Preliminary Master Thesis Report

BI Norwegian Business School

Major in Logistics, Operations and Supply Chain Management

- Scheduling in sports -
A case study

Exam code and course:

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Summary

This paper is the preliminary report of the research topic chosen by two master degree students, with a major in Logistics, Operations and Supply Chain Management, at BI Norwegian Business School, for their Master Thesis.

The work on this report, as well as the final thesis, involves the assistance and guidance of the supervisors. The preliminary report follows the structure set by the school and will be added to the appendix in the final thesis.
The research topic chosen by the students concerns the current state, and the development leading up to it, of scheduling in sports tournaments.

In the first chapter the main topic of the thesis, sport scheduling, is presented. We justify the reasoning behind the topic and present a preliminary research question:
"How to model and solve a relevant sports scheduling problem for |the case company| that best satisfies |the company's| constraints and objectives?"
Limitation of our research are also discussed.

The second chapter reviews literature and develop an outline of the most typical approaches to sport scheduling problems.

How the research will be conducted are presented in chapter 3: Research Methodology. Research strategy, design and quality of research are discussed here.

Finally, we present a timeline for our research period ranging from January 15, 2018 until September 1, 2018

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1.0 Introduction

The choice of topic for our master thesis has been on our minds since we first started our Master of Science program. During our degree we have tried to choose elective courses which combined our interests with real-world usefulness; ranging from coding in python to big data analysis to business optimization. With our elective courses, and our major in Logistics, Operations and Supply Chain Management, both students seem to have found their true interest in optimization using quantitative methods. Scheduling is therefore a research area where we can put our interest to good use and why we have chosen to study and write about the topic in our thesis.

More specifically, we have chosen to study the scheduling in sports tournaments. Sports has become big business, where nations and cities battle to achieve the right to host major events like the Football World Cup or the Olympics. Major events can create jobs, publicity and have economic opportunities if managed correctly by the host and the involved actors. It's not only the major events in sports which have become big business. In many professional sports there are seasonal leagues and tournaments which involve millions of fans and have immense financial investments in players, advertising, merchandize and broadcasting rights. How these events are scheduled and managed have both financial and logistic impact on the actors, such as management, players, broadcasters and media. An optimal schedule depends on who you ask and what their motivation is. Trial-and-error methods have traditionally been the way sports schedules have been created (Fry & Ohlmann, 2012). An example of a good schedule from the host's perspective can be one who avoids the conflict of multiple attractive games to be played at the same time slot, satisfies the different teams' wishes and have as many fair match-ups as possible throughout the tournament. Other actors might only be interested in a schedule which maximizes their own revenue, or one that optimizes the logistics of security. The list of possible constraints and considerations to be made when trying to work out a schedule is near endless. Luckily, with the increase of money invested in sports, new tools and knowledge, scheduling sports tournaments has been subject to increased attention amongst researchers, organizers and practitioners in the area.

1.1 Sports scheduling

Sports scheduling as a term covers a wide range of problems, and there exist many methods which one could use to solve the different classes of problems. For example, only maximizing stadium attendance or simply assigning referees would require two quite different approaches. As mentioned, how sports scheduling is viewed depends on the motivation for the researchers and practitioners involved. The general problem when scheduling a sports tournament, and the one that will be an integral part of writing this paper, is determining the date and stadium of each game to be played. The methods and models used for the general as well as other problems will be discussed later in the paper and when reviewing the existing literature.

This paper will look at real-world problems, which do not have a sole standard objective to be solved. One must consider all aspects before embarking on what can be perceived as a straightforward task. Sports scheduling is said to be as much about developing an appropriate model, as it is about the solution methodology that is employed. Researchers can use previous work for inspiration, and may use existing work for some parts of the problem, but solving a real-world problem is as much of an issue as the choice of solution methodology (Kendall, Knust, Ribeiro, & Urrutia, 2010).

An example of a typical modelling approach in sport scheduling can be found in Ribeiro and Urrutia (2012), where the authors describe the process of working with the Brazilian Football Confederation to schedule annual national football tournaments. The authors started by generating all possible patterns for home and away games. Then they assigned teams to a specific home-away pattern. And in the end, they used an integer programming model to schedule the games according to the abovementioned pattern.

1.2 Case company

A study to solve real-world problems will benefit from having a real-world case company to work with. As mentioned, there are many problems in sports scheduling which can be tried optimized and solved. In the search for a fitting sports organization to our study, we initially pursued to solve most general scheduling problem: determining the optimal stadium and date for the games to be played. However, this study is not limited to the sole purpose of finding the date and stadium for a sport organization. Dependent on the outcome of our search, we will explore extensions and different directions within sports scheduling. Examples of other possible directions include:

1. Cooperate with a sports organization who already has an optimized schedule to compare results. This direction will create less added value for the case company. However, if we get access to the tools utilized by the organization, a comparison can contribute extensively in an academic sense.
2. Studying other scheduling problems, additional constraints or objectives for a sports organization, e.g. optimal schedule of referees, minimizing travel distance etc. If the interest for finding optimal stadium and game dates are low, more niche problems in the operational sports literature will be the next priority. This does not require large changes to the already underlying structure of the thesis.
3. In-depth study on the possible extensions of current models in the research area. Such a direction calls for more extensive reviewing of literature and the methodology for our thesis will change to more qualitative strategy.
4. Use a mock company to create an environment for the general problem to be modeled. This approach will require mock data based on literature. Furthermore, out of the listed approached this is least desired outcome, because it will be more challenging to justify the relevance of topic.

No matter the directional outcome, we need to review the existing literature. Through the literature review in this paper we want to explore the current methods and models. This will give us valuable insight to the most frequently used methods in practice today, and prepare us for further studies in specific problems.

1.3 Research question and problem statement

Preliminary, the decision of which case company to work with is not yet decided. The output of our research should therefore not be restricted by a narrow preliminary research question where we have committed to one specific model and objective function. We have developed a working research question:

"Scheduling in sports: How to model and solve a relevant sports scheduling problem for |the case company| that best satisfies |the company's| constraints and objectives?"

The objectives of the research will first be to analyze inputs, requirements and constraints given by the case company, i.e. a sport tournament host organization. The mentioned analysis will be performed to identify the appropriate modelling approach. Secondly, we will develop a model using the most appropriate optimization approach that satisfies the case company's demand, e.g. integer programming, hybrid methods, constraint programming or metaheuristics. If multiple problems are identified, the thesis will highlight the most appropriate approaches for the different problems.

1.4 Relevance of the topic

The research aims to describe how to identify constraints, general requirements and objectives in a specific sports scheduling problem, and to use these to develop a sports scheduling model with basis in literature. The model will provide the sports organization with a tool to schedule its tournaments. The identification and modelling process can be generalized for research purposes, e.g. how to schedule a sport tournament given specific condition. The hypothesis is that, with proper methodical approaches, the thesis will give practical value and suggestions within the topic of sports scheduling and operations research (OR).

1.5 Limitations

The theoretical field of this study, scheduling of sports tournaments, has had increased attention from researchers in later years. This is not only because of the difficulty of computing the problems in the area and its challenging essence, but motivated by a wave of innovative practical applications (Kendall et al., 2010). The hardness of the optimization problems has made way for different techniques to find a solution: e.g. integer programming, hybrid methods, constraint programming or metaheuristics etc. When picking out the software to use in our study, it should fit the end goal. Excel's solver is feasible up until a given number of constraints and variables, depending on whether the problem is linear or nonlinear. The standard solver included in Excel is also known to be no race horse. Excel and its solver has been used successfully in literature, but older releases were not able to solve scheduling problems with more than six teams (Trick, 2004). The clue is to be smart when formulating the problem. Recalde, Torres, and Vaca (2013) used mathematical programming techniques and with an integer programming formulation were able to formulate a tournament scheduling problem such that any free or commercial optimization software could solve it. In this thesis we are not forced to use a particular software, and have a list of possible contenders ready which will be chosen through testing feasibility and its availability: Gurobi, CPLEX, LINGO and Xpress.

When we started our work on this research proposal, the plan was to see if the NFF would be interested in developing a model in cooperation with us to use in Eliteserien. NFF have already cooperated with the Norwegian research organization SINTEF to develop their league schedules for years using similar practice as to what we had in mind: Decompose the problem into first finding a home-away (HAP) and secondly finding a date for when the teams should meet, both solved under the necessary constraints (Jære, 2017).

In 2006 the optimization group at SINTEF's Department of Applied Mathematics developed the engine "CupCom" for a Norwegian company called Profixio, which could solve tournament schedules at a fraction of the time it took to do manually (Dragland, 2016). In the ten first years of using the CupCom engine, over five hundred thousand matches have been scheduled. Profixio is not pleased with only catering to the Scandinavian market, and seeks to be a global leader in sports scheduling by 2020. Profixio is not alone, and is competing with several other developed sport scheduling software such as Diamond Scheduler and TeamTracky.

2.0 Literature review

There is no general solution to sports scheduling, and OR approaches have been applied by researchers in several sports throughout the years as specific requirements greatly differs in different sports (Kostuk & Willoughby, 2012). Scheduling the Canadian football league (CFL) proved to be more complex than scheduling the National Football League (NFL) in America. For example, NFL plays 15 of their 16 weekly matches on Sundays, while the CFL has their games spread from Thursday till Monday.

The specific requirements when scheduling a tournament also has big differences within the same sport. South American and European soccer is an attractive field in sport scheduling research. Della Croce and Oliveri (2006) scheduled a double-round robin tournament in Italy, where they balanced the requests from the soccer teams with the requests from the broadcaster. Durán et al. (2007) scheduled the professional soccer league in Chile using an integer linear programming model. The model was implemented in Chile since the schedule was viewed as more attractive by fans. The scheduling of the Danish football league's triple round-robin tournament is illustrated by Rasmussen (2008) using integer programming. Bartsch, Drexl, and Kröger (2006) created an OR model for the professional leagues in Austria and Germany. Kendall (2008) analyzed travel efficiencies for soccer teams over the Christmas holiday in England. His approach managed to cut the total travel distance by 25 percent, while satisfying all the restrictions set by the league. It is no standard way of doing sports scheduling, and the problem at hand will differ profoundly with varying environment such as objectives, constraints, sports, geographical area and tournament type. This literature review makes an outline of the most typical approaches to sport scheduling problems and serves as basis for the collection and analysis of data in the thesis.

Kendall et al. (2010) offer a complete annotated bibliography from over 160 journal articles, that is a collection of modelling approaches and literature, on the topic of sport scheduling up until 2010. Rasmussen and Trick (2008) examines literature on round robin tournament scheduling, and Ribeiro (2012) gives a review of problems and applications in sport scheduling. For graph based models and resource based models, Drexl and Knust (2007) surveyed the topic. These literature reviews serve as the base of our research, and in the section below we will go into more details about different aspect related to sport scheduling and findings in more recent literature.

2.1 Tournaments

There are two main types of sports scheduling problems: temporally constrained problems and temporally relaxed problems. Temporally constrained problems have a minimum number of rounds where each team play exactly one game in each round, in the planning horizon. Tournaments like these are called compact tournaments. In a temporally relaxed problem the number of rounds are generally greater than the minimum games required to schedule all games, which means that some teams do not have to play every round (Kendall et al., 2010).

2.2 Round robin tournaments

In a single round robin tournaments (SRR) or double round robin tournament (DRR) we have an even number of teams *n* indexed by $i \in \{1, \dots, \mathrm{n}\}$. The teams must play maximum one game in each round R and face each other team exactly once in SRR and twice in DRR, and correspondingly three times in triple round robin (3RR) and four times in quadruple (4RR). Denoted that each team need to play every other team $\ell \geq 1$ times.

The number of games available to schedule the games is $\binom{n}{2}\ell = n(n-1)\ \ell/2$, and is equal to $(n-1)\ell$ (Kendall et al., 2010).

The home team *H* is the team that play at their own stadium (home game) and an away team *A* is the team that visits the home team's stadium (away game). In double round robin tournaments, the same team will both be a home team and an away team, when the same opponents play two games against each other. When the second phase has the exact same sequence of games as the first phase, but with opposite home teams, the literature refers to “mirrored” double round robin tournaments. When the number of teams are odd, a team does not play in each round, the literature refers to this as a “bye” (Ribeiro, 2012). $n = \tilde{n} +1$ denotes that a dummy team has been introduced for scheduling purposes. When a team is scheduled to face the dummy team, the team gets a bye.

Which teams and in what sequence they will play against their opposing teams and the corresponding stadium is displayed sequentially in a home-away pattern (HAP). Home games, away games and byes are presented in a sequence for every team, often in a vector, denoted with H, A and B (bye). The HAP needs to satisfy certain constraints, like fair and proper pairing. When analyzing a HAP problem to see if it’s feasible is namely called the HAP Set Feasibility Problem (Briskorn, 2008).

Scheduling round robin tournaments represents two main tasks:

> (1) Determining which teams $ij \in \{1,...,n\}$ plays against each other in each round $t = 1,...,(n-1)\ \ell$ (i.e. timetable) (Kendall et al., 2010).
>
> (2) the home-away pattern (HAP). These tasks have been solved in the literature sequentially (first the timetable, then the HAP) or the other way around, that is fitting a home-away pattern into a given timetable (Ribeiro, 2012).

In most football leagues in Europe the round robin tournament format is used. In Norway, as an example, Eliteserien use a double round robin format (Goossens & Spieksma, 2012).

2.3 Break minimization

Minimizing the number of breaks have been a topic explored by various researchers. Breaks are consecutively played home or away games by the same team (de Werra, 1981, 1988). The objective has been to minimize break in most of the literature, to ensure fairness and attractiveness (Drexl & Knust, 2007). When solving the traveling tournament problem however, Urrutia and Ribeiro (2006) showed that to minimize traveling distance, lots of breaks can be preferable.

2.4 The traveling tournament problem

The traveling tournament problem (TTP) has the objective of minimizing the total distance traveled (Bonomo, Cardemil, Durán, Marenco, & Sabán, 2012; Easton, Nemhauser, & Trick, 2001; Ribeiro, 2012; Ribeiro & Urrutia, 2007). Only minimizing breaks and ensuring good home-away pattern can be problematic for teams and players in areas where large traveling distances are involved. TTP deals with a set of distances between each team's stadium. Instead of minimizing games, the models introduces constraints where it sets a upper limit *u* and an lower limit *l* on consecutive home (or away) matches a team is allowed to play (Easton et al., 2001). As previously mentioned, the computational difficulty has acted as motivation for researchers in the area. For many years, the largest problem solved to optimality with TTP had only six teams. By an intricate branch-and-price algorithm described in Irnich (2010), the first 8-team TTP instance was solved.

2.5 Other common objectives

The *carry-over effect* is an effect a team has on its opponent, which carries over to the opponents next game (Russell, 1980). The balancing of this effect has been explored in various problems to ensure fairness in the tournament (Kendall et al., 2010; Ribeiro, 2012).

For tournaments scheduled with more than one group, an objective can be to ensure that *weak and strong teams* do not play against each other consecutively to ensure fairness.

A *group changing schedule* is when no team plays against teams of the same group in two consecutive games.

Some sports organizers, especially sports organizers in amateur leagues, have a desire that the objective function *minimize costs*. For all teams a cost c_{ijt} is incurred. Here the objective is to minimize total cost or maximize total revenue or benefits. An interesting version of this objective is when Durán, Guajardo, and Wolf-Yadlin (2012) among other things experimented with different tournament structures when schedule to ensure Chile's Second Division Soccer League's profitability and public sentiment.

Balanced tournament design (BTD) is when no team play more than two times on the same stadium (Kendall et al., 2010).

Trick, Yildiz, and Yunes (2012) created the *umpire scheduling problem*. Umpires are referees in baseball. The problem assigns teams of four umpires to a given schedule. A unique constraint in this problem is that the umpires have no home base and a sub objective is to ensure that umpires are not assigned to the same team too many times. The main objective in this problem is to minimize the total distance traveled by umpires with considerations to each of their travel distance, days off and number of games umpired.

2.6 Optimization approaches

Kendall et al. (2010) identified four common approaches to optimization problems in sport scheduling; *integer programming, decomposition, constraint programming and metaheuristics.*

The *decomposition* approaches are often used in combination with integer programming approaches where the problems are divided into smaller problems that are solved sequentially. Subproblems are solved by either scheduling which teams play against each other first, and then solving the home and away problem, or the opposite.

Heuristic approaches are used to find suboptimal solutions with approximation algorithms because computing time and difficult formulations in integer programming can be very resource demanding for complex problems.

Integer programming utilizes mathematical optimization where some of the variables are restricted to integers and *constraint programming* utilized variables and constraints that are related to each other.

2.7 Constraints

Different sports tournament research works with different constraints. In our research a main objective will be to identify the best feasible scheduling model that satisfies a sports organizations requirements and constraints. Since constraints often are vaguely expressed by the sports organization, Kostuk and Willoughby (2012) prioritized constraints in categories ranging from "must-haves" to "nice to have" when scheduling the Canadian Football League.

Rasmussen and Trick (2008) presents the most typical constraints in sports scheduling, namely (1) *place constraints,* (2) *top-team and bottom-team constraints,* (3) *break constraints,* (4) *game constraints,* (5) *complementary constraints,* (6) *geographical constraints,* (7) *pattern constraints* and (8) *separation constraints*. We refer you to the authors, where references to specific literature with these constraints are listed.

Nurmi et al. (2010) gives a more specific outline of typical constraints in the sport scheduling problem. The constraints are denoted below with the same number as in the original source, C##. When solving for a real-world sport organization, the constraints will differ with the organization's preferences. As theoretical basis for modelling and collecting data we have made an attempt to combine the listed constraints from Rasmussen and Trick (2008) and Nurmi et al. (2010):

(1) *Place constraints:*

When a stadium, for some reason, is unavailable or is especially attractive in a certain round, place constraints is required. Constraints like these ensures that a certain team's game is played home or away at a specific time.

C03. Each team plays at least m1 and at most m2 games at home.

C04. Team i cannot play at home in round r.

C05. Team i cannot play away in round r.

C06. Team i cannot play at all in round r.

C07. There should be at least m1 and at most m2 home games for teams i1, i2, … on the same day.

(2) *Top-team and bottom-team constraints:*

Ex: Constraints that take special consideration for particularly strong or weak teams.

C28. Teams should not play more than k consecutive games against opponents in the same strength group.

C29. Teams should not play more than k consecutive games against opponents in the strength group s.

C30. At most m teams in strength group s should have a home game in round r.

C31. There should be at most m games between the teams in strength group s between rounds r1 and r2.

C32. Team i should play at least m1 and at most m2 home games against opponents in strength group s between rounds r1 and r2.

C33. Team i should play at least m1 and at most m2 games against opponents in strength group s between rounds r1 and r2.

(3) *Break constraints:*

Ex: Constraints that wants to avoid breaks in certain rounds.

C12. A break cannot occur in round R.

C18. Every team must have exactly k number of breaks.

(4) *Game constraints:*

Constraints that sets certain games at specific rounds and time. Media broadcasting of games are among the reasons for such constraints.

C10. Game i-team against j-team must be preassigned to round R.

C11. Game i-team against j-team must not be assigned to round R.

C24. Game i-team against j-team cannot be played before round R.

C25. Game i-team against j-team cannot be played after round R.

C34. Game i-team against j-team can only be carried out in a subset of rounds R1, R2, R3, …

(5) *Complementary constraints:*

If teams share stadiums, complementary constraints ensure that home games are not played by both teams in a round.

C23. Team i wishes to play at least m1 and at most m2 home games on weekday1, m3 – m4 on weekday2 and so on.

(6) *Geographical constraints:*

Constraints that ensure that games are scattered in a wide geographical area.

Nurmi et al. (2010) did not identify any specific constraints that fits this category.

(7) *Pattern constraints:*

Pattern constraints ensure that particular game types like home games, away games and byes have a maximum or minimum range that can be played sequentially by a team. Upper and lower bound of breaks, sequences of home games etc. are examples of pattern constraints.

C01. There are at most r rounds available for the tournament.

C02. A maximum of m games can be assigned to round R.

C08. Team i cannot play at home on two consecutive calendar days.

C09. Team i wants to play at least m1 and at most m2 away tours on two consecutive calendar days.

C13. Teams cannot have more than k consecutive home games.

C14. Teams cannot have more than k consecutive away games.

C15. The total number of breaks must not be larger than k.

C16. The total number of breaks per team must not be larger than k.

C17. Every team must have an even number of breaks.

C22. Two teams play against each other at home and in turn away in 3RR or more.

C26. The difference between the number of played home and away games for each team must not be larger than k in any stage of the tournament (a k-balanced schedule).

C27. The difference in the number of played games between the teams must not be larger than k in any stage of the tournament (in a relaxed schedule).

C36. The carry-over effects value must not be larger than c.

(8) *Separation constraints*

Separation constraints are constraint that ensure that there is a lower limit of rounds between game with the same pair of teams.

C19. There must be at least k rounds between two games with the same opponents.

C20. There must be at most k rounds between two games with the same opponents.

C21. There must be at least k rounds between two games involving team i1 and any team from the subset t2, t3, …

C35. A break of type A/H for team i1 must occur between rounds r1 and r2.

3.0 Research methodology

Research methodology is the process chosen to systematically solve a research problem (Bryman & Bell, 2015). This section will detail the research strategy, design and method utilized to conduct the research. Choices regarding the method and approach to research will be angled to support the overall objective of our study. Detailing a systematic approach used to collect data, developing a model and ultimately answer our research question contributes to the overall quality of our research.

3.1 Research strategy

Research strategy is "...a general orientation to the conduct of business research" (Bryman & Bell, 2015, p. 37). Quantitative research emphasizes quantification in the collection and analysis of data while qualitative research emphasizes words. In the modelling phase we will only utilize quantitative methods. The collection of input data and the identification of constraints, requirements and objectives will to some extent be qualitative, as some inputs might not be expressed quantitatively. *Appendix 1* highlights some of the contrasts between qualitative and quantitative research data collection methods. The methods are suited for different tasks and to fill in the gaps this thesis will combine quantitative and qualitative research, namely what Bryman and Bell (2015) refers to as mixed method research. In the relationship between theory and research we will make use of a deductive approach where data collection and modelling will consistently be based on theory.

In addition, with the models reviewed we will impose an axiomatic research approach. When explaining axiomatic research Meredith et al. (1989) proposed that "..the primary concern of the researcher is to obtain solutions within the defined model and make sure that these solutions provide insights into the structure of the problem as defined within the model".

3.2 Research design

"A research design provides a framework for the collection and analysis of data" (Bryman & Bell, 2015, p. 49). The research will employ an explanatory sequential case study design, see *figure 1*. The explanatory sequential design entails that qualitative data are collected prior to the quantitative data. Constraints, requirements and objectives of the case company can't be identified by quantitative data collection alone. The qualitative data will be collected through semi-structured interviews and conversations with the case company. Except from the modelling phase, a large part of the quantitative phase will be to convert some of the qualitative data into quants that can be used in modelling purposes.

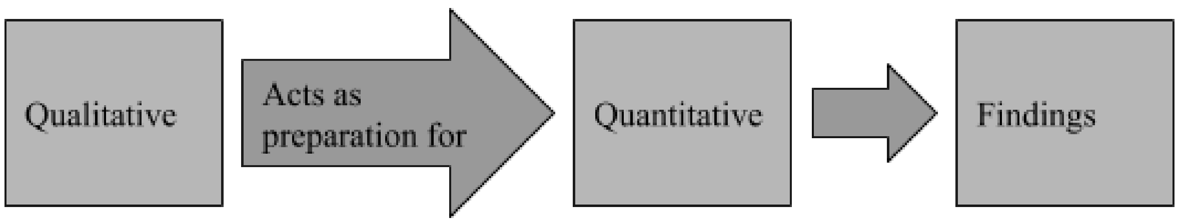

Figure 1. (Bryman & Bell, 2015, p. 647)

A case study will focus on a bounded situation and are therefore distinguishable from other designs. It allows for a detailed analysis of a single problem. A case study design enables a combination of several research methods and reduces the reliance of a single method (Knights & McCabe, 1997) and Thomas (2011) argues that an pragmatic approach concerning methods when dealing with case studies is beneficial. Case study as a design choice are further encouraged by Normann (1970) for research where a broad conceptual framework are applied in complex systems. The sports organization (our case company) are referred to as a *representative* case where we "... explore a case that exemplifies an everyday situation or form of organization" (Bryman & Bell, 2015, p. 70).

3.3. Data collection

Primary data is collected by the researcher himself, whilst secondary data involves exploring existing materials (Bryman & Bell, 2015). Secondary data collection will take place prior to collecting primary data. This is the most appropriate approach to data collection when dealing with a single case study. Because the need of primary data can first be identified after collecting secondary data.

From research articles, reports, books, company databases and web pages secondary data will be collected and consists of topics concerning sports scheduling in OR, modelling, optimization, sports characteristics and other data specific to the sports organization at hand.

The collection of primary data will consist of semi-structured interviews and conversations. Semi-structured interviews "...refers to a context in which the interviewer has a series of question in the general form of an interview schedule but is able to vary the sequence of questions….the interviewer usually has some latitude to ask further questions in response to what are seen as significant replies." (Bryman & Bell, 2015, p. 213). Since the case company sometimes can express their constraints and desires vaguely (Kostuk & Willoughby, 2012), follow-up question can be necessary to get a full understanding. Semi-structured interviews give us the flexibility to require all the necessary information to solve our problem. The development of an interview guide will be based on secondary sources. The interviews will aim to identify the sports organization's objectives, requirements, constraints and preferences. In the case where the organization for example wishes to minimize total distance traveled by the teams (TTP), other data, such as distances, need to be collected. The interviews will be conducted by both the researchers, in person.

3.4 Quality of research

Bryman and Bell (2015) identified the three most important criteria to ensure quality in the research: reliability, replication and validity.

Reliability is related to the question whether the study is repeatable or if the measurements are consistent. The development and use of any model, data or existing literature will be written in an explanatory matter. This ensures ease of troubleshooting, repeatability and understanding for external readers.

Replicability is related to whether the findings can be replicated. By reviewing the literature, we will develop an interview guide, that is used to identify the constraints, that will be attached to the final thesis. With consent we will also add copies of interviews with notes and all materials provided by the case company (Ellram, 1996).

According to Bryman and Bell (2011) validity is concerned with the integrity of the conclusion that is generated from a piece of research. The main issue with the research design in this thesis is concerning external validity. Generalizability and that the phenomenon studied is represented by the result, is reflected by external validity. Case studies has been subject to criticism for a lack of generalizability (Ellram, 1996). The results of our study can be beneficial for other researchers or sports organizations facing problems with similar constraints. Also, the way we collect and develop the variables and constraints in the model is a challenge where our described experiences can be of high value. This thesis' approach to a sports schedule problem will not be applicable to every problem of similar nature. The results are derived in a specific context and will be preferred by readers with an aligned epistemological perspective.

4.0 Project plan

A project timeline for our master thesis is illustrated in *figure 2*, and will be briefly explained.

1. We have already touched upon the importance of cooperating with an organization in our study. To research the possible organizations to cooperate with, and to establish a working relationship with them, will be top priority in the coming weeks.
2. We will continue to review the existing literature, with an emphasis on new findings in later years. Preparing us to embark the different approaches which exist in sports scheduling
3. Formulating the methodology to ensure quality of research.
4. Developing an interview guide is to ensure quality of research and mitigate variations due to errors in the collection of data (Bryman & Bell, 2015)

5. The collection of data will be done through interviews as discussed in section 3.3. Meetings with the sports organization naturally overlaps with this step, where we also will agree on scheduling problem, all its constraints, requirements and so forth.
6. Analyzing the data will be a crucial part of the thesis. As mentioned, when agreeing on the necessary constraints with the case company, they can often be expressed vaguely. Interpreting and analyzing the constraints to assign them numerical values will be required, as well as prioritization. We are prepared to be handed over historical and necessary data, and dependent on how experienced the case company is, we designated quite a lot of time to examine this data.
7. The core of our thesis is scheduling models. A good amount of time is designated on this step as well, as trial and error will be an integral role of modelling.

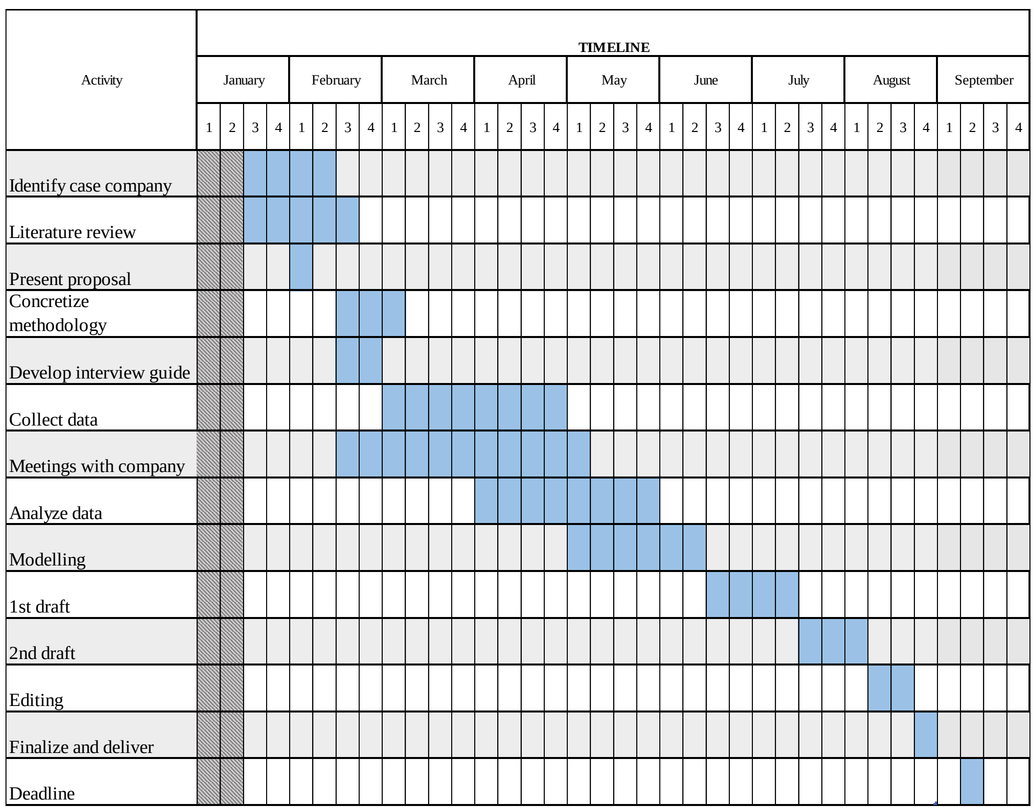

Figure 2. A predicted Master Thesis Timeline

5.0 Reference list

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6.0 Appendices

Appendix 1: General differences between quantitative and qualitative research. (Bryman & Bell, 2015)

Quantitative	Qualitative
Numbers	Words
Point of view of researcher	Point of view of participant
Researcher distant	Researcher close
Theory testing	Theory emergent
Static	Unstructured
Generalization	Contextual understanding
Hard data	Deep data