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A web-based Cycling Manager Game - Individual Time Trials and Mass Start Road Races based on Simulations

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Abstract

Professional road cycling is the focus of several research fields to enhance training methods, bike materials, and other related parameters. Research data are also used in manager games, where results are applied to predict a realistic outcome of road cycling races. The cycling-related parameters can be calculated using mathematical formulas to estimate the draft, power, speed, and energy of cyclists. Additionally, cyclists are studied in real race situations, and the importance of team-mates is assessed for the overall duration of a race. Several games try to emulate the various impact factors of a bike race and offer the possibility to manage cycling teams and influence individual cyclists' race performance through tactical instructions. However, there is no multiplayer manager game, where the cyclist's strength values get updated dynamically during an entire season. The strength values are based on each cyclist's real-life results. Another feature is that players can use detailed tactical instructions in multiplayer races for their cyclists against other players.

Therefore, the RadSimTool Project is the effort to design, implement, and evaluate a sophisticated cycling manager game. The game provides a novel manager experience for cycling fans who want to get deeper into their teams' management. Players can compete against each other within a web-based game. The implemented game uses real-life results of cyclists to update the strengths of randomly created cyclists, which are connected to their strength values. In combination with a player's tactical instructions for their team, the strength values are used to simulate cycling races. The simulation algorithms rely on the mathematical background to calculate power, speed, and energy over each cyclist's race. This work reveals the potential of the created game. It assesses the quality of the generated strength values and the simulation algorithms for individual time trial races and mass start races. The focus for evaluating the two simulation algorithms was on the comparison of the simulated results with the result times and results of real cycling races with the same stage profile to show how accurate the

simulated results are. However, to evaluate the usability of the RadSimTool website, a user study with 12 participants was used. It showed that even though most users liked to use the website, the lack of detailed tutorials about the different tactical instructions and no detailed information about the different race situations made it hard for inexperienced users to evaluate the results and learn for future races.

Kurzfassung

Der professionelle Straßenradsport steht im Fokus mehrerer Forschungsbereiche, um Trainingsmethoden, Equipment und andere damit verbundene Parameter zu verbessern. Forschungsdaten werden auch in Managerspielen verwendet, wo die Ergebnisse zur Vorhersage eines realistischen Ausgangs von Straßenradrennen eingesetzt werden. Die radsportbezogenen Parameter können mit mathematischen Formeln berechnet werden, um den Windschatten, die Leistung, die Geschwindigkeit und die Energie von Radfahrern zu schätzen. Zusätzlich werden Radfahrer in realen Rennsituationen untersucht und die Bedeutung von Teamkollegen für die Gesamtdauer eines Rennens bewertet. Mehrere Spiele versuchen, die verschiedenen Einflussfaktoren eines Radrennens nachzubilden und bieten die Möglichkeit, Radteams zu managen und durch taktische Anweisungen Einfluss auf die Rennleistung einzelner Radfahrer zu nehmen. Es gibt jedoch kein Multiplayer-Managerspiel, bei dem die Stärkewerte der Radfahrer während einer ganzen Saison dynamisch aktualisiert werden. Die Stärkewerte basieren auf den realen Ergebnissen der einzelnen Radrennfahrer. Eine weitere Besonderheit ist, dass die Spieler in Multiplayer-Rennen detaillierte taktische Anweisungen für ihre Radfahrer gegen andere Spieler verwenden können.

Das RadSimTool-Projekt ist also der Versuch, ein anspruchsvolles Radsport-Managerspiel zu entwerfen, zu implementieren und zu evaluieren. Das Spiel bietet ein neuartiges Managererlebnis für Radsportfans, die tiefer in das Management ihrer Teams einsteigen wollen. Die Spieler können in einem webbasierten Spiel gegeneinander antreten. Das implementierte Spiel verwendet reale Ergebnisse von Radsportlern, um die Stärken von zufällig erstellten Radsportlern zu aktualisieren, die mit ihren Stärkewerten verbunden sind. In Kombination mit den taktischen Anweisungen des Spielers für sein Team werden die Stärkewerte verwendet, um Radrennen zu simulieren. Die Simulationsalgorithmen stützen sich auf den mathematischen Hintergrund, um Leistung, Geschwindigkeit und Energie über das Rennen für

jeden Radfahrer zu berechnen. Diese Arbeit zeigt das Potenzial des erstellten Spiels auf und bewertet die Qualität der generierten Stärkewerte und der Simulationsalgorithmen für Einzelzeitfahrrennen und Massenstartrennen. Der Schwerpunkt für die Bewertung der beiden Simulationsalgorithmen lag auf dem Vergleich der simulierten Ergebnisse mit den Ergebniszeiten und -ergebnissen realer Radrennen mit demselben Etappenprofil, um zu zeigen, wie genau die simulierten Ergebnisse sind. Für die Bewertung der Benutzerfreundlichkeit der RadSimTool-Website wurde hingegen eine Benutzerstudie mit 12 Teilnehmern durchgeführt. Sie zeigte, dass, obwohl die Mehrheit der Benutzer die Website gerne nutzte, das Fehlen von detaillierten Anleitungen zu den verschiedenen taktischen Anweisungen und keine detaillierten Informationen zu den verschiedenen Rennsituationen es unerfahrenen Benutzern schwer machten, die Ergebnisse zu bewerten und für zukünftige Rennen zu lernen.

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1 Introduction

In recent years, data analysis methods became very popular for professional road cycling races. The cycling teams try to optimize the training, equipment, and tactical strategies to increase the performance during the races. Therefore, professional road cycling races are the focus of several research fields. Researchers studied professional cycling races, cyclists, and the behavior of cyclists during the races. Some of them focus on defining the mathematical foundations for the cyclists' essential factors, such as slipstream, speed, power, or the energy tank during the different race situations. Whereas Jones et al. (Jones, Vanhatalo, Burnley, Morton, & Poole, 2010) defined the critical power (CP) model without regeneration of the energy tank (W'), Skiba et al. (Skiba, Chidnok, Vanhatalo, & Jones, 2012) approach introduced with W'_{bal} a recoverable energy tank.

Other researchers study the cyclist's shape and optimize the training for cyclists to increase their performance level. Researchers also study cyclists' tactical behavior during the races and the importance of teammates working together during a race to achieve their common goal and win the race. Whereas Padilla studied (Mignot, 2016a) different race strategies, Hoeningman et al. autocitehoenigman2011cooperation simulate the behavior of cyclists in groups with an agent-based system, and Tim Olds (Olds, 1998) studied breakaway groups.

Games that allow the players to manage their favorite sports team are popular, and Manager-Cycling games try to simulate the sport and races to give the players the experience to manage a cycling team over several seasons. Whereas some of them provide a great single-player experience with 3D races, other games offer a multiplayer manager experience. However, no game offers a multiplayer experience and realistic dynamic strength values during an entire season with simulated races based on mathematical foundations and the players' tactical instructions for their cyclists.

The research focus of the RadSimTool lies in creating a dynamic system to simulate cycling races based on realistic cycling strength values, tactical

instructions for the cyclists by the managers, and physical and mathematical foundations. Thus, the simulation algorithm implements mathematical formulas for the simulation of the cyclists during a race. Therefore, the focus is on separate simulation algorithms for mass start road cycling races and individual time trial races. Although the system randomly generates the cyclists, each cyclist's strength values connect to strength values generated from a cyclist's real-life results. The algorithm uses the managers' tactical instructions and cyclists' strength values to simulate the race.

By combining these functionalities, the created system can simulate realistic and dynamic cycling races in a novel way. Whereas other cycling games, e.g., the Pro Cycling Manager game, update their real-life database only a few times per year, the RadSimTool provides dynamic strength values based on the cyclists' latest results.

The cyclist's performance data and energy system simulation allows cycling strength values and evaluates cyclists' performances for different races. Therefore, the designed system creates a great basis for further implementations and optimizations to increase simulated races' quality further.

1.1 Motivation

The goal of the project is to design and implement a web-based multiplayer cycling manager game. The main features for the RadSimTool Project are dynamic strength values for the cyclists of the teams. Each cyclist is rated with such strength values to create a realistic cycling environment with certain team structures. Strength values are updated with the latest results of real cycling races. The overall process is quite simple: players should register on the website, create their team, and participate in cycling races in the game with their cyclists. The players can use tactical instructions to define how their cyclists should act within the races. There are two different types of races, mass start road cycling races and individual time trial races, which can be simulated with specific algorithms. The focus of the simulation is to simulate a realistic behavior of cyclists. Therefore, the algorithms are based on mathematical formulas for the calculation of power and speed. The energy recovery system is another feature to simulate the cyclists' energy tank and allow cyclists to recover partially during the races. The RadSimTool Project's implementation is evaluated regarding the usability of the website

and the quality of the simulation algorithms.

1.2 Structure

Chapter 2 discusses related work for this thesis to point out differences to existing research. It starts with an introduction to cycling and demonstrates the importance of statistics, results, and cycling performance data. It follows a brief overview of cycling races' prediction before the focus shifts to mathematical backgrounds and cycling race simulation. The chapter concludes with a discussion of the strengths and weaknesses of popular cycling manager games. Under consideration of the previous chapter, Chapter 3 defines the functional and non-functional requirements for the RadSimTool Project. Furthermore, the conceptual architecture describes the structure of the RadSimTool. Chapter 3 also evaluates the requirements formulates and discusses the design decisions.

Based on the requirements and design decisions, Chapter 4 focuses more on the required tools and frameworks for actual implementation. It evaluates the required tools for data mining, managing, and processing and discusses the client/server architecture requirements for the RadSimTool and data editor website. The generation of strength values for cyclists and cycling races simulation is mostly done with specific tools and frameworks are discussed in detail. Chapter 5 examines the RadSimTool Project's implementation, based on the defined requirements from Chapter 3 with the tools and frameworks from Chapter 4. Therefore, the first part of the chapter focuses on implementing the data, mining, managing, and processing. The second part of the chapter describes the RadSimtool Project website's implementation and the implemented tactical instructions for the game.

In the last part, the implementation of the simulation of cycling races is described. Chapter 6 discusses the evaluation of the project with the study design. It describes the research questions for the evaluation. Those questions are examined in detail to reflect on solutions and problems within the implementation. Chapter 7 focuses on the learned lessons during this project. The final Chapter 8 summarizes the entire RadSimTool Project and gives an outlook for further work to improve players' long-time motivation.

2 Background and Related Work

Nowadays, services that use predictions and recommendations become part of our daily life and are often used together. Recommendations tell the user what is good. For example, ranking movies for the user according to the users viewing history and how the user and other people have rated the movies is considered for recommendations. Predictions are slightly different, and they do not say which movie is good or bad. Predictions build a model and learn from data and make assumptions about what will happen in the future.

When people use the internet and visit websites, predictions and recommendation techniques decide which advertisement suits the user best or what products they would be most interested in. Therefore, in 2016 NET-FLIX has announced a prize to increase the accuracy of its recommendation system (Bennett, Lanning, et al., 2007). Predictions and recommendation techniques are not only relevant for advertisement and promotions although also social media services. Every second, thousands of new videos are uploaded to YouTube, and new posts are made on Twitter or Facebook. Especially for the owners of such websites/social media services, it is a special task to show people videos, tweets, and posts relevant to them (individualized profile). Hence, the high amount of data makes it important to predict which video or which posts the users prefer and which posts the users want to watch or read. Therefore, prediction and recommender techniques are used to solve individual video, tweet, and post announcements.

Another important technology is digital games. Digital games can bring us into a fantasy world like in World of Warcraft (Blizzard, 2004), can simulate real life as in The Sims series (EA, 2017) or can also simulate live sport as in FIFA Football (EA, 2018). In sports simulations like the before stated FIFA Football video game series (EA, 2018) the players can play the game in different gaming modes. Players can control a single football player on the field, control the whole team during the match, or control a team together with another player in a multiplayer mode. Additionally, it is also

possible to become the team manager, do necessary team preparation before the games, and then use the stated gaming modes. Players not only can play the matches, but they can also simulate them. Since digital sports games are not only for entertainment, they also teach the player the rules of the games and make them aware of the idea and the fascination behind each sport's discipline. Since most games use real data, a player also learns about the game's athletes and teams. They learn to recognize the teams by their jerseys, team colors, emblems, and logos. Databases using licenses for the real teams and athletes also teach the players the athletes' strengths and weaknesses.

Today, not only men can learn and learn to recommend and predict from databases. As mentioned, also computer can make to that. Hence, recommendations and predictions also become important in many other fields, as predicting results and making recommendations about outcomes of sports events (Bunker & Thabtah, 2017). New technologies allow collecting more statistical data during sports events. Robin Praet has used recommendation techniques to predict sports results in tennis (Praet, 2017), and Carson Leung used data mining in sports in his approach to predict the results of college football games (Leung & W. Joseph, 2014).

Another example is Dimension Data, as this company collected 3 billion data points during cycling races(Gray, 2017), including results of up to five years. With this large amount of data and machine learning techniques, Dimension Data makes predictions during cycling events, as the yearly held 21 stages of the Tour de France, one of the most important cycling events worldwide. Dimension Data shows the viewers and other interested parties of the Tour de France Live-Tracking on their website (TourDeFrance, 2017a). Dimension Data also offers predictions of the possible stage winner, the next attackers, or if a breakaway will make it to the finish without being caught by the other cyclists during the race. However, Dimension Data also uses other information like historical data and former results of cyclists for predictions of a race.

Cycling is one of the most famous sports. The Union Cycliste Internationale (UCI) organizes the sport worldwide, with professional races, World Championships, and Olympic Games for men, women, and juniors. Especially professional road cycling is popular all over the world. The UCI publishes the regulations for the sport (UCI, 2017), updates them, and makes sure the cyclists, teams, and organizers follow the rules. With new technolo-

gies to collect data during races and training, it is possible to optimize the training and performance through races. The collected data about heart rate, cadence, and speed of the most relevant cyclists can be shown live on tv. For specific events, the data can also be shown live on websites like Velon.cc (VelonCC, 2017), or the Tour De France website (TourDeFrance, 2017b) where cooperation with Dimension Data allows the fans to see live analyses and predations during the races (Gray, 2017). Websites like STRAVA (Strava, 2017) allow professional athletes and hobby athletes to collect data with their cycling computers or mobile phones and upload them to their services to analyze and optimize their training. All these data can be used to evaluate the cyclists' performance and get information about the stages. However, it also can be used to predict winners or outcomes of races.

2.1 Cycling

Modern bicycles with nearly the same proportions as still used today, with two same-sized wheels, a mobile handlebar, pedals, and gears, were introduced in the 1880s and 1890s. Simultaneously, while the income of people increased, working hours decreased, and prices for bicycles dropped. For these reasons, at once, bicycles become affordable for many people in many regions of the world, especially in European countries such as Belgium, France, Netherlands, Spain, and Italy. Hence, the popularity of cycling increased, and bicycle races became organized by sports newspapers (Mignot, 2016b). Whereas the newspapers organized the races, companies of other economy branches as manufacturers for bicycles and tires started forming and supporting cyclists in teams. These bicycle and tire manufacture also started to pay their cyclists and sponsoring them with food and equipment. Since the bicycle market was booming in these years, the team owning manufacturers wanted the best cyclists for their teams, to show that their equipment is the best, which the fans should buy. It was a chance for cyclists to earn money from winning races, or when companies paid them to use their bikes, or when the cyclists were engaged for the manufacturer's teams. But also, newspapers paid the best cyclists when they wanted to participate in their organized races.

Sport newspapers saw their chance to get more popular with advertisements through the organization of the bicycle races. Whereas stadium sport

like football was easy to watch and follow over the whole duration of a match, because the whole competition was inside the stadium, these were different for bicycle races. The races were often organized between two cities and over long distances (Mignot, 2016b). In 1891 the race from Bordeaux to Paris went over 572 km and last several hours until the cyclists reached the finish in Paris. Even though bicycle races were free to watch for everyone along the route of the races, people needed to buy the organizer's newspaper to see pictures from the winners and read the races' results. Since the popularity of the races also increased the newspapers' sales amounts, it led to more bicycle races (Mignot, 2016b).

Some of the first races as Liege-Bastogne Liege, first organized in 1892, Paris-Roubaix (1896), the Tour of Lombardy (1905), Milan-San Remo (1907), and the Tour of Flanders (1913), was one of the first organized races. These five races are still one of the biggest races today, after over 100 years, and are known as the classics or the five monuments of cycling in the modern world of cycling (Mignot, 2016b).

At the beginning of the 20th century, cycling races started to take part over several days and the French sports newspaper L'Auto, organized the first Tour de France in 1903, which led to over 2,428 km. The success was so huge that their competitor Le Velo went bankrupt (Mignot, 2016b). In 1909, the Italian newspaper La Gazzetta Dello Sport organized a similar Tour through Italy, the Giro d'Italia, and in 1935 the Spanish newspaper Informaciones organized for the first time the Tour of Spain, the Vuelta an Espana (Mignot, 2016b). These three-week stage races are called Grand Tours and are still the biggest and most important stage races over several days in modern cycling like the five cycling monuments stated above.

Whereas newspapers organized the races, manufacturers of bicycles invested themself in the cyclists and teams. Manufacturers already paid small wages to their cyclists. However, the wages were very small, and cyclists' main income was the prize money itself. Not all the cyclists belonged to teams. There were still independent cyclists without a team. However, having a team behind a cyclist has benefits to the strongest and most enduring cyclists. The team's support allows a supported cyclist to save energy through the races, let their teammates work for them, protect them during the races, keep them out of the wind, and work against other teams. Whereas most cyclists still had small wages and not everyone won prize money in a race, the teams used to split the prizemoney over the team,

the teammates, and mechanics and stuff. Supporting the champions was a huge advertisement for the manufacturers and having them at their races increased the sales for the newspapers (Mignot, 2016b).

2.1.1 Union Cycliste Internationale - UCI

The Union Cyclist Internationale (UCI) was founded in 1900 by the national cycling organizations of France, Italy, Switzerland, Belgium, and the USA (Mignot, 2016b). The UCI decides the rules for the professional cycling sport, not only for road cycling but also for all other disciplines as a mountain bike, cross bike, competitions in velodromes and artistic competitions on bikes, and many more. After two cyclists died in 1960 due to drugs' use and influence, the UCI was also the first professional sports organization that introduced rules against doping in 1960 (Mignot, 2016b). The UCI organizes the World Tour as the highest level in professional road cycling. Below this, there is the Professional Continental Tour and semi-professional Teams, with not all athletes being professionals and paid cyclists by the teams are the Continental Teams.

Whereas the UCI makes the rules, licenses Teams, and makes the calendar. The only races organized by the UCI are the World Championships every year, which gives organizers, as the ASO (Amaury Sport Organisation), a lot of influence, which organizes the Tour de France and many other important races (Mignot, 2016b).

2.1.2 Mass Start Road Races

All these early organized cycling races were mass start races, and each race or stage of a tour was organized between two cities. In mass-start races, each cyclist starts simultaneously, and they directly race against each other. The races lead over long distances and usually took several hours. In the 20th-century new stage races were introduced that took over several days, or even three weeks, as the three Grand Tours mentioned above (Mignot, 2016b). While some of the early races last over 500 kilometers, the distances became shorter, and Grand Tours shortened their stages to about 200 or 250 kilometers.

The profiles of stages in stage races and one-day races lead the cyclists

over different terrains. Some stages are mostly flat and often end with a mass-sprint at the end of the race. Simultaneously, others include hills during the stages or finish with a climb on a hill as classics like the Fleche Wallone and Liege-Bastogne-Liege. Other races include high mountains, and the cyclists must sometimes climb over more than 5000 meters in one stage. Some stages and races also finish on mountains. These mountains are classified from category four, which are often still hills, to category one and horse category (HC), which are the highest or hardest climbs. The category of a climb depends on the length and the average steepness. However, the UCI allows every organizer to classify the climbs themselves, allowing many different interpretations. Whereas nowadays, most races lead over modern roads, some classics still use sections over cobblestone or sand. Two of the most famous cobblestone races are the Ronde de Vlaanderen and Paris-Roubaix, both count to the five monuments of cycling and even the Tour de France, which sometimes includes a stage with cobblestone sectors (Mignot, 2016b).

2.1.3 Time Trials

In the 1934s Tour de France, its organizer introduced the first individual time trial (TT) as a stage in a Grand Tour (Mignot, 2016b), to equalize the impact of stages with mountain finishes on the general classification, to make the general classification not only depended on the climbing results. In individual time trials, the cyclists competed against each other alone. Without any teammates, everyone must finish the stage alone. Whereas the early time trials were over long distances over sometimes more than 100km (Mignot, 2016b), today's time trials in professional road racing are regulated by the UCI (UCI, 2017) with a distance up to 50km for Olympic Games and World Championships, and up to 80km for other events. However, most time trials have a length of about 10 to 50 kilometers. While the profiles and lengths of races and the stages of tours vary, the time trials' profiles vary and can be on a flat track, over hilly terrain, or up to a mountain. Since 1967, when the Tour de France introduced short time trials before the first stage (Mignot, 2016b). These so-called prologues take part over distances between some hundred meters or only a few kilometers. They are often used to present the cyclists to the audience without huge time differences

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for the general classification.

2.1.4 Team Time Trials

Another type of time trial is team time trials, where the teams compete together against the other teams. The distances are like normal time trials and the cyclist's race as a team. The team's result time is taking after the 5th cyclist reached the finish (UCI, 2017). In team time trials, the cyclist at the front must work more than the cyclist on the group's back. By rotating, everyone gets to rest, some at the back. The goal is to go as fast as possible by still reaching the finish with at least five cyclists. The others can be dropped after doing their work early in the race or after a flat tire or defect on the bike. However, often weaker cyclists cannot follow the pace of the better ones for the whole distance. Therefore, it is important to have a well-balanced team. There are also other team time trials, where only teams of two or four cyclists race together.

2.1.5 Hammer Series

The Hammer Series was introduced in 2017 (HammerSeries, 2017) as a new attractive race format for both the teams and the fans. The stages are shorter than in traditional stage races, and the courses make it easier to watch and follow the race for visitors along the track, bypassing them several times. The series aims to find the best team, whereas, in traditional races, the individual general classification takes the focus. The Hammer Series is split over three days, where the teams compete in the Hammer Sprint, Hammer Climb, and Hammer Chase against each other.

On the first day, the teams collect points and bonus seconds on a course with two climbs. On the second day, the course is flat. The teams can earn points and bonus seconds again for the third day, when the teams compete in a team time trial against each other, the leading team after the first two teams start first, and the following teams try to chase the former starting teams. In the end, the team which finishes first wins the Hammer series (HammerSeries, 2017).

2.1.6 Professional Cycling Teams and National Teams

Most bicycle races always have been raced in sponsored teams or as individual competitors. However, the world championships and the Olympic Games are traditionally an expectation, where cyclists compete in national teams against each other. The only discipline at the world championships that are not raced in national teams but professional teams in the team time trial, where the professional teams compete against each other (UCI, 2017).

With the increasing number of bicycle manufacturers and other cycling industry companies that sponsored teams, some teams simply had a large budget than other ones. Hence, these teams, which had significant money, contract the world's best cyclists in their teams and even bought some victories by paying the other teams (Mignot, 2016b).

The imbalance and influence of the rich teams caused the Tour de France's organizers to decide to allow only national teams anymore in the 1930s at the biggest three-week stage race. However, in the 1950s and 1960s, cycling has changed, and many companies outside the bicycle industry-sponsored now team (Mignot, 2016b). The new sponsors did not advertise the bicycles anymore. However, they advertised through their jerseys and wanted their best cyclist to show these jerseys in the Tour de France. Due to the new sponsors and the change of interest for them, the Tour de France organizers allowed professional sponsored Teams to participate in the Tour de France again in the late 1960s.

Whereas most races allow team sizes of six to eight cyclists in each team, the Grand Tours had until 2018 teams of nine cyclists. However, due to the domination of some teams, and a lot of crashes, caused by the high number of cyclists in nervous race situations, races like the Grand Tours, the five monuments, and some other top-level UCI World Tour races reduce the number of cyclists in their races in 2018. Some traditional stage races as Paris-Nice, allow only seven cyclists in each team anymore, and the Grand Tours reduce the team sizes to eight cyclists (UCI, 2017).

2.1.7 Under 23 Races

Many world tour teams have a U23 development team to develop talents and sign them for their professional teams when they reach the necessary level. Some of these under 23 Teams only compete in under 23 races. Others

are categorized as continental teams and compete in lower-level races. In comparison, the professional cycling races most races in sponsored teams, a lot of the big junior and under 23 races are still raced in national teams in a nations cup (UCI, 2017). The Tour d'Avenier, the U23 Tour de France, is still raced in national teams.

2.2 Cycling Statistics and Results

Since the first cycling races, when the newspapers organized cycling races to sell more exemplars of their papers (Mignot, 2016b), results and statistics of races, teams, and cyclists have become even more important. Whereas it was the newspaper's interest when they organized their races, it became in the following years more important to cyclists and teams when they raced for better contracts and sponsors. However, being one of the best cyclists, and leading in the rankings, allowed the cyclists to get invited to profitable one-day show races to earn more money than in the big races. Nowadays, the teams' sponsors are not only on the kits of the cyclists and the equipment. The most important sponsors, which pay the most money, are also part of the team names. Therefore, teams are interested in results, but they also need time on tv, especially in the big races or in races important for the team's sponsors. Depending on how often the cyclists show themself on tv, or how often the team is represented in papers, the sponsors pay the team more money over the season. Whereas results and representation in the press or media are important for the cyclists and teams' income, other statistics like race data of the cyclists or data about training performances are important to optimize the training and increase the cyclists' performance.

2.2.1 Live Data During Races

Websites like VelonCC (VelonCC, 2017) allow the users to have live data of participating cyclists during professional cycling races. The users can look up several data, like speed, cadence, power, and participating cyclists' heart rate. The official websites of big races like the Tour de France offer information about each cyclist (TourDeFrance, 2017a). The information is also shown during live tv coverage to give the viewers more information about each cyclist and the current race situation. Timing companies like

the Swiss Timing Ltd. (SwissTiming, 2020) also offer live timing for cycling races, car races, and other sports events. That allows users to follow the races on their website. Especially for individual time trials, where each cyclist competes alone against the time, the websites offer each intermediate time and the time and position in the finish, live during the race.

2.2.2 Websites for Cycling Results

Whereas live data helps cyclists, teams, and fans during a race, tv stations only show the Top 10 for the stage and classification rankings, one of the reasons this might be that not all the cyclists have already arrived at the finish when the tv broadcast stops. As mentioned before, in the early days of cycling races, the results were printed in the organizer's newspapers (Mignot, 2016b). However, nowadays the fans do not need to buy newspapers anymore to get the full results. Websites specialized in cycling offer the full results as soon as they are available. For example, websites like Pro Cycling Stats (ProCyclingStats, 2020), CQ Ranking (CQRanking, 2020) or the official website of the UCI (UCIWebsiteResults, 2020), where they offer results for each of their sports events.

The official UCI website (UCIWebsiteResults, 2020) offers mainly results for the races and their official rankings. However, websites such as CQ Ranking (CQRanking, 2020) and Pro Cycling Stats (ProCyclingStats, 2020) offer their rankings and a lot of additional details and statistics about the races, cyclists, teams, and results. CQ Ranking even rewards a physical CQRanking Reward to the winner of their ranking. Whereas CQRanking offers mainly individual results, Pro Cycling Stats also provides the whole classification rankings and more detailed results. They also have stage profiles for almost every stage.

2.2.3 Performance Data

Since new technologies lead to smaller devices in everyone's daily life, the same is true for the devices used during training and races. Whereas some years ago, cycling computers could only show the speed, nowadays, those devices can collect data as the power output, cadence, speed, heart rate, GPS position, or grade of the street. However, those data can be collected

on the cycling computers and analyzed later with the trainers. These data can also be submitted in real-time to the team's car, or to the race officials, to be shown live during the race, for fans at home in front of their tv's, or on the races official website (TourDeFrance, 2017a) or websites like VelonCC (VelonCC, 2017). VelonCC offers live data for cyclists who participate in professional cycling races and share the data with the service. VelonCC and the official Websites use live data to provide fans a deeper inside into the sport and the race. The cyclist's team leaders can use the data to be better informed about their cyclists' condition in the race and help them optimize their further decisions, whether they shall use more or less afford.

Services like STRAVA (Strava, 2017) not only allow to upload the training or race data to their servers, and make it visible for other users, and make it possible for them to compare each other's performance during races or training. They also allow the users to have live segments during their cycling rides. That allows the cyclists to see how they perform compared to other cyclists or how they have performed on this segment before.

All these data can not only be used for providing more data during races. However, they can also provide better data during the training, optimize training sessions, and make the training more efficient. Rozendaal studied and evaluated together with the Team Sunweb, a professional road cycling team, the effect of training on the cyclist's performance (Rozendaal, 2017). Rozendaal and Team Sunweb used data and statistics to optimize the training and increase the cyclist's performance. The Sunweb Team not only optimized the training to gain a long-term performance increase for the cyclists, but they also optimized the training to reach the performance peeks during the seasons when the cyclists wanted to perform at their maximum.

2.3 Prediction in Cycling

Millions of people follow their favorite sports events, teams or athletes, by watching their football games or cycling races to see if they win or deliver a good performance. Social media services make it easy to follow the athletes to get more detailed information about their performance, training, or other things like interviews. Consuming all this information gives the fans a deeper inside into the sport. Many of the fans try to predict the sports events' outcome and bet their money on it. Others compete with their

friends, who predict the correct results. Before starting the sports events on tv, the experts are asked about their predictions for the outcome. Therefore, several scientists tried to predict the outcome of all kinds of different sports. Leung et al. (Leung & W. Joseph, 2014) used sports data mining to predict college football games results, and Bunker et al. (Bunker & Thabtah, 2017) used a machine learning approach to predict the results of sports. And many more approaches had the same goal, to predict the outcome for sports events as accurately as possible. Even Google predicts the game's outcome depending on the result and statistics during a football game.

Ofoghi et al. (Ofoghi, Zeleznikow, Macmahon, & Dwyer, 2010) used a machine learning approach to predict the winning patterns in track cycling omnium in cycling. Olds (Olds, 1998) evaluated the behavior of breakaway groups and defined a mathematical approach to calculate the chances of breakaway groups in cycling to reach the finish before the chasing groups. Also, Dimension Data (Gray, 2017) collected billions of data points during important professional road cycling races and used machine learning to make predictions of the race. Some are used as inserts during live tv coverage to give the fans additional information.

2.3.1 Predictions for Time Trials

Individual time trials in road cycling are similar to time trials on the track. In both disciplines, the cyclists try to maintain steady power output and speed. Ofoghi et al. (Ofoghi et al., 2010) used an approach with machine learning in track cycling omnium to predict winning patterns. Whereas Smith et al. (Smith, Dangelmaier, & Hill, 1999) studied the critical power relation with a cyclist's time trial performance on-road cycling time trials. However, time trials on the track are typically indoor events with the same track layout for every race. In individual time trials in road cycling, the cyclists start after each other and with time gaps between them and the time trials last several hours (UCI, 2017), different wind or weather for the cyclists.

Some time trials are flat, and others include hills or even mountains. Some time trials have easy parkour without difficult corners. Others require the cyclists to navigate through difficult sections. Therefore, a cyclist's performance depends not only on his power output but also on how well the

course suits his weight and abilities. Padilla et al. (Padilla, Mujika, Cuesta, & Goiriena, 1999) studied the differences of critical power capabilities within a professional cycling team.

The number of time trials in road cycling is also extremely limited over the season, and they are often part of a stage race with other stages within a few days. Or time trials are part of a grand tour like the Tour de France (TourDeFrance, 2017b) and take part after three hard weeks where the cyclists are tired from the previous stages. Therefore, the outcome of time trials depends on many factors, and the limited number of time trials and the different requirements make it hard to have enough data to predict the outcome of all the races. Whereas the favorites, with more and better results, are typically easier to predict. Other cyclists have only a few good results and can sometimes not show their full potential because they have or had to work for their teammates on other stages to help them reach the team's goals.

2.3.2 Predictions for Mass Start Races

Whereas in time trials, the tactical options are more limited, and the distances are shorter, making it easier to predict the outcome of a race. Mass-start races' character is influenced by much more factors, depending on the team's strategies and the stage's profile. Sometimes the teams of the favorite cyclists for the general classifications have no interest to win every stage and are allow other cyclists, who have no impact on the outcome of the general classification. Often the outcome of race situations depends on a lot of other cyclists, how they turn out. For example, an attack's success depends on how many cyclists follow the attack, how strong the cyclists are, how many teams follow the attack, or if a team has more cyclists in the group than others. Therefore, there are many different outcomes possible, and teams try to use their cyclists to achieve their goals. Mignot (Mignot, 2016a) studied the behavior and strategies of cyclists during mass start races in professional road cycling.

How difficult it is to predict a race's outcome also depends on the profile of the stage, whereas a mass sprint often decides flat stages because the teams of the sprinters use their help and work together with the other teams. Usually, the teams keep cyclists together and try to bring their sprinters

with as many helpers as possible into the final kilometers to decide the race in a mass sprint and give their sprinter the chance to win the stage. Manaspà et al. (Menaspa, 2015) studied and evaluated mass sprints in professional cycling races and used a ranking system, depending on how well the sprinters performed, depending on how many helpers the team brought on the last two kilometers. The more difficult a stage's profile is the more teams, who have no sprinters or cyclists to decide the stage final, try to decide the race earlier. However, the more challenging the stages get, the more likely it gets that the best cyclists will end up as the race winners. Especially for one-day races, where the best cyclists try to win themself, and no tactical thinking, they influence their performance for the following stages.

2.4 Simulation of Cycling Races

Cycling, and especially professional road cycling, is a complex sport with many factors that influence a cyclist's performance and race outcome. Therefore, simulating cycling races and a cyclist's behavior during a race depends not only on the simulation of a cyclist's physical shape. For example, Padilla et al. (Padilla et al., 1999) and Rozendaal (Rozendaal, 2017) both evaluated the physical strengths of cyclists in two different professional teams. How fast a cyclist can go and how much energy the cyclists can spend also depend on the street's surface and grade, the wind speed, and wind direction. It also depends on the energy left in the cyclist's energy tank (W-Bal). Depending on how early or late in the race the cyclist needed to go over their critical power limit, how good the cyclist could recover from that effort. And on how much the group's position provides him with a draft and makes it possible for the cyclist to save energy. And achieve the same speed as the cyclists in front of him.

However, the outcome of the race depends not only on the individual strengths of the cyclists but also on individual strategies and team strategies. Mignot studied (Mignot, 2016a) the strategic behaviour in road cycling competitions. Therefore, Mignot evaluated professional cycling races and what strategies the teams and cyclists use in different races, such as flat, hill, or mountain stages. Mingot also evaluated race situations, for example, the three-player interactions, and defined what game theories suit the situations

best and can be used for them.

2.4.1 Simulation of Cyclists Behaviour in Professional Road Cycling Races

Hoeningman et al. (Hoenigman, Bradley, & Lim, 2011) created an agent-based model simulation of cycling races, where they studied the influence of defection and the cyclists' cooperation behavior, depending on their physical strengths, teammates, and cooperation probabilities during a road cycling one-day race. Therefore, Hoeningman et al. simulated 160 km flat races without changes in wind, surface, or street grades. The behavior of their model matches observations they made in real-life professional cycling races. As an example, they were reading the cyclist's power meter data for the races. The result of the study, states, that weaker cyclist reaches better results when they defect. For middle-level cyclists in their study, the cooperation strategy had no significant impact on their results or their teammate's results. However, for the best cyclists, cooperation with other cyclists helps them to achieve better results. The agent-based model from Hoeningman et al. uses no energy model where the cyclists can recover during the race.

2.4.2 The Mathematics of Energy in Cycling

Whereas Hoeningman et al. (Hoenigman et al., 2011) used an agent-based approach to simulate cyclists' behavior in groups, Tim Olds (Olds, 1998) studied breakaway groups and if the chasing groups can catch the breakaway groups before the finish. They used the remaining distance, together with the VO2max (maximal oxygen consumption) Level of the cyclists and their left energy, and calculated each cyclist's leading time in the groups. The approach guesses a group speed and calculates if the group's cyclists can obtain the speed to the finish. Whereas in smaller groups, cyclists must go into the lead more often and therefore need more energy, bigger groups have an advantage and have a faster group speed. According to Olds, especially with groups from 1-5 cyclists, they have a much higher disadvantage than groups with more than five cyclists. Olds also take the draft into account when cyclists can rest behind the ones in front of them. Also, the wheel-

distance, which directly inputs how much the draft reduces the power needed behind one or more cyclists, is part of Olds calculation. However, as the agent-based model by (Hoenigman et al., 2011), Olds uses no kinetic recovery model. Whereas Hoeningman et al. (Hoenigman et al., 2011) use different leading times for co-operators or defectors, Olds cyclists share the lead evenly among the cyclists in a group. They use a constant speed to the finish, with no changes in grade or wind. And no tactical strategies like the "cat and mouse" tactics influence Olds approach.

For the simulation of the cyclists during a race, Hoeningman et al. (Hoenigman et al., 2011) and Olds (Olds, 1998) use Equation 2.1 from Kyle (Kyle, 1979), to calculate the necessary power (P) to achieve the required speed for the cyclists. Several factors influence the required power, the impact of the surface resistance of the street P_{roll}, the impact of the air resistance P_{air}, and the impact of the grade of the street P_{grade}.

$$P_{tot} = P_{air} + P_{roll} + P_{grade} \tag{2.1}$$

However, Hoeningman et al. (Hoenigman et al., 2011) and Olds (Olds, 1998) both simulate only flat professional cycling races and therefore do not include P_{grade} into their power Equation 2.2.

$$P_{tot} = P_{air} + P_{roll} \tag{2.2}$$

$$P_{air} = kCF_{draft}v^3 \tag{2.3}$$

The equation uses the parameter k, which includes the factors of air density and projected frontal area of the cyclists. CF_{draft} is calculated by Equation 2.4 and v is the cyclist's speed.

$$CF_{draft} = 0.62 - 0.0104d_w + 0.0452d_w^2 \tag{2.4}$$

The CF_{draft} Equation 2.4 calculates the factor of draft, that a cyclist gets from another cyclist in front. Therefore, the equation includes the constants 0.52, 0.0104 and 0.452. Only the parameter d_w is variable, d_w is the distance between those two cyclists in meters. For $d_w \geq 3$, the $CF_{draft} = 1$ and there is no benefit for drafting.

$$P_{roll} = C_r g(M + M_b)v \tag{2.5}$$

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Hoeningman et al. (Hoenigman et al., 2011) calculates P_{roll} with a parameter C_r and g as the gravitational coefficient, M is the cyclist's mass in kg and M_b is the mass of the bike.

To calculate the time to exhaustion in minutes (T_{lim}) for a cyclist, Olds (Olds, 1998) uses Equation 2.7 :

$$\ln\left(T_{lim}\right) = -6.351 \ln\left(f\dot{V}O_{2max}\right) + 2.478 \tag{2.6}$$

Olds uses the $f\dot{V}O_{2max}$, the fraction of the cyclists $\dot{V}O_{2max}$, whereas Hoeningman et al. (Hoenigman et al., 2011) replaces that part with $\frac{P_{tot}}{Max_{10}}$. Max_{10} is the maximal power, a cyclist can perform for 10 minutes, and Max_{20} is the time for 20 min. Hoenigman uses the T_{lim} to simulate the left energy of each cyclist after every minute of the race simulation.

$$T_{lim} = -6.351 \ln\left(\frac{P_{tot}}{Max_{10}}\right) + 2.478 \tag{2.7}$$

Swain (Swain, 1998) explains in his article the Equation 2.8 to calculate the power P, that a cyclist needs to achieve the speed s, which equals Equation 2.1. However, Swain includes P_{grade} in his equation, to also be able to calculate the power output for sections that are not only flat.

$$P = k_r Ms + k_a Asv^2 + giMs \tag{2.8}$$

$$P_{grade} = gi(M)s \tag{2.9}$$

In this equation, P is the power in watt, k_r is the rolling resistance, M is the combined mass of bike and cyclist, s is the speed on the road. For the air factor, v the speed through the air, k_a is the air resistance coefficient, A is the combined frontal area of the cyclist and the bike together. The third part of the equation also uses the gravitational acceleration constant g and the street's grade i. If there is no wind, $s = v$.

The speed s can be calculated, by inputting the power P_{tot} and solving the equation. For downhill sections, where P_{tot} can be assumed to be zero. s can be calculated by Equation 2.10:

$$s = \left(-\frac{giM}{k_a A}\right)^{1/2} \tag{2.10}$$

2.4.3 Critical Power and Energy in Cycling

The critical power (CP) concept is defined as the power output (P) of a cyclist, where the cyclist still performs an aerobic activity. Whereas, above this CP, the cyclist changes to anaerobic activity. The approach by Jones et al. (Jones et al., 2010) introduces a mathematical formula to define the CP model.

$$P = \frac{W'}{t} + CP \qquad (2.11)$$

Smith et al. (Smith et al., 1999) approach show how the CP is related to the time trial performance. Whereas CP is an important indicator for a cyclist's endurance performance, the W' defines the time a cyclist can spend above his CP by performing an anaerobic exercise. Therefore, Mulder et al. (Mulder, Noordhof, Malterer, Foster, & de Koning, 2015) calculated the anaerobic work during time trials of different lengths.

In training, cyclists try to optimize how long they can ride above their CP and have a higher CP. That allows the cyclist to do longer aerobic work before doing anaerobic work, and therefore saving W'. When a cyclist uses all the energy and W' is empty, the cyclist can no longer perform above the CP. Rozendaal (Rozendaal, 2017) evaluated the cyclists' data that race for the Team Sunweb and showed the impact on training optimization within a season over several seasons. The CP and W' could not be used during cycling races for a long time. However, since the invention of power meters, a device to measure the power output, the cyclists' power output can be shown on the cycling computers or sent to a screen in the team car, both during races and training. Knowing and calculating the W' allows the cyclists to optimize their power output during a race, to regenerate their W', avoid emptying it and try to save energy for later in the race.

2.4.4 The Critical Power Curve

The time a cyclist can perform on certain power output is different for each watt value. Therefore, professional and hobby cyclists use software like Strava or GoldenCheetah (GoldenCheetah, 2020) to calculate their critical power curve (CPC). This curve is a collection of all the watt values and how long the cyclist can maintain that power output. In sprints, cyclists can achieve watt values for 15 seconds, whereas their peek my last only a few

seconds (Menaspa, 2015). In comparison, lower watt values can be obtained over the distances of time trials (Smith et al., 1999). Or during a professional road race that lasts several hours. Software like Strava, Zwift, or Golden Cheetah, also allows the cyclists to do a test to calculate the average power a cyclist can maintain over one hour, called the functional threshold power (FTP). Figure 2.1 shows the CPC plot for a ride in GoldenCheetah, with the W', CP, Pmax, and FTP in the top right corner, and Figure 2.2 shows a summary for the same ride and how long the cyclist ride in each of the power zones, that are visualized with the CPC. For each P, it calculates the interval length. Additionally, Figure 2.3 shows a screenshot from GoldenCheetah with the cyclists P during the ride in yellow, the heartrate in red, the speed in green, and the cadence in blue.
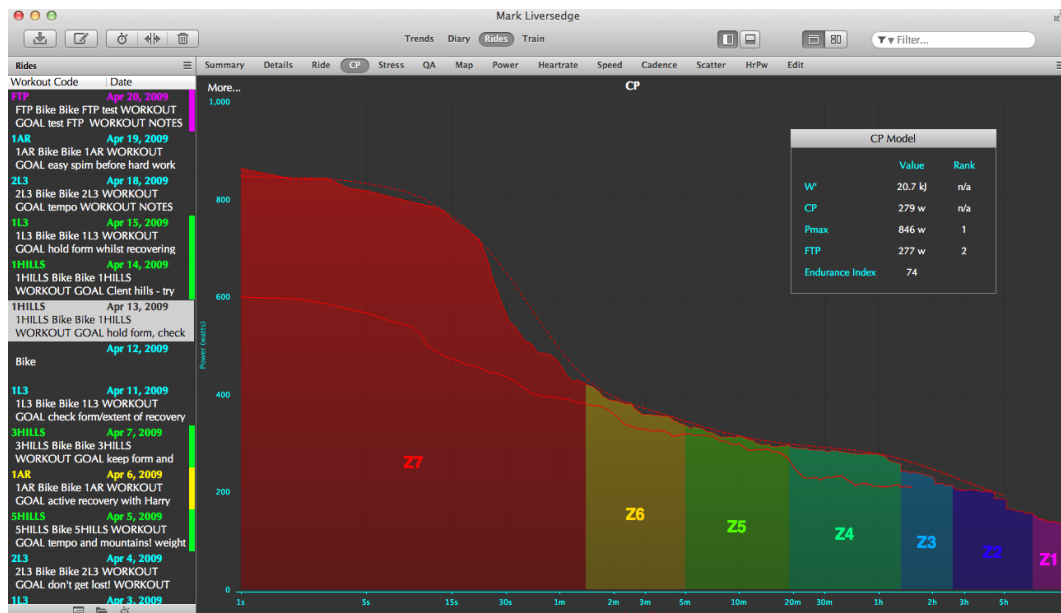
Figure 2.1: The CPC calculated in the GoldenCheetah software (GoldenCheetah, 2020)

Padilla et al. (Padilla et al., 1999) studied the differences for different cyclists' performance levels in a professional cycling team, including several Grand Tour winners. For the study, Padilla et al. defined four groups of cyclists, uphill, time trial, allrounders, and flat road specialists, to group the cyclists, before running medical tests on the cyclists, measuring the power output of the cyclists, together with other data. Padilla stated that

Figure 2.2: Ride summary in the GoldenCheetah software (GoldenCheetah, 2020)

the average maximal power output for cyclists who perform best on the flat terrain is higher than for cyclists specializing in hills or mountains. The uphill specialists have the lowest average maximal power output of the four defined groups. However, the average maximal power output per kilogram of the uphill cyclists was the highest compared with the other groups.

2.4.5 Calculating Energy Recovery

Whereas the approach of Jones et al. (Jones et al., 2010) defined the CP model without regeneration of W' and the agent-based model of Hoeningman et al. (Hoenigman et al., 2011), also use no energy recovery system to simulate flat cycling races. However, cyclists in real races regenerate their W' by performing under their CP.

Skiba et al. (Skiba et al., 2012) approach introduce W'_{bal}, where the energy for an anaerobic workout gets restored when the cyclist's power output is below the cyclist's CP. Equation 2.12 shows Skiba's integral algorithm for

Figure 2.3: Ride plot in the GoldenCheetah software (GoldenCheetah, 2020)

the point in time (t):

$$
W'_{bal} = W' - \int_0^t W'_{exp}(t) e^{-\frac{t-u}{\tau_{W'}}} dt \tag{2.12}
$$

$$
\tau_{W'} = 546 \cdot e^{-0.01 \cdot D_{CP}} + 316 \tag{2.13}
$$

$$
W'_{exp}(t) = \begin{cases} 0 & where\, P(t) < CP \\ P(t) - CP & else \end{cases} \tag{2.14}
$$

The power (P) at time t is $P(t)$ and $W'_{exp}(t)$ is the amount of P above the CP at t. (t-u) is the time in seconds between the segments above CP. $\tau_{W'}$ is the time constant, that defines how fast the cyclist regenerates W'. Whereas 546, 0.01, and 316 are constants, the D_{CP} value is the difference between the CP and the average of all the P's below the CP.

Goossens (Goossens, 2018) compares Skiba's original integral approach (Skiba et al., 2012) with the differential approach by Skiba et al (Skiba, Fulford, Clarke, Vanhatalo, & Jones, 2015) and Andy Froncion. With the

differential version, the further the cyclist performs under the CP, the faster the regeneration is. The closer the W'_{bal} gets back to the maximum, the slower the regeneration gets.

Differential algorithm:

$$W'_{bal}(t) = \sum_0^t (CP - P(t)) \cdot \begin{cases} 1 & where\, P(t) > CP \\ \frac{W' - W'_{bal}(t-1)}{W'} & else \end{cases} \tag{2.15}$$

Mark Liversedge (Liversedge, 2014) implemented the Differential Algorithm for the GoldenCheetah software (GoldenCheetah, 2020). However, Liversedge stated that the integral computation for W'_{bal} was expensive to calculate. Therefore, Dave Waterworth (Waterworth, 2014) posted an optimization for the algorithm, making it easier and faster to calculate. Figure 2.4 shows a plot in GoldenCheetah, with the changes for W'_{bal} during a ride in red and the P in yellow.

Waterworth optimization of the integral algorithm:

$$S(t) = \sum_0^t (W'_{exp}(t)) \cdot e^{\frac{t}{\tau_{W'}}} \tag{2.16}$$

$$W'_{bal}(t) = S(t) \cdot e^{\frac{t}{\tau_{W'}}} \tag{2.17}$$

2.5 Games

Since the first video games were developed, they motivated people to keep playing them. Alexei Pashitnow, a Russian scientist, invented Tetris in 1884. Even so, Tetris seems to be an easy game to play. It is hard to beat the game. What motivates the players to keep playing it again and again. John Brzustowski (Brzustowski, 1992) studied if it is possible to beat the game's arcade machine version. Tetris become one of the most sold video games of all time, and Nintendo bundled it with the Nintendo Game Boy system to sell it. Even in 2019, Tetris 99 was release, where 99 players compete against each other at the same time on the Nintendo Switch system (Nintendo, 2019).

Over the years, developers introduced different models to earn money with their games. The traditional way to sell games is still to pay once for a
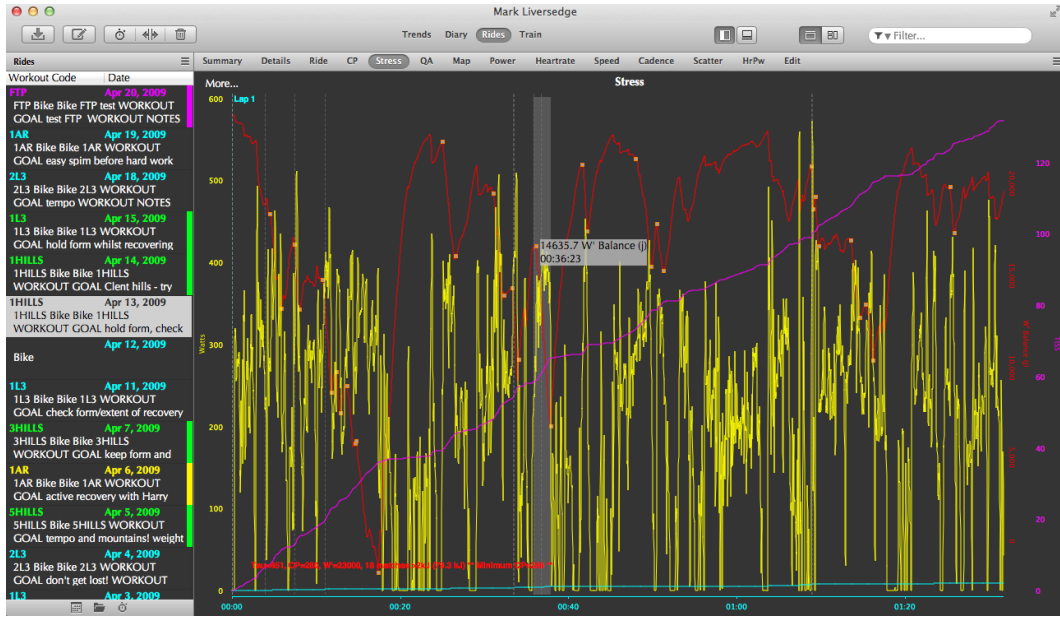
Figure 2.4: The W'_{bal} plotted in red and the Power Output in yellow using the GoldenChee-
tah software (GoldenCheetah, 2020)

game, and the customer owns the game. However, for other games as World of Warcraft and iRacing, the players must buy for the game content, such as cars and tracks in iRacing, or new game worlds in World of Warcraft. Additionally, the developers charge a monthly fee for the servers that are required to play the game. Other games like Fortnite release their game Free2Play, where the players can play the game without any costs. However, to keep the game updated and earn money, Fortnite sells game content, such as different colors or designs for objects. Electronic Arts, one of the biggest publishers for video games, earns more money with loot boxes for their FIFA Ultimate Team game mode (EA, 2018), than for selling the game itself. On special occasions like Black Friday, or other events, which bring new content to the game, they sell special, limited promo packs. Within a few minutes, these packs get sold out not only on PC but also on XBOX One and PlayStation 4 and allow Electronic Arts to earn millions of dollars within a few minutes by selling their loot boxes to the players.

However, developers not only try to find new ways to earn more money, but they also try to keep the players playing the game more. In comparison,

some games have big game worlds that take many hours to explore. Other games insert a competitive mode into the games or promote them as ESport games, where the players compete against each other for climbing up in ranking systems. Blizzards organize big competitions for Overwatch. Electronic Arts does the same for their FIFA Series, and even smaller games like iRacing or rFactor2 organize virtual racing series, with thousands of dollars for the winners. iRacing partnered with Porsche and organized the Porsche eSports Supercup (iRacing, 2019) where the players drive the virtual Porsche 911 GT3 Cup car in iRacing to compete for $100,000.00 . When the first F1 races of the 2020 season were canceled, the F1 cooperated with the official F1 Video Game to organize a Virtual F1 race with many real F1 drivers. The races got broadcasted over the internet and tv stations. Some real racing drivers used video games to practice and competed against others during the race free time.

Car racing is not the only real sport that organized virtual races in 2020. Cycling teams and associations organized virtual races with computer software like Bkool (bkool, 2020) or Zwift (Zwift, 2020). Zwift offers 3D stages and virtual 3D worlds such as London. Cyclists can practice in those virtual worlds and even compete in races against each other. Therefore, the players/cyclists use their real cycling bikes together with devices that measure the power (watt) a cyclist produces. Together with other sensors, the devices can simulate downhill and uphill sections. Teams organize virtual training days with their fans and races against other teams. When the official Ronde van Vlaanderen got canceled in 2020, a virtual race, using the Bkool software, got organized (rondevanvlaanderen, 2019) where 13 professional cyclists competed from their homes against each other. Over the last 32 km of the real race, the race took place and got broadcasted on TV instead of the real race.

2.5.1 Sport in Games

Games that simulate sport in the role of a sports team manager or doing the sport have virtually been some of the most popular games over the last years. Games like the FIFA series (EA, 2018) allow the players to play their favorite teams and use their favorite players to play football matches, alone against the AI, offline together with or against their friends, or compete online

against other players. In the Ultimate Team game mode, the players can build up their teams and compete online against others. During the week, by using the "Division Rivals" mode, and at the weekend in the most competitive mode, by playing 30 Matches against other players, and achieving the best rankings. What motivates the players to get better, spend more time, money on the game modes loot boxes, and increase their ranking positions every weekend. The game rewards the players for playing by giving them in-game content. The game also has a manager mode, where players can manage their teams and play the matches themself, by controlling each player, like in the other modes. There exist manager games across many different sports fields, allowing the users to take the manager's role for their favorite team. Some of the manager games are only playable alone in a Single-player mode, whereas others offer multiplayer modes. These multiplayer modes can be a Hot-Seat mode, where the players switch the seat and take rounds to manage their teams, or they can also be over the internet, playing against or with other players all over the world. Whereas in the early days, software on the clients has been used to play the games and manage the teams, the internet brought the opportunity to play with and against other people and brought up web-based solutions for the manager games. Running on a server and having the users logging in to the websites and managing their teams become a popular and easy alternative to the client-based games.

2.5.2 Manager Games

In manager games, players choose a team, and their goal is to lead it to success. The chosen team can be a real team, a fictional team, or a fictional team bases on a real team. Many games also give the opportunity to create an own team and manage it from the lowest division to the highest and win the major sports events with it. Players get into the role of the manager of the chosen team. They can develop the team, influence the success and results by scouting other teams and choosing the right tactics in the right situations, just like the managers would do in a real-life situation. Developing and improving the current team might lead to success in the future. It's necessary to find and improve new talents. Not all the manager's actions are limited to the sport-related part. Often the games have a financial component, making it necessary for the managers to stay within the financial limits, but also

allowing the managers to improve the infrastructure, upgrading the fanbase, and finding a new and better sponsor to expand the financial range for the team. The RadSim05 (Radsim05, 2020), Pro Cycling Manager Series (ProCyclingManager, 2020) and the Online Cycling Manager (Lissner, 2020) are examples for cycling based games where the players can manage their teams.

2.5.3 Real Data vs. Fictional Data

Whereas some manager games, like the Pro Cycling Manager Series (ProCyclingManager, 2020) hold licenses for leagues, teams, and athletes to use their names in their databases, not all the manager games offer real data for the athletes and teams. Like the Online Cycling Manager (Lissner, 2020), some games allow the users to create their teams instead, choose their team name, design their logos for them, and have the athletes being generated by the game. The game then randomly creates names and builds up its database without any connections to real athletes or teams. Within a real/licensed dataset, real teams have the same players in their team as in reality. Still, with time going on and the players managing their team over several seasons, the real data gets mixed with fictional data created by the game. This fictional data can be newly created players, new talents, new stuff for the team, and new sponsors and new teams.

Manager games are based on a database. In the databases, the athletes have different attributes, depending on the sport. In football, that would be how good they can shoot on the goal, or how good they can pass the ball to their teammates (EA, 2018). There are other important attributes in cycling, like how good they climb up mountains or hills, or how good they are in a sprint, and how good they are in time trials or on cobblestones. Different factors are depending on the different types of stages or races. Databases rely on real data to capture the right values for each attribute and each athlete, whereas, in fictional databases, they can procedural be generated according to given parameters. These parameters could be that a cyclist who shall be attending the Grand Tours does need not only good climbing attributes but also a good hill, time trial, and especially a good regeneration over three weeks (ProCyclingManager, 2020).

2.5.4 Client-Based vs. Web-Based

Traditional manager games or client-based manager games as the Pro Cycling Manager Series (ProCyclingManager, 2020) were run on a single computer and played alone in a single-player mode or together with other people in front of one pc, by changing the seat (Hot-Seat mode). With the increasing power and capacity of computers, it got possible to calculate and simulate the results depending on more parameters than before. It makes them more complex and more realistic.

With the internet and web-based manager games like the Online Cycling Manager (ProCyclingManager, 2020), a new chance opened, playing with and against other players together, instead of playing against computer-controlled teams. Some client-based manager games introduced manager modes over the internet with others. However, with web-based manager games, a new opportunity opened. It was no longer necessary to be on a single machine. With the web-based solutions, managers could log in over a website and manage their team in any browser, at home, at work, or nowadays on smartphones and tablets. Managers cannot only enter and do their actions over the internet, but the calculations and simulations for the results and all the game logic can be done faster by the game server.

2.5.5 Forum Based Manager Games

Forum-based manager games can be in the form of fantasy leagues, played over an online-forum, but also manager games can be played together with other people over a forum. Whereas fantasy leagues rely on real results, manager games allow the users to write tactics and manage their team. Members of the forum simulate a result based on the tactics of all the involved managers. The RadSim05 (Radsim05, 2020) is a forum-based cycling manager game. The users manage their teams, nominate them for races, get good results, and win points for the ranking. The managers can also trade them with other managers and try to improve their team. Traditionally, the results are created by one of the users who is not taking part in the race. He reads the tactics of the teams and decides how the different tactics influence the race. The user who simulates the race writes down the race's key events, which leads to the result. The strengths of the cyclists usually depend on their real-life performance in this race or similar

races. Therefore the user who simulates the race must try to predict how good the cyclists would perform.

2.6 Cycling Manager Games

There are several different software systems, as GoldenCheetah or Zwift, where the users can cycle in virtual worlds against each other. However, cycling video games are relatively rare, especially with a 3D race mode. Nowadays, the most popular video game for pc and consoles that also offers 3D-races is the client-based Pro Cycling Manager Series (PCM) (ProCyclingManager, 2020). The game is also the official video game for the Tour de France, the most important cycling race. The players can manage their favorite professional cycling teams in a single-player mode or create their cyclist and compete as a single cyclist and try to get the best in the world. The players can use a simulation option to only generate the result for races or use the 3D-mode to play the stages and have the most impact on the outcome of the race that they can. The game also offers different online multiplayer modes, where the players can use the 3D-mode, to compete against others. However, there is not an online or offline multiplayer mode where the players can manage their teams. Whereas the PCM offers a 3D-mode, but no online manager mode, the other two games, which will be discussed in this section, offer a multiplayer manager experience but no 3D-mode. The Online Cycling Manager (OCM) (Lissner, 2020) is a web-based game that offers a massive multiplayer managing experience. There is no limit for the number of players that are divided into several divisions, and where it might take several real years, to get up into the highest divisions. The races are simulated, and the users can use some limited options to give their cyclists some roles and instructions for the race. The third game is the RadSim05 (Radsim05, 2020) a forum-based manager game. Whereas the other games have algorithms to simulate the races and limited tactical options, the RadSim05 offers great creativity for the players. The players create the content, they also write the tactics for their teams textural, what allows more option, then for quick simulations, and a lot of freedom. The race result is also created by the users, who do not participate in the race themself.

2.6.1 Pro Cycling Manager Series

The Pro Cycling Manager Series (ProCyclingManager, 2020) is the most famous cycling video game. It offers players to manage their favorite team or nation for almost every race from real-life. Players can play each of those races in their 3D-mode. Players who want to focus on the managing part can simulate those races. The game offers several different online modes for those players who like to compete against other players in 3D races. Those modes include mass start races, individual time trials, team time trials, and other cycling competitions like track races, which are not part of the game's manager or single-mode. The game is the official game for the Tour de France and therefore includes licenses for many races and real stages, for example, the final stage of the Tour de France every year with the finish at the Champs-Élysées. Figure 2.5 shows the cyclists of a team with licensed cyclists in Pro Cycling Manager 2017. Many teams with their cyclists are also officially licensed. Those cyclists and teams not officially licensed by the game are named a little different from the real cyclists.

Figure 2.5: The cyclists list for a licensed team in the Pro Cycling Manager 2017 game. (Pinget, 2017)

2.6.2 RadSim05

The RadSim05 is the oldest German cycling sim (Radsim05, 2020). The website and game are a forum, and it is similar to a fantasy league. The players manage their teams. Those teams are organized into two divisions. The players can nominate for each race during a season, transfer cyclists with other teams, and win points for the different rankings. At the end of the season, the worst teams of the first division get demoted. And the best teams of the 2nd division get promoted. The Pro Cycling Manager Series offers 3D races and simulates races with their algorithms.

The RadSim05 (Radsim05, 2020) uses the player's knowledge about the sport to simulate the races. Players who take part in the races must write tactical instruction for each stage before the race start. One player is the result-maker, who does not take part in the race, reads all the tactics and, depending on, the profile and cyclists. The result-maker subjectively decides how good the cyclists are, how the tactics workout against the other tactics, and how the race is decided. In the end, a result is provided with the time differences to the other players.

Therefore, the results are more subjective than the results of the Pro Cycling Manager (ProCyclingManager, 2020). However, it allows multiplayer management. And Even though the cyclists' strengths differ, depending on the knowledge and preferences of the result-maker. Whereas the database of games like the Pro Cycling Manager Series relay on a database that is released with the game and only updated once a year, the result-maker also considers recent results, which makes the cyclists' strengths more up to date.

2.6.3 Online Cycling Manager

Both the Pro Cycling Manager Series and the RadSim05 (Radsim05, 2020) use real-world cyclists and races. Whereas the Online Cycling Manager (Lissner, 2020) is slightly different. The game is a website-based multiplayer game, where thousands of players can participate at the same time. The players are divided into ten divisions, and the new players who start their journey as a manager create their teams, with a few fantasy cyclists. They can increase the strengths of the cyclists depending on their potential by training and participating in races. There is also a scouting system, where it is possible

to find new talents or to buy some on the market. New players start in an extra Division 11. After a few races, they get promoted. The higher they get, the more points they can earn, and cyclists get more experience. Figure 2.6 shows a team overview in the Online Cycling Manager game, where the teams, cyclists, and staff are randomly generated. Whereas in games like the Pro Cycling Manager Series (ProCyclingManager, 2020), it is possible to simulate several seasons within a few hours. The Online Cycling Manager is much slower. Cyclists need to regenerate between races, and only one or two races are available to participate per day within each division. Within a week, a team might only be able to participate in one to three races.

The cyclists can be improved, and the staff, the scouting system, material, and merchandising. A season takes 90 days. Cyclists get older and need to be replaced when they get to retire. Therefore, to improve the team and reach the highest division, it may take years to improve the team.

2.6.4 Database and Values for Athlete Strengths

As mentioned in the sections before, some games like the Pro Cycling Manager Series (ProCyclingManager, 2020) have licensed many cyclists and therefore use real names and images for the cyclist. Other games, such as the Online Cycling Manager (Lissner, 2020), use complete fantasy cyclists and teams. However, the names are not as important in games as the values the games use to define each cyclist's strength. The Pro Cycling Manager Series, therefore, an overall value, together with 13 values, to define the strength of a cyclist. The Online Cycling Manager uses only eight values, together with an average value, to define the total strength. Two additional values for race shape and discipline help to define the cyclist's shape for a race. Dimension Data (Gray, 2017) collects billion of data during the big races and uses them not only to make predictions of the outcome of a race and to define the strengths of cyclists. However, the RadSim5 uses the users' knowledge, and therefore, a cyclist's strengths during a race, depending on the result makers' personal preferences.

Team BramBros 🇦🇹 📋 ⬛

Team Info	
Manager:	**Bradom**
Registered at:	27/1 - 2015
Rank:	756 th 🌐 5 th 🇦🇹
Division:	9 - Division I (86)
Cash:	177.687 $

Extras	
Canteens:	24
Energy bars:	24
Free scouts:	0

Advert

Press Releases
No press releases available..
Write press release

Team BramBros Jersey

Change logo

Rider	Age	CL	DH	HL	SP	FR	CB	TQ	TT	DP	RS	AV
🇦🇹 Bastian Trimmel ⬛	39	27	28	67	74	60	25	76	36	90	30	49
🇦🇹 Christian Hinterseer ⬛	28	91	27	72	25	28	25	39	26	93	30	42
🇦🇹 Christopher Friesenbichler ⬛	31	25	48	83	34	34	26	34	26	90	30	39
🇧🇪 Dominick Vogels	35	65	30	29	30	28	26	28	28	64	30	33
🏴 Dunc Katich ⬛	34	30	28	76	77	28	25	46	27	90	30	42
🇦🇹 Ernst Wanner ⬛	35	38	31	31	39	72	27	67	52	97	30	45
🇨🇭 Erwin Lugar ⬛	30	31	31	27	26	29	25	27	43	70	30	30
🇦🇹 Heribert Porsche ⬛	28	30	28	25	86	73	26	54	26	91	30	44
🇩🇪 Hermann Streicher ⬛	28	38	32	30	25	25	25	29	28	67	30	29
🇦🇹 Joshua Kniewasser ⬛	32	28	27	83	70	48	25	27	26	90	30	42
🇦🇹 Louis Inthaler ⬛	34	36	27	49	31	81	26	69	74	90	30	49
🇨🇭 Matthias Bergers ⬛	27	35	30	26	30	29	28	29	28	97	30	29
🇦🇹 Per Hellensteiner ⬛	38	25	31	51	45	69	27	68	64	90	30	48
🇦🇹 Remo Walchhofer ⬛	26	28	28	31	85	37	25	68	27	96	30	41
🇦🇹 Robert Reiter ⬛	39	51	54	42	81	86	27	55	27	90	30	53
🇵🇹 Samuel Espírito Santo ⬛	27	25	30	27	35	33	26	27	28	88	30	29
🏴 Stefan Owen ⬛	30	42	31	50	83	52	27	53	39	99	30	47
🇦🇹 Valentin Pall ⬛	27	35	26	26	33	27	26	29	28	72	30	29
Riders: 18 Average:	32	38	32	46	51	47	26	46	35	87	30	40

Figure 2.6: The cyclists list for a team in the Online Cycling Manager game. (Lissner, 2020)

2.6.5 Information About Stages in Games

The outcome of a race heavily depends on the profile of a stage. Flat stages suit higher and more heavy cyclists better, where these cyclists can produce total power (Padilla et al., 1999) and, therefore, convert that quality to more speed on flat roads. In other states, where the cyclists must pass hills or

even high mountain passes, they need to overcome many high meters. The longer and steeper the climbs are, the more advantage smaller cyclists with less weight have (Padilla et al., 1999). Whereas the heavier cyclists can produce total power output, smaller cyclists who are specialized in climbs can produce more power per kg which allows them to have an advantage over the heavier cyclists on uphill sections of the stages. Therefore, cycling games need to define what cyclist strengths are important for the different stages. Whereas the Pro Cycling Manager Series (ProCyclingManager, 2020) uses real profiles to design 3D stages for their 3D-mode. The Online Cycling Manager (Lissner, 2020) uses parameter values from zero to nine for each of the eight strength values to show the users what strengths will be considered in their race simulation.

The La FlammeRouge projects (Rouge, 2020) goal is to digitalize every important summit and provide users an editor, where the users can upload stage profiles or profiles of summits or mountains. The website provides a collection of GPS files for stage profiles and offers image graphics of the stage profiles. Some race organizers use the profiles and provided images for their races.

2.6.6 Shape and Fitness in Cycling Games

In cycling races, the physical shape of the cyclists decides who will win and who will not be able to follow the final attacks. Hoeningman et al. (Hoenigman et al., 2011) use a shape system during the races' simulations, where the cyclists lose energy during the race and with no refilling of the energy. The more energy they use during the race, the less they have in the final when the race might be won against others. In cycling, the cyclists with the best chances for success are supported by their teammates. They keep their leaders out of the wind, bring them drinks and food, pace in front of the group to achieve the team goals, and try everything to prevent the leader's energy-filled as much as possible. However, for cycling, the energy during a race is important, and the physical fitness, which cyclist try to optimize to reach their goals during the season to have a higher W' or a higher CP for the races they want to perform best at.

The current fitness system in the Pro Cycling Manager Series was introduced in 2017 (Pinget, 2017) and introduced a fitness peak that gives the

cyclists performance boosts for the following weeks. Figure 2.7 shows the shape general shape system for cyclists, and Figure 2.8 shows a cyclists shape for a specific race during the season. The cyclists collect points for participating in races, training, and training camps to reach this fitness peak until they reach 100 points. Increasing the fitness and shape value also increases fatigue and at a certain fatigue level, which reduces the impact of the fitness and shape. This shape system requires good planning of the cyclist's season and rewards the manager with better race performances to reach the season goals.

Figure 2.7: The shape system for a cyclist in the Pro Cycling Manager 2017 game. (Pinget, 2017)

In the Online Cycling Manager (Lissner, 2020) the fitness is represented as race shape (RS), and the discipline (DP) represents the motivation of a cyclist to deliver a good result. To achieve a good Race Shape, the cyclist needs to take part in races. However, the more races a cyclist participates in, the more the discipline and motivation reduce because of the fatigue. The higher both values are, the more likely, the cyclists achieve better results and perform at their optimum.

The RadSim05 (Radsim05, 2020) only has a very simple system for the

Figure 2.8: The shape for a cyclist before a race during the season in the Pro Cycling Manager 2017 game. (Pinget, 2017)

shape of the cyclists, and it highly varies on the user who creates the result. The cyclists only have a list of the races they participated in before and how the creator of the result rates that. The shape depends on the result creators' preferences and changes with the different users. Therefore, it is hard to predict how to plan a season. The shape depends on the number of race days and how many the cyclists had before the race.

2.6.7 Discussion

Table 2.1 gives a brief summarisation overview for the different features for the three games discussed in this section. These games are Pro Cycling Manager (PCM), Online Cycling Manager (OCM), and Radsim05 (RS05).

All three games, discussed in this section, focus on allowing the players to manage their team and compete with their teams in races. Whereas cyclists compete in the PCM manager single-player mode against computer-controlled teams, the OCM and RS05 allow the competition against other real managers. There are three divisions in the PCM manager mode, with the

best teams in the top division, professional continental teams in the second division, and continental teams in the third division. The game follows the UCI Rules (UCI, 2017), and the teams are sorted into the starting divisions, according to their real ones. However, with passing seasons, the teams get promoted and demoted, and therefore, the structure of the divisions changes. The PCM single-player mode allows the managers to play the races in 3D-mode or to simulate them. By simulating the races, the managers can complete whole seasons within a day, and quick progress, with the fast development of the cyclist's strengths, and to improve the team faster.

Seasons in the OCM and RS05 take more time for the managers, whereas the RS05 follows the real season, and therefore takes a whole year until a team can get promoted into the higher division. A season in the OCM takes 90 real days. However, promotion and demotion in the OCM happen as soon the points in the last 90 days reach the points gaps to qualify for another division. After 90 days, results get removed. Whereas the PCM can be played quickly and spending time allows the players to improve the team faster, the OCM and RS05 progress is limited to the game's natural progress, and players can only invest a limited effort every day. Therefore, not every game suit each person. Players who prefer faster progress might have more fun with the PCM, whereas people with limited time every day, who want to do just a little work on their teams, might prefer the OCM or the RS05.

The shape systems in the three games are different from each other. However, all three systems require good planning of each of their cyclists' seasons to achieve good results. In comparison, the RS05 has a system where a human decides on the race days the cyclists had so far, but still subjective because every user might decide differently from each other. The other two games' systems also require good planning of the race days to get the cyclists in top form. However, both systems have clear parameters, and the players know what they must do to get the best out of their cyclists when they need them in top form.

The PCM's key feature is the 3D-mode, where the players can control their cyclists in a 3D race with beautiful build stages, and some of them are designed after real stages. However, it is also possible to quickly simulate the races and get a result generated by an algorithm. Both the PCM and the OCM offer a quick simulation for races where the players have few tactical options and give the cyclists roles for the race, and the algorithm decides the outcome of the race. The RS05 stands here out, and there is no quick

simulation. However, the user who created the race does that job manually. That allows the users all kinds of tactical opportunities, which would not be possible in the other games, except in the PCMs 3D-mode, where the manager controls the race in a lifetime.

Cyclists and teams in the PCM have real names and strength values according to their real-life strengths, and many of the teams and cyclists are officially licensed. That allows the users to choose their favorite teams and play with their favorite cyclists. However, since the manager mode is only available for single players, there are no human competitors. Therefore it is easier to get the cyclists the manager wants into their teams. Whereas in the RS05, with up to 32 teams and managers, recruiting the favorite cyclists can be difficult because there is a big competition with the other teams. The OCM does not use real data. However, recruiting and developing cyclists is an important part of the game. In contrast, the PCM has only a single-player mode, and the RS05 allows a maximum of 32 players. The OCM has no limit for players and teams.

Therefore, there are more people to compete against to reach the highest divisions in the game.

2.7 Summary

Professional cycling road races are complex team sport events where the teams use a strategy with their cyclists to achieve the race's best possible outcome. The outcome of a race often depends on the cyclists' physical strengths, the stage profiles, the tactics and strategies, and how the other teams react to the individual cyclists' actions. Also, environmental factors, like the width of the street, the surface, wind, and weather influence the cyclists' performance, and therefore, the races' outcome. Professional road cycling races last several hours, with stages sometimes taking over 200km. This requires the cyclists to work together and save energy during the race or recover after higher efforts to be able to fight for the victory in the final of the race.

To simulate these energy models, the critical power model from Skiba with the recovery of energy, the calculation of speed, how much power is necessary to achieve the speed, together with the inclusion of the factor of the draft and the grade of the street, allow simulating road cycling. The

Game	PCM	OCM	RS05
Single Player (SP)	YES	NO	NO
SP Managers	1	-	-
Multiplayer (MP)	YES	YES	YES
MP Managers	-	1000+	32
Platform	Video Game	Website	Forum
Free2Play	NO	YES	YES
Database	Licenses	Fantasy Data	Real
Stages	Real 3D Stages	Fantasy	Real Profiles
Results	3D Race Mode, Algorithm	Algorithm	Subjective User Prediction
Teams	Licensed	Fantasy	Real Names
Cyclist Strengths	13 values	8 values	Subjective User Prediction
Real Cyclists	YES	NO	YES
Real Teams	YES	NO	YES
Real Stages	YES	NO	YES
3D Races	YES	NO	NO
Quick Simulation	YES	YES	NO
Manual Results	NO	NO	YES
Shape System	YES	YES	NO
Real Days per Season	can be <1	90	365

Table 2.1: Comparison of the Cycling Games discussed in this section.

simulation of time trial races, where the cyclists race alone against each other, is easier to simulate than mass start races, with no impact of other cyclists and tactics through the races. However, with different tactical options, mass start cycling races are more complex to simulate since more factors influence the race outcome.

Whereas the OCM offers a manager experience with league structure against other humans, the tactical instructions only include roles for each cyclist during the race, and a single tactical instruction can be chosen. The simulation uses probabilities to decide the race winners, and only the result is shown, without any further details about the race situations during the stages. The PCM offers a great single-player experience, where the

players can manage their teams and improve their cyclists. The races can be simulated or played in a 3D-mode with great tactical freedom throughout the stage. However, the online multiplayer mode does not include a manager mode, and players can only compete in 3D races against each other. The third game, the RS05, allows both a manager experience against other human managers and a wide tactical range. The races are simulated by a member of the RS05 who does not participate in the race. Therefore the managers can write their tactical instructions in textural form. According to all the managers' tactical instructions, the creator of the race result simulates the race.

The OCM allows only fictional cyclists, with a few tactical instructions and no information about the races' situations. The PCM allows an amazing single-player experience and multiplayer 3D races. However, the multiplayer database is static, and cyclist strength values do not change through the season. The RS05 offers multiplayer manager experience, a wide range of tactical instructions, and changing cyclists' strengths through the season. However, creating the race results and simulating the races requires a lot of work by the website members, and the outcome of the races and the strengths of the cyclists often depend on the subjective preferences of the race creator.

Therefore, the goal of the RadSimTool is to design a website that allows the players to create their teams and provide a multiplayer manager experience against other human players. The RadSimTool shall allow the managers to nominate their teams for the races and create tactical instructions for different race situations. And include a dynamic strength value system, where the cyclist's performances in the game depend on both the cyclist's shape in the game and the real cyclist's performances, to which the cyclist strength values for the cyclists in the game are linked to.

3 Requirements and Design

Chapter 2 discussed how cycling races developed over time and different games that focus on simulating the sport and offer manager game modes. The players can manage their cyclists and compete against other players with their teams. Further, Chapter 2 discussed the required mathematical equations to simulate cycling races. That builds the basis for the development of a new web-based manager game. The game shall allow the players to manage their team, plan their cyclist's seasons nominate them for races, and define tactics for the races. The races get simulated by a simulation algorithm that generates strengths for the cyclists based on real results and uses them to simulate the races' outcomes. Therefore, the project is called the RadSimTool.

Chapter 3 discusses the functional- and non-functional requirements together with the design decisions for implementing them. The first section discusses the functional requirements for the RadSimTool. It divides it into three main parts, data mining, managing, processing part, the RadSimTool game website, and the race simulation. Therefore, each section of this chapter is structured into these three parts and discusses the requirements and design decisions.

3.1 Functional Requirements

The project aims to create a system where data from real life can be used to generate values for cyclists and simulate races for a web-based cycling manager game. Therefore, the project is structured into three parts. The first part is collecting, managing, and processing data from real life. The second part is the RadSimTool website, where the players can use a user interface to manage their teams. The third part is the simulation of cycling races. The generated strength values for the cyclists and the managers' tactical instructions are used to simulate different cycling races. Figure 3.1 shows the

concept for the RadSimTool and an overview, how this chapter is structured.
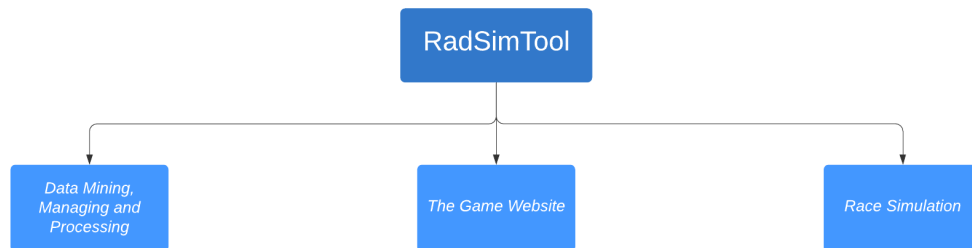
Figure 3.1: The Concept for the RadSimTool, divided into three main parts. The Data Mining, managing, and Processing, the RadSimTool game website and the race simulation.

3.1.1 Data Mining, Managing, and Processing

Collecting data from real life and the quality of these data is important to generate good strength values for the cyclists. Therefore, good data sources are necessary to collect all the required data to generate realistic strength values for the cyclists. The system shall collect real result data from websites with a database editor that allows admins to visualize the results and extend or modify the data manually if needed. Therefore, this section is structured into three parts, data mining, data managing, and data processing. Figure 3.2 shows how this section is structured and visualizes the data transfer between these parts and the database.

(1) Data Mining: Collecting the Required Data

The first requirement for the data mining, managing, and processing part of the project, is the mining and collecting of data from cycling results and statistic websites. The data scraping process, where a script shall parse results from websites and save the collected data into a database.
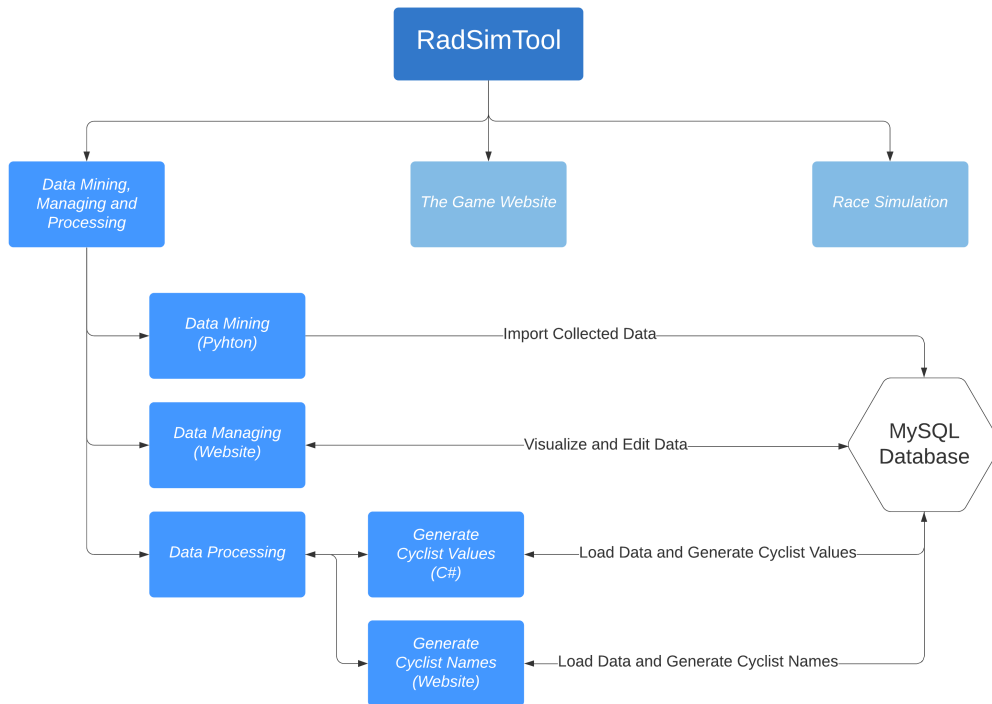
Figure 3.2: The structure of the data mining, managing and processing section.

(2) Data Managing

To visualize the data and offer an administration tool for the collected data, the system shall include a website to manage the data with a user interface. The administrators can browse through each season's races and results, edit, delete, or create new data entries.

1. The users can navigate through the different years, where race results exist.
2. Users get a list with the races for the chosen year.
   3.1 Users can show the races stages and information.
   3.2 Users can delete the race.
      i. Users can show the races stages and information.
      ii. Information, like the name, date, country of the races can be edit.

iii. New stages can be created for the selected race.
iv. The stage information and details can be edited by the users.
v. Stages can be deleted together with their results.
vi. Users can select a stage and show results and stage details.
vii. Results for a stage can be deleted.
viii. Results can be imported for a specific stage.

5. Users can click on a cyclist's name to get forwarded to the cyclist detail page.

5.1 On the cyclist detail page, users get an overview of the average and top results of a cyclist.
5.2 The overview includes statistics for all the different profile types and races.

(3) Data Processing

At the third step of the data collecting, management, and processing part, the collected and managed data must be processed and used to calculate cyclists' required values from real results over the last seasons. Additionally, the data is used to generate names for newly generated cyclists in the game.

A - Generate Values for Cyclists

The collected data shall be used to generate the strength values for the cyclists in the game. The algorithm shall cluster the results according to the stage profiles to use the results to generate the specific strength values. To avoid using real names of cyclists in the game, the data shall also be used to create unique cyclist names for the game.

B - Generate Names for Cyclists

To generate cyclists for the game, they shall get real cyclists' strength values, together with a randomly created name. Therefore, the name generation algorithm shall create new names by combining random first names and last names from the real cyclists in the collected data from real life. These names shall be unique within the game and have no cyclist with the same name combination in the collected data.

3.1.2 The Game Website

The second part of the project is the RadSimTool game website. This website offers the players a user interface to play the game. With this website, the players can manage their team, plan the race days for their cyclists, nominate their cyclists for races, and define the tactics. Players can also look up the race results and look up several statistics provided in the RadSimTool. The RadSimTool was developed to give the players of the RadSim05 additional information and statistics.

New players can register themself on the website, create a manager name and create a new team for the game. After the creation of the team, new cyclists are added to the team. With this team, the managers can start their journey and nominate their cyclists for their first races.

The key features for players on the website shall be team management, where players get an overview and statistics about their teams. Other key features are the race calendar, an overview with all the races for a selected season, where the players can select a race and subscribe their teams to that race. After selecting the teams, the players can define the tactics for the race and look up the results for each race after the simulation is finished.

Figure 3.3 shows the concept for the main pages of the RadSimTool website.

(1) Login and Session Handling

A login system with session handling shall be implemented to prevent none registered users from playing or looking up the state of the game. The users can register with their e-mail address, password, and username. Session Handling shall ensure that only registered users can log in to the game, and managers can only manage their teams.

1. Only registered users can use the game.
2. Users can create an account and create their team to play the game.
3. Users can log in with their e-mail address and password to manage their teams and play the game.
   3.1 Users stay logged in until they log out or the session expires automatically after a certain time.
4. Users can log out.
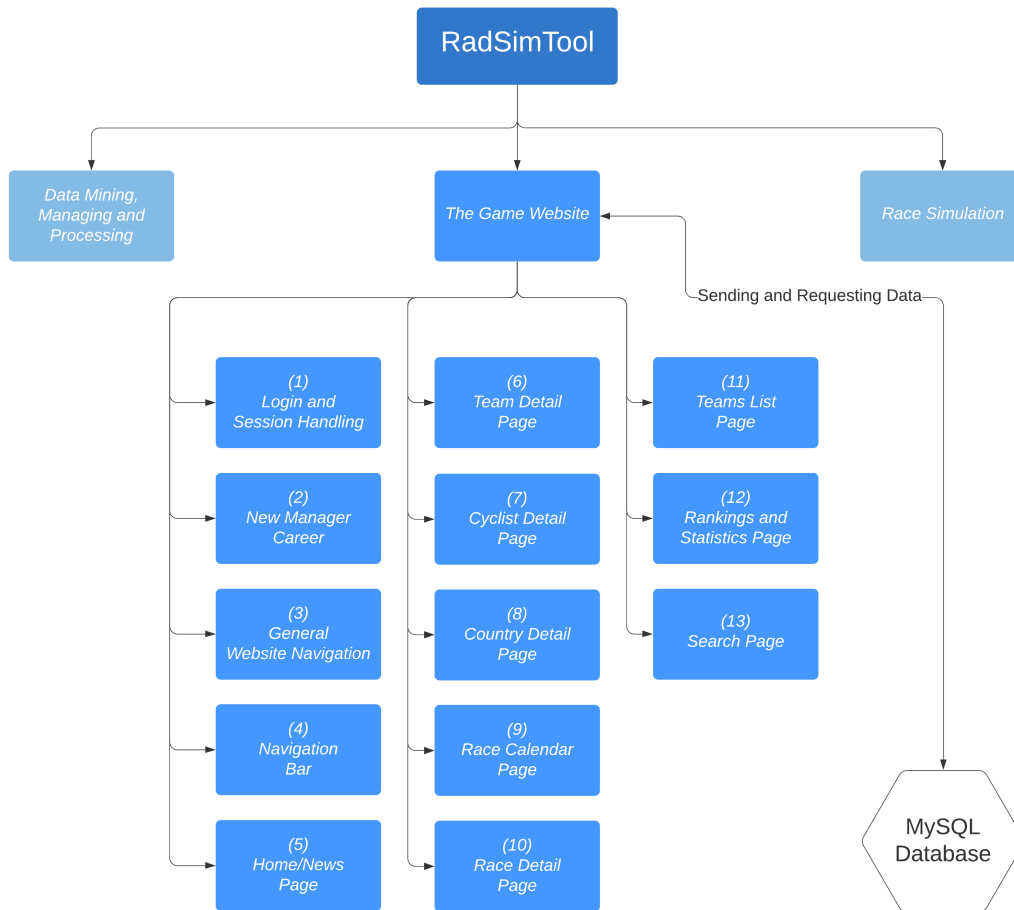
Figure 3.3: The main pages of the RadSimTool website.

(2) Start Into a new Manager Career

The first step into a new cycling manager career shall require the users to register themself with their e-mail address, password, and username. After the users create their account, they shall get to the "Create Your New Team!" page to choose a team name and their teams' country. Finally, the team shall be filled with a randomly generated cyclist. These cyclists shall be linked to real cyclists within the system. This link shall ensure that the game's cyclists' strength changes with their linked cyclist's performances in real

cycling races.

1. The users can log in with their newly created account.

   1.1 The users can create their own team.
   1.2 Users can choose their unique team names.
   1.3 Users can choose the country of their newly created team.

(3) General Website Navigation Functionality

To maintain a clear navigation functionality throughout the website, a navigation bar shall provide easy navigation. Whereas the navigation bar offers links to the main menus and pages, key information shall be clickable and forward to them according to detail pages. Therefore, important information like team names, cyclist names, race names, and country names and flags shall be clickable across the website to allow uniform navigation across the entire website. That requires the following functionalities:

1. Users can click on the race name to get forwarded to the race's race detail page.
2. Clicking on the cyclist names in the result list shall forward the user to the cyclist detail page.
3. The Users can click on the team names to get to the Team detail page for the clicked team.
4. A click on the country flag forwards the users to the country detail page.

(4) Navigation Bar

As mentioned before, the navigation bar shall provide on each part of the website that the users can navigate to the main features of the RadSimTool website:

1. Users can click on "MyTeam" to open more navigational operations!

   1.1 Users can click on "Squad" to get to their team detail page.
   1.2 Clicking on "Successes" forwards the users directly to the Success overview page on the team detail page.

    1.3 By clicking on "Planer", users get forwarded to a season planer for their team.

    1.4 A click on "Planned Races" forwards the user to the list of all races that the users have planned cyclist to race it.

    1.5 A click on "Raced Races" forwards the user to the list of all races that the user's team participated in this season.

    1.6 Clicking on "Points Diagram" forwards the user to a diagram with the teams collected points this season, compared with the last two seasons.

2. Users can click on "Teams" to get forwarded a list of all teams in the game.

3. A Click on "Calendar" shall forward the user to the current season's race calendar page.

4. Users can click on the magnifying glass symbol to get forwarded to the Search page, where the users can search for cyclists by their name.

5. Users shall see their username. A click on it leads the users to the user profile page.

6. The "Logout" button shall log the users out and forward the user to the website's start page.

(5) Home and News Page

The home and news page shall provide the users with general information, as an overview of rankings on the right side, upcoming races on the left side. Below the upcoming races, the news feed contains the latest results. The users have the following functionalities on this page:

1. Users can use the upcoming race box to get an overview over the next races.

2. The Users can click on the race's name to get to their race detail page, where they can nominate their team.

3. Each result has its result box, with information about the race and the top five of the race's result.

    3.1 Users can click on the race name to get forwarded to the race's race detail page.

    3.2 Clicking on the cyclist names in the result list shall forward the user to the cyclist detail page.

    3.3 The Users can click on the team names to get to the team detail page for the clicked team.

    3.4 A click on the country flag forwards the users to the country detail page.

4. The right side of the news and home page shall show boxes with the top 5 of the main rankings.

    4.1 Users can click the cyclist names in the result list shall forward the user to the cyclist detail page.

    4.2 The users can click on the team names to get to the team detail page for the clicked team.

    4.3 A click on the country flag forwards the users to the country detail page.

(6) Team Detail Page

The team detail page shall provide the users with a team overview, including a list of all the cyclists and some additional information about them.

1. Users can use the team detail page to get a list of all the cyclists in their team.

    1.1 Users can click on the Country flag to get forwarded to the country detail page.

    1.2 Users can click on the cyclist name to get forwarded to the cyclist detail page.

2. Users can use the success overview to get a list with all the team's top results during the chosen season.

    2.1 Users can sort the success list by result rank.

    2.2 The list can be sorted by cyclist name.

    2.3 The list can be sorted by race.

    2.4 The success list can be sorted by the achieved points for the ranking.

    2.5 The list can be filtered by the race and stage type.

    2.6 The list can show only results with points.

    2.7 The list can show only results with wins.

    2.8 The list can show only results with podiums.

3. Users can use the cyclist values overview to get a list with all the cyclist and their strength values for the different profile types.

    3.1 Users can sort the list by the different strength values.
    3.2 The list can be sorted by cyclist name.
    3.3 The list can be sorted by the cyclist's nation.
    3.4 Users can click on the names to get to the cyclist detail page.
    3.5 Users can click on the country flag to get to the country detail page.

4. Users can look up the planned races. This includes all the races, the manager chooses a cyclist to participate with in the future.
5. Users can look up all the races the team participated in for the current season.
6. Users can look up a scoring diagram with an overview graphic, showing the collected points of the last three seasons.

(7) Cyclist Detail Page

The cyclist detail page shall show the name, detailed information about the cyclist, and results for the selected cyclist. The page shall offer the users the following options:

1. Users shall see the name of the cyclist at the top.
2. Users can click on the cyclist's country flag to get forwarded to the country detail page.
3. Users can look up the cyclist's successes for each season.

    3.1 Users can click on the race name and get forwarded to the race detail page for that race.

4. Users can click on the planer to get an overview of all the races for the current season.

    4.1 Users can click on the race name and get forwarded to the race detail page for that race.
    4.2 The race planer can be sorted by date or category.
    4.3 Users can click on the "+ add" button to add a race to the cyclist's planned race program for the season.
    4.4 Users can click on the "- sub" button to remove a race from the planned race program.

(8) Country Detail Page

The country detail page shall include a list of all cyclists for a specific country. For each cyclist, the list shall contain the name, team, and points for the main season ranking.

1. Users can click on the cyclist names to get to their detailed cyclist page.
2. Users can click on the team names to get forwarded to the team detail page.

(9) Race Calendar Page

Users can use a race calendar page with a list of all the races for every season. These views shall include the date of the race, the race name, the country of the race, and the races' category. Additionally, users shall see quick information about how many cyclists are allowed to nominate for a specific race, how many cyclists the manager has already planned or nominated for a race.

1. Users can click on the name of the race to get to the race detail page.
2. A Click on the country flag of the race shall forward the users to the country detail page.
3. Users can select a specific season; the selected season is listed on the race calendar page.

(10) Race Detail Page

The race detail page is the heart of the RadSimTool website, where all the strings come together, and the RadSimTool website connects with the simulation algorithm for the race simulation. The users shall get an overview of the race and their team. Users can plan and nominate cyclists of their team for the race and look up the nominated teams of other users in the "Start List" section of the page. The "Tactics" section shall provide an overview of the user's nominated team, and the users can add new tactical instructions for their team to the race. In the "LiveRace" section, the events of the race shall be visualized for the users after the race is simulated. After the simulation is finished and the LiveRace is over, the race results shall

be published in the "Results" section. Here, the users can look up the full results for the simulated race.

A - **Race Overview**
The "Race Overview" section shall provide general information about the race and the race stages for the users. If the race is over, the Top 10 shall be displayed here too. The users can click on the names of cyclists on this page to get forwarded to the cyclist detail page and on the stages to see more details.

1. Users can click on a stage to get to the detailed stage result.
2. Users can click on a cyclist name in the result list to get to the cyclist detail page.
3. Users can click on a team name in the result list to get forwarded to the team detail page.
4. Users can click on a country flag in the result list to get to the country detail page.

B - **Team Nomination**
In the "Team Nomination" section, users shall have a list of their cyclists with some information about their race days so far in this season. Planed cyclists are displayed in the "Planed Cyclists" list, and nominated cyclists get added to the "Nominated Cyclists" list.

1. Users can click plan a cyclist for a race.
2. Users can click nominate a cyclist for a race.
3. After cyclists got planed for a race, users can add them to the nominated list.
4. Cyclists from the planned list can be removed from the "Planed Cyclists" list by clicking on the remove icon.
5. Users can add all planed cyclists to the "Nominated Cyclists" list.
6. Users can remove nominated cyclists from the "Nominated Cyclists" list to change them as planned cyclists.
7. Users can move all nominated cyclists to the "Planed Cyclists" list with a single click.
8. Users can click on the grown icon to define a captain for the race.

9. Users can click on the star symbol to mark this race as a race highlight for the specific cyclist.

C - Stages

The stages shall contain a list of all the stages for a race. This list shall display the main information for every stage, the number of the stage in the race, the name of the stage, the distance, profile type, and race type. The race type can be a mass start road race, individual time trial, or prologue. The users can click on a stage to show the detailed stage profile visualized on top of the stage list.

D - Start List

Users can use the "Start List" to look up all the teams and the nominated cyclists who participate in the specific race. The cyclists of each team shall be grouped, and the team captains who shall lead the team in the race shall be in the first position. The team captain always has the number 1 in the team, and the remaining cyclists shall be sorted by alphabet and incrementally numbered.

1. Users can click on a cyclist name to get to the cyclist detail page.
2. Users can click on a team name to get forwarded to the team detail page.
3. Users can click on a country flag to get to the country detail page.

E - Tactical Instructions

Tactical instructions and roles for cyclists shall allow the users to define how their cyclists shall behave during the race. Therefore, the users can use this section to add tactical instructions for a race. The defined tactical instructions shall be sorted by the starting kilometers and visualized in a list. The entries shall include the cyclist, team, and the defined settings for the tactical instructions in this list.

1. Users can select a tactical role for every cyclist.
2. Users can add new tactical instructions for a cyclist.

   2.1 Users can select the type of the tactical instruction.

    2.2 Users can define a kilometer range, "From KM" "To KM" to define the range where the instruction shall be active.

    2.3 A slider shall allow the users to define what percentage the cyclists shall perform at.

    2.4 Users can select cyclists for the tactical instruction.

    2.5 Users can click on the "save" button to save the tactical instruction.

3. Users can delete a tactical instruction.

F - LiveRace (Not Yet Implemented)

The LiveRace overview contains a list of all the events during a simulated stage to visualize the race for the users. Therefore, users can select a specific stage of the race. It shows messages for attacks, following cyclists, pacing cyclists, breakaways, and sprints to allow the users to better understand the race. A stage profile on the top of the page shall give the managers an overview of the stage details.

1. Users can click on the stage names to select a different stage.
2. Users can click on a cyclist name to get to the cyclist detail page.
3. Users can click on a team name to get forwarded to the team detail page.
4. Users can click on a country flag to get to the country detail page.

G - Results

The results section shall provide the users with result lists and rankings for the race. Users can switch between the results. Result entries in the result list shall include the position, the country flag and name of the cyclist, the team country flag and team name, the points won for the world ranking, the total time needed for the race stage, and the time difference to the winners. General classifications, which require collecting points, shall show the points instead of times.

1. Users can click on the different ranking names in the list to display the according to result or ranking.
2. Users can click on a cyclist name to get to the cyclist detail page.
3. Users can click on a team name to get forwarded to the team detail page.

4. Users can click on a country flag to get to the country detail page.

H - Race Statistics (Not Yet Implemented)
For more statistics about the cyclist's performances during a race, the race statistics page shall provide the users with visualizations of selected cyclists' performances during the race. Therefore, the power output change, energy tank W'_{bal}, or the speed during the stage can be visualized and compared with other cyclists from the own team or other teams.

1. Users can select cyclist to display in the data visualizations.
2. Users can move over the data and see the data for each compared cyclist at this point during the stage.

(11) Teams List Page

With the team's page, users can get a list of all the teams in the game. The list includes the team name, the team's country, the team's division, the team manager name, the points, and victories. The users can click on the table headers to sort the lists by this information.

1. Users can click on the country information to get to the country detail page.
2. Users can click on the team name to get to the team detail page.
3. Users can sort the list by clicking on the different table headers.

(12) Rankings and Statistics

The RadSimTool website shall provide rankings and statistics for the users. Therefore, the ranking page shall list relevant rankings and statistics. The main rankings are the general point and victory ranking for the teams and single cyclists. For the country ranking, the users can look up the ranking by points and victories. To provide the users an easy overview of all the winners of each race, there shall be a calendar list with the winners, their teams, and the points for the winner of the races. Additionally, a winner list, grouped by the race categories, shall provide the users more statistics and information.

1. Users can click on the rankings on the left side and select them to display in the ranking list.
2. Users can click on a cyclist name to get to the cyclist detail page.
3. Users can click on a team name to get forwarded to the team detail page.
4. Users can click on a country flag to get to the country detail page.

(13) Search Page

To allow users to search for a specific cyclist, the search page shall provide them a text field to input a part of a cyclist's full name. The search result shall be displayed in a cyclist list with some additional information about the cyclists listed.

1. Users can insert a part of a cyclist's name or the full name into the text field to search for a specific cyclist.
2. Users can click on the search button to search for the inserted cyclist.
3. Users can click on a cyclist name to get to the cyclist detail page.
4. Users can click on a team name to get forwarded to the team detail page.
5. Users can click on a country flag to get to the country detail page.

3.1.3 Simulation of Cycling Races

The third part is the simulation of cycling races, both for mass start road races and for individual time trials. Therefore, software with a simple user interface shall be developed. The interface shall allow the admin to browse through the races and choose the race they want to simulate with the simulator. To simulate the race, several functionalities are required. The simulation shall allow using real cycling race profiles and the generated values for the cyclist's strengths. Also, the simulation shall use the equations from Chapter 2 to calculate the power with Equation 2.11 and with Equation 2.10 the speed of cyclists. Additionally, the simulation shall support simulating the energy tank $W_{(bal)}$ with Equation 2.12, through the races by using the equations from Skiba et al. (2012) and the optimized version of Waterworth (2014) to simulate the reduction and regeneration of the cyclist's energy tanks. Using the tactical instructions, which the team managers defined

with the RadSimTool website for the race, the simulation shall simulate the race itself. Therefore, the algorithm shall also simulate the behavior of every cyclist through the race. To offer the managers different race modes, the algorithm can simulate mass start road cycling races and simulate individual time trials for road cycling.

1. Users can select a year, race, stage combination to simulate the race.
2. Users can generate and update strength values for a specific profile type and year.
3. Users can simulate time trials or mass start road races.

   3.1 Users can browse through the cyclists to display the performance data (power, speed, energy tank) for the simulated race.
   3.2 Users can go through the simulated race with each time step to see the race situations at that time.
   3.3 Users can see the result lists for the simulated race with the time differences.

3.2 Non-Functional Requirements

In the last sections, all the functional requirements for the RadSimTool are described. These functional requirements define the functionality of the RadSimTool. However, there are also non-functional requirements for the RadSimTool. The non-functional requirements in this section include the extensibility, flexibility, and maintainability of the project. It also includes the quality of the generated values and data quality for the collected data, the language for the RadSimTool, privacy, usability, and the website's security.

Extensibility
The system shall be designed to offer a good basis for further extensions. These possible extensions can be adding new tactical commands to the simulation, adding other types of races. Whereas the project focus on the generation of only a few strength values, like the strength in sprints and time trials, the system shall provide a good basis to increase the quality of the calculation for other strength values, like the strengths for mountains or hills. The admins shall also be able to create new races for the race calendar and expand the number of races available for every season.

Flexibility

To allow users to define tactical instructions in front of a race and to navigate their cyclists through the race. The system shall provide a set of tactics that includes the most common tactical approaches during professional cycling races. These commands shall allow the simulation to simulate the races and guarantee the race's outcome, depending on the users' used tactics.

Data Quality

During a professional road cycling season, cyclists typically have not more than 80 race days during the season. Therefore, most cyclists have only a few results for all the different race types and profiles. For the data processing process, collecting the important race results and collecting information about the race type and profiles for a race is important. This information can be used to identify the required results for the generation of cycling strength values and create statistical overviews for a cyclist's performances during the different seasons. To achieve good results, data quality is important to be able to separate the results into the right categories and use the results in the data processing progress to achieve the goals.

quality

The project aims to achieve high quality for both the generated cyclist values and the simulated races. The strength values shall represent the cyclist's real strengths. Those strengths shall link cyclists in the game and simulation with real cyclists. The races' simulations shall provide high-quality results, with realistic outcomes for cycling races, especially for time trial races, where fewer tactical opportunities influence the race outcome. However, mass start races shall follow realistic events triggered by tactical commands during the races.

maintainability

Cyclists Strength values shall be updated with new real races taking place during the season. Therefore, the system shall provide features to import recent results and update the cyclist's strengths with those newly collected data. To maintain the collected data, admins can create, view, and modify the race information, the stage information, and the races' results with a data editor.

language
Since the RadSim05 is a German-speaking forum and user group. Therefore, the original RadSimTool was developed for German-speaking users. However, since the RadSimTool shall be available for a wider user base. To make the RadSimTool accessible for more people, the language for the RadSimTool shall be English.

privacy
The privacy of users using the website shall be secured. Therefore, only data required for the functionality of the website shall be collected from the users. To get access to the website, users require an account for the RadSimTool. Only the username, password, and e-mail address are collected from the users at the account registration. However, for the website functionality and session handling, also the usage of session cookies is required. These cookies shall only be used for providing the functionality of the website and not for advertising purposes.

usability
The website shall provide good usability with easy access to the key features of the website. Providing the users with intuitive features to manage their teams and nominate teams for the races shall help increase the user experience and shall reduce the time required to manage the teams. This information shall always be linked and clickable throughout the website to navigate the website and get easy access to information about cyclists, teams, and races.

Security
Security is an important requirement. Therefore protecting the website from common attacks, like cross-site scripting or SQL injections, is important for the development process. W3Schools (2020b) explains how SQL injection works and what developers can do to prevent their websites from that type of attack. Websites typically allow the user to insert text into text fields and save them into a database. For example, the username and password, at the creation, or a search field. However, whereas users typically insert meaningful phrases, the attackers use the text fields to insert parts of SQL queries to modify the SQL query from the website to manipulate or exploit

data from the database. To prevent SQL injections and protect the database's data, the developers shall use the bind parameter functionality to handle user input for SQL queries. The bind parameter methods replace user input with parameters. These parameters are inserted into the queries at execution time, and the SQL engine takes care that the bind parameters are valid and not used as part of the SQL code.

Cross-site scripting is the usage of input fields to place the script into the website. Other users will then run those scripts. These can be avoided by replacing specific elements from the user's input text into forms. W3Schools (2020a) explains the problem on their website and shows an example of how to solve the problem.

3.3 Conceptual Architecture

The previous sections discussed the requirements and designed a system for the RadSimTool. Therefore, the visualization of the requirements, the conceptual architecture describes the structure of the RadSimTool. Figure 3.4 visualizes the conceptual architecture diagram with the main functionality parts of the RadSimTool. The Diagram includes the three parts of the RadSimTool, the data mining, managing, and processing part in blue, the RadSimTool game website in grey, and the Race Simulation software in Yellow. The MySQL database server is visualized as a white hexagon.

The 1st part, visualized in blue, includes collecting the required data with a Python script and importing the data into the MySQL database on the server. After collecting the required data for the data managing process, a website is created. The admins can look up the visualized data from the database, edit them and create additional entries for the race results. And the last step is data processing. The collected data is used to generate new cyclists with random names for the RadSimTool game on the website and the WinForms application, using the collected data to generate cyclist strength values for the race simulation.

The 2nd part, visualized in grey, includes the RadSimTool game website, divided into the client-side and server-side. The client-side is developed in HTML/JavaScript/CSS and visualizes the PHP server that creates the PHP websites. Therefore, the client sends the user interactions to the server, and the server-side create new website content and sends it back to the

client-side. Managers in the game can nominate their cyclists and define tactical instructions for their cyclists for a specific stage, and the data is stored in the database.

The 3rd part is visualized in yellow and includes the race simulation. Therefore, a WinForms application is created to load real stage profiles, and the nominated cyclists for each team, together with the tactical instructions for the races, are loaded from the database server. The race simulation uses these data to simulate the races and save the cyclist's performance data, the events during the race, and the database server's result to display on the RadSimTool game website for the managers.
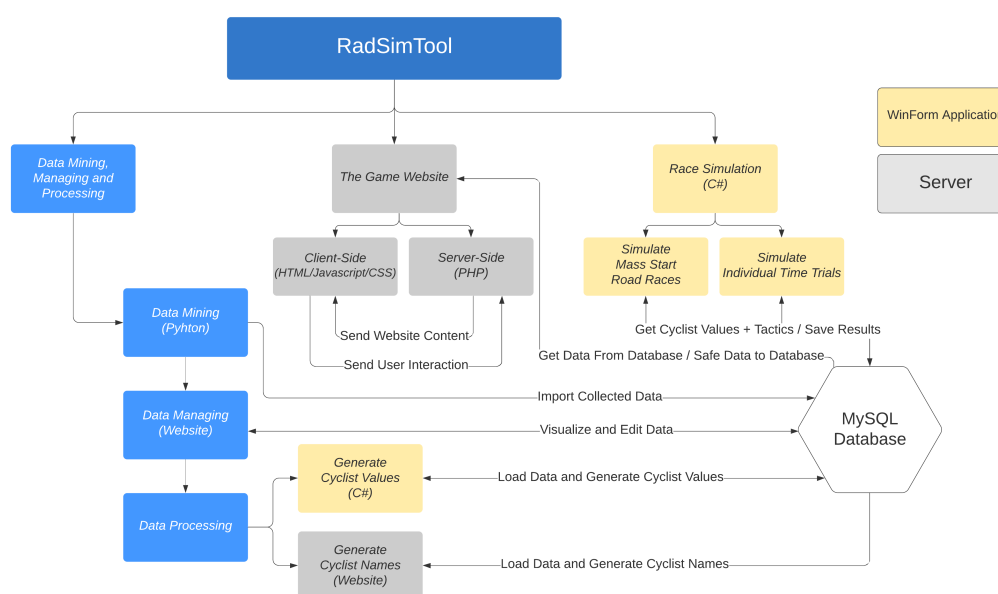
Figure 3.4: The Conceptual Architecture Diagram of the RadSimTool.

3.4 Design Decisions

The previous sections discussed the functional and non-functional requirements for the RadSimTool, and Figure 3.4 described the conceptual architecture for it. In this section, the requirements get evaluated, discussed,

and design decisions are made. The discussion evaluates the requirements for the data mining, managing, and processing part. It also evaluates the decisions on what tools, frameworks, and programming languages shall be used to implement the requirements. For the RadSimTool game website, the focus is on how the website will be implemented, how the game is designed to achieve great playability, and how it can keep users motivated. For the simulation of cycling races, the focus is on how the different types of cycling races shall be implemented and what frameworks shall be used. For the cycling races simulation, it is required that the tactical instructions and cyclist roles for cycling races are defined. Therefore, the required tactical instructions and cyclist roles must be implemented into the cycling race simulation.

3.4.1 Data Mining

For the data mining process, a script shall run through websites to collect results for cycling races and additional information about the stages. Therefore, different approaches must be considered. One option can be the usage of JavaScript to run a script from the website. JavaScript runs the script on the client-side, whereas an approach with PHP would run the process on the server-side, using the server's execution time for the process of data collecting. A third approach is to use Python to run a script and collect all the required data and save them into a file or directly into the database. Python is fast and provides effective features to parse the content, handle the lists and build a data tree. Since a Python script can also be run from the server but also from a local machine, it offers great flexibility and will be used for the data mining process. The python script runs over a specific race category and collects all the results for the year. Therefore, the script can be used to collect results from different race categories and different seasons.

The collected data could either be directed imported into the database or saved in files before they get on the database server. Since the python script shall run alone without any database connection, the collected data will be saved into a file. Since the python script builds a data tree with the collected data, a solution with saving this data tree into a file, saving the data tree into a JSON file, comes with several advantages. The JSON file format can

be read and used by many different programming languages. It can be used with PHP or JavaScript to import the data to the database server. It is also human-readable. Another advantage of saving the data into files instead of direct database import is that data of several years and different race categories can be saved into different files. The files can be used as a backup for the database, and it allows the users to load only specific data into the RadSimTool database.

3.4.2 Data Managing

For the data managing process, a website is created to allow importing and managing the data. Therefore, an import feature allows the import of JSON files with the proper data tree. Like the rest of the RadSimTool website, the data editor is split into a client and server-side. The client uses HTML, JavaScript, and CSS to create the user's view and allow dynamic interactions. To load parts of the website dynamically, and do not require to load all the website content new. The RadSimTool uses Asynchronous JavaScript and XML (AJAX) to send asynchronous calls to the server and load dynamic content to update the page. On the server-side, PHP and the database server are used to handle user input, create the new pages and send them to the client.

3.4.3 Data Processing

The data processing for the RadSimTool requires access to the database server. It uses the data mining data to generate strength values for cyclists and generate random names for newly created cyclists in the RadSimTool game. Since the RadSimTool has no licenses for any teams or cyclists from real life, and to avoid legal issues, cyclists in the RadSimTool game that are created for teams shall have random names.

Generating Cyclist Names
These random names shall be generated from the list of real cyclists in the database with a PHP function on the server-side. However, generated cyclist names are randomly selected, unique, and independent from the cyclist's real name. Therefore, for every newly created cyclist, a random first name

and a random, last name are selected from the database. Both names shall be independent of the real name and the new name unique in the database of real cyclist names and cyclist names in the RadSimTool game. To achieve a more realistic combination of last names and nations, the generated cyclists' country is linked to the last names of the cyclist's country. Whereas the cyclists have random names in the RadSimTool, the cyclists in the database are still linked to the real cyclist to allow dynamic strength values for the cyclists depending on the cyclist's real-life race performances.

Generating Strength Values
The name generation shall be handled by the server-side of the RadSimTool, with PHP functions generating new cyclists and names. The algorithms for the strength values generation are developed offline within the software tool to simulate cycling races. Since the simulation requires lots of performance time, and the website shall not be affected by these, the simulation and strength value generation shall be run offline. That provides the simulation of races with more resources and usage of parallelization to reduce the simulation time. The software will be developed with C# as a Windows Form application since Visual Studio provides many different software features without writing much code or using other plugins. These features include graphs for the race profiles, the race energy tank, speed, and power output through the race.

To generate the different strength values, different requirements must be achieved, whereas for generating sprint values, the cyclist's performances in mass sprints are compared to each other, the generation of time trial values shall use functions for energy, power, and race simulations, to generate the cyclist strength values. This project aims to achieve good and realistic strength values for the time trial and sprint strength values. Whereas other strength values, as mountain, hill, and flat, use only basic algorithms. Therefore, more detailed approaches are left for further work.

3.4.4 The Game Website – RadSimTool Game

As the data editor website, the RadSimTool game website is also developed with HTML, JavaScript, and CSS on the client-side. The server side uses PHP and a MySQL database to create the pages for the clients. Users can

interact with the website to perform dynamic actions and load new data asynchronous with AJAX calls. To secure the functionality of the website across different platforms and devices, the website uses Bootstrap. The Bootstrap framework is used to create the website with Bootstrap elements. Bootstrap elements allow designing dynamic, interactive websites that scale for different resolutions and devices.

Data Visualizations and Graphs
To achieve a high information quality for graphics and visualizations. These visualizations shall allow providing the users with additional information about the races, cyclists, and teams. Therefore, these visualizations shall be created with Data-Driven Documents (D3), a JavaScript library to create data visualizations and graphs for websites. In the RadSimTool, D3 is used to visualize stage profiles for races, points statistics for teams and cyclists to visualize performance data for cyclists during the races. Cyclists have an energy tank and perform at different power levels in watt to achieve the speed during the stages. Therefore, these performance data shall be visualized using D3 after the races, and features shall allow the managers to compare different cyclists' performance data with each other.

Teams and Cyclists
The RadSimTool uses fantasy teams. Therefore, every manager must create an own team after registration. Teams require a unique name, a unique 3-letter short name, and the country its origins. After creating the team, the squad gets filled with 20 random cyclists. The minimum number of cyclists for a team is 20 cyclists. However, managers can have a maximum of 25 cyclists in their team. The cyclists get randomly selected from the cyclists with cyclist strength values in the database. These strength values are linked to a real cyclist and change with the linked cyclist's real-life performance. However, to avoid legal issues, the created cyclists for teams get random names and country information, as explained in the section about generating cyclist names (3.4.3).

Retired, Suspended and Injured Cyclists
Cyclists' strength values get calculated from cyclists' real-life performances. Cyclists who are not competing at professional cyclist races cannot get

updated cyclist values anymore. Therefore, retired, suspended, or injured cyclists with no results within the last six months can be removed from the team. If a team has less than 20 cyclists in the squad, new random cyclists get generated to fill up the squad to the minimum size.

Rewards
To increase the motivation for achieving better results and keep managers playing the game, managers can get new cyclists for their teams. Depending on how well the team performed within different time intervals, managers get rewarded with new cyclists. Managers can choose whether they want the rewarded cyclists in their squad. Since the maximum team size is 25 cyclists, the team can be filled up from starting 20 cyclists to the maximum number of cyclists. However, if the limit is reached and managers get rewarded new cyclists, they can choose a cyclist to remove for the new cyclist.

3.4.5 Race Calendar

The races in the RadSimTool game are divided into seasons. A full season takes 365 days and starts in January and ends in December. Therefore, the race calendar includes races throughout the year. These races can be created in the database and require information about the race and the stages. The RadSimTool website is created to display one-day races and stage races. Whereas new races can be created, and old ones can be removed, the main collection of races shall remain for every season. Therefore, the same races are taking place every year.

Race Information
Races require a lot of information to allow the users to plan their season, nominate their teams, and define their tactics. Therefore, the races must include information about the country of the race, the date of the race, the name of the race, the category of the race, and the allowed cyclists. For each race, at least one stage is required. The stages include information about the name, the distance, the profile type of the race, the stage type, and, if possible, the stage profile itself. Whereas the profile type is only a categorization of the race into the hill, mountain, flat, hill finish, or mountain finish, the profiles themselves include the profiles' GPS data and visualize

them for the users as a graphic of the evaluations during the stages. The stage type defines whether the stage is an individual time trial (ITT), normal mass start stage, prologue (P), or team time trial (TTT).

One Day Races and Stage Races
Whereas one-day races only include one stage, stage races can include up to 21 stages, since 21 stages are the maximum amount of stages in real professional cycling stages races at the three Grand Tour stage races. Therefore, the website also displays general classifications and points and mountain classifications for stage races.

Race Categories
Races in the RadSimTool are divided into different categories to give some races more importance than others. Table 3.1 lists all the categories for the RadSimTool, discussed in this section. The higher the category, the more points can be won by the cyclists, and the lesser important race categories offer fewer points for the participating cyclists.

The highest categories for stage races are Grand Tours, which are raced over three weeks. There are only one of the highest categories (GT1), and there can be only two more Grand Tours for one season (GT2). Other stage races, which last less than ten days, are categorized as 2.HC for the highest category (HC) of one-week stage races. The lower 2.1, 2.2, and 2.3 categories are for less important stage races.

One-day races (ODR) are categorized into five categories. In contrast, the 1.M categories are like the Grand Tour categories for stage races. 1.M races are the highlights of the season for cyclists focused on ODR. There can only be five races of the 1.M category representing monuments of the cycling race calendar. These races are the most iconic in the RadSimTool and stay the same race and the same category for every season. For all the other top-level ODR, the category is 1.HC, whereas less important ODR are categorized as 1.1, 1.2, or 1.3 races.

Another category for cycling races in the RadSimTool is under 23 (U23) races. These races are especially for youth cyclists under 23. U23 races are categorized as stage races (2.U) or ODR races (1.U). Additionally, there can be races at the RadSimTool World Championship for U23 cyclists. These races are categorized as U23RR for the U23 road race and as U23TT for

the U23 individual time trial (ITT) race at the RadSimTool World Championships.

The RadSimTool World Championship also includes races for the best cyclists in the RadSimTool world. Therefore, the road races are categorized as 1.CM and the individual time trials (ITT) as 1.CMTT. There can also be races for national championships for cyclists. These races are ranked by the importance of the nation throughout the last season in the country ranking. And can be 1.CN1-5 for road races or 1.CN1-5TT for ITTs. The countries are ranked between 1 and 5.

Cyclists in real professional cycling can wear special kits throughout the following year for winning the world championships or national championships. In the RadSimTool, cyclists earn milestones and badges displayed on the cyclist's details page or next to the cyclists at different rankings and other lists.

Points for Rankings

Races in the RadSimTool calendar are divided into different categories, discussed in the section before. Therefore, cyclists can earn a different amount of points for different race categories. The higher the level of the race, the more points can be earned. Whereas at ODRs, only points for the general classification of the race can be earned, stage races and Grand Tours also provide points for the general classification leader after every stage and points for every single stage's top finishers. The number of points for the single race depends on the stage race category the race counts to.

These points are used to calculate the three main rankings of the RadSimTool. The RST individual ranking includes single cyclists, the RST team ranking includes all the teams, ranked by the points, and the RST country ranking includes the points for the different countries earned by their cyclists. These rankings can be looked up in the rankings section.

3.4.6 Software and Database for Race Simulation

The RadSimTool website for the game and data managing process for collecting data during the data mining process is developed with a client-server structure. Where the client uses HTML/JavaScript/CSS and server-side PHP and a MySQL database server. However, the race simulation and generation

ID	Icon	Name	Description
1	GT1 RST	GT1	Grand Tour 1, 3-week stage race
2	GT2 RST	GT2	Grand Tour 2, other two Grand Tours
3	2.HC RST	2.HC	highest category (HC) one week stage race
4	2.1 RST	2.1	4th category for stage races
5	2.2 RST	2.2	5th category for stage races
6	2.3 RST	2.3	6th category for stage races
7	1.M RST	1.M	Highest category for one day races
8	1.HC RST	1.HC	highest category (HC) one day races
9	1.1 RST	1.1	3rd category for one day races
10	1.2 RST	1.2	4th category for one day races
11	1.3 RST	1.3	5th category for one day races
12	2.U RST	2.U	Under 23 (U23) stage races
13	1.U RST	1.U	U23 one day races
14	1.CM RST	1.CM	world championship road races
15-19	?.?? RST	1.CN1-5	national championship road races
20	1.CM RST	U23RR	world championship U23 road races
21	1.CM RST	1.CMTT	world championship ITT
22-26	?.?? RST	1.CN1-5TT	national championship ITT
27	1.CM RST	U23TT	world championship U23 ITT

Table 3.1: List of all race categories in the RadSimTool.

of cycling strength values are created with an offline software application,

developed in Visual Studio as a WinForms application and C#. The offline software provides either the online database or an offline database to get results from required real races to generate cyclist strength values. Those values can then be uploaded into the online MySQL database for use on the website. Using an offline application also allows for more performance on a desktop computer without influencing the website's performance and using more cores with parallelization during the simulation process. Since the race simulation is also simulated in the same software, the algorithms to generate cyclist strength values allow algorithms and functions to simulate the cycling races.

Race Simulation

The race simulation uses stage profiles to simulate the stages, therefore, the elevation, grade of the road, and other information about the stage. The race is simulated along the stage and uses them according to profile changes to impact the cyclist's performance, strength, power, speed, and energy. The simulation also uses the nominated cyclists and the defined tactics and race roles for cyclists from the managers on the website to use the instructions to influence the cyclists' behavior during the race and shape the race outcome. The software shall not only simulate mass start road cycling races, but it also shall simulate individual time trials, where cyclists race alone against the time. For both types of races, the required cyclists' strengths for flat, hill, hill finish, mountain, mountain finish, sprint, and the according to time trial values that are generated with the software feature to generate cyclist values are used for the simulation of the races. The strengths influence the performance level of the cyclists during the stages for different race sections. The strength values can be loaded from the online MySQL database server together with the nominated cyclists, their race roles, and the tactical instructions. The race result with the total time, time differences, and all the performance data through the stage is uploaded to the database server and visualized on the RadSimTool website.

A - Tactical Instructions and Cyclist Roles For Races

Whereas tactical instructions allow the managers to decide when a cyclist shall act during a race, roles for cyclists define the hierarchy in a team and allow them to simulate the behavior of them during a race. For example,

cyclists help higher hierarchy teammates during stages, or cyclists defined as lead-outs work for the team's sprinter in the final sprint in a race to help the sprinter to get positioned as good as possible during the final kilometers and allow them to fight for the victory in the sprint. The following list includes all roles and tactical instructions for the managers to choose from for a stage.

1. Race Roles for Cyclists

   1.1 Captain
   1.2 Co-Captain
   1.3 Sprinter
   1.4 Lead Out Sprinter (LOS)
   1.5 Lead Out 2 (LO2)
   1.6 Lead Out 1 (LO1)
   1.7 Helper
   1.8 Breakaway

2. Tactical Instructions

   2.1 Cyclists X,Y,Z pace in front of the group from KM to KM
   2.2 Cyclists X,Y,Z pace against breakaway groups from KM to KM
   2.3 Cyclist X attacks at KM
   2.4 Cyclist X follows attacks from KM to KM
   2.5 Cyclist X follows attacks from cyclist Y
   2.6 Cyclist X protect cyclist Y from own team from KM to KM
   2.7 Breakaway with cyclist X
   2.8 Cyclist X helps teammate Y to breakaway
   2.9 Cyclist X work against cyclist Y in breakaway
   2.10 Cyclist X work against team Y in breakaway
   2.11 Cyclist X fights for mountain points
   2.12 Cyclist X fights for sprint points
   2.13 Cyclist X positions cyclist Y on the back wheel of sprinter Z

B - Simulation of Mass Start Road Races
For mass start road cycling races, the tactical instructions and race roles for cyclists defined by the managers greatly impact the race outcome. The race outcome is simulated according to the stage profile, cycling strengths, and different tactical instructions. The simulation algorithm loads the cyclist's

strengths from the database and uses the strength values to simulate each cyclist's power output, speed, and energy throughout the stage.

C - **Simulation of Individual Time Trial Races**
Whereas mass start road races use the tactical instructions from the team managers to simulate the outcome of mass start races, the simulation of individual time trial races requires no tactical instructions. However, the simulation algorithm for individual time trial races uses the strength values for time trial races and the races' stage profiles to simulate the race outcome. During individual time trials, every cyclist must perform on their limit to finish with the quickest time and without overpowering through the stage. However, to optimize the performance throughout the stages, an algorithm shall optimize the cyclist's power output to achieve the fastest possible time. Depending on the profile and the cyclist's strengths values for the profile sections, cyclists have an advantage or disadvantage over other cyclists during the race. However, a daily form factor shall also influence the races' outcome since several cyclists in the RadSimTool are based on the same real cyclist's strength values.

3.5 Summary

Chapter 2 discussed the cycling sport, the mathematical background for cycling, and different cycling manager games. Evaluating the cycling manager game's functionalities and features, the focus in chapter 3 was on designing a cycling manager game with the focus on providing a multiplayer experience. The RadSimTool provides a game website where the users can manage their teams, plan their cyclist seasons, nominate their cyclists for races, and define tactics for the different stages throughout the season. The game website shall also provide the users with statistical information and visualizations for the cyclist performances through the races to allow the managers to learn from the data and achieve a better result at upcoming races.

Whereas some games discussed in chapter 2 use static strength values for the cyclists or only subjective strength assumptions by other users for multiplayer races. The focus for the RadSimTool is to create a dynamic strength system, depending on cyclists' real performances during real-life

cycling races and depending on the cyclist's shape within the RadSimTool. To achieve this functionality, the RadSimTool collected data from real races and generates strength values for the game's cyclists. To avoid legal issues, the cyclists in the RadSimTool game are created with fantasy names, with no reference to the real cyclist the strength values are connected to.

Whereas the managers define the tactical instructions and nominations for the races, are done on the RadSimTool website, the simulation of cycling races is done on an offline software tool that uses the tactical instructions from the game website database and the database for the strength values, to simulate cycling races. Therefore, the simulation uses two different algorithms to simulate individual time trial races and mass start road races. Those races are simulated offline to prevent the server from doing these expensive simulations and impacting the game website's performance.

The chapter focused on functional requirements and design decisions and discussed non-functional requirements for the RadSimTool. The focus for the RadSimTool is on developing a platform that can be extended to provide more types of races, more tactical instructions and allow for updating the simulation algorithm with further functionalities such as wind or weather impact on the cyclists during races. Whereas the focus for generating cyclist strength values in the RadSimTool is on generating individual time trial and sprint values, the system can be extended with better strength values for the hill or mountain values for cyclists. Therefore, the data quality from the collected race results and additional information about the races is required since they impact the quality strength values quality.

4 Tools and Frameworks

Chapter 4 discusses the required tools and frameworks to implement the discussed requirements and design decisions for the RadSimTool from chapter 3. Chapter 3 discussed the functional and non-functional requirements for the data collecting, managing, and processing process, the game website's requirements, and the data editor website. The functional and non-functional requirements for the simulation of cycling races and the generation of cyclist values were also discussed. The project uses a client-server architecture for the websites and an offline client to simulate races and cyclist values calculation to achieve these requirements. However, the offline client also requires access to the online database server to load the required data and update the database with new results or cyclist values. Therefore, Chapter 4 gives an overview of the used tools and frameworks used to develop the different parts of the project to achieve the requirements from Chapter 3.

4.1 Data Mining, Managing, and Processing

The system shall collect data from websites and import them into the project to generate the required strength values for cycling races' simulation. Therefore, the data mining process will use Python to collect the required data. The Python script creates a JSON file with the collected information, and the data can be imported into the database.

Data Mining with Phyton
Python is a programming language developed by Guido van Rossum (Foundation, 2020) and provides versions for Windows, Macintosh, Linux, and other platforms. Python also provides several libraries for data processing. Therefore, Python is used in the project to parse websites and collect data from them. The Python script shall collect the required data and save them into JSON files to import the collected data into the database.

Saving Collected Data with JSON Files
The JavaScript Object Notation (JSON) is a data format introduced by Douglas Crockford (Crockford, 2020). JSON is a data-interchange format and easily readable for humans. Therefore, it is supported by many different programming languages. The data collected with the Python script shall be stored in JSON Files. And the database editor provides a feature to import the data from the JSON files into the database.

4.2 The Game Website and Data Editor Website

The game website and the data editor website are both developed the same way the structure is divided into a client and server-side. Whereas the client-side uses Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript to visualize the users' information, the server-side uses PHP and a MySQL database server.

4.2.1 Client

On the client-side, the client gets the HTML code from the server and uses CSS and Bootstrap to visualize everything. Therefore, JavaScript and Bootstrap are used to create a dynamic and interactive website for the users. For the data visualization, the website takes advantage of Data-Driven Documents (D3) to create visualizations and provide additional information.

HTML5/CSS3/JavaScript
HTML 5 websites are divided into three parts, plain HTML code, which defines the website's data and structure. CSS3, which defines the design and look of the website. JavaScript allows making static websites dynamic. Users can change things on the website, click buttons, and other interactions. JavaScript changes the website or performs AJAX calls to send or load data to the server. The project uses JavaScript for parts, where user interactions require the dynamic update of the side. The nomination view at the race detail page and the planner on the team detail page offer dynamic interactions when users update their nominated teams. The home menu is also loaded dynamically with JavaScript, and information on the calendar page

is loaded dynamically with JavaScript. An AJAX interface allows reloading data from the database dynamically from the server without loading a new site.

Bootstrap
Bootstrap is "the world's most popular front-end open-source toolkit" (Bootstrap, 2020) developed by Twitter. The framework provides developers with features to design websites. Bootstrap provides a predesigned CSS and uses JavaScript plugins to allow the developers to create dynamic websites for desktop computers and mobile devices. Therefore, Bootstrap uses a grid system to divide the website into sections. The developers can use those sections to place content and design the look of the website. The project uses Bootstrap to design a website that can be used on both desktop computers and mobile devices. Therefore, Bootstrap's grid system is used to structure the website and place the content within the grid. With additional CSS, the general design is modified to fit the project's needs.

D3js
Data-Driven Documents (D3) was introduced by Mike Bostock (Bostock, 2020) in 2011. D3 is a JavaScript library and allows the developers of websites to create interactive and dynamic data visualizations for web browsers. Therefore, D3 allows to bind data to the Document Object Model (DOM) and visualize them differently, for example, by using Scalable Vector Graphics (SVG), HTML, and CSS. Developers can use these features to design all types of different interactive and dynamic visualizations. The D3 website provides a large list of tutorials and examples to inspire and help developers to find the best visualizations for their needs. The project uses the D3 library to create charts to visualize results, stage profiles, point charts, and performance data for cyclists, with detailed charts about their speed, power output, and energy during the races.

4.2.2 Server

On the server-side, the project uses PHP together with a MySQL Database. The website's main parts are programmed with PHP and handle creating the HTML page for the client. Therefore, PHP loads the required data from

the database and sends the created HTML page to the client. To implement session handling and a login system, the project uses a basic framework with no further features that collect only the required information's from users at registration.

PHP

PHP was introduced by Rasmus Lerdorf in 1995 and is short for "PHP: Hypertext Pre-processor" (ThePHPGroup, 2020). It is an Open Source scripting language and can be used on the server-side for creating dynamic websites. An alternative to PHP is using JAVA on the server-side. However, PHP is easier to set up. It also is supported by many web hosting services. Therefore, the project uses PHP to develop the server-side parts. PHP handles creating the websites, handles the send input from the users, and creates the next websites. With AJAX calls from the client-side, PHP provides access for the client-side to request specific data from the server.

MySQL Server

MySQL is a widely used Open-Source database software (Oracle, 2020b). It was introduced in 1994 and is now developed by the Oracle Corporation. MySQL is provided by many web hosting services, together with the Linux operating system, Apache web server, and PHP programming language. This combination is called LAMP (Linux, Apache, MySQL, PHP). Also, combinations that use MariaDB are called LAMP, and combinations, with PostgreSQL, are named LAPP. The XAMPP bundle, software to run a local server for testing websites on a pc, used to use MySQL and uses MariaDB since versions 5.5.30 and 5.6.14 [1] . However, XAMPP should not be used to run an online web server, and therefore offers to install guides to run servers on services like the Amazon Web Services (AWS). Since providers of Webhosting still widely use the LAMP architecture with MySQL as the database server. The used Webhosting service uses a LAMP architecture with a MySQL database server. Therefore, the system will use a MySQL database server to store the data. PHP on the server-side will provide access to the data for the designed websites.

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[1]Announcement - MariaDB in XAMPP: https://www.apachefriends.org/blog/new_xampp_20151019.html

PHP Framework: Log in and Session Handling

To secure session handling and provide the website with a login system for the users, the project uses a framework written by Peter Bradley [2] . The framework only provides session handling and a login system, with no additional features. Whereas the framework only provides the minimal features to fit the session handling and login system requirements. Other more professional options would be using a professional framework, like Laravel, CodeIgniter, or Zend Framework. Ten popular PHP frameworks are discussed at the Raygun website [3]. Since the RadSimTool only required a simple login functionality and session handling, no professional framework was used. However, for further work, using a professional solution should be considered.

4.3 Simulation of Cycling Races

Whereas the Game Website and database servers are online accessible, the code for the simulation of cycling races and the generation of the cyclist's strength values is written in C# and run offline on a local machine. Running the simulations offline allows for safe performance on the online servers and provides better performance on a local machine than running the simulation online. Therefore, a C# program is developed where the simulation can use more resources and the simulation can take advantage of faster and more CPU kernels when required.

WinForm Application

C# is an object-oriented programming language designed and developed by Microsoft (Microsoft, 2020). Microsoft also provides a professional development environment with Visual Studio to design software for Windows systems. Therefore, Visual Studio provides libraries like the Windows Forms library and the Windows Presentation Foundation (WPF). Whereas WPF is the newer and more modern library with support for more graphical features, Windows Forms allow the creation of quick, simple programs,

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[2]GitHub for Bradley's Framework: https://github.com/peredurabefrog/phpSecureLogin

[3]RayGun: Popular PHP frameworks https://raygun.com/blog/top-php-frameworks/

with still a lot of features. The project's simulation software requires only a simple, rudimentary user interface. The admins can navigate the races and simulate them or start the generation process for new cycling values. Therefore, using Windows Forms fulfills the required needs and is chosen over WPF.

MySQL Connector

The MySQL Connector is a library provided by the Oracle Corporation on the MySQL website (Oracle, 2020a). The connector provides the features to establish connections with C# programs in Visual Studio and a MySQL database. Therefore, the project used the library to build the connection to the MySQL database on the online database server to get required data and upload simulation results, and generated cyclist values to the webserver.

4.4 Summary

To fulfill the requirements from Chapter 3, to collect data, the project uses a Python script to collect data from websites. Python scripts can be run locally but also used to run automatically and direct from the server. For the game website and data editor website, a client/server architecture with HTML5/CSS3/JavaScript on the client-side. The usage of Bootstrap allows the design of a modern website, whereas D3 provides the features to create graphical visualization on the website.

PHP and a MySQL database on the server-side build the structure for the websites. PHP is used to create dynamic websites and send them to the client to display for the users, and the usage of a database server allows access to the data from the simulation software. To avoid running the software from a server and saving performance, the simulation software is developed as an offline program with C# in Visual Studio. This protects the code and allows the usage of better hardware compared to some online servers. Therefore, the simulation can take advantage of more processor cores.

5 Implementation

Chapter 5 discusses the RadSimTool project's implementation based on the functional and non-functional requirements from chapter 3 with the tools and frameworks discussed in chapter 4. Therefore, the chapter is structured into three parts, the implementation of the data mining, managing, and processing part, the implementation of the RadSimTool game website, and the implementation of the software tool to simulate races for the RadSimTool game using the tactics and cycling strengths from the RadSimTool game website. The data mining, managing, and processing part describe the process to collect the required data with a script. It builds up a database with the collected data to use them for the data processing part where the cyclist strengths are generated and used on the RadSimTool game website and the software to simulate the cycling races. The RadSimTool game website provides the users the GUI to manage their teams. This chapter explains the process to implement the required functionalities to offer the users a great play experience. The final part of the chapter is the simulation software to simulate cycling races with the generated cycling strengths and the tactical instructions of the managers from the RadSimTool website. It explains the technical requirements and different parts of the simulation process.

5.1 Data Mining, Managing, and Processing

Collecting data from real life and the quality of these data is important to be able to generate good strength values for the cyclists. Therefore, good data sources are necessary to collect all the required data. Many websites offer results for cycling races. However, not every website offers the same amount of additional information to the race results. Some also offer additional information about the stages, profiles, distances, date, and country in which the race takes place. All these data can later be used to categorize the stages

and use them to calculate the different strength values of the cyclists.

5.1.1 Collect Real Data from Cycling Result Websites

Several statistic websites offer results for professional cycling races during the season. The UCI has its own data center for results on their official website (UCIWebsiteResults, 2020), and other websites like CQRanking (CQRanking, 2020) and Pro Cycling Stats (ProCyclingStats, 2020) publish results too. For the generation of cyclists results, the quality and quantity of available data are important for the data mining process. Whereas CQRanking only offers limited result lists, as the stage result, without the stages classifications and the reduction of results from old seasons, data from the official UCI and Pro Cycling Stats websites suit the project's needs better.

The UCI results and the Pro Cycling Stats results from both include the result for every stage. They also include the rankings for the general classifications and other rankings, like the points classification, mountain classification, and youth classifications, for the daily performance and the total rankings for each stage. Whereas Pro Cycling Stats includes no download or export function, the UCI website offers the functionality to export every result as an Excel file. This Excel file also includes data that is not visible in the result table on their website, where only the rank, start number (BIB), rider name, nation, team name, age, result time, IRM, and points are shown. The Excel File also includes data like the gender of the cyclist and the age.

Additional to the result for every stage, data about the stage is required to classify the stages, group them, and use that data later to generate strengths for all the cyclists. Whereas the UCI website offers no information about the stages, Pro Cycling Stats offers additional information on their website, such as the name of the stage, start and finish place, length of the stage, and information about the stage's type. That includes information about if the stage is a time trial, team time trial, prologue, or normal mass start stage and what profile the stage is. The stage profiles are classified into flat stages, hill stages, hill finishes, mountain stages, and mountain finishes. Table 5.1 shows the required data for results.

Additional to the data for results itself, it is also necessary to collect data about the races. These data must include the name of the race, the country

Data for Results	Description	Required
Rank	Rank at the stage.	Yes
Bib	The start number.	Yes
Last name	Cyclists last name.	Yes
First name	Cyclists first name.	Yes
Country code	Two letters country code (AT)	Yes
Team name	Name of the cyclist's team	Yes
Result time	Time the cyclist finished the stage with.	Yes
IRM	Special information (DNF, DNS, DSQ, ...)	Yes
Gender	Cyclists gender	No
Age	Age of the cyclist	No

Table 5.1: Required result information for data collecting.

the race takes place in, the start date, the end date of the race, the number of stages of the race, and an URL to the data source of the race result. This data helps the data editor display the races with the right information and helps the data managers browse faster through the data lists to check-up data. Table 5.2 shows the required race data collected with the Python script.

Data for Race	Description
Race name	The name of the stage.
Country	Main country the race.
Start date	Start date of the race.
End date	End date of the (stage) race.
Amount Stages	Amount of stages for the race.
Source URL	URL leading to the source website.

Table 5.2: Required race information for data collecting.

Additional information about the races and information about the stages are required to generate strength values for cyclists from real result data. These data must include the stage name, the number of the stage in the race, the date of the stage, and the race's distance. Whereas some races include only stages within a single country, others cross borders through stages or organize stage races with stages in different countries. Therefore, the data

must include the country of each stage. To classify the stages, whether it is a mass start race, an individual time trial or team time trial, or even a prologue at the start of a stage race, information about the type of the stage also needs to be included in the data collecting process. To be able to use the data to create the strengths of the cyclists for different profiles, the collected data also need to include information about the type of the profile, whether it is a flat stage, a hill stage, a mountain stage, or even a hill or mountain finish. Table 5.3 shows the required stage data that is collected with the script.

Data for Stage	Description
Stage name	The name of the stage.
Stage Number	Number the stage is raced in a stage race.
Country	Country the stage is raced in.
Date	Date of the stage.
Distance	Distance of the Race in km.
Type	- / ITT / P / TTT
Profile type	Flat / Hill / Hill Fin / Mount / Mount Fin

Table 5.3: Required stage information for data collecting.

The Python script can be modified to collect results for a specific year and race group. Therefore, the script can collect World Tour results or results for lower categories too. The script creates a data structure with the collected race and stage information and the different collected results and rankings from the website. The JSON file is created and saved by the script. That allows to run the script for different years or race levels and collect the data into different JSON files to import and create a database for the RadSimTool with the wanted races. That allows flexibility when the database is filled with the data.

5.1.2 Database Design

Figure 5.1 shows the database schema for the RadSimTool database.

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Figure 5.1: Database schema for the RadSimTool database.

5.1.3 Database Editor

To import the data and manage them, a User Interface is created. This database editor runs on the website and makes it possible for the users to browse through the data, manage and edit it. For the navigation, the website visualizes the data in a hierarchy with the year as the top note. The year is followed by the races, stages, and results. An import feature allows the users to fill the database automatically or manually. A header shows where the user is and allows an easy way to navigate back up in the hierarchy.

5.1.4 Importing Data

Importing the data into the database and adding the information to the database editor can be done manually or automatically. For the manual approach, the user can create new races and add stages to them. Afterward, the user fills each stage's results by importing a CSV file with the database editor's import function. This CSV file is generated from the Excel file that the user exported from the official UCI website.

The automatic approach uses a Python script that runs over the race list on the Pro Cycling Stats website to fetch all the required data about the races, stages, and results. This information is saved in a JSON data structure and saved into a file. With the "import JSON file for the season"-function in the Database Editor, the function automatically fills the database with the additional data.

5.1.5 Generate Values for Cyclists

The collected data are required to generate the values for the strengths of the cyclists. Therefore, results are clustered according to their profiles to use the results to generate strength values for the cyclists. The different types of profiles are almost flat stages, hill stages, stages with hill finish, and stages with mountain finishes for mass start road races. Whereas in real life also races with cobblestone parts exist, the thesis uses no cobblestone sections. There are several reasons for leaving cobblestones out of focus. Cobblestone races are extremely limited to just a few races during the year. Whereas for the best cyclist, values and rankings can be generated, for weaker or average cyclists, there are only a few or even no results, even if they might perform

well on that terrain. Another reason for not including these sections is the limited information in GPX data, where cobblestone sections are.

The focus of the thesis is on generating good values for sprinters and individual time trialists. The different characteristics for the different values as flat, mountain, hill, mountain finish, hill finish, and sprinting, require different approaches for a good quality of the generated cyclist's strength values. Therefore, generating strengths, such as a hill, mountain, hill finish, and mountain finish, is simpler than the generation of sprint values, where the thesis focuses on. For the simulation of time trials, the important values are also clustered into flat, hill, mountain, hill finish, mountain finish, and general time trial values. However, also for these different values, the amount of data is often limited. Therefore, values for different years and two years together are generated to get more data points.

5.1.6 Generate Names for Cyclists

Every cyclist in the game is linked to a real-life cyclist with generated strength values in the database. Whenever a new cyclist in the game is created, a real random cyclist gets selected and linked to the newly created cyclist. Whereas cyclists in the games have only a link to a single real cyclist, many different game cyclists can link a real cyclist. To keep the different cyclist with links to the same real cyclist's strength values apart from each other, the cyclist is crated with a random name and nation. The cyclist gets a random first name and a random last name from all the cyclist in the name generation database, and a random nation is selected for the cyclist. To avoid two cyclists with the same name combination, the names are checked with all the real cyclists and game cyclists to create unique name combinations. To create more realistic data, the cyclists also could get only names from the selected country. Additionally, the generation of a cyclist can include random birthdays, age, weight, and height. For this thesis, all the cyclist has the same height, weight, and no aging.

5.2 Define Tactics for Races

After the players nominated their cyclists for a race, they can use the view of the tactics to specify the tactics for the race. Whereas there are only basic

instructions as the power intensity is needed for time trial races, mass start road race stages offer more options for the players to impact the race. On the tactics page, the players find an overview of their nominated cyclists and can define roles for the race for each of them.

The managers can choose a limited amount of tactics. That amount can vary from race to race to increase the difficulty for the race. The defined tactical instructions are listed on the right side, sorted by the km when the instruction shall be activated.

The following list contains all the roles that the managers can choose for their cyclists. The captain is the leader of the team and gets supported by the other cyclists. Co-captain is also a cyclist that gets supported by the team and shall achieve a good result. The sprinter is the Leader on flat stages, where the team works for this cyclist to achieve a good result or win the race in the bunch sprint of a big group at the end of the race. Therefore, the sprinter gets supported by up to three cyclists in the final of the race. The lead-out 1 (LO1) brings the team's lead-out on the last two kilometers of the race, this cyclist requires good flat and time trial skills, and the LO1 must pace for one kilometer to reach the last kilometer and position the team in front of the others. After the LO1, the Lead Out 2 (LO2) requires good flat and time trial skills and leads the Team on the last 500 meters. The lead-out sprinter (LOS) opens the sprint and tries to bring his sprinter in front of the others for the last 250 meters. In the final of the sprint, the sprinters give their maximum and try to win in front of the other sprinters. The helper role defines cyclists who work for their teammates during the race and help chasing groups or protecting their captains or sprinters. Cyclists who have probably no chance to win in the final of the race, or try to achieve another strategy by breaking away, have the breakaway role. These cyclists try to break away to increase their chances to finish the race in front of the chasing groups. The different cyclist roles are listed in table 5.4.

The tactical instructions for a mass start road race allow the managers to shape the race to their team's advantage. Table **??** shows all implemented tactical instructions for races in the RadSimTool.

Race Role	Description
Captain	Cyclist leads the team for the stage.
Co-Captain	Cyclist can act free, to perform well.
Sprinter	Cyclist shall sprint in the final punch sprint.
Lead Out Sprinter	LOS - Last helper in sprints. Sprint strength.
Lead Out 2	LO2 - 2nd helper for sprinter. Time trial strength.
Lead Out 1	LO1 - 1st helper for sprinter. Time trial strength.
Helper	Helps or protects cyclists. Paces in the group.
Breakaway	Cyclist who shall get into the breakaway group.

Table 5.4: Race roles for cyclists in the RadSimTool races.

#	Tactical Instruction
1	Cyclists X,Y,Z pace in front of the Group from KM to KM
2	Cyclists X,Y,Z pace against breakaway Groups from KM to KM
3	Cyclist X attacks at KM
4	Cyclist X follows Attack from KM to KM
5	Cyclist X follows Attack from Cyclist Y
6	Cyclist X Protect Cyclist Y from own Team from KM to KM
7	Breakaway with Cyclist X
8	Cyclist X helps teammate Y to breakaway
9	Cyclist X work against Cyclist Y in breakaway
10	Cyclist X positions Cyclist Y on the back wheel of Sprinter Z

Table 5.5: Tactical instructions for cyclists in the RadSimTool races.

5.3 Tactical Instructions for Races

Tactical instructions are the link between the managers using the game website and the cyclist's behavior in the simulation of cycling races. The simulation requires a clearly defined set of tactical instructions, to use them at certain times during the race simulation, to shape the race outcome. Therefore, the instructions are divided into two parts: cyclists' roles during a race and the real tactical instructions that cause cyclists to attack, follow attacks, work for their teammates, or breakaway. Tactics make the race

dynamic and the outcome unpredictable.

5.3.1 Roles for Cyclists

Roles for cyclists allow the managers to redefine the role a cyclist must play during a race. Whether the cyclist is the team leader and must try to win the race or the cyclist is a teammate that supports the team in a specific way. Roles also define who does work in groups, for a teammate in a group, when there is no specific tactical instruction. This section discusses the different cycling roles that the simulation support.

1.A - **Captain**
The leader of each team is the team captain. The captain's role is to reach the best result possible with the other team members' support. During stage races, the captain fights for the win in the general classification (GC). The helpers protect the captain. In general, the captain stays with the other team leaders if possible until the part of the race is reached, where the attacks start, and the race is decided.

1.B - **Co-Captain**
Like the captain, the co-captain has freedom from the team to try to perform as well as possible. Whereas the captain is the main leader, the co-captain gets supported too and might get a chance if the captain's strategy does not work out as planned.

1.C - **Sprinter**
A sprinter is the fastest cyclist on the team when it comes to a mass sprint from a bigger group. In races with an almost flat profile or little hills with flat final kilometers, the best sprinters' teams try to work in the sprinter's group to hold the group together or chase breakaway groups before the race can be decided on the last kilometers by the sprinters. A single cyclist can position the sprinters behind the lead-out train of another team or use their own lead-out train. The lead-out can contain up to three cyclists that support the sprinter and bring the sprinter on the last 250 meters of a race, where the sprinters fight for victory.

1.D - Lead Out Sprinter (LOS)

In a lead-out for a sprinter, the lead-out sprinter (LOS) is the last cyclist before the sprinter starts the final sprint. The LOS sprints from the last 500 meters to the last 250 meters and must position the team's sprinter in front of the others and give the Sprinter an advantage for the final 250 meters. Therefore, the LOS must have good sprinting abilities that make it possible to beat the other teams' LOS.

1.E - Lead Out 2 (LO2)

Before the LOS gets released on the last 500 meters of a race, the lead-out 2 (LO2) must position the LOS as well as possible. The goal is to perform better than the other teams. The LO2 requires good flat and time trial skills, and the LO2 works from the last kilometer to the final 500 meters.

1.F - Lead Out 1 (LO1)

As the LO2, the lead-out 1 (LO1) requires good skills for time trials or flat passages. The job of the LO1 is to start the sprint positioning by cycling as fast as possible for one kilometer, leading the lead-out from the last two kilometers to the last kilometer of the race, and providing the lead-out train with a good start, a benefit over the others. Also, the lead-outs must work during the race to achieve the team's goals.

1.G - Helper

The helper role is for the cyclists in a team, with the job to support their teammates. Helpers work in front of the group, spend their energy to pace for their teammates, chase other breakaway groups, help their teammates achieve their goals, or protect the captains and sprinters during a race to help them save energy for the later part of the race.

1.H - Breakaway

In general, the start of a race is marked by the cyclists trying to get into the breakaway group. This early phase of the race is a game where teams work for and against different cyclists and achieve a group that most teams can agree with, to let them away at the race start and build the breakaway group. The cyclists with the role to go into the breakaway groups have the role breakaway. These cyclists have, in general, no chance to win the stage

with a conservative strategy. Teams with no good sprinters or captains for the stage's terrain also try their luck with a breakaway. A breakaway group tries to finish in front of the other groups and have a smaller number of competitors in the fight for victory.

5.3.2 Tactical Instructions

Whereas roles define the ranking of a cyclist in the team and the cyclists' main goals, tactical instructions define the cyclist's actions at a certain moment in the race. This moment can be declared with kilometers (KM) during the race when the tactical instruction gets activated. This can be either a kilometer mark when the cyclist must act or a kilometer range where the action must be maintained.

2.A - Cyclists X, Y, Z Pace Infront of the Group From KM to KM
During a race, teams might want to pace in front of the group. Therefore some of their cyclists are changing the lead or supporting other teams to pace. The goal might be to increase the speed when the race gets closer to the finish, pacing faster at a mountain climb, force cyclists with no good climbing skills to fall behind, or spend more energy, and have less energy in the finish of the race. Changing the lead with several other cyclists allows the pacing cyclists to rest behind the other pacing cycling after they did the lead. Therefore the cyclists can pace longer than a single cyclist could do. The "Pace Infront of the Group" tactic allows the managers to send up to three cyclists (X, Y, Z) from their team to pace in front of the group with a certain amount of their power. The amount of time the cyclists spend in front of the group is defined within a kilometer (KM) range. They are defining the kilometer when the cyclists start pacing in front and when they stop again.

2.B - Cyclist X Attacks at KM
Attacking during a race to get an advantage over the rivals might be the common approach to win a race. However, attacking requires more energy than following an attack or staying in the group and let the teammates do the work to chase the attacking cyclists. The "Cyclist X Attacks at KM"

tactical instruction offers the managers the option to declare the KM mark when the cyclist X must attack and try to escape the current group.

2.C - **Cyclist X Follows Attack From KM to KM**
Following attacks requires less energy than attacking self. For this tactic, the managers can define a KM range, within cyclist X must follow other cyclists' attacks. The cyclist only follows the attacking cyclists first and afterward works together with them if a new group was built.

2.D - **Cyclist X Follows Attack From Cyclist Y**
Whereas the tactical instruction to follow other cyclists within a range is limited to a specific KM range, every attack is followed by cyclist X. The tactical instruction to follow a specific cyclist Y with the cyclist X allows the cyclist to follow a specific cyclist. That allows the cyclist to follow the most important competitor instead of every attacking cyclist.

2.E - **Cyclist X Protects Cyclist Y From Own Team From KM to KM**
Cyclists in a team can help the leaders to save energy. Therefore the tactical instruction "Cyclist X Protects Cyclist Y from Own Team from KM to KM" makes it possible for the manager to choose a tactic, where a cyclist X protects a cyclist Y within a defined KM range. Therefore, the helping cyclist X protects the teammate and loses more energy, whereas allowing the protected cyclist Y to save energy.

2.F - **Cyclist X Positions Cyclist Y on the Back wheel of Sprinter Z**
On the last kilometers at stages with a sprint finish, managers can either use their own lead-out train with cyclists as LO1, LO2, LOS to support their sprinter, or managers can choose a single cyclist X to position the sprinter from the team Y on the back wheel of one of the sprinters Z from the other teams. This approach requires fewer cyclists to help the sprinter. However, the sprinter Y is more dependent on the quality of the sprinter's Z lead-out train. The sprinter Y is also positioned on the back wheel of Sprinter Z, or even behind other sprinters on the same back wheel. Therefore, sprinter X has no chance to position better than Sprinter Z. This might be an option for sprinters with less good sprint helpers.

2.G - **Breakaway With Cyclist X**
In the early phase of a race, different cyclist wants to get into the breakaway group. Managers can choose cyclists of their team that try to get into the breakaway group. The Tactical Instruction allows them to define a cyclist X, that cyclist will try to get into the group. By adding the tactic for other cyclists, additional cyclists will try to break away.

2.H - **Cyclist X Helps Teammate Y to Breakaway**
To increase cyclist Y's chance of getting into the breakaway, managers can choose the tactical instruction to use cyclist X to help cyclist Y get into the breakaway more likely. Therefore, cyclist Y works for cyclist X in the early phase of the race to help him get into the group.

2.I - **Cyclist X Work Against Cyclist Y in Breakaway**
Some managers want to prevent different cyclists from getting into the breakaway. For example, cyclists with a good chance to win the stage themself, or cyclists in a stage race, that compete with the own teams' cyclists for mountain points or sprint points. Or to have a tactical advantage with more supporters than the other team later in the race. The managers can choose a cyclist X that works against cyclist Y in the breakaway. Cyclist X will work in the group to chase the breakaway groups with cyclist Y in it.

5.4 The RadSimTool Game Website

The second part of the project is the game website. This website will be developed with PHP, HTML, CSS, JavaScript, and a MySQL database that holds the project's data. This website offers the players a user interface to play the game. The players can manage their team, plan the race days for their cyclists, nominate their cyclists for races, define the tactics, look up the race results and look up several statistics provided in the RadSimTool that was developed to give the players of the RadSim05 additional information and statistics.

5.4.1 Login and Session Handling

To get access to the RadSimTool, users need to register for the website. After the user registered, they can log in on the start page. Therefore, the user enters their e-mail address and password. With clicking on the login button, the information is compared with the database. If the information is correct, the users get forwarded to the home page of the RadSimTool game. For the session handling, a cookie is created to save information about the user and the current session.

5.4.2 Start Into a new Manager Career

Figure 5.2 shows how new players can register themself on the website. After the successful registration of new users, the user can log in to the website for the first time to create a new team, as shown in Figure 5.3. Therefore, users create a manager name and a new team for the game. When the team and manager are successfully created, new cyclists are added to the team. With this team, the managers can start their journey and nominate their cyclists for their first races.

5.4.3 General Website Navigation Functionality

For the whole RadSimTool website, the general navigation functionality stays the same. Managers can click on country flags to get forwarded to the country detail page. A click on a cyclist name forwards the managers to the cyclist detail page. To get to the team detail page of a specific team, managers can click on a team name on every page of the RadSimTool to get there. To get to the race detail page, managers can click on the race name of a race on any page in the RadSimTool. This functionality allows easy navigation through the RadSimTool website and allows managers to quickly lookup more information when required.

5.4.4 Navigation Bar

Figure 5.4 shows the navigation bar for the RadSimTool. Whereas the basic bar provides access to the key features of the RadSimTool, users can hover over the "MyTeam" and "Rankings" sections to get additional options and

Figure 5.2: Register page of the RadSimTool.
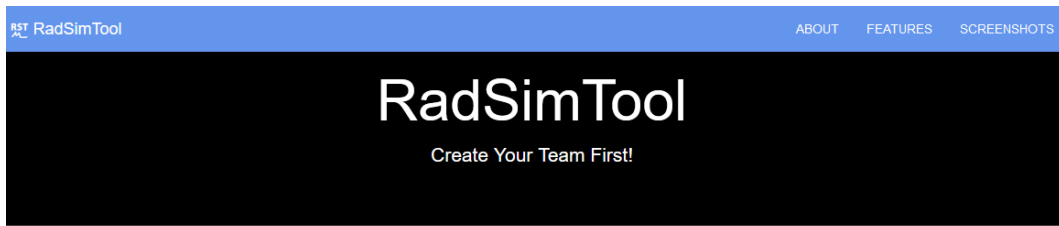
Figure 5.3: Page to create a new team after successful registration of a new user in the RadSimTool.

quick access to the subpages. The users can use the magnifying glass button to get to the search page and the username next to the logout button on the bar's right side. Bootstrap's usage to develop the menu bar offers additional functionality, like reducing a menu button for mobile devices with smaller screens. A click on the button unfolds the whole menu.
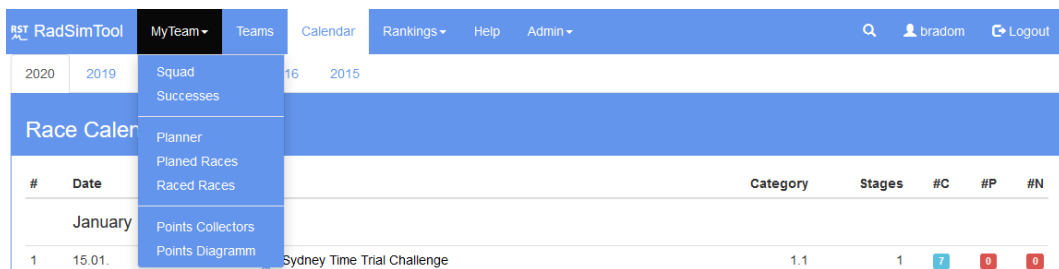
Figure 5.4: Navigation bar of the RadSimTool with the "MyTeam" section hovered and the additional options visible.

5.4.5 Home and News Page

The home and news page is the entry point for every manager. After registration and at every login, the users come to the home and news page as shown in Figure 5.5. Therefore, it provides the users with updates about upcoming races, breaking news about the latest squad announcements or races by other teams, and a list of previous races with the top results. To provide the managers with an overview of the most important rankings, the home and news page's right side offers the top five for the single team and a national ranking of the current season. Figure 5.6 shows the section below the top boxes, with the race result boxes and the country ranking on the right side. This page is created with HTML and JavaScript. The JavaScript code handles the site's creation, and content is loaded dynamically by using AJAX calls to get the required data from the PHP server.

5.4.6 Team Detail Page

To get an overview of their teams, managers can use the team detail page. This page provides the managers with all the important information and functionalities to manage their team properly. The top of the pate is the team information header shown in Figure 5.7. Above the header is a navigation bar to select a specific season for the team detail page. The header includes the team name, a picture/team logo, country of the team, division, manager, number of cyclists in the team, ranking points, and victories in the selected season. On the right section of the header box, managers find a statistic list with successes over the last four years, starting with the selected season. This list includes the overall points for the seasons, wins at general classifications, one-day races, national championships (CN), road races (RR), time trials (TT) stages, leading days at stage races, mountain classifications (KOM) together with points classifications (PC), KOMs alone and PCs alone.

Below this team information header, the managers find a menu bar to select a specific team detail page section. Therefore, the managers can choose between the cyclist list (squad), cyclist values page, successes page, points collectors page, points diagram page, planned races page and raced races page.
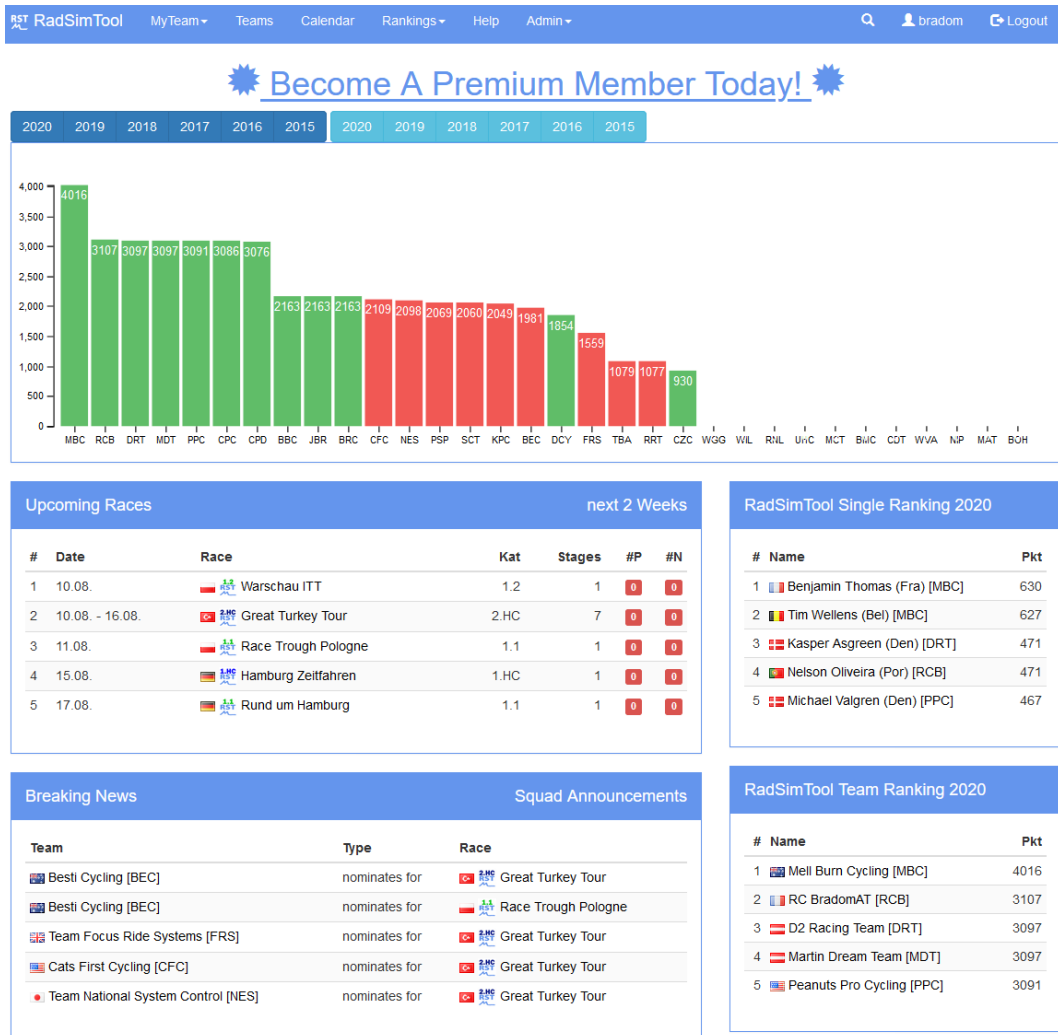
Figure 5.5: Home and news section for the RadSimTool website. The page presents the upcoming races, the latest nominations for races by all teams and a list of the last races with the top results. On the right side the list presents the RadSimTool rankings.

Figure 5.6: Race information section on the news page, and the top-5 box for the country ranking on the right of the RadSimTool.

Figure 5.7: Information header of the team detail page in the RadSimTool.

#	Nat	Name	Champ	Day of Birth	Age	Role		PR | PR	P/RD	Points
1		BÄRTA Martin		2017-01-01	3	none	U23	2 | 5	0.00	0
2		CHIA Thierry		2017-01-01	3	none	U23	5 | 10	0.00	0
3		CLEMENT Timo		2017-01-01	3	none	U23	2 | 2	0.00	0
4		CORBEL Steve		2017-01-01	3	none	U23	2 | 2	0.00	0
5		DEGAND Christophe		2017-01-01	3	none	U23	4 | 4	0.00	0
6		DUMOULIN Sam		2017-01-01	3	none	U23	4 | 4	0.00	0
7		EENKHOORN Patrick		2017-01-01	3	none	U23	1 | 2	0.00	0
8		FAIRLY Dylan		2017-01-01	3	none	U23	0 | 0	0.00	0
9		FINETTO Bram		2017-01-01	3	none	U23	1 | 1	0.00	0
10		FOURNIER Jimmy		2017-01-01	3	none	U23	0 | 0	0.00	0
11		HONIG Daniel		2017-01-01	3	none	U23	0 | 0	0.00	0
12		MASSON Mauricio		2017-01-01	3	none	U23	0 | 1	0.00	0
13		MOTTIER Dries		2017-01-01	3	none	U23	2 | 2	0.00	0
14		PHINNEY Gianni		2017-01-01	3	none	U23	1 | 1	0.00	0
15		PORTE Mihkel		2017-01-01	3	none	U23	1 | 1	0.00	0
16		QUINZIATO Stepan		2017-01-01	3	none	U23	0 | 0	0.00	0
17		STACHOWIAK Roy		2017-01-01	3	none	U23	0 | 0	0.00	0
18		SWIRBUL Max		2017-01-01	3	none	U23	1 | 2	0.00	0
19		TURGOT Alex		2017-01-01	3	none	U23	0 | 0	0.00	0
20		WEENING Thomas		2017-01-01	3	none	U23	1 | 1	0.00	0

Figure 5.8: Squad section of the team view in the RadSimTool. The list includes all the cyclists in the team and is sortable by the different headers.

A - Squad

On the squad page, the managers have an overview of their team. They see all their cyclists, with information about the cyclists and statistics for the team's successes. The team management page also includes information about the planned and raced races and a diagram for the collected points every month. By clicking on the cyclist's name, the website navigates the users to the cyclist's profile site, and with a click on the national flag, the manager gets to an overview page for the nation. Figure 5.8 shows the team view in the RadSimTool.

B - Cyclist Values

The cyclist strength value page for the team detail page shows a list of all the teams' cyclists with their strength values for sprinting, flat, hill, mountain, time trial flat, time trial hill, and time trial mountain. The list can be changed

Figure 5.9: Strength values for the cyclists in the team view. The values section shows a sortable list with all the strength values in the RadSimTool.

for every season to compare the strength values over the different seasons. Figure 5.9 shows the strength values for a squad in 2019. The list can be sorted by the different strength values or the cyclist names. The whole page is generated by the server-side with PHP with no dynamic elements. When a different subpage is requested, the whole page is generated again.

C - Successes

Figure 5.10 shows the successes view of the team detail page. The successes provide the users with a list of all the selected team results for the selected season. Managers can use the buttons above the list to select specific results, ranking types or navigate the pages. The table headers can also sort the lists. Therefore, managers can sort the list by position, result type, country of the cyclist, cyclist last name, race, and points. The page is created on the server's side with PHP, and user interaction leads to a whole page reloads.

Figure 5.10: Successes list for the selected season of the team detail page in the RadSimTool.

D - Points Collectors

The points collectors page is similar to the squad view shown in Figure 5.8. However, it shows all cyclists for a team and only the points they won for the shown team. Therefore, cyclists that left the team during the season because they got removed from the team for any reason, or released to get a better cyclist, are represented with their points in this list. The view can also be shown for earlier seasons and includes a cyclist that is no longer on the team. The whole page is generated on the server-side with PHP. Whenever the lists get sorted, the whole page is generated again.

E - Planned and Raced Races

The planned races view is only visible to the team's manager to avoid other managers getting secret information about the team's season planning. Figure 5.11 shows the planned races view with the list of races where at least one cyclist is planned for so far. Managers can click on the race names to get to the race detail page to nominate or plan the whole team for the race. The list also shows the number of stages for the races, the race category, and how many cyclists are planned or nominated so far. Depending on how many cyclists are planned or nominated, the number of backgrounds changes the color. For no selected cyclists, the background color is red. For several cyclists between zero and the allowed total number of cyclists for the race, the background color is yellow, and for the right number of selected

#	Date	Name	Stages	Category	#P	#N
		Planned Races 2020				
		January				
1	15.01.	Sydney Time Trial Challenge	1	1.1	1	0
2	22.01.	Summer Australia Race	1	1.HC	1	0
3	25.01.	Great South Australia GP	1	1.1	1	0
4	27.01.	New Zealand TT	1	1.1	1	0
		February				
5	13.02.	GP North Spain	1	1.1	1	0
		March				
6	11.03.	Prova Di Primavera Italiana	1	1.HC	1	0
		May				
7	03.05.	Belgium Hills Monument	1	1.M	1	0
		August				
8	11.08.	Race Trough Pologne	1	1.1	3	6

Figure 5.11: View for planned races for the team detail view in the RadSimTool.

cyclists, the background color is green.

Whereas the planned races are only shown to the teams' managers, the raced races view is visible to everyone. The raced races view for the team detail page shows all the races with at least one nominated cyclist. The list includes the same information as the list for the planned races, and the color scheme for the background colors at the amount of planned and nominated cyclists is the same.

5.4.7 Cyclist Detail Page

The cyclist detail page offers detailed information and statistics about every cyclist in the RadSimTool game. For the cyclist's manager, the cyclist detail page also provides a season planning tool to allow to get an overview of the cyclist's season. The general information about the cyclist in the top header box includes his name at the top, with the last name written in uppercase letters, the linked team name of the cyclist, the division of the team, the country of the cyclist, the birthday, the cyclist id in the game, and the role of the cyclist in the team. The information shows the cyclist's race days for this season, the victories, and points for the single ranking on the header

box's right side. Below the cyclist, the header information box is the menu items for the cyclist detail page.

A - **Cyclist Successes**

The successes page shown in Figure 5.12 of the cyclist detail page includes a milestone box for the cyclist. This box shows the cyclists' achievements, including wins at monuments, national and world championships, and won races in grand tours general classifications, stage wins, leading days, points, and mountain classifications. It also includes overall wins for HC category one-day stage races and HC category overall wins in stage races. Below the milestone box, the successes box shows the results for the cyclist in the selected season. Whereas the country flags and race names are clickable, and the race list is sorted by the date of the race. The list includes information about the type of successes, like general classification (GC) or S-1, for the first stage of a race. The position for that type and the won points are also listed.

B - **Raced and Planned Races**

The raced and planned races sections for the cyclist detail page are like these sections for the team detail page shown in Figure 5.11. However, for the cyclist detail page, the view shows a list of all the races. The cyclist was nominated and raced already for the selected season. The list is sorted by the start date of the race and includes the date, the race name, category graphic, and country flag together with the number of race days of the event. The whole page is created with PHP on the server-side and send to the client. The users can click on the country flags and race names to get forwarded to the according to detail pages. The Planned race view is like the raced races view. However, the planned race view gives a list of all the races planned for the cyclist and, therefore, only visible for the cyclist's manager.

C - **Season Planner**
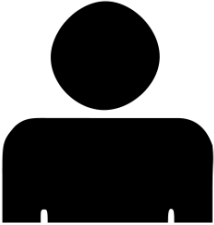
The manager can use this page to plan the cyclist's season by adding or removing races to the cyclist's race calendar. Whereas already raced or nominated races are marked as green, races that are only planned so far are marked as yellow. Figure 5.13 shows the season planning tool. The races can

5 Implementation

Figure 5.12: Cyclist detail page with the cyclists successes view selected in the RadSimTool.

either be sorted by date or by race category, and the total amount of planned and raced race days is displayed on top and bottom of the list. Managers can also choose whether the cyclist shall be the captain or not by clicking on the chess figure. The planer is created with PHP on the server-side. However, the users' dynamic changes, like adding or removing races to the race calendar for the cyclist, are handled by JavaScript. JavaScript handles the user interactions and updates the look of the website for the managers, whereas AJAX calls are used to send the commands to the server to update the database.

5.4.8 Country Detail Page

The country detail page provides the manager with a quick overview of a selected country. The view shows the list of all cyclists for the selected country and their race days and points for the selected season. The list includes the country flag, cyclist name, birthdate, age, team country flag, team name, race days, and points in the individual RadSimTool ranking for the selected season. The whole page is created by the server-side with PHP, without any dynamic elements. When a new subview is selected, the whole page is reloaded.

Managers can also look up the results for the national championships for the selected country. The results can be shown for the road race or for the individual time trial. This list includes the country flag, cyclist name, team country flag, team name, and points achieved for the selected time trial.

5.4.9 Race Calendar Page

To offer the managers a good overview of the upcoming races, the race calendar page offers the users a list of all the races for the current year. As shown in Figure 5.14, this list includes information about the start and end date, the country where the race takes place, the category of the race, the number of stages, and the name of the race. A click on the race name forwards the user to the race overview page. To fill the race calendar for each season with races, the admin can create races and add them to the database. These races can be fictional or use real profiles for the stages to simulate them.

#	Date	Name	Stages	Category	H	C	Raced
		Renntage:	4 / 10				
January							
1	15.01.	Sydney Time Trial Challenge	1	1.1	☆	👤	− sub
2	22.01.	Summer Australia Race	1	1.HC	☆	👤	− sub
3	25.01.	Great South Australia GP	1	1.1	☆	👤	− sub
4	27.01.	New Zealand TT	1	1.1	☆	👤	− sub
5	29.01.	New Zealand Ocean Race	1	1.1			+ add
6	31.01.	Melbourne Cycling Classics	1	1.M			+ add
February							
7	04.02.	Catalunya Spring Race	1	1.1			+ add
8	05.02.	GP Andalucia	1	1.2			+ add
9	06.02.	Around the Provence	1	1.2	☆	👤	− sub
10	07.02.	Côte d'Azur Time Trial	1	1.2			+ add
11	08.02.	Algarve Time Trial	1	1.1			+ add
12	10.02.	Valencia Super Time Trial	1	1.HC			+ add
13	13.02.	GP North Spain	1	1.1			+ add
14	14.02.	GP Lisbon	1	1.1			+ add
March							
15	11.03.	Prova Di Primavera Italiana	1	1.HC			+ add
16	18.03.	Italian Spring Race	1	1.HC			+ add
April							
17	25.04.	Amsterdam Race	1	1.HC			+ add
18	28.04.	The Great Wall Race	1	1.M			+ add
May							
19	03.05.	Belgium Hills Monument	1	1.M	☆	👤	− sub
July							
20	01.07.	Test Race Flat	1	1.HC			+ add
21	02.07.	Test Race ITT	1	1.1			+ add
22	03.07.	Hügel Zeitfahren St. Kathrain	1	1.2			+ add
23	04.07.	Bergzeitfahren Zets	1	1.1			+ add
August							
24	10.08. - 16.08.	Great Turkey Tour	7	2.HC			+ add
25	10.08.	Warschau ITT	1	1.2		🏆	✔

Figure 5.13: Season planner for managers of the selected cyclists detail page in the RadSim-Tool.

Figure 5.14: Race calendar for the season 2020 in the RadSimTool.

5.4.10 Race Detail Page

The race detail page offers an overview with information for the race. It also allows the manager to plan their teams, nominate them and define the race's tactics. For the team nomination, the managers can choose cyclists from their team list and add them to either the planned list or to the final nominated list. The cyclist's list includes the nation information, the name, planed race days, the raced days, the current season points, and the buttons to add the cyclists to the planed or nominated list. The planned list allows the manager to keep the team hidden from other cyclists until the team gets nominated and is public shown to the other players in the Start list of the race.

Depending on the type of the race, the race header shows different information for the managers. Whereas, for one-day races, the header shows the type of the stage, the profile type of the race, and also the distance for the race as shown in Figure 5.15. However, the race header for stage races shows the number of stages instead, in addition to all the common information, such as the race name, country, date, allowed number of cyclists, category name, and category graphic. The menu strip for the race detail page allows accessing the different subpages.

Depending on the selected stage at stage races, or the only stage at one-day races, the race detail header includes a race profile created with 3Djs. This profile graphs is implemented with JavaScript on the client-side and uses the GPX files on the server to load the stage profiles and places them in the race detail header as shown in Figure 5.15. The JavaScript functions load the stage and show the elevation profile for it. Managers can click on the profile to change the view. Whereas the default view shows only 1.5 times more of the elevation maximum, the alternative view includes a limit of 3000 meters high meters. Therefore, it gives a view where managers can get a better overview, how easy or hard this stage is, when the profile shows a lot of climbs with only a few high meters, compared to stages with long climbs up to 3000 meters.

A - **Race Overview**
Depending on the type of race, the race overview shows different content for the users. Whereas one-day races are single events with only one stage, stage races can take over several stages. Therefore, the overview page for

Figure 5.15: Race header for one day races with the stage profile default view in the RadSimTool.

stage races shows different information compared to one-day races, where only the general classification for the race is shown to the users. Figure 5.16 shows the race overview page for one-day races.

However, the overview includes a list of the winners of the different classifications. It also includes a list of stage winners and the general leaders after each stage for stage races. The whole page is developed in PHP and gets the data from the database server. Users can click on the country flags, cyclist, and team names to get to the according to detail pages for more information. Figure 5.17 shows the race overview page for stage races.

B - **Team Nomination**
On the race detail page, the team managers can use the nomination page to get an overview of their cyclists. Figure 5.18 shows the nomination page of the website. It shows the whole squad in the left table and the nominated team in the bottom-right table. Cyclists that are planned but not nominated so far are still on the top-right list. Managers can select one cyclist in the team as captain and mark the cyclist with a grown.

C - **Stages**
Figure 5.19 shows the stages view for the race info page. The view is created with PHP and send from the server to the client. The list provides the users with an overview of all the stages. The list includes the date, country of the

5 Implementation

General Classification

Pos	Name	Team	Pkt	Time	Time Difference
1	DIDIER Kevin	Team National System Control [NES]	83	00:47:25	0
2	CONCI Erwann	Cats First Cycling [CFC]	81	00:47:40	15
3	CHIA Thierry	Por Sze Pro Cycling [PSP]	80	00:47:54	28
4	SÉNÉCHAL Jhonatan	Team National System Control [NES]	79	00:48:01	36
5	MONTAGUTI Stepan	Ring Radsport Team [RRT]	79	00:48:02	36
6	TEN DAM Adam	Besti Cycling [BEC]	79	00:48:07	42
7	FOURNIER Sébastien	Team Focus Ride Systems [FRS]	78	00:48:15	50
8	ZHUPA Pedro	Team National System Control [NES]	78	00:48:22	56
9	PEDERSEN Anthony	Besti Cycling [BEC]	78	00:48:24	58
10	SHELDEN Willie	Team National System Control [NES]	78	00:48:25	59
11	BOUCHARD Daniel	Ring Radsport Team [RRT]	77	00:48:32	67
12	DUMOULIN Sam	Por Sze Pro Cycling [PSP]	77	00:48:37	72
13	RODRÍGUEZ Pierre-Luc	Team Focus Ride Systems [FRS]	76	00:48:46	80
14	BLYTHE Martyn	Krokodil Pro Cycling [KPC]	76	00:48:51	86
15	BONNAFOND Urko	Cats First Cycling [CFC]	76	00:48:51	86

Figure 5.16: Race overview page for one day races in the RadSimTool.

#	Name	Team	Pkte
GC	QUINTANA Nairo	Bears Mega Pro Cycling [BMC]	160
PC	SAGAN Peter	Wohnen in Lungau Cycling [WIL]	15
KOM	KUSS Sepp	Team Laptop Jackpot [TLJ]	15

#	Name	Pkte	#	Name	Pkte
E-1	Marcel Kittel (Ger) [AND]	25	L-1	Marcel Kittel (Ger) [AND]	8
E-2	Nairo Quintana (Col) [BMC]	25	L-2	Nairo Quintana (Col) [BMC]	8
E-3	André Greipel (Ger) [TFS]	25	L-3	Nairo Quintana (Col) [BMC]	8
E-4	Peter Sagan (Svk) [WIL]	25	L-4	Nairo Quintana (Col) [BMC]	8
E-5	Rafal Majka (Pol) [TFS]	25	L-5	Nairo Quintana (Col) [BMC]	8
E-6	Alex Dowsett (Gbr) [ABS]	25	L-6	Nairo Quintana (Col) [BMC]	8
E-7	Ian Stannard (Gbr) [AND]	25	L-7		

Figure 5.17: Race overview page for stage races in the RadSimTool.

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Race Overview | Nomination | Stages | Start List | Tactics | LiveRace | Results | Admin Mode | Simulate Race

Fahrerliste:

#	Nat	Name	Age	RD	GD	Pkt	P	N
1		ARSLANOV Laurens	3	0	0	0	☑	☑
2		BODNAR Huub	3	0	0	0	☑	☑
3		DAVIES Gianni	3	0	0	0	☑	☑
4		DEGENKOLB Adam	3	0	0	0	☑	☑
5		MALUCELLI Alexander	3	1	1	0	☑	☑
6		MARANGONI Andrew	3	0	0	0	☑	☑
7		MATYSIAK Sasha	3	0	0	0	☑	☑
8		OSORIO Kévin	3	0	0	0	☑	☑
9		PEDERSEN Anthony	3	2	2	0	☑	☑
10		PHILIPSEN Daniel	3	2	2	0	☑	☑
11		PICHOT Xabier	3	2	2	0	☑	☑
12		PIRES Gino	3	0	0	0	☑	☑
13		QUINZIATO Laurent	3	0	0	0	☑	☑
14		REIHS Vladimir	3	0	0	0	☑	☑
15		STACCHIOTTI Will	3	0	0	0	☑	☑
16		STACHOWIAK Bram	3	2	2	0	☑	☑
17		TEN DAM Adam	3	2	2	0	☑	☑
18		VOSS Bert-Jan	3	0	0	0	☑	☑
19		WALLS Nikolay	3	0	0	0	☑	☑
20		YAMAMOTO Igor	3	2	2	0	☑	☑

Geplante Fahrer: ⊖ ☑

#	Nat	Name	Age	RD	GD	Pkt	P	N
1		BODNAR Huub	3	0	1	0	⊖	☑
2		MATYSIAK Sasha	3	0	1	0	⊖	☑

Nominierte Fahrer: ⊖

#	Nat	Name	Age	RD	GD	Pkt	N	H	C
1		PEDERSEN Anthony	3	3	3	0	⊖	★	♟
2		MALUCELLI Alexander	3	2	2	0	⊖	☆	♟
3		PHILIPSEN Daniel	3	3	3	0	⊖	☆	♟
4		PICHOT Xabier	3	3	3	0	⊖	☆	♟
5		STACHOWIAK Bram	3	3	3	0	⊖	☆	♟
6		TEN DAM Adam	3	3	3	0	⊖	☆	♟
7		YAMAMOTO Igor	3	3	3	0	⊖	☆	♟

Figure 5.18: Nomination page for a race in the RadSimTool.

Figure 5.19: Stage list for a race in the RadSimTool. The list includes the stage details and the stage winners.

stage, stage name, distance, race type, and profile type of the stage for every stage. Additionally, the list includes the one points, the winning cyclist, and the winning team with both the name and country.

D - Start List

On the start list page, managers overview all the teams that have nominated a squad for the selected race. The team names sort the list. The cyclists are sorted by the last name, except the team captain, who is placed in the first position. The start numbers are generated from 1 for the team captain to the maximum number of allowed cyclists. The first team starts with 00, the next with 01, and it gets incremented up to the last team. Figure 5.20 shows the start list page for a race in the RadSimTool. All the cyclist and team names are clickable to link to their profile pages.

E - Tactical Instructions

The tactics section of the race detail page is the key element to provide the managers with the features to manage their team in the best way for the races. Therefore, managers must get an overview of the stage profile. With information about the different sections of the race. The profile changes depending on the selected stage. Figure 5.21 shows the tactical instruction section. To allow managers to create tactical instructions for their teams, the view of the tactics provides a list with all stages on the left and a list with the teams ominated cyclists o

The nominated cyclist list includes the country, and cyclist name, together with the race days so far, the cyclist's role during the race, and a plus

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Race Overview | Nomination | Stages | Start List | Tactics | LiveRace | Results | Admin Mode | Simulate Race

Besti Cycling [BEC]
001. Anthony PEDERSEN
002. Alexander MALUCELLI
003. Daniel PHILIPSEN
004. Xabier PICHOT
005. Bram STACHOWIAK
006. Adam TEN DAM
007. Igor YAMAMOTO

Cats First Cycling [CFC]
011. Erwann CONCI
012. Tiago BAKIRCI
013. Domen BATTAGLIN
014. Urko BONNAFOND
015. Gonzalo HAAS
016. Carlos PATE
017. Hideto VAN DEN BROECK

Krokodil Pro Cycling [KPC]
021. Martyn BLYTHE
022. Dries BEPPU
023. Robert CUMMINGS
024. Ty GAUDIN
025. Lluís HESJEDAL
026. Mehdi KONING
027. Romain MATYSIAK

Por Sze Pro Cycling [PSP]
031. Thierry CHIA
032. Christophe DEGAND
033. Sam DUMOULIN
034. Dries MOTTIER
035. Gianni PHINNEY
036. Mihkel PORTE
037. Thomas WEENING

Ring Radsport Team [RRT]
041. Stepan MONTAGUTI
042. Artem BATEK
043. Daniel BOUCHARD
044. Nicola HANSEN
045. Robbert LOWNDES
046. Nigel MOLLY
047. Pim ĐURASEK

Sidibu Cycling Team [SCT]
051. Alexander ISTA
052. Bryan BUCHMANN
053. José Joaquín CONTADOR
054. Odd Christian DE ROSSI
055. Hideto IMHOF
056. Artur SOUCY
057. Frederik SPOKES

Team Bradom AT [TBA]
061. Kamil MINNAARD
062. Erwann FUMEAUX
063. Carlos HAUSSLER
064. Jonas MORI
065. Edoardo OWSIAN
066. Jelle RYBALKIN
067. Murilo WYSS

Team Focus Ride Systems [FRS]
071. Maciej DEIGNAN
072. Sébastien FOURNIER
073. Steven FREIBERG
074. Edvald GROENEWEGEN
075. Marcel LATOUR
076. Jérémy MORTON
077. Pierre-Luc RODRÍGUEZ

Team National System Control [NES]
081. Kevin DIDIER
082. Nicholas DE KORT
083. Riccardo KNOX
084. Imerio LIGTHART
085. Jhonatan SÉNÉCHAL
086. Willie SHELDEN
087. Pedro ZHUPA

Figure 5.20: Start list for a race in the RadSimTool.

button to add new tactical instructions for the cyclist. The selection box for the race role allows for defining a single role for the selected stage. This includes no role, captain, co-captain, sprinter, lead out cyclist 1, lead out cyclist 2, lead out cyclist 3, and breakaway. Those roles impact the behavior of the cyclists during different race situations. The sprinter and the lead-out cyclists especially define the outcome of punch sprints for big groups at sprint stages. The selection box uses AJAX calls and JavaScript to save the selection changes to the database.

However, to add tactical instructions for the cyclist, the managers must click on the plus button to add new tactical instructions for the selected cyclist box. This box is created with a JavaScript function called by click event on the plus button. The box includes the cyclist name in the header and a selection for the wanted tactical instruction. The list includes eight instructions and can later be updated to provide more tactical instructions that are implemented in the simulation software. Depending on the selected tactical instruction, the box provides different elements to add information for the tactic. Those elements can be the "from km" mark, the mark where the instruction shall be active, and the "to km" mark, where the instruction

shall be deactivated. Managers can also choose a percentage for how much energy the cyclists shall invest to achieve the goal. Whereas some instructions only allow cyclists from the own team, others provide a selector with a list of all the teams and cyclists taking part in the race. With a click on the Save button, the new tactical instruction gets saved into the database. Afterward, the website reloads with the new instruction in the right section of the page with the other tactical instructions. This list is sorted by the "from km" value to give a good overview of the race.

F - Results

The race detail page's resulting view shows the selected result list sorted by the race's fastest cyclist. The list includes the position, cyclist's country, last name, and first name. The team information also includes the country, team name, and short name for the team. At the end of the list, the time and time difference to the winner is displayed. Users can click on the country flags, cyclist names, and team names to get to the according to detail pages for more information. Therefore, the Results page is developed with PHP. All its content is loaded from the server, and the results are stored in the database.

As for the overview page shown in Figure 5.16 for one-day races, the results view only shows the general classification for one-day races too. However, whereas for one-day races, the race results only show the general classification for the single-stage, race results for stage races include additional information. Figure 5.22 shows the race results view for stage races with a stage selected. The view includes a list with options to select a specific stage or classification for the race to show in the right result list box.

5.4.11 Teams List Page

Players can use the team's page to see an overview of all the teams created so far by the managers in the RadSimTool. Figure 5.23 shows the page in the RadSimTool. For each team, the list includes the team name, short team name, country, division of the team, the manager, the points collected in that year, the victories, and finance value. Whereas the table is sortable by each of these information categories, managers can click on the country flags and team names to get to the specific detail pages to see more information.

Race Overview | Nomination | Stages | Start List | Tactics | LiveRace | Results | Admin Mode | Simulate Race

Tactics: Stage 2 | 205 km (- | FLAT) - Cyclists: **Tactics for Stage 2**

Stage 1

Stage 2

Stage 3

Stage 4

Stage 5

Stage 6

Stage 7

#	Name	RD	Shape	Fresh.	Role	GC	PC	KOM	H	C
1	CHIA Thierry	12	-	-	Leadout C1	-	-	-	☆	♟ ✚
2	BÁRTA Martin	9	-	-	-	-	-	-	☆	♟ ✚
3	CLEMENT Timo	9	-	-	-	-	-	-	☆	♟ ✚
4	CORBEL Steve	9	-	-	-	-	-	-	☆	♟ ✚
5	DEGAND Christophe	11	-	-	Leadout C2	-	-	-	☆	♟ ✚
6	DUMOULIN Sam	11	-	-	Leadout C3	-	-	-	☆	♟ ✚
7	FOURNIER Jimmy	7	-	-	Sprinter	-	-	-	☆	♟ ✚

Add New Tactical Instruction for: BÁRTA Martin

Tactic Type:

Cyclist X (Y,Z) Increase Pace

From KM:

from km

To KM:

to km

Percentage:

50

Cyclist Y - ID:

-

Cyclist Z - ID:

-

Save

Team Tactics:

Leadout: LO1 - LO2 - LOS - Sprinter

Pace: YES / NO / HELP LEADER

Work against Breakaway: YES / NO / HELP LEADER

Por Sze Pro Cycling [PSP]   ✖

Sprinter

FOURNIER Jimmy

Por Sze Pro Cycling [PSP]   ✖

Leadout L1 -- TT - Flat Stark

CHIA Thierry (50%)

Por Sze Pro Cycling [PSP]   ✖

Leadout L2 -- TT - Flat Stark

DEGAND Christophe (50%)

Por Sze Pro Cycling [PSP]   ✖

Leadout L3 - Sprintstark

DUMOULIN Sam (50%)

Por Sze Pro Cycling [PSP]   ✖

Pace from KM 5 to KM 180

Cyclist 1: CORBEL Steve (60%)

Cyclist 2: BÁRTA Martin (60%)

Cyclist 3: CLEMENT Timo (60%)

Por Sze Pro Cycling [PSP]   ✖

Attack at KM 50 from

CLEMENT Timo (50%)

Por Sze Pro Cycling [PSP]   ✖

follow Attacks

from: ISTA Alexander

with: BÁRTA Martin (70%)

Por Sze Pro Cycling [PSP]   ✖

Attack at KM 75 from

CLEMENT Timo (50%)

Por Sze Pro Cycling [PSP]   ✖

Increase Pace from KM 180 to KM 195

Figure 5.21: Tactical instruction view for a race in the RadSimTool.

Race Overview | Nomination | Stages | Start List | Tactics | LiveRace | Results | Admin Mode | Simulate Race

Results:

Stage 1

Stage | General Classification | Points Classification | Mountain Classification | Youth Classification | Team Classification

Overview:

General Classification
Points Classification
Mountain Classification
Youth Classification
Team Classification

Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6
Stage 7

Pos	Name	Team	Pkt	Time	Time Difference
1	CHIA Thierry	Por Sze Pro Cycling [PSP]	82	00:50:22	0
2	CONCI Erwann	Cats First Cycling [CFC]	82	00:50:32	9
3	ZHUPA Pedro	Team National System Control [NES]	78	00:51:22	59
4	FOURNIER Sébastien	Team Focus Ride Systems [FRS]	76	00:51:39	77
5	DUMOULIN Sam	Por Sze Pro Cycling [PSP]	76	00:51:44	82
6	DEGAND Christophe	Por Sze Pro Cycling [PSP]	76	00:51:46	84
7	BLYTHE Martyn	Krokodil Pro Cycling [KPC]	75	00:51:54	92
8	BAKIRCI Tiago	Cats First Cycling [CFC]	75	00:52:01	99
9	BUCHMANN Bryan	Sidibu Cycling Team [SCT]	74	00:52:17	114
10	ISTA Alexander	Sidibu Cycling Team [SCT]	73	00:52:26	124
11	DE ROSSI Odd Christian	Sidibu Cycling Team [SCT]	73	00:52:29	127
12	BEPPU Dries	Krokodil Pro Cycling [KPC]	73	00:52:30	128

Figure 5.22: Race page with the results of stage one for a stage race in the RadSimTool.
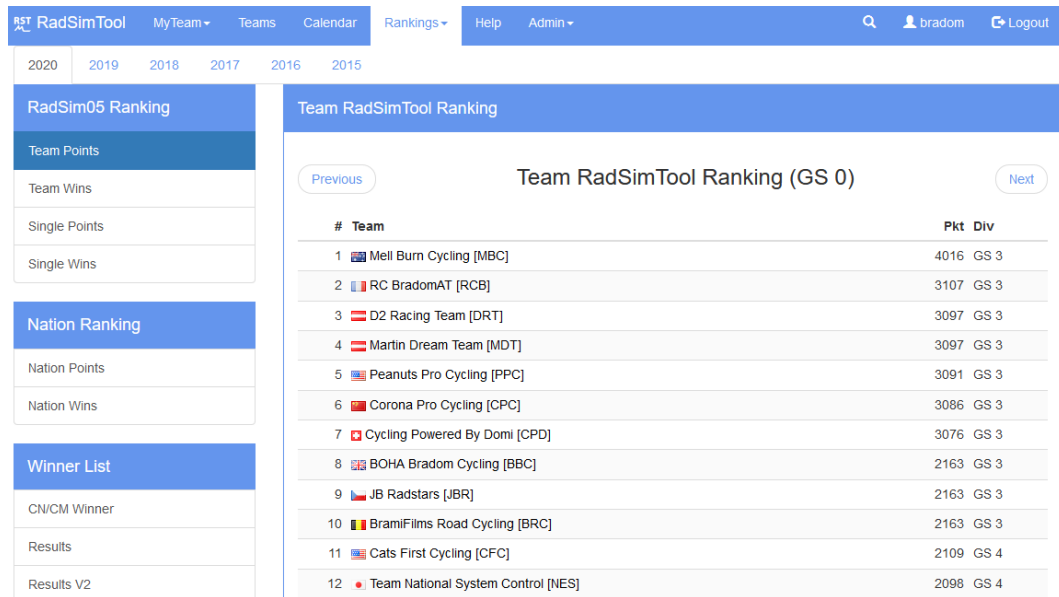
Team Overview/Statistik

#	Team	Nat	Div	Manager	Punkte	Siege	Kontostand
1	Alps Pro Team [AST]	KAZ	DIV 1		3462	4	0,00
2	Anonym and Digital Team [AND]	ITA	DIV 2		4237	17	0,00
3	Aqua Berg Synonym Cycling [ABS]	IRL	DIV 1		5591	18	0,00
4	Bears Mega Pro Cycling [BMC]	USA	DIV 1		9330	32	0,00
5	Besti Cycling [BEC]	AUS	DIV 0	BestiM4n4ger	0	0	0,00
6	Boden Ofen Heizen [BOH]	GER	DIV 1		3061	9	0,00
7	BOHA Bradom Cycling [BBC]	GBR	DIV 0	d5BradomAT	0	0	0,00
8	BramiFilms Road Cycling [BRC]	BEL	DIV 0	d3Master	0	0	0,00
9	Canadian Doors Team [CDT]	USA	DIV 1		6610	10	0,00
10	Chance Zwei Cycling [CZC]	GER	DIV 0	DerAllerZweite	0	0	0,00
11	Computer Online Functions Team [COF]	FRA	DIV 2	rafbra1c	1036	4	0,00
12	Continental Cycling Cooporation [CCC]	POL	DIV 2		1859	4	0,00
13	Corona Pro Cycling [CPC]	CHN	DIV 0	testy	0	0	0,00
14	Cycling Junior Rodeo Team [CJR]	SPA	DIV 1	daN	6024	16	0,00
15	Cycling Powered By D1 [CPD]	SLO	DIV 0	LastTester	0	0	0,00

Figure 5.23: Team list page for the RadSimTool, with a list of all the teams created so far for the game.

Figure 5.24: Team ranking in the RadSimTool.

5.4.12 Rankings and Statistics

Rankings and statistics allow the managers to look up their teams and cyclists and compare them with the other teams. Figure 5.24 shows the team ranking with a list of all the teams, their country, name, points, and division. Managers can choose between the different seasons for each ranking. Whereas the team points ranking shows the collected points for the season, the team victory ranking shows the teams' victories and sorts the ranking by them. All the rankings are created with PHP on the server-side. When a different ranking is selected, the whole page is reloaded.

Single rankings are similar to team rankings. However, the single ranking also includes the cyclist name and country. It also shows the won races or points for the cyclists instead of the teams. Figure 5.25 shows the single ranking for points, and Figure 5.26 shows the country ranking with the points won by cyclists of the different countries. The list includes information about the country flag, name, and the country ranking level the team is ranked for the next season's national championships.

Single RadSimTool Ranking

Single RadSimTool Ranking (1 - 100)

Previous   Next

#	Cyclist	Team	Points
1	THOMAS Benjamin	Mell Burn Cycling [MBC]	630
2	WELLENS Tim	Mell Burn Cycling [MBC]	627
3	ASGREEN Kasper	D2 Racing Team [DRT]	471
4	OLIVEIRA Nelson	RC BradomAT [RCB]	471
5	VALGREN Michael	Peanuts Pro Cycling [PPC]	467
6	VAN EMDEN Jos	Cycling Powered By Domi [CPD]	466
7	SCOTSON Miles	Martin Dream Team [MDT]	466
8	SCHACHMANN Maximilian	Corona Pro Cycling [CPC]	466
9	TRENTIN Matteo	Corona Pro Cycling [CPC]	466
10	DOWSETT Alex	D2 Racing Team [DRT]	465

Figure 5.25: Team ranking in the RadSimTool.

Nation RadSimTool Ranking

Nation RadSimTool Ranking (1 - 100)

Previous   Next

#	Nation	CNN	Punkte
1	Italien	CN 1	6494
2	holland	CN 1	5215
3	Frankreich	CN 1	5178
4	Belgien	CN 1	4619
5	Deutschland	CN 1	3467
6	australien	CN 2	3308
7	daenemark	CN 2	2561
8	england	CN 2	2460
9	kolumbien	CN 2	1435
10	suedafrika	CN 2	1389

Figure 5.26: Nation ranking in the RadSimTool.

Figure 5.27: Result list for the different races sorted by the category of the races in the RadSimTool.

Ranking: Other Rankings
There are other rankings and statistics, including the results for the different years for every race. Figure **??** shows the result list sorted by the category first and by the date of the races second. Therefore, the category boxes are sorted by the highest category for races GT1 and GT2 first, followed by the HC and 1.M categories. The last ones are the winners of under 23 races, followed by winners of the World Championships. The list shows all the race names and the information about the winners. The winners' information includes the cyclist name, cyclist country flag, team name, team country flag, and the points for the winner of the race. Whereas Figure **??** shows the races sorted by category, the ranking version V2 sorts the races by date.

Other additional rankings are the rankings for race days and points per race day. Like Figure 5.25 that shows the individual cyclist ranking, the average race days ranking shows the average points and race days instead of the total points. The list including the cyclist country flag, cyclist name, team country flag, team name, average points per race day, and race days
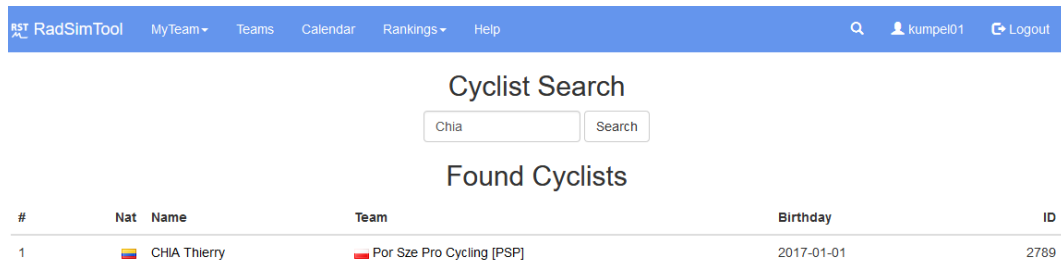
Figure 5.28: Search page with the result for "Chia" in the RadSimTool.

for the selected season. Whereas this ranking is sorted by the race days, the same ranking is available, sorted by the average points per race day.
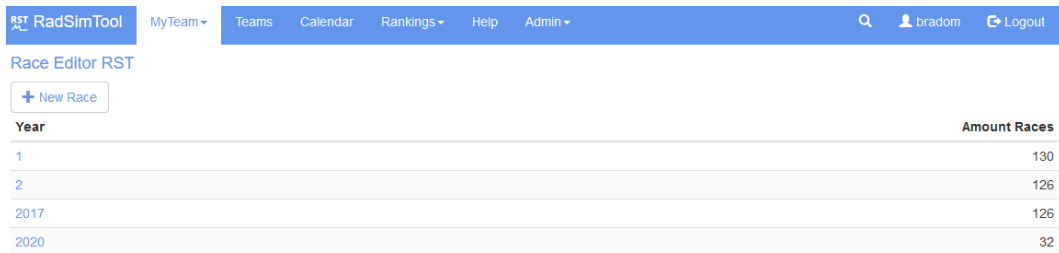
5.4.13 Search Page

The search page provides the managers with a tool to search for cyclist names. Therefore, managers can insert the whole name or just a part of the searched cyclist name into the search text field. The search combines first name + last name, and therefore this order must be maintained to get the wished results for the search. The search form sends the query to the server-side, and the server creates the page with PHP new to show the search results. Figure 5.28 shows the search result for "Chia", and therefore, the result list for found cyclists with Thierry Chia from the Por Sze Pro Cycling team. The listed information includes the birthday, cyclist id, team name with the country flag, and cyclist name with country flag.

5.4.14 Admin Page

The admin page provides functionality to help maintain the RadSimTool game. Therefore, the page is only shown to users with administrator permissions. Admins can use buttons to calculate different rankings for the game. They can also create a new season and access the race editor page for real results, import real-life data, and the race editor page for RadSimTool game data. Admins have the permissions to make changes, create races and manage and maintain teams.

Figure 5.29: Race editor for the RadSimTool. There is a race editor for imported real data and for created races and stages for the RadSimTool game.

5.4.15 Race Editor Page for Real Data and Game Data

To manage and edit the races and stages for both the imported real results or to create races for the RadSimTool game, the race editor is designed to provide the admins with the functionality required for the maintenance. Both race editors are separated with different database tables in the background, and Figure 5.29 shows the editor's entrance point. The start page is created with PHP and lists all the years with created races. To give the admin a quick overview of the available data, the years are listed with each year's number of stages. To create a new season for the list, admins can use the "+ New Race" button and create a new race for a new season or an existing one. Or the admin can click on a specific year to get to the race list for that year.

The header of the race editor page shows a list with the position in the navigation through the database. Therefore, the first part is the "Race Editor" text and links back to the start page. The second part is the selected season and links to the race list for that season. The third part is the selected race name and links to the selected race page, and the last part is the name of the selected stage result.

Editor: Create New Race
By clicking on the "+ New Race" button on the start page of the race editor or on the races list for a specific year, the create a new race page shown in Figure 5.30 is loaded, and the admins can insert the required data into the formula to add a new race to the database. The formula for the race creation requires the year the race belongs to, name of the race, country the race is

raced in, category of the race, start date, end date, number of stages, and the allowed number of cyclists the race. There can also be the URL of the real race website, and the URL to the race logo added to the database for real races. Whereas the year or season must be a number, it can be used to create a new season by adding races for a new year.

Editor: Race List

After a race is created and saved into the database, the admins see the race editor's race list page. The race list page of the 2020 season of the RadSimTool is shown in Figure 5.31. It shows a list of all races for the selected season. The list includes information about the date of the race, country, name, amount of stages, category, the minimum and the maximum number of cyclists. For each entry, an edit and delete button is added to perform an action and manage the races easily.

Editor: Edit Races

Clicking on the edit button leads the admins to the edit race page. Whether the selected race is a one-day race with only a single-stage or a stage race over several stages, the edit page shows different information. For stage races shown in Figure 5.32, the edit race page includes a list with all the stages for the race and with a points and mountain classification additional to the general classification. However, for one-day races, there is only one stage and the general classification. Whereas the results for real data of one-day races are imported as stage results, the results for one-day races in the RadSimTool game are saved as general classifications.

Admins can either add new stages by clicking on the "+ New Stage" button and use the create new stage formula to add a single stage, or admins can use the "+ All Stages" button to create all the stages for the race. The algorithm creates stages up to the number of stages with different numeration, names, and date, starting with the race's start date. The stages list includes information about the number of the stage in the race, date of the stage, name, distance type of the race, profile type, amount of results in the database for the stage and as for the race list, it also includes an edit and deletes button for every stage in the list. Deleting a stage also deletes the result entries for that race. On the left side of the edit race view, the race data can be edited and saved.

Figure 5.30: Editor for stages in the RadSimTool race editor.

Figure 5.31: List of races for the select year 2020 in the RadSimTool game race editor.

Editor: Edit Stages

The edit stage formula is the same for creating a new page or editing a new page. Figure 5.33 shows the formula to edit an existing page. Admins can define the number of the stage in the race, the name, country, distance in a kilometer, date of the stage, the stage profile URL, the type of the stage, and the stage's profile type.

Editor: Result List

For the race result editor of real races, after clicking on the name for a stage or classification result, the view shows an import or delete button for that race, as shown in Figure 5.34. A click on the import button forwards the user to an upload page for real results, as shown in Figure **??**. When results are imported, the result list shows a list of the imported real results. The list includes information about the result rank, IRM, country, last name, first name, age, team name, result time, and bib. Whereas the IRM is information about whether the cyclist reached the finish, did not finish (DNF), did not start (DNS), or got disqualified (DSQ). The BIB is the start number at the real race included in the imported data set.

Figure 5.32: Editor for stage races in the RadSimTool race editor.

Figure 5.33: Editor for stages in the RadSimTool race editor.

Figure 5.34: Result list for an imported real result in the RadSimTool race editor.

General

Type	Avg	Count	Min	Max
Avg_GT_GW	0	0	0	0
Win_GT_GW	0	0	0	0
T_5_GT_GW	0	0	0	0
T10_GT_GW	0	0	0	0
T20_GT_GW	0	0	0	0
T30_GT_GW	0	0	0	0
T50_GT_GW	0	0	0	0
Avg_WT_GW	15.3333	3	5	35
Win_WT_GW	0	0	0	0
T10_WT_GW	5.5000	2	5	6
T10_WT_GW	5.5000	2	5	6
Avg_WT_O_D	0	0	0	0
Win_WT_O_D	0	0	0	0
T10_WT_O_D	0	0	0	0
T20_WT_O_D	0	0	0	0

Mountain

Type	Avg	Count	Min	Max
Stages	15.0000	5	1	31
Stage_Wins	1.0000	1	1	1
Stage_Top10s	4.0000	2	1	7
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	15.0000	5	1	31
Wins_WTs	1.0000	1	1	1
Top10s_WTs	4.0000	2	1	7
Avg_One_Day	0	0	0	0
Win_One_Day	0	0	0	0
T5s_One_Day	0	0	0	0
T10_One_Day	0	0	0	0
T20_One_Day	0	0	0	0
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	0	0	0	0
ITT_Wins	0	0	0	0
ITT_Top10s	0	0	0	0

Mountain Finish

Type	Avg	Count	Min	Max
Stages	20.4000	5	2	57
Stage_Wins	0	0	0	0
Stage_Top10s	4.0000	2	2	6
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	20.4000	5	2	57
Wins_WTs	0	0	0	0
Top10s_WTs	4.0000	2	2	6
Avg_One_Day	0	0	0	0
Win_One_Day	0	0	0	0
T5s_One_Day	0	0	0	0
T10_One_Day	0	0	0	0
T20_One_Day	0	0	0	0
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	0	0	0	0
ITT_Wins	0	0	0	0
ITT_Top10s	0	0	0	0

Hill

Type	Avg	Count	Min	Max
Stages	33.0667	15	1	120
Stage_Wins	1.0000	1	1	1
Stage_Top10s	5.2000	5	1	10
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	33.0667	15	1	120
Wins_WTs	1.0000	1	1	1
Top10s_WTs	5.2000	5	1	10
Avg_One_Day	10.0000	3	1	16
Win_One_Day	1.0000	1	1	1
T5s_One_Day	1.0000	1	1	1
T10_One_Day	1.0000	1	1	1
T20_One_Day	10.0000	3	1	16
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	5.5000	2	4	7
ITT_Wins	0	0	0	0
ITT_Top10s	5.5000	2	4	7

Hill Finish

Type	Avg	Count	Min	Max
Stages	31.1667	6	1	151
Stage_Wins	1.0000	3	1	1
Stage_Top10s	1.0000	3	1	1
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	31.1667	6	1	151
Wins_WTs	1.0000	3	1	1
Top10s_WTs	1.0000	3	1	1
Avg_One_Day	4.0000	2	1	7
Win_One_Day	1.0000	1	1	1
T5s_One_Day	1.0000	1	1	1
T10_One_Day	1.0000	1	1	1
T20_One_Day	4.0000	2	1	7
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	0	0	0	0
ITT_Wins	0	0	0	0
ITT_Top10s	0	0	0	0

Flat Road

Type	Avg	Count	Min	Max
Stages	67.0000	1	67	67
Stage_Wins	0	0	0	0
Stage_Top10s	0	0	0	0
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	67.0000	1	67	67
Wins_WTs	0	0	0	0
Top10s_WTs	0	0	0	0
Avg_One_Day	0	0	0	0
Win_One_Day	0	0	0	0
T5s_One_Day	0	0	0	0
T10_One_Day	0	0	0	0
T20_One_Day	0	0	0	0
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	31.0000	2	1	61
ITT_Wins	1.0000	1	1	1
ITT_Top10s	1.0000	1	1	1

Cobble Stone

Type	Avg	Count	Min	Max
Stages	0	0	0	0
Stage_Wins	0	0	0	0
Stage_Top10s	0	0	0	0
AVG_GTs	0	0	0	0
Wins_GTs	0	0	0	0
Top10s_GTs	0	0	0	0
AVG_WTs	0	0	0	0
Wins_WTs	0	0	0	0
Top10s_WTs	0	0	0	0
Avg_One_Day	0	0	0	0
Win_One_Day	0	0	0	0
T5s_One_Day	0	0	0	0
T10_One_Day	0	0	0	0
T20_One_Day	0	0	0	0
P_Avg	0	0	0	0
P_Wins	0	0	0	0
P_Top10s	0	0	0	0
ITT_Avg	0	0	0	0
ITT_Wins	0	0	0	0
ITT_Top10s	0	0	0	0

Figure 5.35: Cyclist statistic page with statistics for stage type and races for a real cyclist in the RadSimTool race editor.

Editor: Import Real Race Results

To import real results, the import features can be used. Those functions allow to import a CSV file created from the official UCI Website (UCIWebsiteResults) or to import a JSON file created with the Python script to parse websites and collect real race results. That JSON data structure is imported and added to the RadSimTool database and can be managed by the race editor administrators.

Editor: Cyclist Statistic Page

The cyclist statistic page in the real race editor can be used to get detailed statistics about a cyclist's performance for a selected season. The page is shown in Figure 5.35 and provides information for the different types of stages. The statistics include results for mountain, mountain finish, hill, hill finish, flat road, cobblestone, and general classifications at different races.

The statistics also include time trials (ITT) or prologue (P) for the different types and include different performance data for world tour (WT) races, one-day races, and grand tours (GT). The statistics include wins, top five results, top ten results, and top twenty results. Whereas for most races, only the top results are important, for general classifications at GTs, also top thirty and top fifty results are included in the statistics. For each statistic, the list includes the average position, the number of results, minimum and maximum results. The statistic list provides a good overview of a real cyclist's strengths and allows them to compare different cyclists with each other.

5.5 Simulation of Cycling Races

The third part is the Simulation of Cycling Races, both for mass start road races and for individual time trials. Therefore, software with a simple user interface will be developed. The interface allows the admin to browse through the races and choose the races they want to simulate with the simulator. Several functionalities are required to simulate the races, starting with the loading of real profiles for races, calculating power and speed, and simulating energy through the races and the simulation of the races themselves. This algorithm simulates the behavior of every cyclist through the race.

5.5.1 Simulation Software Tool

Whereas the RadSimTool website for the game runs on a server and provides access over the internet to the game and the database, the software tool to simulate cycling races for the RadSimTool game is created as a WinForms application developed in C# with the Visual Studio 2013. The software can access the online database server to get the races, nominated cyclists, tactics, and cyclist's strength values from the MySQL database server and use them to simulate cycling races. The software tool also provides the functionality to generate cyclists' strength values using the online database for real race results. The generated strength values are uploaded into the game database and can be used to simulate upcoming races.

However, the main functionality of the software tool is the simulation of cycling races. Those simulations are divided into two race types, using the same physics to simulate the races. Whereas the simulation for individual time trial races simulates each cyclist alone without any tactical impact on the race outcome, the simulation of mass start road races is much more complex. It simulates different races' situations and tactical instructions during the races.

Start View - Selecting Race and Stage
Therefore, the start view shown in Figure 5.36 provides the administrators with the necessary menu to select a specific season, race, and stage to simulate. The race list changes with the selected season, and the stage
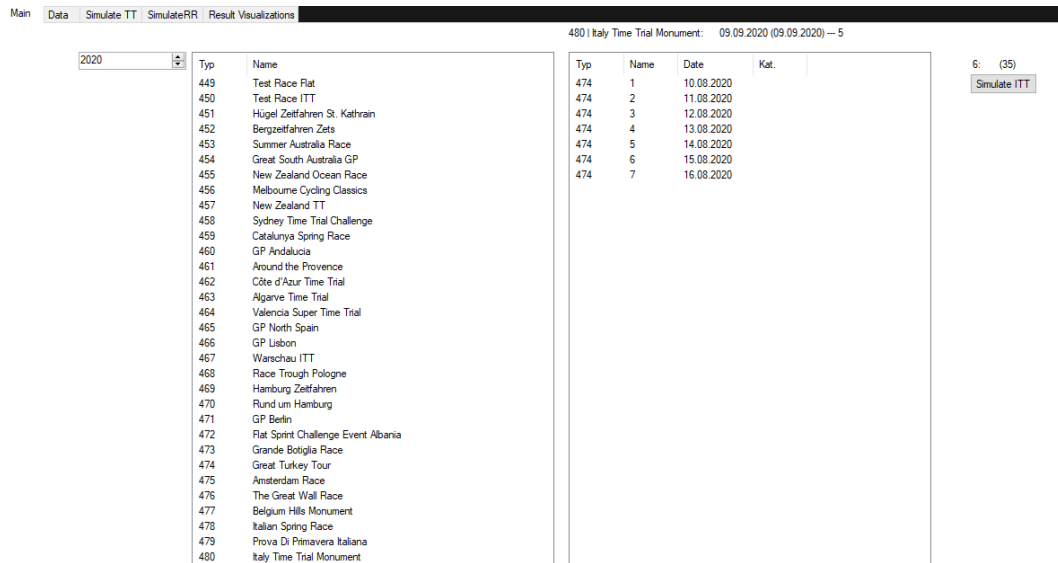
Figure 5.36: Start page for the simulation software of the RadSimTool.

list show the stages for the selected race in the second list. Depending on the selected stage type, the simulation button on the right leads to the simulation of individual time trials or mass-start road cycling races.

Simulation Windows for Time Trials and Road Races

After selecting the race and stage that shall be simulated, the user gets forwarded either to the window for the simulation of time trials or mass start road races depending on the selected stages race type. The simulation window provides a button to simulate the according to the stage and a simple result list after the race is simulated. It also provides information about the stage profile and performance graphics for each cyclist for mass start road races. A Simple 2D graphic provides the users with information about the race situations. The 2D graphic can be created for every time step during the race.

Window for Graphical 2D Race

Figure 5.37 shows the window for graphical 2D races. The user can select a cyclist in the top left selection box, a time mark on the second selection box, and the group number in the list box. Depending on the selected cyclist,
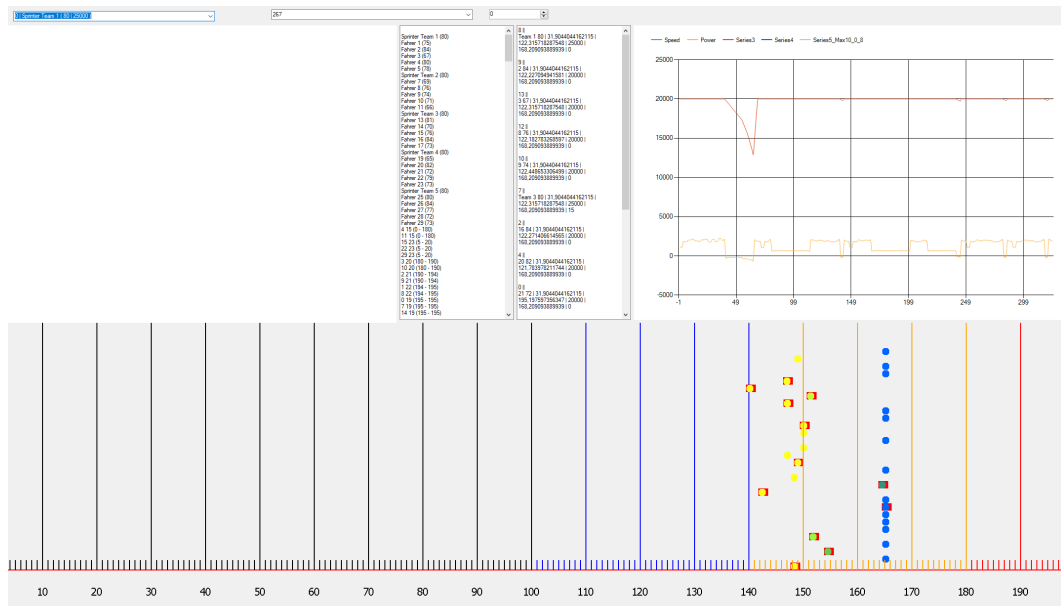
Figure 5.37: 2D race graphic for mass start races.

the performance data is visualized in the top right graphic. The graphic shows the selected cyclist's power output over the stage and the right line of the energy tank during the stage. The blue line shows the speed of the cyclist. The two lists on the left side of the performance graphics show race information in the first list, and the right list shows the cyclists for the selected group at the selected race situation with the cyclist's performance data for the selected race situation and the tactical behavior at that point in the race. The bottom 2D race graphic shows the whole stage, with the markers representing the kilometers of the race. The cyclists are represented with dots. Depending on the group of cyclists, the color of the cyclist changes, and the pacing cyclists are marked in red. The graphic shows the dropped cyclists behind the peloton (blue) on a sprint stage on the stage's final kilometers.

5.5.2 Real Profiles and GPX data

Different road cycling stages have different profiles, whereas some stages are almost flat, others include hills or even mountains, with different lengths of

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climbs and different grades of the streets. The simulation algorithm includes an import functionality for real profiles to simulate those profiles, with GPX data for the course. The GPX data is a GPS exchange format. It includes information about the profile, and each data point includes information about latitude and longitude and information about the elevation. This data can be imported from GPX files that are exported from services such as OpenStreetMap (OpenStreetMap, 2020). The data can be used to calculate the grade of the street during each moment in the simulation of the race. The grade information is important for the calculation of power and speed.

Listing 5.1: The XML Structure of GPX Files

```
<?xml version="1.0" encoding="UTF–8"?>
<gpx version="1.1" ... >
        <trk><name><![CDATA[ TestRoute ]]></name><trkseg>
                <trkpt lat="39.95085" lon="32.79131"><ele>839</ele></trkpt>
                <trkpt lat="39.95091" lon="32.79134"><ele>849</ele></trkpt>
        </trkseg></trk>
</gpx>
```

Generating GPX Profiles

GPX profiles are used in the simulation software to simulate real-world stages. Those stages can be created manually on websites like bikemap.net[1] or OpenStreetMap.org[2]. Those and other services allow the creation of routes and export them as GPX files. These GPX files can be used to import the stages into the simulation software. Projects like the la FlammeRouge project[3] collects stages of real cycling races and provides them to view on their websites or download them. However, for the RadSimTool game, the races are created manually with fantasy stages.

Importing GPX Profiles

Since GPX files use an XML structure, they can be read and parsed with XML parsers. Therefore, the RadSimTool website uses the D3.js feature to import XML files and parse them before visualizing them. However, the simulation software is developed in C# and therefore uses the XMLDocument class to load the files and parse them for "trkpt" data. For each track point, the import function creates an object with latitude (lat), longitude (long),

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[1]https://www.bikemap.net/
[2]https://www.openstreetmap.org/
[3]https://www.la-flamme-rouge.eu/

and elevation (ele). Additionally, the object includes the distance between the last point and the new one, the total distance until this point, and the street's grade. To calculate the distance between two GPX points, the GeoCoordinate class of the Microsoft .Net framework is used. The GeoCoordinate provides the functionality to calculate distances between two points of that class. For the calculation of the grade between two GeoCoordinates, the function calculates the distance between the two GeoCoordinates, the high meter difference between them, and calculates the grade of the street with Equation 5.1. The List with those GPX object elements is later used to simulate the race and decide about the cyclists' strengths for the different parts of the races. Many of the GPX files contain a lot of "trkpt" entries. However, for the simulation, only a limited number of steps are required. Therefore some entries can be removed without losing important information for the race simulation. Profiles with intervals of ten to 100 meters can be used for the races.

$$grade = distance * \tan(\arcsin(\frac{highmeters}{distance})) \tag{5.1}$$

Simulating Cyclist Strengths with Profile Data
Depending on the street's grade, the algorithm uses a different strength value for the cyclist for each part of the stage. For individual time trials, cyclist strength values for flat and hill time trials are considered. The values include flat, hill, mountain, mountain finish, hill finish, and sprinting for road races. Whereas the other values depend on the street's grade, the sprint strength value is explicate used in final sprints for the stage win. Depending on the grade of the current stage part from the profile, the simulation algorithm chooses the strength value that is the best fitting. For flat roads with little up or downhill grade, the flat value is used, and for uphill above five percent, the hill value is used. For Races categorized as Mountain races, mountain values instead of hill values are used. Here cyclists need to pass many high meters over the total stage, and climbers that can perform well over longer uphill passages perform best in those sections.

For uphill passages, less weight is a big advantage. For flat roads and downhill sections, more weight can allow cyclists to go faster. In the simulation, all cyclists have the same weight and height. Therefore, the strength values are the main factor and shall represent the simulation's cyclist's

strengths. The cyclists have no double advantage over other cyclists without weight differences since their strengths are already represented with the strength values.

5.5.3 Power and Speed Calculation

Before the system can simulate the energy model, both power and speed need to be calculated for each cyclist during every simulation step. Equation 2.1 in chapter 2 Chapter 2 shows the formula to calculate the power output required for a specific speed depending on the surface of the road, the grade of the street, and wind resistance, such as the impact of drafting. Whereas a cyclist at the front of the group requires more power to maintain the group speed, cyclists behind the cyclist benefit from drafting and maintaining the speed with less power output.

Calculate Power and Speed of a Cyclist
To calculate power and speed in the simulation uses the formulas described in Chapter 2. To calculate the required power for a cyclist at a certain moment in the race, Equation 2.8 from Swain(Swain, 1998) is used to calculate the power P.

$$P = k_r Ms + k_a Asv^2 + giMs \tag{5.2}$$

The simulation uses no wind. Therefore, $s = v$, and the formula can be solved by s to calculate the speed. Table 5.6 shows a list with all the parameters for the equation and the values used for them to calculate the power and speed of cyclists.

5.5.4 Energy Simulation

One of the fundamental functionalities for the simulation of cycling races is a good working energy model. Therefore, the simulation needs a model like the critical power model by Skiba et al. (Skiba et al., 2012) or the optimization by Mark Liversedge (Liversedge, 2014). The model must provide an energy recovery system, where riding below the critical power leads to energy recovery, whereas riding above the critical power empties the energy tank W'. Simulating cycling races contains the energy simulation for up to 200 cyclists and needs to be updated every second during the race.

Parameter	Value	Description
P	Result	Power in watt
k_r	0.005	Rolling resistance surface
M	70	weight kg (cyclist + bike)
s	?	Speed
k_a	0.5	Wind resistance (no wind)
g	9.8067	Gravitational Constant (m/sec^2)
i	?	Gradient of the street (5% = 0.05)
A	0.28/0.3/0.4/0.6	Combined frontal area (bike + cyclist)

Table 5.6: Parameters for the power and speed calculation.

Implementation of the Energy System

The system to simulate a cyclist's energy tank uses the critical power (CP) concept. To simulate energy recovery, the algorithm uses the differential algorithm by Skiba et al (Skiba et al., 2015):

$$W'_{bal}(t) = \sum_{0}^{t}(CP - P(t)) \cdot \begin{cases} 1 & where\, P(t) > CP \\ \frac{W' - W'_{bal}(t-1)}{W'} & else \end{cases} \tag{5.3}$$

The algorithm compares the power at a time step with the cyclist's CP. when the cyclist performs above the CP, the energy tank empties, and when the cyclist performs below the CP, the cyclist's power tank recovers. Therefore, the algorithm runs over all the whole power history for the stage and adds the last time step to the calculation.

Listing 5.2: Pseudo Code to calculate the left energy after an afford.

```
leftEnergyWithPowerForSeconds(watt, seconds, cp)
{
        w_bal = maximal_aerobic_energy;
        power_difference = 0.0f;
        diff_bal = 1.0f;

        foreach (PowerMoment pm in _power_history) {
                power_difference = cp - pm.power;
                if (pm.power > cp)
                        diff_bal = 1.0f;
                else
                        diff_bal = (maximal_aerobic_energy - w_bal) / maximal_aerobic_energy;
                w_bal += pm.seconds * power_difference * diff_bal;
        }

        power_difference = cp - watt;
        if (watt > cp)
                diff_bal = 1.0f;
        else
```

```
    diff_bal = (maximal_aerobic_energy − w_bal) / maximal_aerobic_energy;
w_bal += seconds ∗ power_difference ∗ diff_bal;

return w_bal;
```

5.5.5 Shape System

To simulate a variance in a cyclist's consistency, the simulation requires a simple shape and fitness system. One part of this system is the generation and updating for the cyclists' strengths, using real-life race results in the background. That leads to dynamic strengths throughout the season. The advantages are a symbiosis between the shape during real life and in the game. However, in the game, several cyclists can be created from one single real cyclist. Therefore, the cyclists have the same strengths. To create a variance between those cyclists, the races' simulation contains a random daily form factor. This random factor increases or decreases the cyclist's values for a race and makes the race more diverse.

5.5.6 Simulation of Individual Time Trials

In individual time trial (ITT) races in road cycling, the cyclists start separately from each other, with a time gap between each cyclist. Therefore, ITTs are less tactical than mass start races, where all the cyclist start at the same time. For the simulation of an ITT, the simulator imports the stage's profile and the time trial strength values for each cyclist that competes in the race. Depending on the street's grade, different strength values are considered for each part of the race. Simulating the ITT requires the calculation of power and speed together with the energy simulation. Each cyclist must be calculated separately. Depending on the cyclists' strengths, the algorithm calculates each cyclist's possible speed that the cyclist can maintain over the distance of the time trial. After every cyclist is simulated, the cyclists get ranked by their total time to have the final race result.

Simulation Algorithm for Individual Time Trials
The default approach to simulate time trial races and generate results uses only the critical power (CP) represented by the cyclist's strengths for the different time trial strength values for flat, hill, or mountain terrain without

further optimization. The algorithm uses the stage profile information to decide whether it is a flat, hill, or mountain part and simulates for each track point in the stage profile the race. For every step, the algorithm gets the CP value and calculates the speed and the required energy for the segment between the new and the last track point. The next step's distance traveled is then added to the cyclist's total distance, and the required seconds are added to the cyclist's total time.

Listing 5.3: Code for calculating time trial results.

```
is_time_trial = true;
stage_profile = loadStageProfile();
cyclists = loadCyclistAndStrengthsForRace();

calculateTimeTrialResult(Cyclist cyclist) {
        percentage = 1.0f;
        time = 0.0f;

        for(int counter = 0; counter < stage_profile.Count; counter++) {
                gpx_entry = stage_profile[counter];
                profile_type = gpx_entry.getProfileType();
                critical_power = cyclist.getMax10ForTerrain(profile_type, is_time_trial);
                distance_in_meters = gpx_entry.distance * 1000;
                speed = cyclist.calculateSpeed(cp, gpx_entry, is_time_trial);
                current_watt = cp;
                seconds_needed = distance_in_meters / speed;
                reduce_energy = cyclist.reduceEnergyByLastTimestep(current_watt, cp, seconds_needed);
                cyclist.distance += distance_in_meters;
                time += seconds_needed;
        }

        return time;
}
```

Optimization of Time Trial Results

The basic algorithm uses only the critical power (CP) for the calculation of the race. However, to optimize the cyclist's performances for different stage profiles, the implementation uses two more approaches and takes the best result for the race. The second approach adds a constant factor to the power output to simulate the constant reduction of the energy tank until the cyclist reaches the finish with no energy left. However, the third approach finds race sections where the cyclist can recover the energy tank and uses more difficult parts of the stage to increase the power output and empty the energy tank in those sections. The best time is used as the final time for the cyclists at the race.

5.5.7 Simulation of Mass Start Stage Races

Whereas ITTs are easier to simulate, with only one cycling to simulate at one time, simulating mass start races requires simulating cyclists' behavior during a race and how other cyclists react to events during the cycling mass start road race. Therefore, a set of tactics is required, which is discussed before in this chapter. The races' simulation starts with loading the profile and necessary information about the cyclists, their strengths, and each team's tactics. When the race is simulated, the updates are calculated for each time step, depending on the position in the race and the group, the cyclist's energy is updated, and tactics for the next time steps are collected to define the new events in the race. The tactics from the managers shape the race and the outcome of it. Whereas some tactics are dynamic and can happen at every point during a race, others like the simulation of sprints are more limited, especially mass sprints. The simulation of lead-out trains on the last kilometers of the race is specific events that happen at a specific time in the race. To simulate sprints, a clear structure is designed to simulate sprints at the end of a race. Therefore, the behavior of all the sprinters and their lead-outs is simulated. Also, the impact of weak helpers and bad positioning in the final is simulated.

Race Preparation and Loading Nominated Cyclists
At the beginning of the simulation process, the stage profile gets loaded, if available, according to the GPX file. Afterward, the algorithm loads all nominated cyclists from the online database server. Suppose the nominated team is valid, with the right number of cyclists and no cyclists taking part in other races at the same time for each cyclist. In that case, their strength values get loaded, and all tactical instructions for the team are loaded into the tactical instruction list. For every cyclist's strength value, the daily shape factor is generated and used to increase or decrease the strength value by the generated factor.

Simualtion Algorithmn
The simulation algorithm for road races starts the race at km = 0 and time = 0. A time step is chosen and can later be changed to simulate situations in more detailed steps. The time steps are set to $time_{in_{s}}seconds = 20$, and the finish distance is set to the distance of the loaded profile. Whenever a

cyclist reaches the finish line, the cyclist is removed from the cyclist's list to simulate and added to the *race_results* list with information about the cyclist and the finishing time. At the start, each cyclist is part of the first and only group so far in the race, the "Peloton".

The simulation loops until each cyclist reached the finish or is removed from the race due to other reasons like abandon cyclists. At first, the kilometers and time are updated since the last time step by the race's first cyclists' distance. Every cyclist's distance is compared with the finish distance, and cyclists who reached the finish are removed from the race. For each group, the handleGroupTactics() function is called to handle the tactical instructions. Tactical instructions like attacks are handled, and the cyclists who pace in the group are chosen.

Each group's leading cyclist has no slipstream and cannot save energy like the following cyclists in the list. By iterating through the pacing cyclists list over different time steps, the cyclists can rest behind the others and save energy for their lead. Depending on the cyclist's behavior, the required power and speed are calculated, and the energy tank is updated, and the performance is saved after every time step of each cyclist's performance history.

After the group tactics are handled, the cyclist's list is sorted by the new distances and grouped into new groups, depending on the distance between the cyclists. At the end of the race, after all, cyclists are removed. The race result and the cyclists' performance data are uploaded to the database server.

Listing 5.4: The code for simulating mass start road races.

```
speed_to_km = 60.0f / 1000.0f;

simulateRR(race, stage) {
        loadCyclistsTacticAndProfile();

        groups.add(new Group(1, 'Peloton'));
        time = 0.0;
        km = 0.0f;
        finish = stage.distance;
        time_in_seconds = 20;

        List<Results> race_results = new List<Results>();

        while(cyclists.Count > 0) {
                km = cyclists.First.distance;
                time += time_in_seconds;

                for (counter = cyclists.Count() - 1; counter >= 0; counter--) {
                        Cyclist c = cyclists[counter]);
                        if (c.distance >= finish) {
                                race_results.Add(new ResultEntry(time, c, null));
                                cyclists.Remove(c);
                        }
```

```
        }

    foreach (Group group in groups)
            handleGroupTactics(group, group.id, speed_to_km, km, _finish);

    groups = reStructureGroups(sortCyclistsByDistance(cyclists));
    }
    return cyclists.Count;
}
```

Simulate Sprint Finals

An algorithm to handle the race's final sprints is used to simulate mass sprints with different lead-outs for the race's final two kilometers. Each team can have lead-out trains to help their sprinters to win the stage.

The LeadOutTrain objects are created at the start when the tactical instructions for the race are loaded. During the stage, they have no impact on the race. However, at the final of the race, the tactical instructions get relevant when a group of cyclists gets on the last two kilometers of the race. Two kilometers are chosen for sprint stages, where big groups reach the finish and sprint for the stage wins, and the value might vary for different stage types. When the tactics are active, the algorithm runs over each LeadOutTrain in the list.

Depending on the left distance to the finish, the active cyclist of the lead-out is chosen. The first cyclist is the lead-out 1 (LO1) and should pace for the distance of one kilometer with the maximum possible power for that distance. The strength values for that cyclists are the flat time trial value. For the second cyclists, the lead-out 2 (LO2), the strength value is a flat time trial too. However, the required distance is only 500 meters, and the following lead-out sprinter (LOS) brings the team's sprinter on the last 250 meters of the race. The required strength value for the LOS is the sprint strength value. The last cyclist in the lead-out train is the sprinter (S) of the team and requires as high sprint values as possible to be able to compete against the other sprinters. Additionally, cyclists without a lead-out train can get the position by a single helper behind one of the top sprinters. However, those cyclists start behind that sprinter into the race. The more cyclists try to position behind a sprinter. The less effective the positioning for the sprint might be.

The time steps are reduced before the sprint starts to simulate it in more detail. Each lead-out hierarchy is simulated together. Therefore, for each of the cyclists, the maximal power to the target kilometer mark is at every

time step. All cyclists go at the speed of the best lead-out train. Cyclists behind their current pacing cyclist have slipstream. However, the pacing cyclists weaker than the top lead out will empty their energy tank before they reach the kilometers goal. Therefore, lead-outs are sorted behind the top lead out depending on the time mark. Their pacing cyclist could not go the speed anymore. Depending on how many lead-outs were better than the pacing cyclist, the next cyclist in the lead-out train of that team starts with a penalty. The penalty points that decrease the next cyclist's critical power (CP), and therefore, decrease the chance for the next lead-out cyclist to position the team best.

After the LOS is simulated, the sprinters start on the final 250 meters of their sprint. They sprint with an average of around 1,500 watts. All sprinters try to fight for victory. As with the cyclists before, the sprinters with weaker lead-outs get a penalty for their CP. To give a handicap for the chance to win against the better-positioned sprinters.

Cyclists with no LO1, LO2, or LOS before them are positioned behind the cyclists with a helper before them and get the same penalty as the other lead-outs without a helper before them. The cyclists behind the sprinters of the lead-out train start with penalties. The penalties depend on the order they got positioned behind the sprinter of the lead out.

The ranking of the sprinters in the final is the final stage result, and the remaining cyclists in the group are sorted randomly behind the sprinters.

5.5.8 Differences for the Algorithms

Whereas the formulas and algorithm for the energy simulation stay the same, the parameters for the speed and power calculations change for the individual time trial races simulation. Cycling teams use different equipment for time trials, compared to mass start road races, like special time trial bikes or wheels. Those changes increase the bikes' aerodynamic and allow the cyclists to use a better aerodynamic sit position. Higher air pressure for the wheels and the special equipment allows the cyclists to achieve better performance in time trial races. Therefore, the parameter A for the air resistance from the combined cyclist and frontal bike area are reduced for time trial simulations to allow the cyclists to achieve better results. Also, the rolling resistance coefficient k_r can be reduced due to better rolling wheels.

5.6 Summary

Chapter 5 discussed the implementation of the RadSimTool Project. Whereas Chapter 3 discussed the functional and non-functional requirements for the RadSimTool. Based on the design decisions made in Chapter 3, Chapter 4 discussed the required tools and frameworks for the different parts of the project. Chapter 5 discusses the implementation of the RadSimTool with the discussed tools and frameworks based on the discussed requirements and design decisions. Therefore, the chapter discusses implementing the data mining, managing, and processing part of the project. The implemented Python script is used to collect the required data for races, stages, and results to build the database. This database is then be used for the data managing and processing parts. The chapter discusses the required and optional data and how the JSON data structure is built and used to import the data into the RadSimTool database.

Based on the imported results, the algorithm to generate the strength values for cyclists uses the collected information to create strength values for the cyclists in the database. Depending on the season, cyclists have different strength values, and different results are considered for the generation of the strength values. Depending on the profile types, cyclists have different strengths that influence their performance during the race simulations. Whereas the generated strength values are based on a real cyclist's performance, the names used to display in the RadSimTool game are generated randomly. More than one cyclist can base on the same strength values. Therefore, the random daily shape is used to bring more diversity into the race's outcome. Also, the different tactical instructions and roles for cyclists during races that are implemented are discussed, and their influence on the race is discussed in this chapter.

For the implementation of the RadSimTool game website, HTML/CSS/-JavaScript is used on the client-side and PHP, and a MySQL server is used on the server-side to generate the website and handle user interactions. Chapter 5 explained the implementation of all the features for the RadSimTool game website and discussed the tools and frameworks used to create those features.

The last part of the chapter discusses implementing the simulation software tool developed with Visual Studio as a WinForms application how GPX data are structured and used to create and import real stage profiles. The

mathematical formulas used for implementing the simulation algorithm are discussed to calculate the power and speed of cyclists and the formulas and algorithms for the simulation of the cyclist's energy tanks. For different race types, different algorithms handle the simulation of the races. Therefore, the algorithm's implementation for individual time trials is discussed, and the differences to the algorithm for mass start races are explained. Individual time trials require no tactical instructions. The simulation of mass start road races is heavily influenced by the tactical behavior of the different cyclists. The algorithm for the simulation of punch sprints of big groups at the end of stages is required to simulate the outcome of races with sprint finals. Therefore, the different lead-outs for teams can be simulated, and sprinters can get advantages or disadvantages for the last 250 meters of the race based on their lead-outs quality.

6 Evaluation

Chapter 6 discusses the evaluation process for the RadSimTool. Therefore, the evaluation process is structured in two parts. The first part focuses on the quality of the generated cyclist's strength values and simulated race results compared with real-life results. Since the focus for this thesis is on the simulation of individual time trial races and mass start races with mass sprint finals. The evaluation process focuses on those two race types and strength values. The second part focuses on the user experience with the RadSimTool game and the usability of the website. Therefore, a test study with participants who play the RadSimTool game for two weeks is used to evaluate the usability. Afterward, the participants answer a questionnaire about their experience with the RadSimTool game.

6.1 Study Design

The study is designed to evaluate the quality of the generated strength values and simulated race results in the RadSimTool and test the user experience and usability of the RadSimTool game website. Therefore, the research focus, questions, and methodology are discussed, how real results can be compared with the simulated results, and how a user study evaluates the RadSimTool users' experience.

6.1.1 Research Focus and Questions

The evaluation aims to evaluate the quality of the simulation algorithm and the usability of the RadSimTool website. The focus of the research questions RQ1 is on the accuracy of the simulated races compared to real races and the quality of the generated strength values. With the research questions RQ2, the focus is on the RadSimTool Website's usability with a user study.

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Therefore, the following research questions are defined, and the results are discussed in this chapter.

RQ1: Can cycling races be simulated accurately based on mathematical foundations and formulas, the performance values of cyclists, and other parameters?

    RQ1.1: Can individual time trial races be simulated accurately compared to real result times?

    RQ1.2: Can mass sprints in mass start road races be simulated accurately compared to real sprint results?

    RQ1.3: Can real results be used to generate cyclist's strength values for the usage in the simulation process?

RQ2: Can managers use the RadSimTool website to manage their cycling team?

    RQ2.1: Can managers use the set of tactical instructions to influence their cyclist's performances?

    RQ2.2: Can managers use the website intuitively and find all the necessary information for the races?

    RQ2.3: Can the managers evaluate their cyclist's performances and tactical instructions to learn and improve for the next races?

6.1.2 Research Methodology

Since the evaluation methodology for RQ1 and RQ2 is quite different, the settings and instructions are discussed separately. The evaluation of the quality of the simulated races focuses on the use of the simulation algorithm. In the user study, the usability of the RadSimTool website is evaluated. The focus is on the usage of the website. Therefore, the study participants use the RadSimTool Project website during the evaluation process and are asked a questionnaire afterward.

6.2 Evaluation of RQ1

To evaluate the simulation algorithm's quality, the simulated races are divided into two types of races. One is individual time trials, and the other

one is mass-start road cycling races. Since the focus in this project is on mass start races with sprint finishes, the focus in the evaluation is on races with that particular outcome in the final of the race. Due to each of the two race types' differences, each requires its algorithm to simulate the races. Individual time trials are races alone against the clock and all other cyclists. Every cyclist races independently from other cyclists, and no tactical instructions are used for the simulation process. However, the simulation algorithm for mass start road races requires interactions between the cyclists in the race. The simulation algorithm uses tactical instructions to handle the cyclist's behavior through the race. The following settings and instruments are required for the evaluation of these two different simulation algorithms.

6.2.1 Settings

Whereas the evaluation of time trial races requires real result times and real stage profiles to compare with the simulation algorithm's outcome, the simulation algorithm for individual time trials can handle stage profiles with flat, hill, and mountain terrain. Therefore, the evaluation compares the outcome of two races for each terrain type with the simulation algorithm's outcome. The times will be created for four different cyclists. To evaluate the outcome of individual time trials, the times required during the stages and the average speed are used for comparison. Also, the time differences between the evaluated cyclists during the different races are used. For sprint stages, the evaluation requires only flat stages. Therefore the evaluation focuses on three flat sprint stages and four sprinters. Whereas, in individual time trial races, time is the most important factor for comparison. For the comparison of the sprint results, the compared sprinters' positions are used to evaluate the quality of the results.

6.2.2 Instruments

For the evaluation, the real race profile GPX data is required to use in the simulation algorithm of the RadSimTool. The results are generated with the simulation algorithm. Those results are compared with real results. As the required real-life data, the data are collected from ProCyclingStats[1], and the

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[1]https://www.procyclingstats.com

race profiles are exported as GPX data from the La FlammeRouge² website. The real results and the simulated results are analyzed, and the quality of the simulated results is evaluated.

6.2.3 Procedure to Evaluate RQ1

The focus for RQ1 is the evaluation of the quality of the generated strength values for cyclists and the simulation algorithms. To evaluate the quality of the results for individual time trials and mass start road cycling races with sprint finishes, the generated strength values are used to simulate cycling races with stage profiles from real-life races and compared with the real outcome of the races.

Individual Time Trials
For individual time trial races, the algorithm simulates each cyclist independently since the cyclists' performance is not influenced by other cyclists' tactics. For the evaluation process, six cyclists with different strengths for flat and hill time trial races are selected. To evaluate the cyclist's performances with real races, four individual time trial races are selected from the most important races during 2019. For each of the races, races for all six cyclists are simulated. The results from the RadSimTool Project are compared with the real results for that races. Since for individual time trials, the time and, therefore, the cyclist's average speed defines the individual results for a stage best. The evaluation focuses on those values compared to the real results.

Mass Start Road Cycling Races Mass Sprint Finishes
Since the focus of the evaluation is on the evaluation of flat mass start stages with sprint finishes, the evaluation of mass start cycling races uses total flat profiles without any elevation changes. To evaluate the quality of both the simulated stages and the simulated final mass sprints of those stages, 12 teams with seven cyclists are nominated for the race. For eleven of the teams, the sprinter and three lead-out helpers are defined to provide the race simulation's required tactical instructions. One team is only nominated

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²https://www.la-flamme-rouge.eu

to provide cyclists to increase the average speed for a race. Therefore, the evaluation of the general simulated race focuses on how the pacing cyclists impact the average speed during the race, how fast the limits of the pacing are, and how well those limits are compared to real races.

The second part of the evaluation focuses on the quality of the simulated sprint strength values for the sprinter of the teams and on the quality of the simulated sprint final compared to real mass sprint finals. Therefore, the simulation uses the tactical instructions for the sprint finals to simulate the race result and collect the data for the evaluation.

6.2.4 Results RQ1

For the evaluation of the simulation algorithm, the focus is to evaluate the algorithm for individual time trial races and mass sprint races with mass sprint finishes in the final. Since the RadSimTool Project focuses on the generation of sprint strength values and time trial strength values for flat and hilly terrain, the evaluation uses those strength values to evaluate the simulated races' accuracy with that strength values.

Individual Time Trial
To evaluate individual time trial races' quality, six cyclists for four races are simulated and compared with the real race results. To provide the same setup for the cyclists, the real profile data were used for the simulation of the four races and are shown in Figure 6.1. The simulated races include two stages with hill profiles and two races with almost flat profiles. The evaluation focuses on the total time, average speed, and time differences to the winners of the races to compare the simulated races with the real results. For all races, the same strength values are used for all four races in the simulation. Without the impact of general or daily shape. The real-life race results show how the cyclist's shape impacts the cyclists' performance during the season and even longer races. Three of the four individual time trial races are from the same stage race, whereas the last race is from a previous race in the season, where the cyclists had a different shape to the main race for them.

The evaluation of the first race shown in Table 6.1 shows that the mean difference for the average speed between the real race and the simulated

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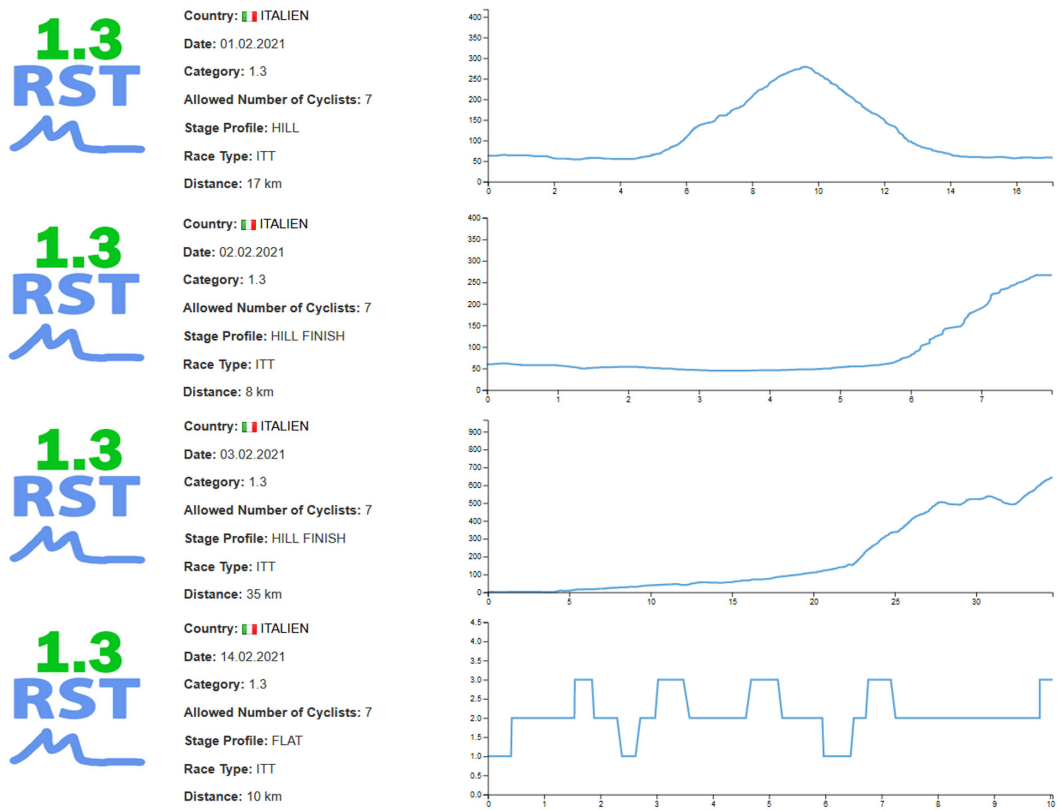
Figure 6.1: Stage profiles of ITT1 at the top, ITT2 (2nd), ITT3 (3rd) and ITT 4 at the bottom.

Name	ITT 1								
	RST			Real			Differences		
	Avg S	Time	Diff	Avg S	Time	Diff	Avg S	Time	Diff
Win	45.63	22:29		46.11	22:07		0.48	00:22	
C1	45.63	22:29	00:00	45.23	22:33	00:26	0.39	00:04	00:26
C2	45.47	22:33	00:04						
C3	45.31	22:38	00:09	45.98	22:11	00:04	0.66	00:27	00:05
C4	44.13	23:15	00:46	44.12	23:07	01:00	0.00	00:08	00:14
C5	43.40	23:38	01:09	43.49	23:27	01:20	0.09	00:11	00:11
C6	43.37	23:39	01:10	45.33	22:30	00:23	1.95	01:09	00:47
Mean	44.55	23:02	00:33	45.04	22:39	00:32	0.60	00:24	00:17
SD	0.96	00:30	00:30	0.94	00:29	00:29	0.64	00:22	00:16

Table 6.1: Evaluation of the first-time trial race (ITT1). The simulation (RST) results and real-life (Real) results for the winner of the races and six cyclists (C1-C6) are listed and compared (Differences). It shows the average speed (Avg S), time, and time difference to the winner (diff) for every cyclist. Mean (M) and standard deviation (SD) show the data analysis for the columns.

race is only 0.603 km/h with a mean time difference for the six simulated cyclists of 24 seconds. The mean time difference cap between the simulated race and the real race is only 17 seconds. Whereas most cyclists have a small time difference, Cyclist C6 has a huge difference in the average speed of 1.95 km/h and, therefore, also a time difference of 1:09. With a mean change of only 0.6 km/h between the real race and the simulated race. It shows that C6 had a sufficient better performance than his time trial strength values. Comparing the other cyclists with their real-life performances shows how close the difference is between those performances and how accurate the race results are, even with C6 performing much better in real life compared to his strength values for the simulation. The mean average speed is 0.6 km/h, still extremely low. C4 has even the identical average speed to his real-life performance, and C5 has a difference below 0.1 in average speed.

Whereas ITT1 was an almost flat stage, with fewer uphill passages, stage ITT2 includes more hill passages. Therefore, it requires better strength values for hill time trial races by the cyclists to achieve a good time. Also, the mean

Name	ITT 2								
	RST			Real			Differences		
	Avg S	Time	Diff	Avg S	Time	Diff	Avg S	Time	Diff
Win	40.18	51:40		40.26	51:52		0.08	00:12	
C1	40.18	51:40	00:00	40.26	51:52	00:00	0.08	00:12	00:00
C2	40.04	51:50	00:10						
C3	39.86	52:16	00:36	40.12	52:03	00:11	0.26	00:13	00:25
C4	38.69	53:39	01:59	37.93	55:03	03:11	0.77	01:24	01:12
C5	37.92	54:45	03:05	37.54	55:37	03:45	0.38	00:52	00:40
C6	38.03	54:35	02:55	39.43	52:57	01:05	1.4	01:38	01:50
Mean	39.12	53:08	01:27	39.26	53:14	01:22	0.49	00:45	00:41
SD	0.95	01:17	01:17	1.12	01:32	01:32	0.47	00:36	00:39

Table 6.2: Evaluation of the second time trial race (ITT2). The simulation (RST) results and real-life (Real) results for the winner of the races and six cyclists (C1-C6) are listed and compared (Differences). It shows the average speed (Avg S), time, and time difference to the winner (diff) for every cyclist. Mean and standard deviation (SD) shows the data analysis for the columns.

average speed for ITT1 was 44.55 km/h in the simulation, and for the simulation of ITT2, it was 39.12 km/h as shown in Table **??**. The evaluation shows that the winning cyclists C1 achieved 40.26 km/h in the real race, with a winning time of 51:52. The same cyclist performed in the simulation at 40.18 km/h and a time of 51:40. The total mean difference in average speed in the evaluation of ITT2 is only 0.4922, with a standard deviation of 0.4676. Since the ITT2 was longer and more difficult, the cyclists' total difference in mean between the simulation and real race was 45 seconds, almost twice as much as for ITT1. As for ITT1, cyclist C6 performed again significantly better in the real race than in the simulated race with the generated strength values. Cyclist C6 performed significantly better, with a 1:38 faster time, cyclist C4 performed significantly slower, with a 1:24 slower time in real life than the simulated race. It shows that where most cyclists perform accurately, the cyclists' profile and shape have a huge impact on the results. However, the general results were again accurately simulated.

Stage ITT3, shown in Table 6.3, is the shortest and the stage with the

Name	ITT 3								
	RST			Real			Differences		
	Avg S	Time	Diff	Avg S	Time	Diff	Avg S	Time	Diff
Win	35.14	13:39		37.21	12:54		2.07	00:45	
C1	35.14	13:39	00:00	37.21	12:54	00:00	2.07	00:45	00:00
C2	35.04	13:41	00:02	35.91	13:22	00:28	0.87	00:19	00:26
C3	34.82	13:46	00:07	34.83	13:47	00:53	0.01	00:01	00:46
C4	33.69	14:14	00:35	36.32	13:13	00:19	2.63	01:01	00:16
C5	32.86	14:36	00:57	35.91	13:22	00:28	3.05	01:14	00:29
C6	33.19	14:27	00:48	36.14	13:17	00:23	2.95	01:10	00:25
Mean	34.12	14:04	00:25	36.22	13:16	00:22	1.95	00:45	00:20
SD	0.92	00:23	00:23	0.77	00:17	00:17	1.045	00:25	00:15

Table 6.3: Evaluation of the third time trial race (ITT3). The simulation (RST) results and real-life (Real) results for the winner of the races and six cyclists (C1-C6) are listed and compared (Differences). It shows the average speed (Avg S), time, and time difference to the winner (diff) for every cyclist. Mean and standard deviation (SD) shows the data analysis for the columns.

hardest climb. The stage is noticeably short, and on the first day of one of the most important races, where the best cyclists see their chance for a victory and wear the leader jersey for the next stages. Therefore, the best cyclists performed significantly better than in the other races compared to the simulated results. Since the simulation uses an algorithm where the cyclists don't empty their energy tank, that might explain the time differences. The winner was 2.07 km/h faster than in the simulation, and the total mean difference in average speed was 1.948 km/h. Only cyclist C3 performed not above his simulated time. Cyclist C3 achieved 34.82 km/h in the simulation and 34.83 km/h average speed in the real race with only a difference of 0.008 km/h. Whereas the other cyclists were all aspirants for the overall victory, cyclist C3 has other aspirations and might not be performed above his critical power as much as the team leaders. The evaluation of ITT3 shows that optimizing the simulation algorithm to simulate cyclists using more power and empty their energy tank throughout the race could increase such races' quality.

Name	ITT 4								
	RST			Real			Differences		
	Avg S	Time	Diff	Avg S	Time	Diff	Avg S	Time	Diff
Win	52.59	11:18		52.71	11:23		0.12	00:05	
C1	52.59	11:18	00:00	51.72	11:36	00:13	0.87	00:18	00:13
C2	52.42	11:20	00:02	52.09	11:31	00:08	0.33	00:11	00:06
C3	52.28	11:22	00:04	52.71	11:23	00:00	0.43	00:01	00:04
C4	51.1	11:38	00:20						
C5	50.42	11:47	00:29						
C6	50.27	11:49	00:31	50.07	11:59	00:36	0.2	00:10	00:05
Mean	51.51	11:32	00:14	51.86	11:34	00:11	0.39	00:09	00:06
SD	0.96	00:13	00:13	0.97	00:13	00:13	0.26	00:06	00:04

Table 6.4: Evaluation of the fourth time trial race (ITT4). The simulation (RST) results and real-life (Real) results for the winner of the races and six cyclists (C1-C6) are listed and compared (Differences). It shows the average speed (Avg S), time, and time difference to the winner (diff) for every cyclist. Mean and standard deviation (SD) shows the data analysis for the columns.

Whereas the races ITT1, ITT2, ITT3 were part of the same stage race, and the cyclists had similar shapes, ITT4 was earlier in the same season. Therefore, many athletes used that race as preparation to get a good shape for the stage race with the other three time trials. The details are shown in Table 6.4, and with an almost flat profile and a distance of 10km, it is also one of the easier time trials. However, since the profile is almost flat and short, it suits another cyclist than the previous time trials. C3 was so far only faster in ITT1 than the other evaluated cyclists in the real races. C3 won ITT 4 and performed with 52.71 km/h and achieved a time of 11:23. Whereas in the simulation, C3 achieved a time of 11:22 and an average speed of 52.28 km/h. However, in the simulation, C1 won with a time of 11:28, and C2 was second with a time of 11:20. C3 performed in the real race only 1 second slower than in the simulation. The other cyclists, who were earlier in the season with the focus to use the race to improve their shape for the main stage race a few months later, performed all at least 10 seconds slower in the real race than their simulated results. The total mean difference for

the participating cyclists' average speed was 0.387 km/h, the lowest mean difference for all evaluated races. And with only a mean time difference of 9 seconds, it shows how close the simulated results are to the real ones.

Mass Start Cycling Races Sprint Finish
Typical mass start cycling races with sprint finish have either flat or hill profiles, with enough distance left after the last difficult hill. The teams who work with their helpers for a mass sprint to control the race and catch the cyclists early enough to allow their sprinters to sprint for the victory in the race's finish. To evaluate the quality of the simulated mass start races and mass sprint finishes with the RadSimTool Project, the evaluation is divided into two parts. The first question is how well the general race is simulated to similar real races. The second question is how good the simulated sprint finals are and how realistic they are compared with real sprint finishes.

For the evaluation of the general quality of the simulated races, the same flat race over 230 kilometers is simulated with four different settings as shown in Table 6.5. The first one with no helpers pacing during the stage, leading to only default pace. This setting led to a total time of 06:08:20 and an average speed of 37.48 km/h. The second setting included six cyclists pacing with 80 percent average intensity during the stage for 215 kilometers. Eighty percent defines 80 percent of the maximal possible power output for cyclists. That resulted in a total time of 05:17:08 and an average speed of 43.52 km/h. In the third set, the pacing cyclist used 87.5 average percentage intensity, leading to a total time of only 05:08:21 and an average speed of 44.77 km/h for the race. Whereas setting four with 90 percent intensity led to a time of 05:37:42, the average speed was 40.87 km/h.

Helpers	Intensity	Time	Avg Speed
0	0	06:08:20	37.48
6	80	05:17:08	43.52
6	87.5	05:08:21	44.77
6	90	05:37:42	40.87

Table 6.5: Required time and average speed for a 230 kilometers flat stage with sprint final, depending on the amount and intensity of used pacing cyclists.

Whereas part one evaluated the general quality of the mass start cycling

races, the second part focuses on the evaluation of the sprint finals itself and the quality of the results. Therefore, three sprinters S1, S2, and S3, are compared with each other for five stages of the same stage race shown in Table 6.6. These three sprinters managed to win together with all the five sprint stages. Whereas sprinter S1 won three of the five stages, S2 and S3 won only one stage during the stage race. Therefore, S1 has a mean final position of 1.6 for the five stages. S2 has a mean of 2.6, and S3 has a mean of 3 for the five stages.

Evaluating the simulated race results with no random daily shape, sprinter S1 beats S2 and S3 since he has the best strength rating for the whole season. Whereas S1 won the simulated race in the RadSimTool Project, S3 finished in place 3, in front of S4, who finished in place 4. It shows that in real life, the performance varies over the different stages. Since there are no random daily shape values that impacted the simulation, it shows how close the real results are to the generated results, considering that the year's best cyclists took part in the simulated race. However, several of those cyclists did not participate in the real race, and only one sprinter managed to reach a better result than cyclist S2 and S3.

	RST	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Mean
S1	1	3	2	1	1	1	1.6
S2	4	5	1	2	3	2	2.6
S3	3	1	6	3	2		3

Table 6.6: Sprint results for the cyclists. The first result is the simulated race from the RadSimTool and the other the five are real stages.

6.2.5 Discussion RQ1

Answering RQ1 and discussing the results of the evaluation for RQ1 and its subquestions, the evaluation results are discussed. Therefore, the simulated results for individual time trial races and mass start races with sprint finishes are compared with real race results. Those are required to be able to answer the questions about the quality of the simulation algorithms. To answer RQ 1.3, the focus is on the generated strength values for cyclists, which are used to simulate the different races.

RQ 1.1 - Quality of Individual Time Trial Races
To evaluate the quality of individual time trial results, the results of four simulated individual time trials are compared with the real-life results for those races. Table 6.7 shows that the evaluation of the four individual time trial races has a total mean difference in average speed overall races of 0.857 km/h with a standard deviation of 0.605 km/h. Also, the total mean time difference of 31 seconds with a standard deviation of 22 seconds comparing the real times with the simulated times for the cyclists shows how accurate the simulated race results are compared to the real race results. However, whereas three of the races had a mean average speed difference below 0.6 km/h, ITT3 has a huge difference of almost 2 km/h. The stage is noticeably short but with a hill finish and the first stage of one of the three most important stage races of the season. The leader of the teams seemed to perform a lot over their average performance. However, other cyclists like C3, who have no focus on the general classification, performed almost exactly as fast in the simulation and real-life with only 0.008 km/h difference in speed and 1-second time difference for the race.

	Differences		
	Avg Speed	Time	Diff
Mean	0,8577	00:31	00:21
Std Dev	0,6052	00:22	00:19

Table 6.7: Total differences between the simulated and the real race results.

The evaluation shows that since the strength values are calculated over a wider range, including several time trial results. The cyclist in real life showed a huge performance improvement with the shape peak. However, since the shape varies over the real race result, it shows that the cyclists' strength values are accurate enough to simulate accurate time trial races with realistic performances of the cyclists. Since the simulation did not include the influence of general or daily shape, the inclusion of shape might lead to a similar performance variation as in the real races. Therefore, it shows that the simulation algorithm for time trial races can be used to simulate races accurately. And since the simulated cyclists performed close to the real-life races, the strength values calculated for time trial races are accurately enough to simulate the races with them.

RQ 1.2 - Quality of Mass Start Races with Sprint Finals
To answer RQ 1.2, if mass sprints in mass start cycling races can be simulated accurately, the evaluation focused on two parts. The first part was the evaluation of the general races, and the second part is the evaluation of the sprint results itself. The results of the general simulation of mass start races showed how the pacing cyclists' number and their pacing intensity affect the total race time and, therefore, the average speed of the races shown in Table 6.5. Whereas no cyclists increased the default pace in setting one, the average race speed was 37.48 km/h. However, increasing the pace with eighth cyclists increased the average speed already to 43.52 km/h. The total race time was only 05:17:08 compared to the 06:08:20 with no pacing cyclists, which was significantly faster.

Therefore, the leading cyclist is using anaerobic energy. However, since the cyclists rotate and change the lead after short intervals, it allows the cyclists to recover during their lead breaks. That shows how good the simulation works since only six cyclists rotating as pacemakers in the main field lead to a significantly lower race time. With this setting, the cyclists still could recover enough to keep in the main group. However, with the fourth setting, the cyclists could not recover enough anymore to hold the pace for the whole race, with only six cyclists rotating and pacing in front of the group. Ninety percent average intensity lead to a drop off from the pacing cyclists, and the race was significantly slower than setting two and three. The race time increased to 05:37:42, and the average speed to 40.87 km/h.

To evaluate these settings' realism, the results are compared to the flat and hill sprint stages of the real Giro d'Italia with mass sprint finishes. The required data is collected from the ProCyclingStats[3] website. The analysis of those seven stages leads to the mean, maximum, and minimum average speed and distance for those seven sprint stages shown in Table 6.8. A maximum average of 44.99 km/h for the real races, compared to 44.77 km/h for the simulated race, showed that the general simulated races are remarkably close to the real results. The minimum average speed of 40.26 km/h is close to setting four. The mean average speed for the seven sprint stages was 42.24 km/h.

Since the evaluation of the race results showed how close the real results are to the simulated result, the evaluation of the simulated sprinters' per-

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[3]https://www.procyclingstats.com

	Amount	km	Avg Speed
mean	7	199	42.24
max	7	239	44.99
min	7	140	40.26

Table 6.8: Real-life maximum, minimum and average for the distances and average speed for seven Giro d'Italia stages from 2019.

formance data is compared with the performance data of real sprinter RS1 through the final 500 meters of a sprint race. The real performance data and Figure 6.2 are from an article on the SRM - Schoberer Rad Messtechnik website (SRMTrainingsSystem, 2014). The figure shows the stage winner's performance of one of the most important stage races during the season. Whereas the power (watt) is visualized in green, the speed (km/h) is visualized in pink, and the cadence(rpm) is visualized with the blue line. It shows how the cyclist has a short increase of power output before starting the final sprint in the last 15 seconds. The cyclist manages to achieve a short peak above 1,600 watts and manages the power output above 1,350 watts until shortly before the finish. The average power over the last 500 meters is 983 watts, and the cyclist achieves an average speed of 62 km/h. during the last 15 seconds, the speed increases up to 65 km/h.

Figure 6.3 shows the performance data of the best sprinter S1 of the simulated sprint stage with the RadSimTool Project. It shows the last 2 kilometers, where the Lead Out Trains and the sprint itself are simulated. The blue line is the speed (km/h), the yellow line is the energy tank (W'_{bal}), and the power output (watt) is visualized in red. The figure shows how the finish speed increases from 45 km/h up to 70 km/h in the last seconds of the race. It shows how the speed increases with each new helper of the sprinter until the sprinter reaches the maximum in the final. The yellow line shows the energy tank of the sprinter S1. It starts to empty with the increased tempo. However, since the sprinter is behind the helpers, the energy can slightly recover as he has a short phase with lower power output before the sprint starts. The power output reaches its maximum above 1,500 watts. After the first peak, the sprinter manages to keep the level slightly above 1,500 watts, and the yellow line shows how the energy tank empties until the cyclist reaches the finish line.
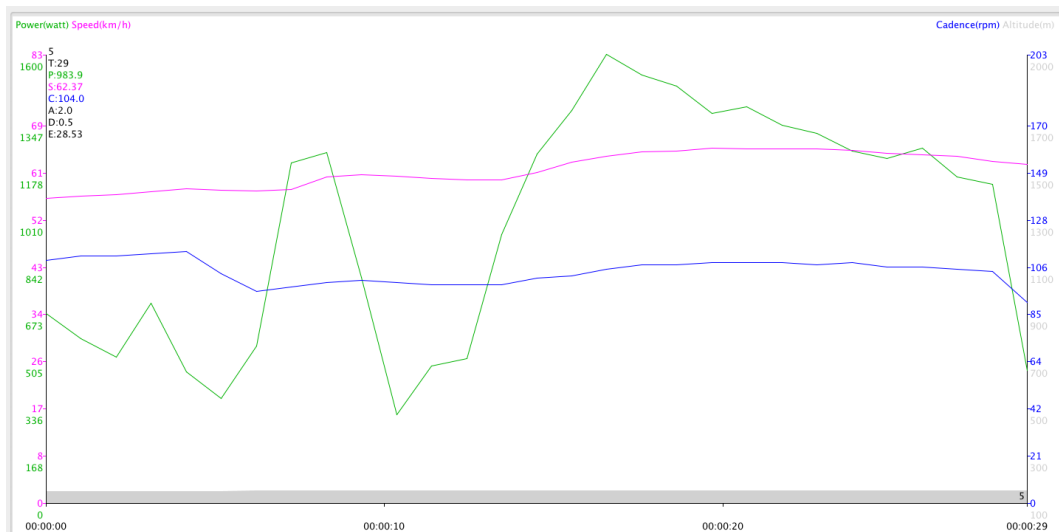
Figure 6.2: Performance data of a Real Cyclist from 2014. It shows the cadence in blue, speed in pink and power in green over the last 500 meter of the stage. (SRM-TrainingsSystem, 2014)

Comparing and analyzing Figure 6.3 and Figure 6.2 shows the similarities of the simulated race and the real sprint final. It shows how similar the sprinter's power output behaves during the final seconds of the race. The evaluation shows how accurate the simulated sprint is compared to the real sprint final.

The evaluation of both parts shows how close the general race time and average speed are compared with real races. It also shows how similar the simulation of the sprinters' power output is to the real ones and how close the sprint results are compared with real-life. Therefore it shows, how accurately the algorithm simulates mass sprint finals in mass start road cycling races.

RQ 1.3 - **Quality of Generated Strength Values**

To answer the question, if real results can be used to generate cyclist's values, that can be used in the simulation process. The simulated results for both individual time trial races and mass start races with sprint finishes were compared with real-life performances. The evaluation showed how close the results are compared with real results, and therefore it shows how well
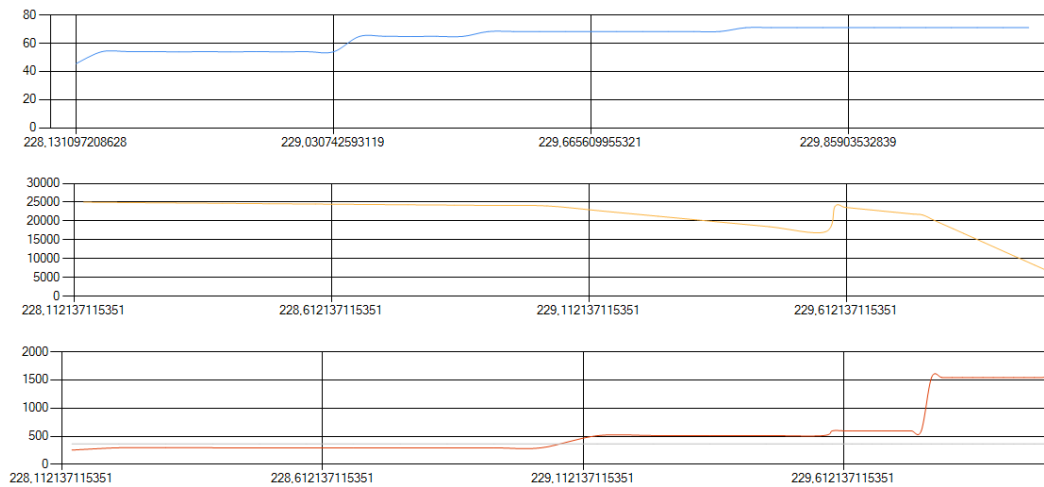
Figure 6.3: Performance data for the winner of the simulated race. The last two kilometers of the race are visualized, with the speed in km/h in blue, the energy tank in yellow and the power in watt in red.

the generated values can be used to realistic simulated races.

6.3 Evaluation of RQ2

For the evaluation of the usability and the user experience with the RadSim-Tool Project, the participants shall pay the RadSimTool game. They must create their team and manage it during the time of the evaluation. To set up the user study with the RadSimTool website, the following settings and instruments were used.

6.3.1 Settings

A brief introduction with information about the RadSimTool and tasks to get started is given to every participant. To create a race program for the participants to compete against the other participants, the race editor is used to create ten different cycling races.

6.3.2 Instruments

For the evaluation of the usability of the RadSimTool website, the user study requires the usage of different tools. The main tool to evaluate the game website is the RadSimTool website, which the participants use to manage their teams. To simulate the cycling races, the simulation engine and algorithms for generating the strength values are used to generate the results. After the last race is simulated, a final questionnaire is sent to the participants to collect information about their experience with the RadSimTool game and website. For the questionnaire, Lime Survey [4] is used to provide the participants the questionnaire.

6.3.3 Questionnaire

After the evaluation process, where the participants use the RadSimTool Project for ten days, they must answer an online survey with demographic questions (A, B), questions for the system usability scale (SUS) (Brooke, 1996), and a questionnaire about their experience with the RadSimTool game and feature (C, D).

A: General Questionnaire with demographic questions.

    A01: Your Manager Name in the Evaluation
    A02: Name of your Team in the Evaluation
    A03: Age
    A04: Do you have any experience with professional cycling races?
    A05: Do you have any experience with manager games?
    A06: Do you have any experience with cycling games?
    A07: Profession
    A08: Field of Study / Job title
    A09: What features would you like to have in the RadSimTool Project to have more fun and a better experience?

B: Questionnaire for more demographic information about the experience of the participants.

    B01: I am an expert in computer usage.

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[4]https://www.limesurvey.org

B02: I am an expert in the usage of video games.

B03: I am an expert in sport manager games.

B04: I am an expert in professional road cycling races (watch/follow them).

B05: I often play video games.

B06: Have you heard about the RadSim05?

B07: Have you heard about the Pro Cycling Manager game?

After the questionnaire for demographic information about the participants, like their age and experience with cycling, video games, manager games, or even cycling games, the system usability scale (SUS) contains ten questions. The SUS was designed by John Brooke in 1986 and further described as a chapter in a book (Brooke, 1996). The SUS provides an indicator for the usability of a system. To calculate the final score, the possible answers range from 1 to 5. For calculating the SUS score between 0-100), the individual results are modified since odd questions are positive indicators, and even questions are negative ones. Therefore, the score for odd questions is reduced by one, and the score for even numbers is calculated by $5 - score$. The sum over all those modified scores is calculated for each participant, and the mean overall participants give the final usability score.

SUS: Questionnaire for the system usability scale (SUS).

SUS1: I think that I would like to use this system frequently.

SUS2: I found the system unnecessarily complex.

SUS3: I thought the system was easy to use.

SUS4: I think that I would need the support of a technical person to be able to use this system.

SUS5: I found the various functions in this system were well integrated.

SUS6: I thought there was too much inconsistency in this system.

SUS7: I would imagine that most people would learn to use this system very quickly.

SUS8: I found the system very cumbersome to use.

SUS9: I felt greatly confident using the system.

SUS10: I needed to learn a lot of things before I could get going with this system.

C: Questionnaire about motivation and realism of the RadSimTool.

C01: The RadSimTool game motivated me.
C02: Winning races motivated me.
C03: Optimizing tactical instructions for races motivated me.
C04: Evaluating the outcome of races and cycling performances motivated me.
C05: I had the feeling that tactical instructions matter.
C06: I find the race results for mass start road races realistic.
C07: I find the race results for individual time trials realistic.
C08: I liked the strength values for the different cyclists.
C09: What would you change for the cyclist's strength values.

D: Questionnaire about the likes and dislikes of the RadSimTool key features.

D01: I liked the general website navigation. (Menu Bar, Click on Teams, Cyclists and Races)
D02: The team overview page helped me manage my team.
D03: I liked the cyclist's list at the team overview page.
D04: I liked the cyclist's strength values list at the team overview page.
D05: I liked the race calendar page.
D06: The race overview page helped me.
D07: The race profiles helped me to manage my team for the races.
D08: I find the nomination process intuitive to use.
D09: What would you change to make the nomination process for races more pleasant?
D010: The stages list was helpful for me.
D011: The start list helped me manage my team for the races.
D012: The tactics section is easy to use.
D013: What would you change in the tactics section?
D014: The results page helped me to manage my team for the next races.
D015: What would you wish to understand the outcome of the race better?
D016: The cyclist's overview page helped me to get a good overview of the different cyclists.
D017: Did you use the race planer section at the cyclist's overview page?
D018: The race planer at the cyclist overview page was useful for me.
D019: What would you change on the Cyclists Season Planer Page?

6.3.4 Procedure to Evaluate RQ2

For the RadSimTool project user evaluation, a race calendar was created with ten cycling races within ten days for the participants. Half of the races focus on individual time trial races, with no required tactical instructions and different stage profiles. All ten stage profiles are fantasy races with GPX profiles created with Bikemap. [5] The five-time trial stages are based on a profile with GPX data. One of the time trials is almost flat, two of the time trials are hill races, and two are mountain stages for the time trial races. All five flat stages are most likely sprint finishes, where it is required from the managers to set up a lead-out train for every race and try to finish as well as possible with their best sprinter. However, the instructions set to allow the managers to perform all kinds of different tactics throughout the race and try to win the races differently.

A set of instructions and information about the study and the RadSimTool project is sent to every participant. Participants must register on the RadSim-Tool website with a new account. After registration, all participants created their cycling team, choosing a team name, short team name, and the country of the team they create. For every team, 20 random cyclists are created randomly based on the data set from 2019 with strength values created for time trial flat, time trial hill, flat and sprinting. The participants then use those cyclists to participate in the ten created races for the evaluation. At the end of the evaluation, the users got a questionnaire about their experience with the RadSimTool game. Those results are discussed in the following sections.

Study Participants

To evaluate the usability of the RadSimTool website and to be able to answer the Research questions RQ2.1 - RQ2.3, the system was evaluated by 12 participants. Table 6.9 shows the participants' demographic and their experience with cycling or manager games. Figure 6.4 visualizes the answers for questionnaire B about the user expertise. The questions in these categories were Yes/No questions, or participants had to rank between 1 and 5. All the participants were male with ages between 19 and 37 (M = 30.33; SD = 4.2). Whereas most participants had no experience with professional

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[5]Bikemap: https://www.bikemap.net

cycling races (9/12), more than half of the participants (7/12) had experience with manager games, and four of the participants (4/12) have played cycling games before. Therefore, the participants are divided into two experience groups, participants with no Experience (UnExp) and participants with great experience (Experts).

Question B01, about the participant's computer usage expertise, was answered with a mean of 3.83 (SD of 0.99). Also, for question B02, the expertise with using video games (M = 3.83; SD = 1.14) was almost identical to B01. However, their expertise in sport manager games (B03 - M = 3; SD = 1.58) was slightly lower. Whereas some of the UnExp participants had some experience with sport manager games, they answered question B04 about their expertise about road cycling races as 1. On the other hand, three of the Experts rated their expertise with five and one with 3. That leads to a mean for all users of 2.17 with an extremely high standard derivative of 1.72. Question B05 showed that the participants often play video games with a mean of 3.5 (SD = 1.19). All the participants in the Expert group have heard about the Pro Cycling Manager game and the RadSim05. In comparison, none of the UnExp participants had ever heard of those games.

6.3.5 Results RQ2

After the evaluation process, where 12 participants played the RadSimTool game for ten days, they created and managed their teams. The questionnaire asked the participants can be used to answer RQ2 if managers can use the RadSimTool website to manage their cycling team. The questionnaire about the usability of the RadSimTool provides us with enough feedback from the participants to answer RQ2.1 - RQ2.3.

Table 6.10 shows the list of the races for the user evaluation and gives an overview of the races, participants, race profile types, problems, and result quality for the races. Only two teams were not nominated for each of the races. Whereas, for eight races, the simulation algorithm worked well and calculated good results. However, for two of the races, tactical instructions caused bugs in the simulation. Those bugs led to problems in the final results and had to be solved before the final simulations.
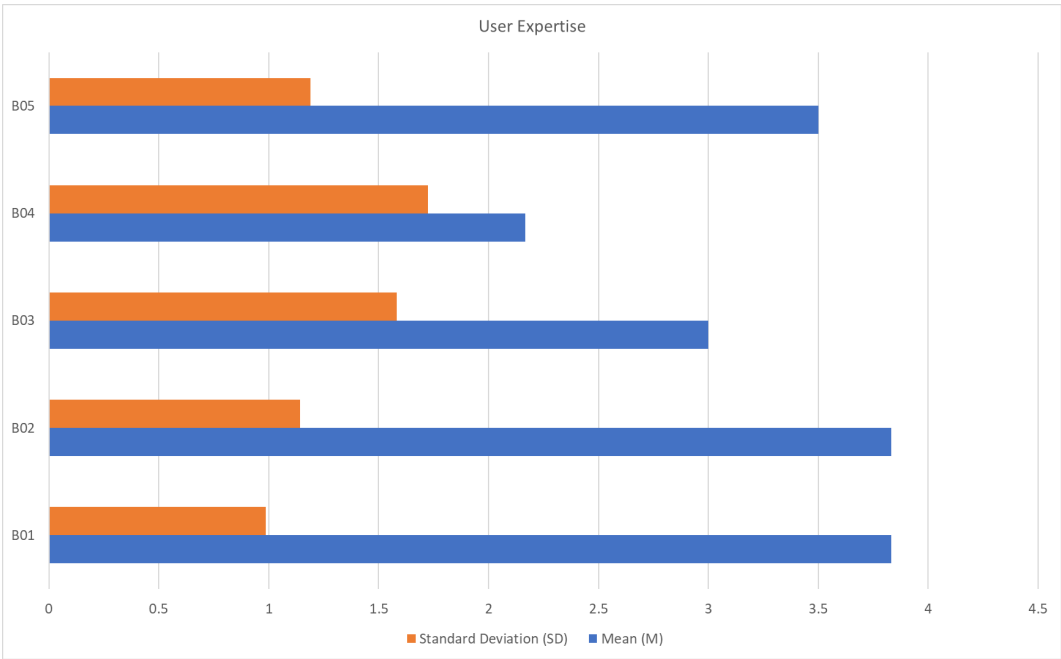
Figure 6.4: Mean (M) and standard deviation questionnaire B about the user experience.

Name	Age	A06	B01	B02	B03	B04	B05	B06	B07
Player 01	30	YES	3	2	1	1	3	NO	NO
Player 02	37	NO	5	5	3	1	5	NO	NO
Player 03	32	YES	3	2	3	5	3	YES	YES
Player 04	32	YES	5	5	5	5	5	YES	YES
Player 05	30	NO	4	5	5	1	5	NO	NO
Player 06	31	YES	5	5	4	3	4	YES	YES
Player 07	29	NO	3	2	1	1	1	NO	NO
Player 08	30	YES	3	4	5	5	4	YES	YES
Player 09	32	NO	5	4	1	1	2	NO	NO
Player 10	19	NO	4	4	1	1	3	NO	NO
Player 11	35	NO	4	4	4	1	4	NO	NO
Player 12	27	NO	2	4	3	1	3	NO	NO
Mean	30.33		3.83	3.83	3	2.17	3.5		
SD	4.25		0.99	1.14	1.58	1.72	1.19		

Table 6.9: Demographic of the participants and their experience with cycling or manager games.

Race #	Type	Profile	Teams	Problems	Results
1	ITT	Flat	11/12	Little	Good
2	RR	Flat	12/12		Good
3	ITT	Hill	12/12		Good
4	ITT	Mountain	12/12		Good
5	RR	Flat	12/12	Simulation Bugs	OK
6	RR	Flat	12/12	Simulation Bugs	OK
7	RR	Flat	12/12		Good
8	ITT	Hill	11/12		Good
9	RR	Flat	12/12		Good
10	ITT	Mountain	12/12		Good

Table 6.10: Races of the user study. It shows, the race type (RR/ITT), profile type, participants, problems and result quality for the races.

Problems and Experience during Race 2

Race 2 was a flat stage with a great likelihood for a mass sprint at the end

of the race. Since it was the first race of that type, the participants were careful with their tactical instructions, and only a few cyclists tried to attack at the front, which leads to several group buildings throughout the race. Some groups merged, and the main group captured others with the pacing helpers for the best sprinters. That lead to a very small group being able to reach the last kilometers, however, the lead-out trains could manage to pick them up at the final kilometers, and the stage ended with a mass sprint where the best sprinters finished first. One participant with one of the best sprinters in the field used the instruction "captain" instead of "sprinter", which lead to a missed opportunity since the sprinter did not sprint in the final. It was also the first race, with all participants nominating a team and taking part in the race. A video was created and linked for the participants on the RadSimTool Website. The video allowed the users to get a deeper insight into the different race situations. It showed what impact their tactical instructions had on the outcome of the race.

Problems and Experience during Race 5
After two individual time trials, race 5 was an almost flat race that should lead to a mass sprint finish if the teams acted correctly and manage to control the race. Whereas at the first mass start race, the participants did not try many different tactical instructions, in this race, many participants tried to do some things differently. That leads to several problems during the stage. One problem was that a participant instructed the team to do two instructions at the same area of the race. That lead to the same cyclist first pacing in the field, then following attacks, and quickly after going back to pacing in that breakaway group instead of following the attacking cyclists further. That made them drop the group and fall back into the peloton. Due to a too big-time interval at the start, the group's cyclists were not collected by the main group. Instead, they felt through the group and ended at the back of the race. Therefore they finished far behind the rest of the field.

An incorrect tactical instruction created another problem. One manager instructed a cyclist to increase the pace twice with the same tactical instruction, which leads to a problem during the simulation. The cyclist was handled twice at every time step and finished in front of all other cyclists. Therefore, the race had to be created again, and several bugs had been removed from the system. After the race was correctly simulated, the result

was quite good, the top sprinters finishing in the front.

Problems and Experience during Race 6
Race 6 was a flat mass start race with a possible sprint outcome. That motivated the participants to try even more different things, and some of the participants tried to declare more than one sprinter for their lead-out train. That leads to a simulation error, where the lead-out cyclists were simulated twice at each time step. Therefore, the cyclists got away from the group and finishing the race 20 seconds ahead of their sprinters. After that problem was solved, the simulated race was quite accurate. However, one cyclist finished quite better than his potential. However, in real cycling races, there are many factors during sprints that might lead to surprises in the final. All 12 participants nominated their teams for the race.

System Usability Scale (SUS)
The SUS score rates between 0-100 and a score above 68 are above average. The scores are structured into five categories. Below 51 is an "Awful" rating, 51-67 is a "Poor" rating, 68 is "OK", 68-80.3 is "Good", and everything above 80.3 is an "Excellent" ranking. The results for the usability evaluation with the system usability scale (SUS) are shown in Table 6.11 and visualized in Figure 6.5. The mean SUS score of 71.04 and a standard derivative of 16.02 showed that there was a high discrepancy between the different participant groups. 7 of 12 participants evaluated the usability with 75+ points, whereas 5 participants only scored the usability under 65 points. Even though most of them evaluated the usability around 60 points, one participant evaluated the usability with only 32.5 points exceptionally low. That might be to the lag of experience in cycling of the user. Together with no tutorials about the different tactical instructions and no details about the different race situations and how the tactical instructions impacted the race.

Whereas the Expert users with experience in cycling races and knowledge about the most common tactical behavior of cyclists and teams during sprint stages evaluated the system over 80 points with a mean of 82.5 points for the SUS and 1.77 standard deviations. Since all the participant's native language was German, some had problems with the SUS questionnaire. Especially with words like "cumbersome", which lead to at least one expert answering Q8 of the SUS questionnaire not as intended.

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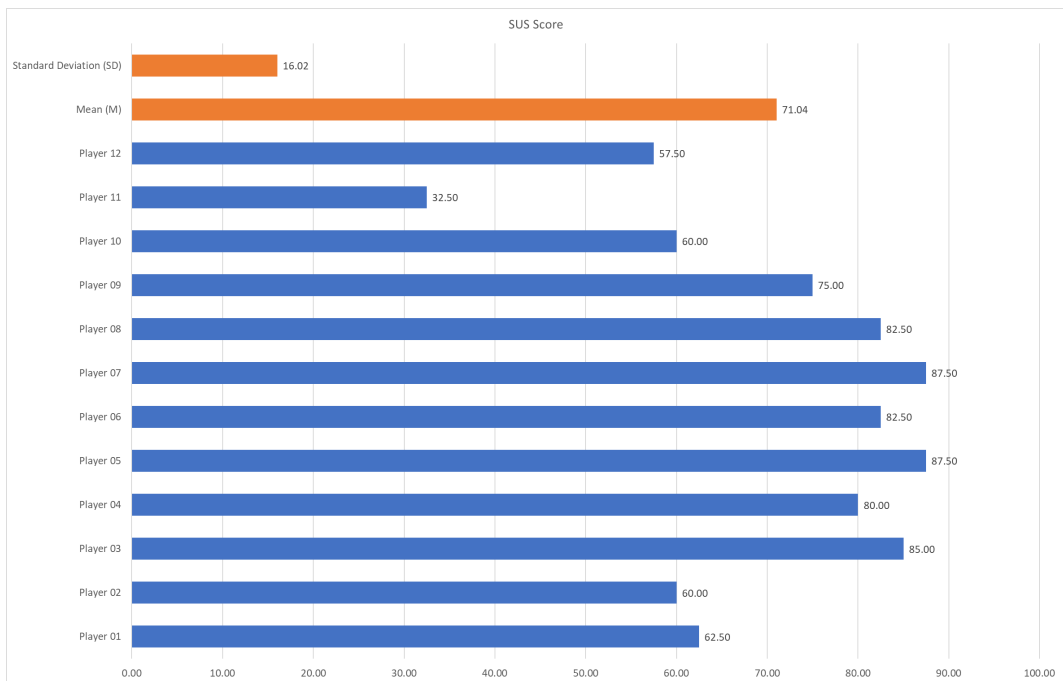
Figure 6.5: The score for all participants in blue, mean (M) and standard deviation in orange for the system usability scale (SUS) questionnaire

Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS
Player 01	2	3	2	3	3	3	3	1	2	3	62.5
Player 02	2	2	2	3	3	3	2	3	2	2	60
Player 03	4	3	4	4	4	3	3	3	3	3	85
Player 04	3	3	3	4	3	4	4	1	3	4	80
Player 05	3	3	3	4	3	3	4	4	4	4	87.5
Player 06	3	4	3	4	3	3	3	3	4	3	82.5
Player 07	2	4	4	4	3	4	3	4	4	3	87.5
Player 08	3	4	2	4	4	4	4	0	4	4	82.5
Player 09	3	3	2	4	2	3	3	4	3	3	75
Player 10	1	2	2	1	3	3	3	3	2	4	60
Player 11	0	1	1	3	2	2	1	0	1	2	32.5
Player 12	2	2	2	1	4	3	2	2	2	3	57.5

Table 6.11: Individual system usability scale (SUS) for each participant.

Questionnaire C - Problems and Wishes for Strength Values
For Questions C01 - C08, focusing on motivation and how they liked the strengths of the cyclists or the results. The mean (M) and standard deviation (SD) results for these questions are visualized in Figure 6.6. The mean for all questions was for all questions around 3.5 (SD = 1.04). Meaning that except for one participant, only two participants did not find the game motivating. And only 3 of 12 participants (25

Whereas the first questions of set C focus on motivation, question C09 asked the participants what they would like to change on the cyclist's strength values. The answers and wishes of most participants were similar. Most participants would like to see more different strength values, like mountain, hill, attacking, downhill values. Also, different stamina values or daily shape. Whereas daily shape was part of the simulation, it was not shown to the participants in the results and made it hard for them to understand their impact. Training and experience increase were other ideas for future features. However, especially participants who did not get good cyclists for their teams wanted to see an equal distribution across the different cyclists' quality when they create their team for the first time. Since some teams had no or only one cyclist with sprint strength values above 60 and others had the same issue with time trial values, they found big
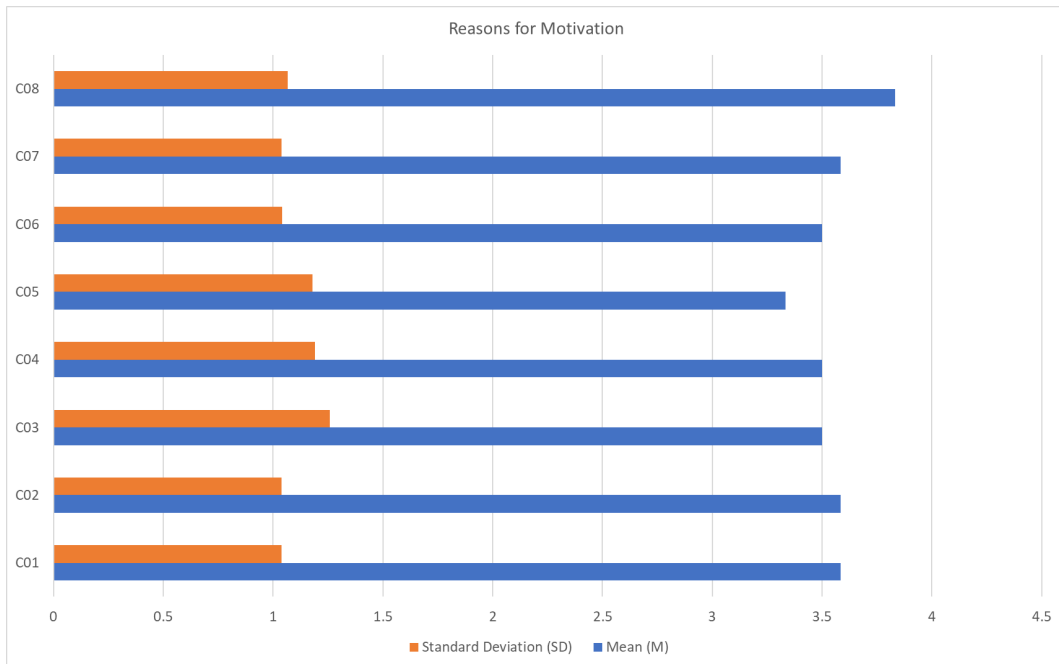
Figure 6.6: Mean (M) and standard deviation for questionnaire C about how the particpants liked the key features of the website.

differences between their cyclists and the top cyclists who had chances to win the races.

Questionnaire D - Evaluating the RadSimTool Website Key Features
Questionnaire set D included questions about how well the participants liked the different key features of the RadSimTool website. They were asked to rate how much they liked the key features of the website. Including features like the general navigation, team overview page, cyclist overview page, race overview page, race calendar page, race profiles, nomination page, result page, or the start list page. Table 6.13 shows questions D01-D08, and Table 6.13 shows questions D10-D18. The mean (M) and standard deviation (SD) for each question are visualized in Figure 6.7 For each of these questions, the mean was around 4, except for one participant being unhappy. The only parts the user rated above 2 were questions D04 and D08. Question D04 was the strength value list on the team overview page,

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and question D08, the intuitively of the nomination process for races.

Question D09 asked the participants what features they would like to see or what would help them nominate their team more easily. Almost all recommendations include that the nomination page does not show the strength values for the team's cyclists. Therefore, it was difficult to know what cyclists to nominate without switching between the team overview page and the race nomination section to nominate the teams.

The only questions with mean scores around 3.0 and 3.4 were D10, D11, and D12. D10 asked if the stages list was helpful for the races. However, since there were only races with single stages, that section did not offer a lot of additional information for the races, leading to this score. For question D11, if the start list helped the participants manage their teams for the races. The short period of ten races was one reason why the participants did not require to learn much about other cyclists and needed to know who is taking part in the races.

Name	D01	D02	D03	D04	D05	D06	D07	D08
Player 01	4	5	4	5	5	4	5	4
Player 02	4	3	4	4	4	4	4	4
Player 03	5	5	5	5	5	5	5	5
Player 04	3	5	4	4	5	5	5	3
Player 05	5	4	5	4	5	4	3	1
Player 06	5	5	2	4	5	5	5	5
Player 07	5	4	5	5	5	3	4	5
Player 08	3	5	5	5	4	5	4	4
Player 09	3	5	4	5	4	4	5	4
Player 10	4	5	4	4	5	4	4	3
Player 11	2	2	2	3	1	1	1	4
Player 12	4	4	3	4	4	4	4	5
Mean	3.92	4.33	3.92	4.33	4.33	4	4.08	3.92
SD	0.95	0.94	1.04	0.62	1.11	1.08	1.11	1.11

Table 6.12: Results of the questionnaire set D part 1.

Name	D10	D11	D12	D13	D14	D15	D16	D17	D18
Player 01	4	3	2		4		4	YES	4
Player 02	3	3	2		4		3	NO	3
Player 03	5	5	4		5		5	YES	5
Player 04	4	3	3		4		4	YES	5
Player 05	3	1	3		3		5	YES	4
Player 06	5	5	4		4		3	NO	3
Player 07	2	1	4		3		5	NO	3
Player 08	4	4	5		5		5	YES	2
Player 09	1	5	2		4		4	NO	1
Player 10	4	4	3		4		4	YES	4
Player 11	2	3	2		1		2	NO	1
Player 12	4	3	4		4		4	NO	2
Mean	3.42	3.33	3.167		3.75		4		3.08
SD	1.19	1.31	0.99		1.01		0.91		1.32

Table 6.13: Results of the questionnaire set D part 2.

Questionnaire D - Tutorials for Tactical Instructions

D12 was another lower-rated question. It asked the participants if the tactic section is easy to use. With a mean score of only 3.167 (SD=0.986), the question scored the lowest of all questions in questionnaire D. As for question D13 shows, many of the participants had problems understanding what the different tactical instructions mean. Whereas the participants from the Expert group had fewer problems with the set of tactical instructions. One participant recommended tactical instructions for individual time trial races, where the managers can decide how much power the cyclists shall invest for each section of the race.

One participant answered the following for question D13:

"...the tactics had no real description what they do, same goes for the % - there is no way for a beginner to know if 20% is much or if 80% is little when it comes to attacking or driving faster. ...".

The answer clearly shows the confusion for most participants about what tactical instructions do and what impact the different options for each have on the race. Many participants also recommended clear tutorials or helpful information on the tactical instruction page to allow new managers
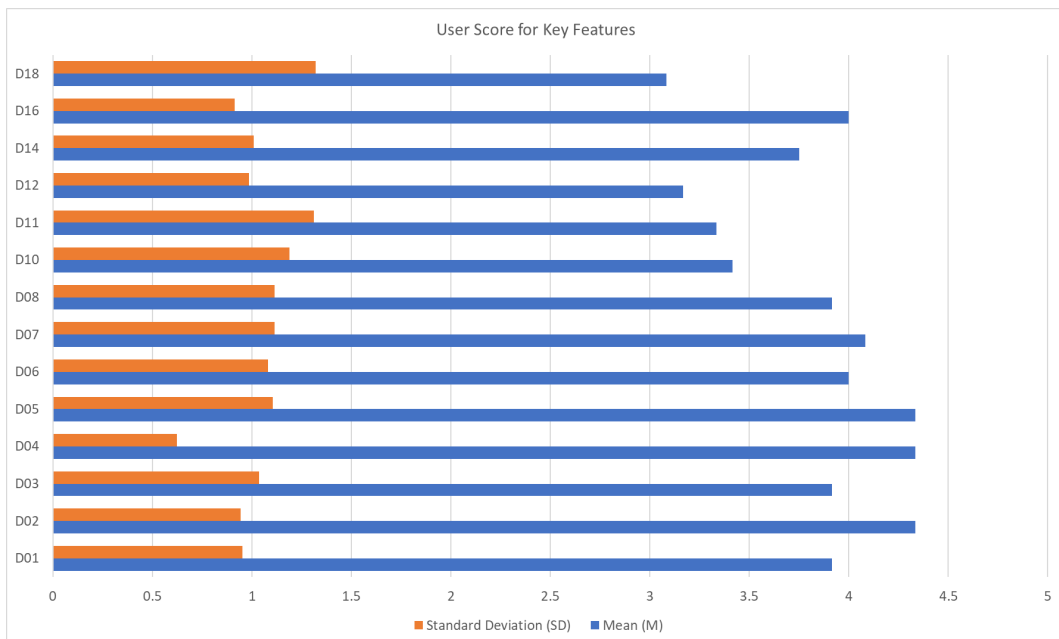
Figure 6.7: Mean (M) and standard deviation for questionnaire D

to understand every possible interaction. Examples from real life were requested to help players with no experience in cycling to better understand the game.

Questionnaire D - Detailed Information for Race Situations
Another important question was question D15. Each participant was asked what features they would like to see in the future to understand the outcome of races better. All the answers had common. Without additional information about how the race developed and what impact the manager's tactics had on the different race situations, it was impossible to clearly understand the races and learn from them for further races. Therefore, everyone wished for more detailed information about the race. Table 6.14 shows the users wishes and recommendations. Another problem was that, especially for inexperienced players, it was difficult to understand the result list's information without further explanations.

Selection of Answers and Recommendations
km to km overview over the race to understand each race situation during the race
line diagrams for cyclists performance stats to find weaknesses in the used tactical instructions
information why a cyclist has an off day
fatigue value to understand off days better
see the tactics of every cyclist at the end of the races
videos or animated visualizations about how the tactics worked out
text/graphical indication of how the race unfolded

Table 6.14: Summary of user wishes and suggestions.

Questionnaire D - Race Planer for Cyclists
With question D17, the participants were asked whether they used the recommended race planner for cyclists. The planer was recommended to use as an introduction task for the participants in the instructions PDF. Only 6 of 12 participants (50

6.3.6 Discussion RQ2 - Usability of the RadSimTool Website

As the evaluation showed, the RadSimTool website provides for most parts of the manager experience enough features to manage the cycling teams. After evaluation of the answers from the questionnaire, it showed that the managers could impact the outcome of a race by using the available tactical instructions. However, it also showed that some instructions' influence needs some fine-tuning to be more accurate in different race situations.

As RQ2.1, RQ2.2, if managers can use the website intuitively and find

all the necessary information for the races, some modifications to the Rad-SimTool website are still necessary to provide a better user experience. The RadSimTool provides all the main features that are required for the users. However, it misses tutorials and information about the different tactical instructions and functionality and their impact on the game. Whereas it is more intuitive and provides the necessary information for the races for expert users, it can make it more accessible for new players and players with less knowledge about professional cycling races.

Also, the last RQ2.3, if managers can evaluate their cyclist's performances and tactical instructions to learn and improve for the next races, showed some weaknesses of the website's current design. Whereas the RadSimTool gives detailed information about the results, it does not give a detailed overview of the race itself. Therefore, players have no information about how their tactical instructions impacted the different race situations. As the evaluation showed, the participants had problems being able to learn from previous races properly. They had to try out different instructions without knowing how exactly they worked in the race for them.

Tutorials For Available Tactical Instructions
During the evaluation, the participants were only provided with a small or no amount of information about the available tactical instructions. As the final survey for the evaluation showed, the lack of information about the tactical instructions and their impact on the different race situations during the races made it harder for the participants to manage their teams properly during the races. Therefore, as further work, all available tactical instructions and their impact on the race's outcome must be provided as a tutorial in the race sections for new or inexperienced users. Of the RadSimTool Project. Those tutorials should range from introduction tutorials for the first steps in the RadSimTool game, to deeper tutorials, about all available tactical instructions and what strength values impact which situations during the races. Or how different behaviors or tactical instructions impact the performance of cyclists.

Optimize Algorithm To Create Initial Starter Teams
Whereas initial starter teams were created randomly during the evaluation process, participants had unequal teams, which led to problems in the

competition. With the other teams since the strength of the cyclists differs widely from team to team. Therefore, the initially created teams must rely on a system to provide more equal teams for the future. The starter teams shall include no too strong cyclists and make tactical instructions and manage the teams during the season more important to be successful during the races.

Detailed Information About The Simulated Races
Visualization of the cycling races is one of the key features required to give the users a better experience and knowledge about the different race situations. The evaluation showed that many participants requested detailed information about the races. The lack of information made it difficult for the participants to learn from previous races and understand their tactical instructions. Therefore, the goal must be to implement a section at the race information page of the RadSimTool Project, where the managers have detailed information about their cyclist's performances.

One important feature is to provide for each cyclist of the manager's team a line graph for the power output (watt), the speed (km/h), and the energy tank (W'_{bal}). Those graphs could be implemented with d3, like the stage profiles, and shall show the change during the whole stage. Also, information about the average and maximum speed, or the average power output and maximum power output, should be shown together with the race result. Another feature should show that details are visualized by different time steps over the whole race. Therefore, the race data must be stored in the database. The website visualizes the information and could show for every time step a list with all groups where the groups can be opened to see all the cyclists in the specific group. The managers can either choose to run the visualization and break it if wanted, click through the time steps, or choose a specific time step they are interested in.

Training and Shape System
The RadSimTool Project focuses on creating an interesting user experience on providing dynamic strength values during a season by using the latest real-life results. To impact the strength values for the different races in the RadSimTool Project. Together with random daily shapes, the dynamic strength values should lead to a variety of different races. However, the evaluation showed that most of the users would prefer additional management

features such as a training and shape system. to be able to have a direct impact on the shape and the strength of their cyclists. Therefore, as Future work, the system could be extended with a shape system, where the shape of a cyclist depends on the training, the previous races, the fatigue, and the daily shape. The daily shape could also be impacted by the general shape, by influencing. It depends on how good the general shape is to be more likely positive or more likely negative than the base strength. Combining those different factors could lead to a system like the energy system during the races, where the recovery depends on the fatigue over the previous days or weeks or the general shape of the previous training or races' intensity.

Mountain and Hill Mass Start Races
Whereas the focus for the RadSimTool Project is on simulating time trials of different profile types and mass start road races with almost flat terrain and likely mass sprint finals at the end of the stages. The evaluation showed that the participants would like more different races and stage types to participate with their teams. Therefore, the generation of strength values must also be extended to generate accurate strength values for hill and mountain terrain. Since the simulation algorithm can already simulate different terrains during a stage, the newly generated strength values could be used directly with the simulation algorithm to provide the players a more variety of cycling races. Since in professional cycling, hill and mountain races are more selective than almost flat stages with mass sprint finals. Those races also allow the managers to have more impact with their tactical instructions on the races since the different cyclists are more likely to reach their limits during different race situations.

6.4 Summary

The RadSimTool Project evaluation was structured into two parts, the research question one (RQ1) and research question two (RQ2). Whereas the goal of RQ1 was to evaluate the quality of the generated strength values and the simulation algorithms for individual time trials and mass start road races with mass sprint finals. The evaluation showed that even though some cyclist's results vary from the real-life individual time trial performances compared with the simulated results. The simulated results are extremely

close for most simulated races with the cyclist's total times and average speed for the stages. Therefore, also the generated strength values for these races are accurate. However, some cyclists performed differently from some of the simulated results. The reason being that those cyclists' performances changed with the cyclist's shape and fitness over the season, compared to the generated strengths, for the average season.

Mass start road races' simulation showed how much pacing cyclists could affect the average speed and total time for a race within the simulation and how close those values are compared to real races. The evaluation of the sprint stages showed how well the sprinters performed to their average sprint performance through several races of the same stage race. The watt values analysis through the final meters of a sprint finish compared with the performance data from a real cyclist showed that the simulation delivers performance data close to the real ones.

To answer RQ2 about the RadSimTool Project's usability, the evaluation of the user study showed that. Almost all participants liked the website, enjoyed playing the game, and had no technical problems. Most inexperienced participants without knowledge about real cycling races had problems understanding the different tactical instructions without detailed tutorials for them. Another problem was the lack of information about the cyclists' performances and the effect of the tactical instructions on the race outcome. Analyzing the system usability score (SUS) for the user evaluation showed an average total score of 71.04, which is a good score above average.

7 Lessons Learned

In this chapter, the most important learned lessons are summarized. Positive and negative aspects are discussed in detail to demonstrate the most important milestones. The early milestones include the initial literature review as well as the identification of useful mathematical models in the field of cycling. The design process was the most time-consuming task due to many iterations. Other milestones include the implementation process and the evaluation of the implemented RadSimTool Project.

7.1 Related Work

The focus in this section was to identify useful literature about cycling and connected mathematical foundations to simulate cycling races. It showed that there are papers that studied the behavior of cyclists in different race situations. Some of them used basic simulations without the usage of a complex energy tank for cyclists. Furthermore, some of the papers described different approaches for calculating the required power output or the energy simulation. It is worthwhile to mention that detailed calculations were not always part of the research. Sometimes authors used simplified or reduced equations to simulate, e.g., flat races. It also showed that most papers did not offer a proper solution for implementing the energy tank of cyclists. However, there were some examples that helped to understand the mathematical models better. With the help of the models, it was possible to identify optimizations to implement a basic simulation algorithm and evaluate different approaches.

7.2 Design and Implementation

The RadSimTool Project is based on the original RadSimTool, which was implemented as a managing tool for the RadSim05. Therefore, several features and the main structure originate from the original website. Those features were used as the basis to develop the features for the new RadSimTool project. Due to the long development and optimization phase for the initial basis program, a robust base with few issues was readily available for the key functionality of the website. Some of the issues could be identified quickly, such as the session handling and login system. The RadSimTool is using simple user management and login systems. It fulfills the important requirements and does collect only a few data from the users. However, using a PHP framework, as a fundament, with a stronger and more secure login system would make a logical decision during the design and implementation process.

Manager games require much information about the cyclists, the races, and different statistics to provide the players with enough feedback to learn from previous races and improve their tactical instructions for future races. During the design process, it was necessary to decide which features to focus on for the implementation. Other features had to be put aside for further work. For example, features as detailed information about the race, statistics, information about the performance, and impact of tactical instructions through the race.

The design decision to implement the simulation software separately from the online infrastructure also has its pros and cons. Races have to be simulated with separate software. However, it provides more and faster computation without impacting the website's user experience during the simulation process. Further optimizations and improvements of the simulation algorithms would allow faster and more automatic simulations.

7.3 Evaluation

To evaluate the different parts of the RadSimTool Project, the focus was to separate it into two parts. The first part evaluated the simulation algorithm, and the second part the usability of the RadSimTool website. Comparing the simulated results with real results allowed us to evaluate the quality of

the simulation algorithms. Every mass start road cycling race has a different outcome. Basically, every single real cycling race is unique, and the outcome is almost always different. Therefore, the focus for mass start races was on flat stages with sprint finishes. The results are compared with the outcome of mass sprints with the simulation algorithms. Additionally, time trial races were observed. Comparing real individual time trial races with the simulated results showed that the main difference in results is the dynamic change of shape of a cyclist over a season.

To evaluate the usability, test users evaluated the RadSimTool website. The evaluation of the usability showed how important it is to provide clear tutorials for tactical instructions. Inexperienced users with less knowledge about professional cycling races had problems understanding what the different tactical instructions do. Another problem was the lack of information about what impact their tactical instructions had on the race. Information about the race and performance data for each cyclist would help to understand the races.

It also showed that generating random starter teams leads to problems with inequal team strengths. Some teams had only a few good cyclists, others had top cyclists for all race types, and some teams did not even have a sprinter in their team. Therefore, a system with equal start teams would lead to a more fun experience and better competition. Limiting the maximal strength for cyclist teams in starter teams might also help. The evaluation showed that the participants would like to have mountain and hill races with mountain and hill strength values. Another wish was a training or shape system, where the managers have more influence on the cyclists' shape.

8 Conclusions and Future Work

Chapter 8 looks back at the project and summarizes the achievements during the process to design, implement, and evaluate the RadSimTool Project. In the first part, the focus is on the conclusion of the project. Whereas in the second part, the focus is on an outlook into the future. Therefore, it discusses future features that make the RadSimTool game a better experience for the players.

8.1 Conclusion

The RadSimTool Project's goal was to create a multiplayer cycling manager experience where real cycling results are used to generate dynamic strength values for the cyclists in the game. Complex algorithms simulate the races based on mathematic formulas for cycling races. The highlights are the simulation of an energy recovery system that simulates the cyclist's behavior more realistically. To avoid copyright issues, the cyclists in the game have randomly created names. Cyclists do have a connection to real cyclists with their strength values. Players manage their teams through the website, where they find all the functionalities they need to manage their team and nominate for races. To influence the outcome of races, players can use a variety of common tactical instructions.

This project also focused on generating realistic strength values for flat races with a sprint finish and individual time trials. For flat sprint stages, flat and sprinting strength values are generated. Whereas for individual time trial races, strength values are generated for flat and hill time trials. Those strength values and the tactical instructions for cyclists are further used to simulate the races with the algorithms. In individual time trial races, each cyclist races alone. The algorithm for individual time trial races requires no tactical instructions for the cyclists and simulates the races different from the algorithm for mass start races. The simulation of the

races was implemented as an offline tool to avoid intensive computations on the website. Consequently, the user experience is not influenced by the bad performance and loading times of the website. The offline tool also provides the functionality to generate strength values for cyclists. The simulation algorithm is simulating every second of the race and uses the tactical instructions as events during the race to create a dynamic outcome of races based on the tactical instructions.

The goal of the evaluation was to answer the two main research questions for the project. Research question one (RQ1) focused on the quality of the generated strength values and simulation algorithms. And research question two (RQ2) evaluated the usability of the RadSimTool website with a user study. The evaluation of RQ1 showed that the strength values allow the simulation of results very close to the real-life results. The evaluation of RQ2 showed that the website works reliably and provides the players with all required features to create a team and manage it to take part in races. However, it also showed that the lack of clear tutorials and information about the features and tactical instructions makes it difficult to understand and use them properly for inexperienced users. Whereas the evaluation showed some weaknesses of the system, it also showed how accurate the simulated results are compared to real results.

During the evaluation, it showed that most participants enjoyed playing the game. Some users suggested more features to have a more in-depth manager experience. Those features include hill and mountain races, stage races, and detailed information about the races. Performance data for each cyclist allow the managers to understand the race better. Therefore, players can learn for the future and understand the influence of tactical instructions better.

8.2 Future Work

The evaluation showed many requested features of the participants. The focus on implementing those features in the future would make the Rad-SimTool more fun for the players. However, there are also other features that would increase the experience with the RadSimTool. Features like more tactical instructions, updated simulation algorithm, stage races, and live multiplayer races. Another important goal must be to increase the long-time

experience for the players. Therefore, features to improve and upgrade the teams and cyclists would help to keep the players motivated.

More Tactical Instructions and Increase the Quality of Simulation
With the current simulation algorithm, the RadSimTool Project provides a reasonable basis for future updates. It can handle the most important tactical instructions for cycling races and uses an energy simulation system used by professional training software. Therefore, the simulation algorithm's additional features like the impact of wind or weather during a cycling race on the cyclist could be developed to give the users a more realistic experience. The impact of wind on the different cyclists could lead to a more exciting and realistic race outcome. Additional race situations like strong crosswinds and the resulting behavior of cyclists could be included in future updates.

Therefore, the simulation must be extended to simulate the cyclists' position and behavior within each group and position cyclists in the groups. It would gain more relevance during races than it is with the current version of the simulation algorithm. The evaluation showed some of the weaknesses of the current implementation on handling overlapping tactical instructions for the same cyclists. However, implementing a system that can handle a stack of different tactical instructions could lead to cyclists' more realistic behavior during the races.

8.2.1 Stage Races - The Holy Grail of Cycling

The focus on the evaluation of the RadSimTool Project was to test the system with only one-day races. Even though there was a mixture of mass start road races and individual time trial races. To provide a more realistic manager experience and variety of races, the most important type of races in real life must be included in the race calendar of the RadSimTool Project. Since the RadSimTool website provides the functionality to show stage races properly and even allows the managers to create tactical instructions for the different stages. There is no support for different classifications, like the general, mountain, sprint, team, or youth classifications, that are common classifications for real professional cycling stage races. For the support of stage races, calculating the different classifications after every

stage and implementing features to the simulation algorithm would be required. Those features must handle intermediate sprints for points of different classification categories during the cycling races. The fatigue over different stages during stage races plays an important factor. This feature requires implementing a shape system to provide realistic changes of fatigue and shape during stage races.

8.2.2 Live Race Multiplayer Feature

In this project, the focus was on creating an algorithm to be able to handle dynamic created strength values, with an accurate energy simulation during the races by an algorithm with logic for the cyclist's behavior during each moment of the race, depending on the tactical instructions by the managers for the specific race. There are many advantages of an approach where the users pre-set their instructions for the race before a race when they have time and come back later to the game website to look up the race outcome. Providing them as much information about the outcome and their performance and other team cyclists could allow them to improve their tactics for future races.

It is easier to get all the players together for a race and have them set their tactical instructions in advance. However, a live-race feature where managers can set the instructions for their cyclists in real-time during the simulation of a race could bring the experience of managing the cyclists during races to another level. With the managers deciding what their cyclists must-do during the different race situations, the simulation algorithm can focus on handling the energy simulation and executing the tactical commands. Without requiring much logic for the cyclist's behavior during races as necessary for a simulation algorithm, the algorithm can be fast and work properly in real-time and online without taking too much processing power. Each approach has its advantages. Combining both for different races might also be an interesting and motivating experience for the users. Therefore, implementing live races could be considered for future extensions of the RadSimTool Project.

8.2.3 Team Upgrade System - Long Time Motivation

Whereas most of the features so far increase the depth of the cycling manager game and focus on more types of races, or better, more realistic cycling races. None of them focused on the long time motivation and features to upgrade teams and cyclists, to motivate players to get a better team and keep playing the team. Therefore, future work could include a system where players can upgrade the team infrastructure, upgrade the equipment, or get new cyclists by playing the game and earning points to invest in better cyclists. Getting better cyclists and competing against the best teams of other players to win important races could motivate the players to keep playing the game.

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