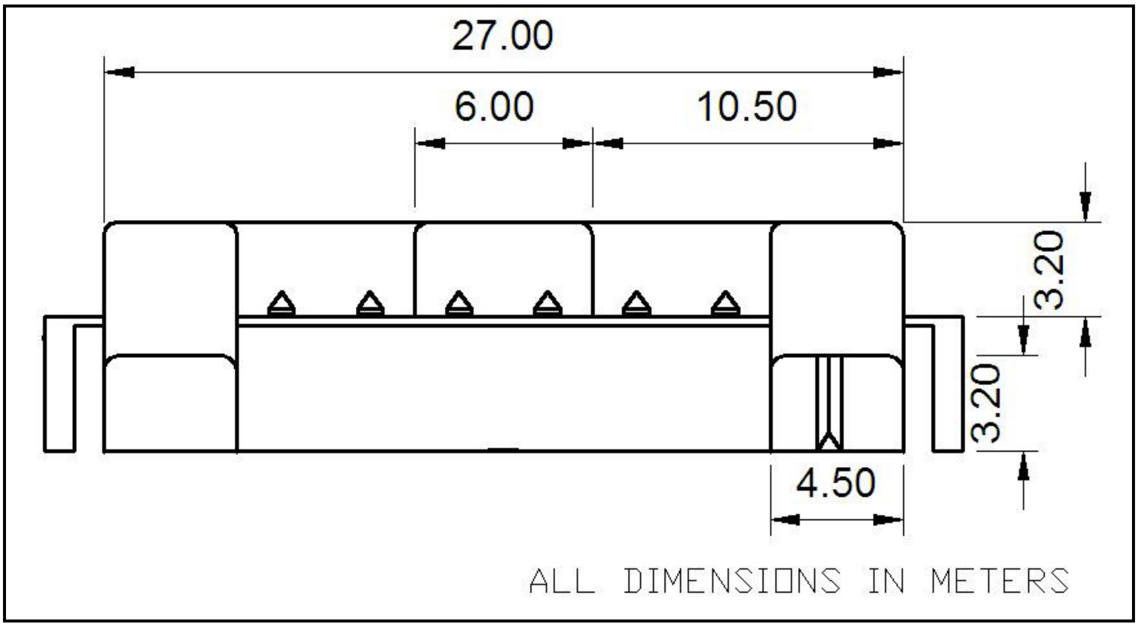

FIGURE A8.2.3: Front View Crossing Junction Switch Cover Dimensions

A8.3: Crossing Junction Access Rail

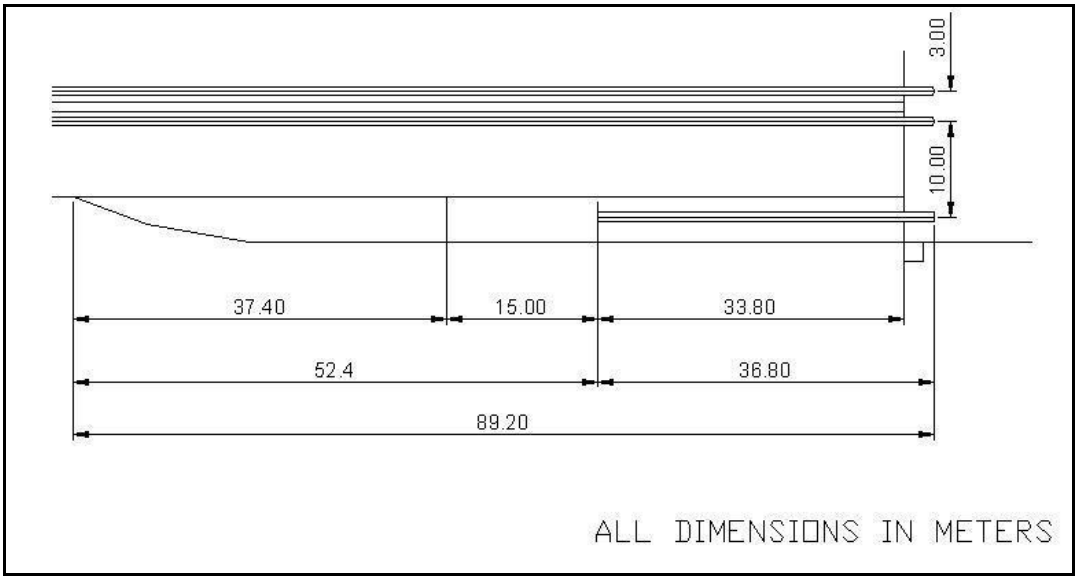

FIGURE A8.3.1: Top View Crossing Junction Access Rail Dimensions

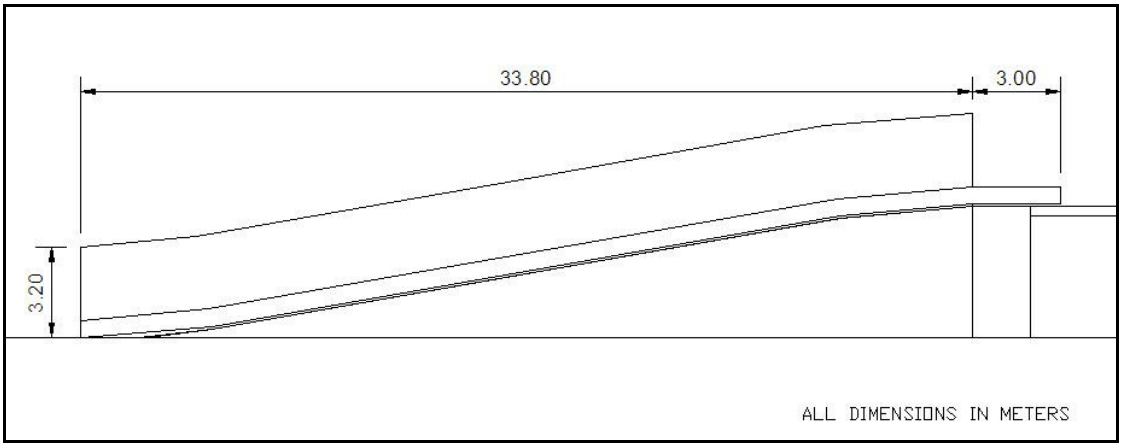

FIGURE A8.3.2: Side View Crossing Junction Access Rail Dimensions

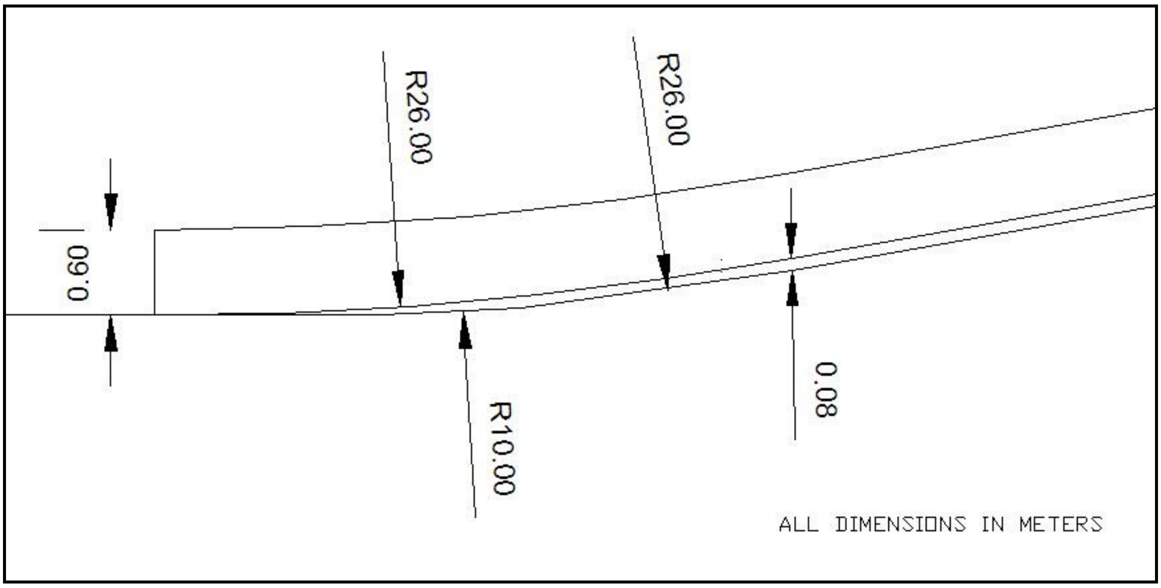

FIGURE A8.3.3: Side View Crossing Junction Beginning Access Rail Dimensions

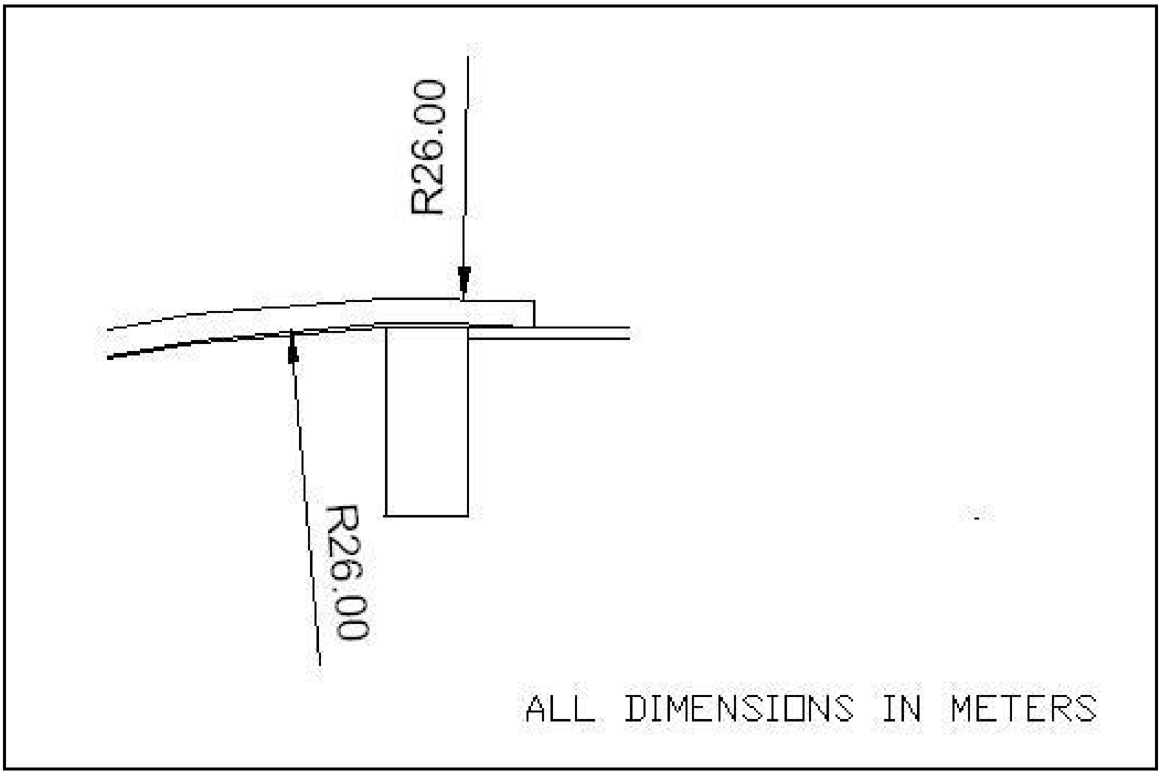

FIGURE A8.3.4: Side View Crossing Junction Ending Access Rail Dimensions

A8.4: Crossing Junction Magnetic Field

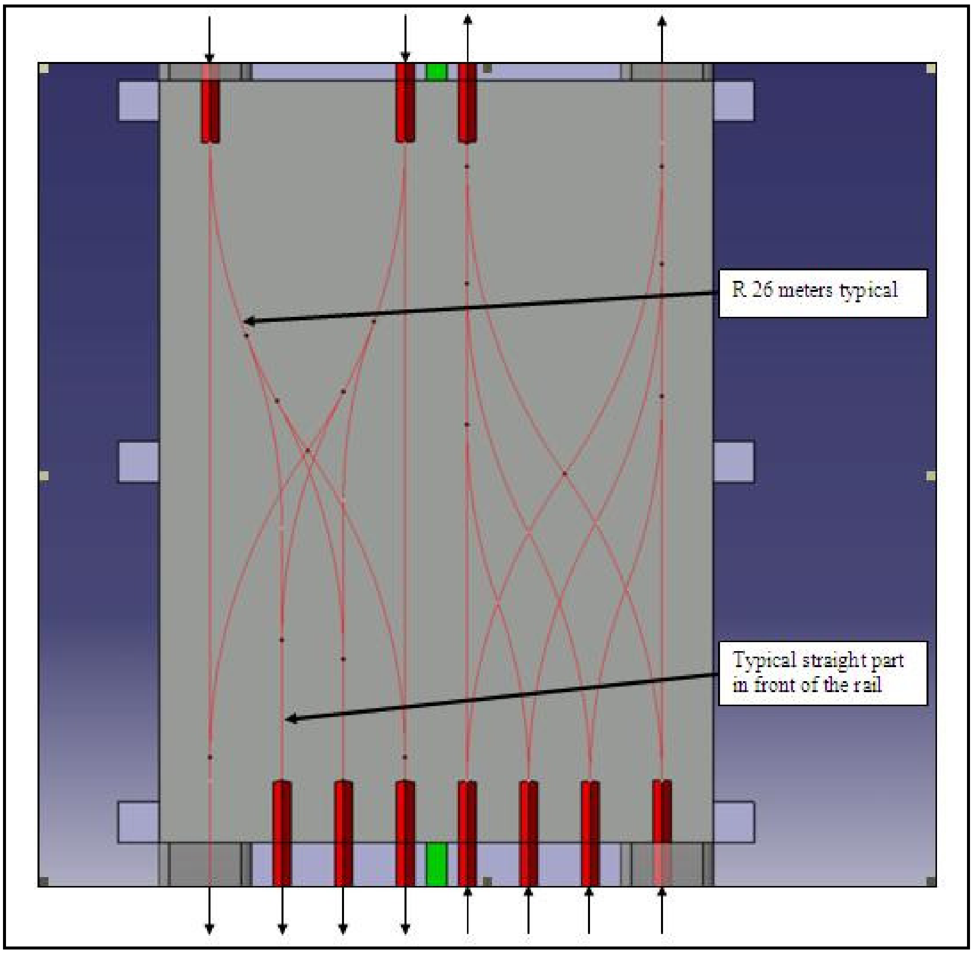

FIGURE A8.4.1: Top View Crossing Junction Magnetic Field Dimensions

A8.5: Crossing Junction Switch Incoming Rails

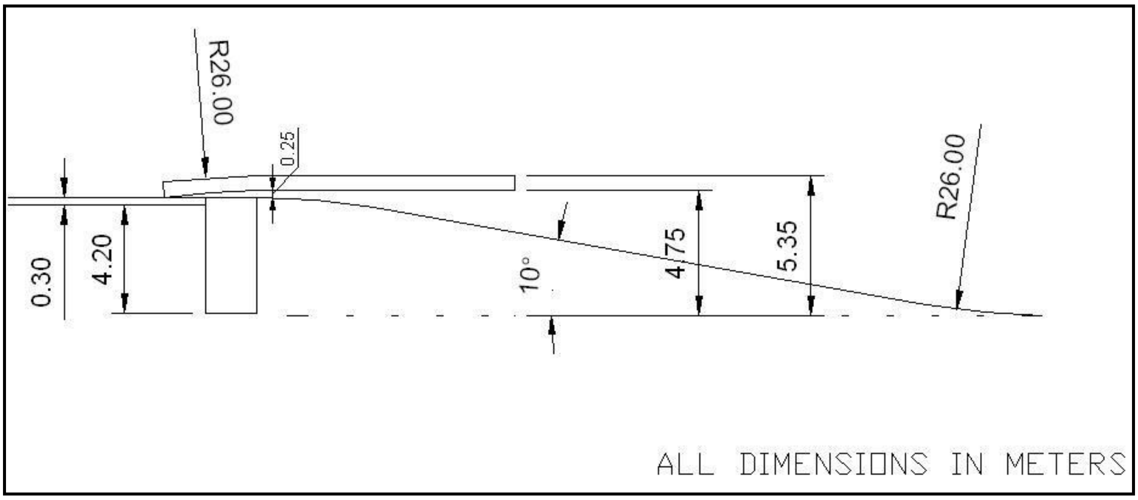

FIGURE A8.5.1: Side View Crossing Junction Switch Incoming Rails Dimensions #1

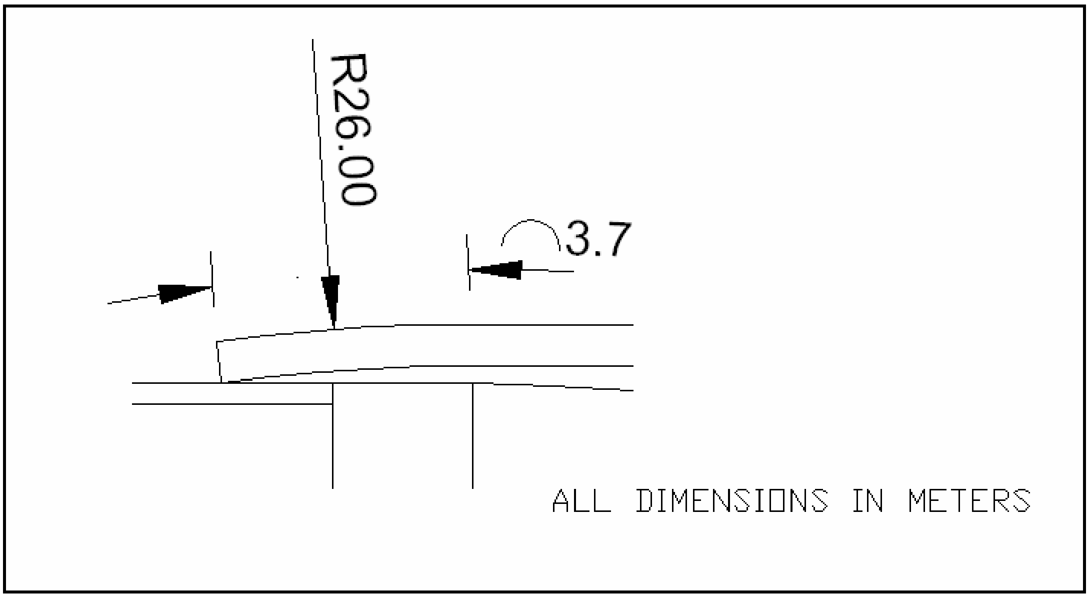

FIGURE A8.5.2: Side View Crossing Junction Switch Incoming Rails Dimensions #2

A9: On/off Switch Dimensions

A9.1: On/off Switch

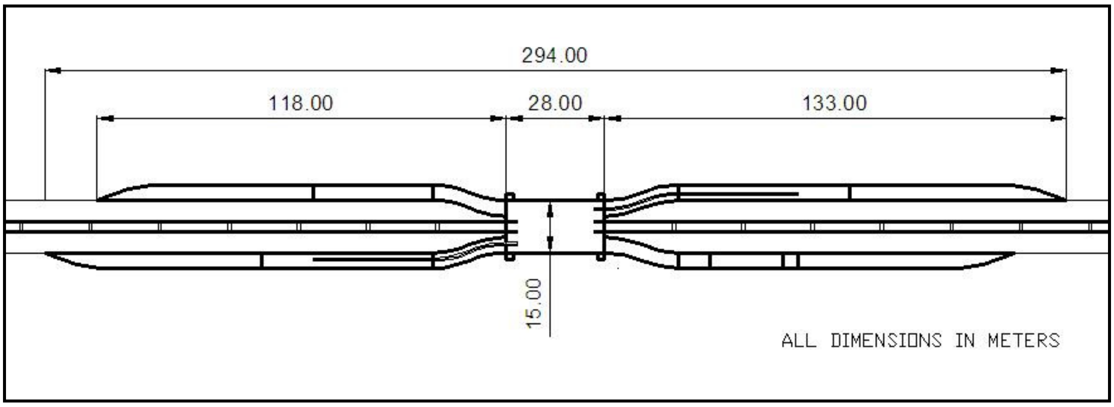

FIGURE A9.1.1: Top View On/off Switch Dimensions #1

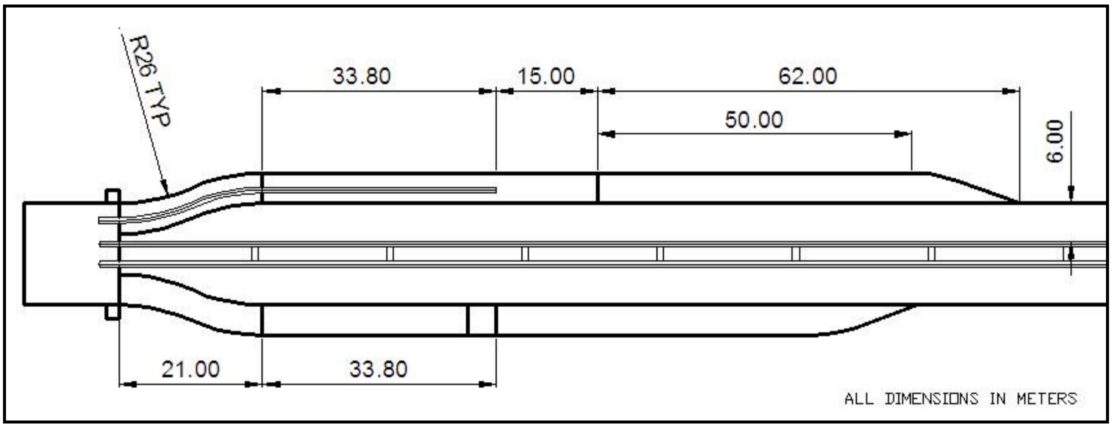

FIGURE A9.1.2: Top View On/off Switch Dimensions #2

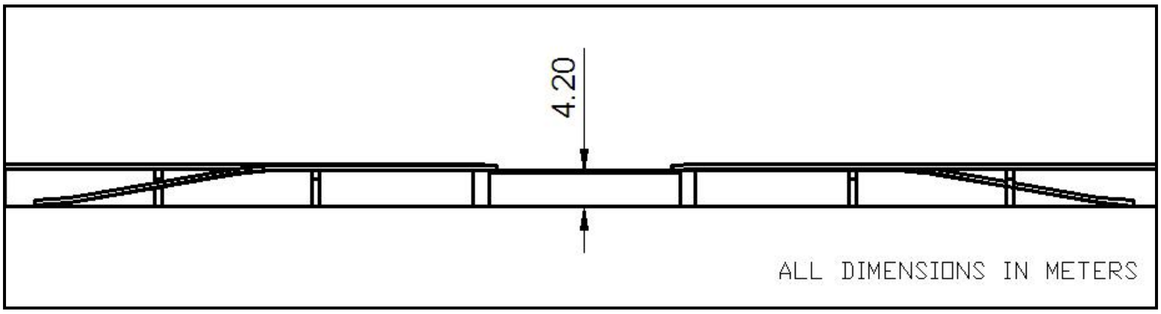

FIGURE A9.1.3: Side View On/off Switch Dimensions

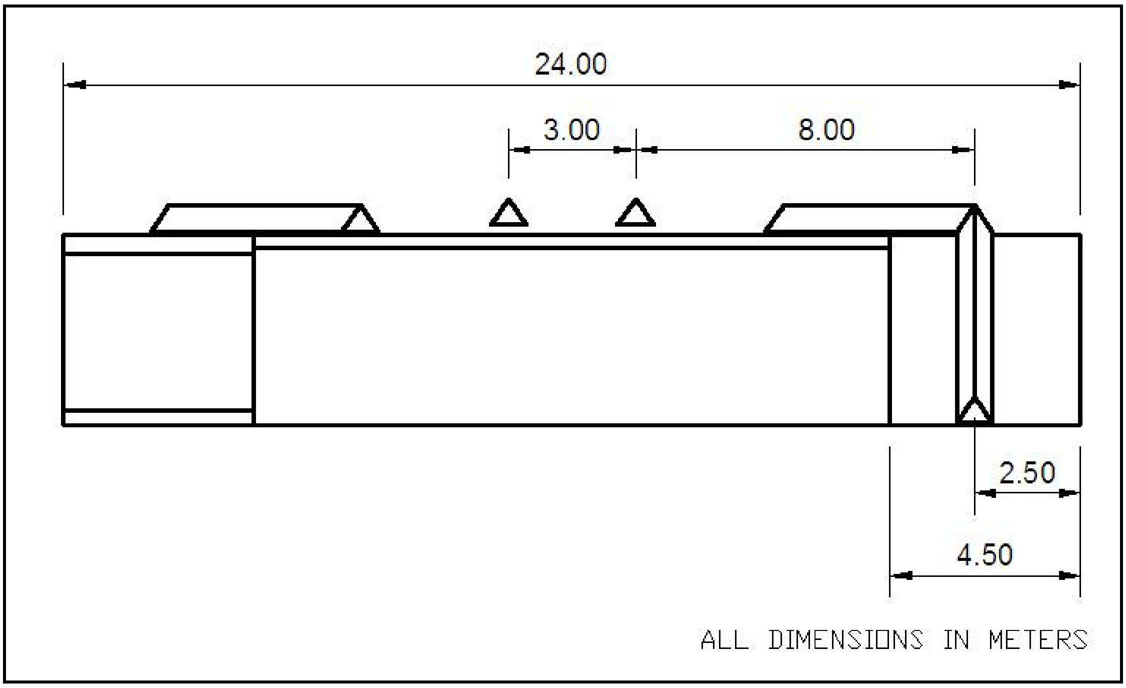

FIGURE A9.1.4: Front View On/off Switch Dimensions

A9.2 On/off Switch Cover

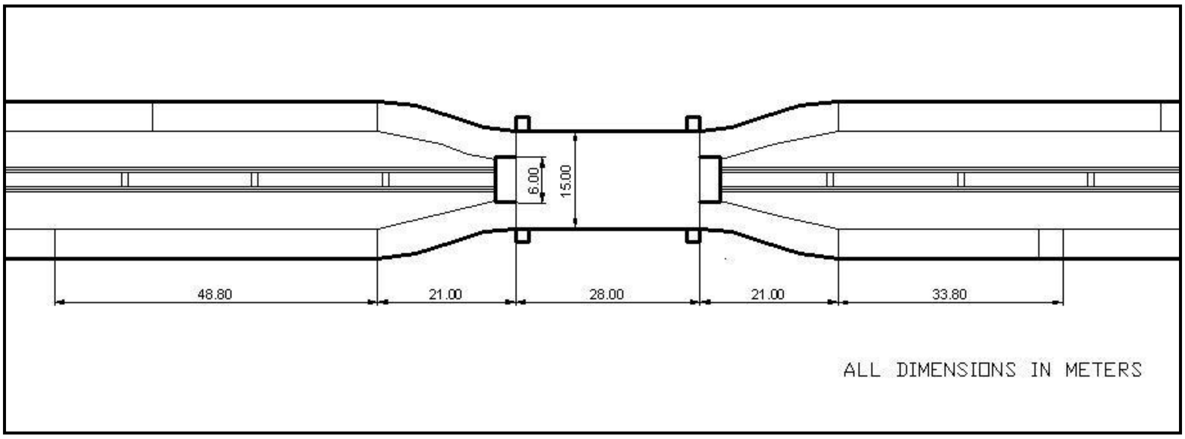

FIGURE A9.2.1: Top View On/off Switch Cover Dimensions

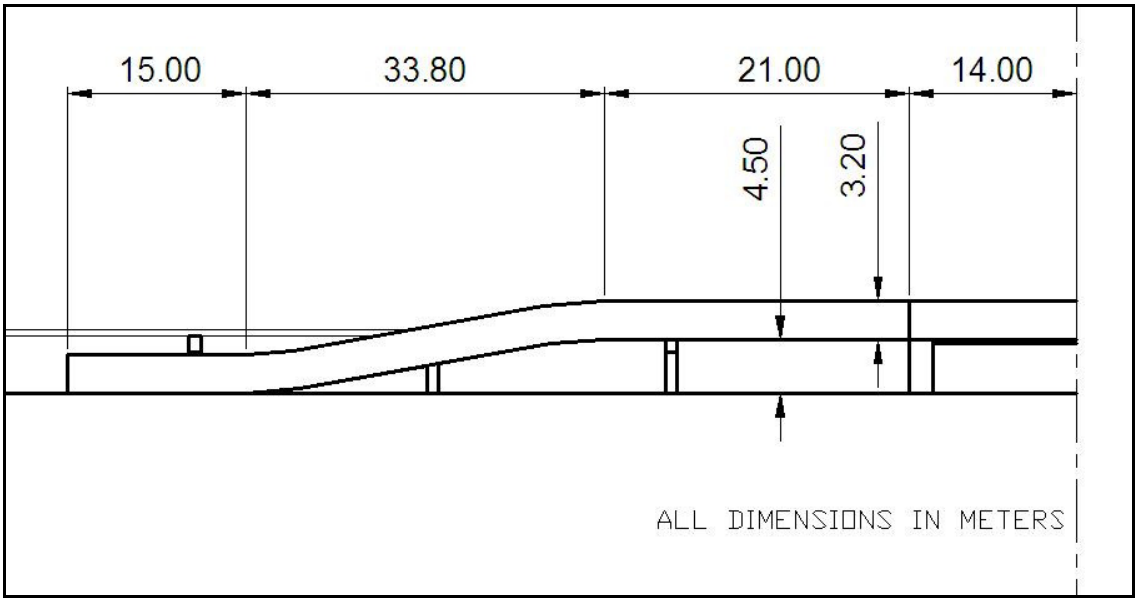

FIGURE A9.2.2: Side View On/off Switch Cover Dimensions

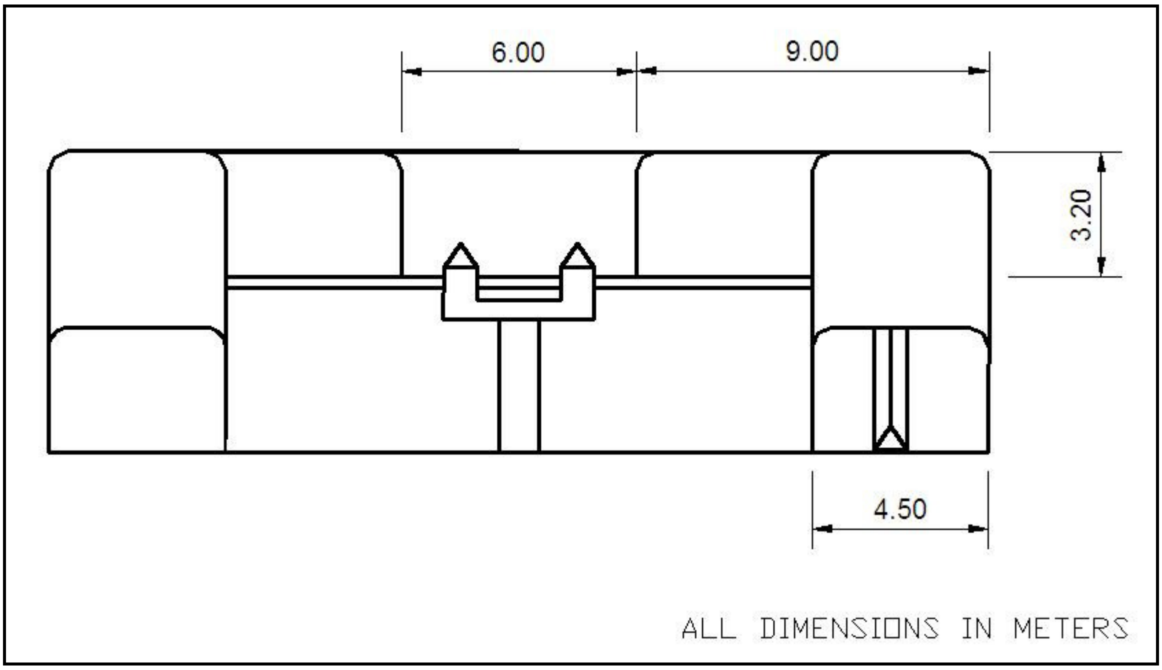

FIGURE A9.2.3: Front View On/off Switch Cover Dimensions

A10: Physical Model

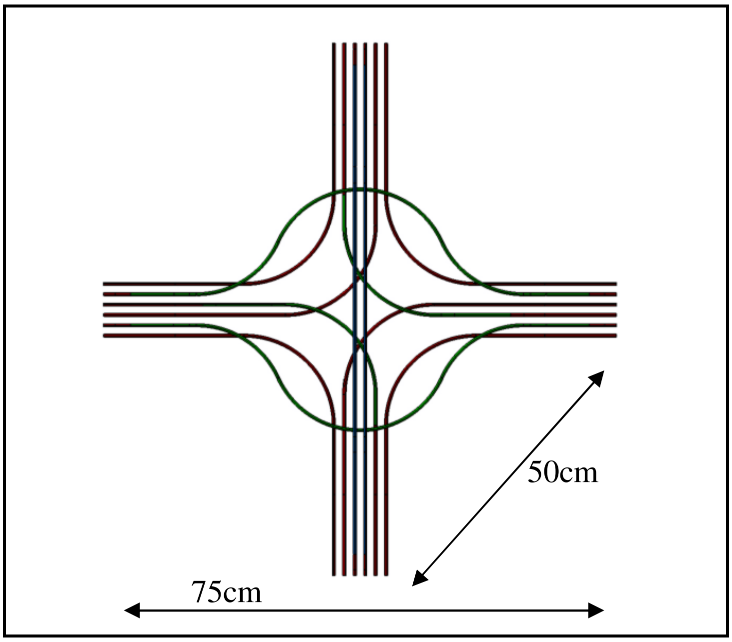

FIGURE A10.1: Physical Model Dimensions

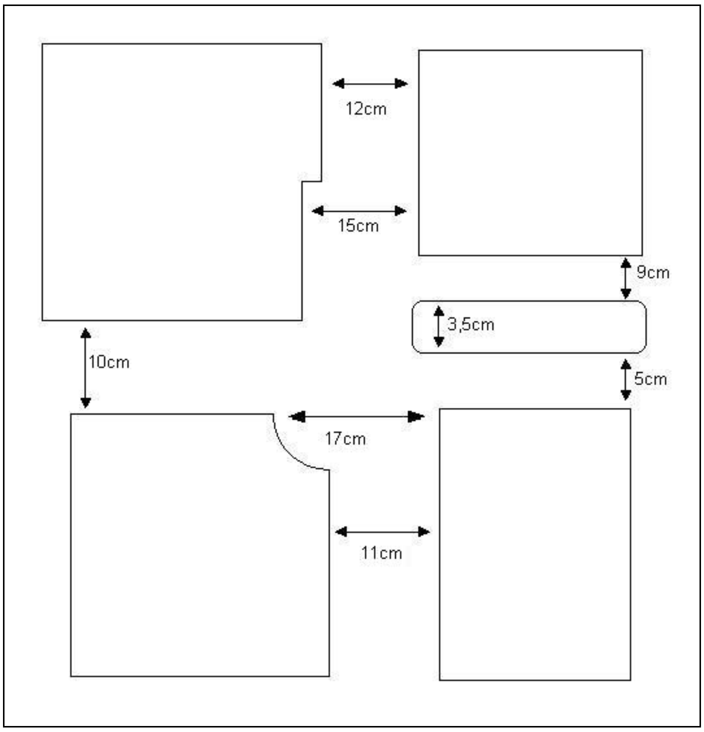

FIGURE A10.2: Physical Model Building Dimensions #1

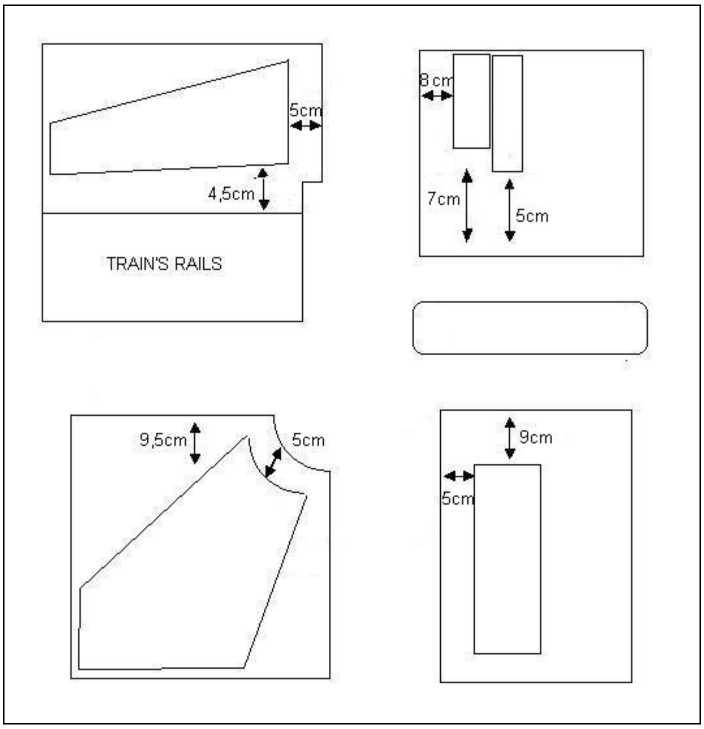

FIGURE A10.3: Physical Model Building Dimensions #2

A11: Group Member Contributions

Group Member Contribution	
Work	Groupmember
Organisation	all
Research	all
Brainstorming, Proposals, Ideas	all
2D drafting ideas	HH,JS
Dimensioning of the junctions	HS,HH,BA
Create 3D Model	HS
Create 2D Model	HS
2D Model Dimensioning	JS,HH
Physical Model	CL,JS
Final Report	BA,HH,CL,HS,JS
Final Report Compilation	BA

Beau Anderson	BA
Hendrik Hölscher	HH
Christian Liv	CL
Hubert Schmid	HS
Jekaterina Seredenko	JS