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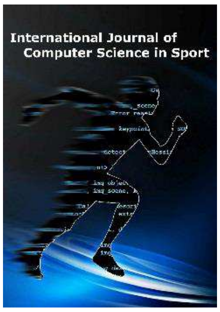


# A Decision Support System for Simulating and Predicting the Impacts of Various Tournament Structures on Tournament Outcomes

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## Abstract

Simulating and predicting tournament outcomes has become an increasingly popular research topic. The outcomes can be influenced by several factors, such as attack, defence and home advantage strength values, as well as tournament structures. However, the claim that different structures, such as knockout (KO), round-robin (RR) and hybrid structures, have their own time restraints and requirements has limited the evaluation of the best structure for a particular type of sports tournament using quantitative approaches. To address this issue, this study develops a decision support system (DSS) using Microsoft Visual Basic, based on the object-oriented programming approach, to simulate and forecast the impact of the various tournament structures on soccer tournament outcomes. The DSS utilized the attack, defence and home advantage values of the teams involved in the Malaysia Super League 2018 to make better prediction. The rankings produced by the DSS were then compared to the actual rankings using Spearman correlation to reveal the simulated accuracy level. The results indicate that a double RR produces a higher correlation value than a single RR, indicating that more matches played provide more data to create better predictions. Additionally, a random KO predicts better than a ranking KO, suggesting that pre-ranking teams before a tournament starts does not significantly impact the prediction. The findings of this study can help tournament organizers plan forthcoming games by simulating various tournament structures to determine the most suitable one for their needs.

KEYWORDS: DECISION SUPPORT SYSTEM, SOCCER PREDICTION, HOME ADVANTAGE, SPORTS SIMULATION, TOURNAMENT STRUCTURE.

## Introduction

Predicting the behaviour of a system is now crucial in our daily lives. This behaviour can be predicted using various types of simulations. Discrete event simulation (DES) (Desa et al., 2013; Fun et al., 2022; Taleb et al., 2023; Zeigler et al., 2019), for example, measures the performance of operations of a system represented by a chronological sequence of events. Its fields of applications include modelling service (e.g., bank and healthcare), telecommunication (e.g., call centre and computer network), transportation (e.g., airport and seaport) and manufacturing (e.g., production line) systems. System dynamics (Ricciardi et al., 2020) replicates nonlinear behaviour of a complex system over time based on mathematical equations, embedding various elements and factors affecting its interested outputs. It has been used in problems arising in complex social, managerial, economic or ecological systems. Other types of simulations are static (time independent) and are used to measure the impact of various configurations on a system's operations. They include simulating the outcomes of matches or sports. To evaluate the efficiency and performance among teams and organizers in sports, qualitative approaches such as data envelopment analysis (Cooper et al., 2007; Taleb et al., 2022) can be used.

Sports are a part of our lives, and one of the things people love, whether as spectators or players. In real life, spectators are interested in predicting the outcomes of a match and verifying their predictions (Csató, 2021; Gu & Saaty, 2019; Healy & Kole, 2021; Sarlis & Tjortjis, 2020). Such prediction can be performed using many available approaches, including statistical, probabilistic and machine learning techniques (Constantinou & Fenton, 2017). The statistical methods use historical data to predict the results of a match. The probabilistic predictions use the attack and defence strength points to generate profits against market odds. The machine learning technique (Alpaydin, 2020), on the other hand, focuses on the use of intelligent methodologies, such as fuzzy logic and neural network, to predict future results.

Match outcomes can be influenced by how a tournament organizer designs a sports tournament (Casanova & Hanley, 2019; Csató, 2020; Smith & Widdop, 2020; Pudovkin & Zenkova, 2021). Typically, the design considers many factors, including venues, the length of a tournament, the number of participating teams and management teams. In general, tournament design relates to the arrangement of a tournament, which may affect its outcomes and consists of the tournament structure, seeding policy and progression rules (Csató, 2021; Yusof et al., 2014). The seeding policy is the process by which teams are assigned relevant positions in tournament brackets before the tournament starts. The progression rules, meanwhile, show how the tournament organizer wishes their tournament to progress for the next rounds. The main focus of this study is how different types of tournament structures can affect match predictions. The well-known types of tournament structures include knockout (KO), round-robin (RR), and hybrid designs of these two structures, such as One Group RR and KO structure, commonly known as 1GRR-KO (Csató, 2019; Dinh et al., 2020; Guyon, 2022; Scarf & Yusof, 2011).

A KO structure is a tournament format where teams compete in pairs, with the loser of each pair being eliminated from the tournament. The winners move on to the next round to face another winner, and this continues until only one team remains as the overall champion. This format creates a sense of urgency, as a single loss can end a team's chances of winning the tournament. There are two types of a KO structure: random KO and ranking KO. In Random KO, teams are randomly matched up against each other in each round of a tournament. In Ranking KO, teams are seeded based on their performance or ranking and then matched up against each other in a predetermined bracket. In the early rounds, higher-ranked teams are matched up against lower-ranked opponents. The winners advance to the next round and usually face tougher opponents as the tournament progresses.

On the other hand, a RR structure is a tournament format where each participant plays against every other participant. This ensures that every team gets an equal number of matches, allowing for a fair assessment of each team's abilities. In a RR structure, teams are usually ranked based on the number of points earned throughout the competition, with the team earning the most points being declared the winner at the end of the tournament. There are two different formats in RR: single RR and double RR. In a single RR structure, each team plays against every other team in the tournament once. For example, in a tournament with four teams, each team will play three matches against the other three teams. In a double RR structure, each team plays against every other team in the tournament twice. For example, in a tournament with four teams, each team will play six matches against the other three teams. Double RR tournaments are considered more fair than single RR tournaments because each team has a chance to play against every other team twice, reducing the impact of luck.

Despite the many types of tournament structures available for designing a sports tournament, not every design is suitable for all types of sports. For example, the RR structure has been claimed to be time inefficient. However, it can increase the probability of the strongest team winning (Csató, 2021; Koning & McHale, 2012). On the other hand, the KO structure is unsatisfactory for a championship event. Nonetheless, it is considered effective since it can decide the winner with the least number of played matches (Csató, 2021; D'Souza, 2010). This reflects that each design has its own advantages and disadvantages. The main question is whether there exists a best design for arranging a sports tournament, especially in soccer.

According to previous studies, no single best tournament design exists for a sports tournament (McGarry & Schutz, 1997; Placek, 2023; Scarf & Yusof, 2011). The best tournament design always depends on the requirement of each tournament. For example, each team should have an equal opportunity to compete against their competitors and play a sufficient number of matches. However, some tournament designs have time constraints and other requirements. Thus, the main challenge faced by tournament designers is how to justify that the selected design is better than the other designs. Unfortunately, there have been few approaches to estimate and evaluate which design is best for a particular type of sports tournament based on relevant criteria. Hence, this paper develops a Decision Support System (DSS) to simulate the impact of attack, defence and home advantage (HA) strength values on teams' performance in a sports tournament (Lepschy et al., 2020; Liu et al., 2019; Pollard & Armatas, 2017). The DSS can predict the outcomes of different soccer tournament structures and help identify the most suitable tournament design that suits their needs.

This study has significant conceptual and practical aspects. Conceptually, it explores the effect of various tournament structures on designing a sports tournament, providing useful information for choosing the appropriate structure. Additionally, using the HA value for each participating team can enhance the accuracy of match prediction. Practically, the DSS model offers a decision-making tool to evaluate tournament structures, enabling a more effective and efficient choice for tournament organizers in designing future tournaments.

The rest of this paper is organized as follows. Section 2 provides a review of relevant literature on tournament structures, theories and models used in this paper. Section 3 discusses the research design for determining the best tournament structure for soccer. Section 4 describes how to calculate attack, defence, and HA strength values and implements the DSS to predict match outcomes. Section 5 discusses the findings of this study. Finally, in Section 6 and conclusions are drawn.

## Literature review

### *Tournament Structures*

A tournament is an important social institution and is possibly most popular in sports competitions, such as the FIFA World Cup. It is a method for ranking a set of agents or teams (Guyon, 2022; Ryvkin & Ortmann, 2008; Vu et al., 2009). The prominent way of ranking is through tournament structures. Tournament structures indicate how the matches are arranged without mentioning which teams will be paired (Csató, 2021, Hameiri & Moore-Berg, 2022, Scarf & Yusof, 2011).

The KO or elimination tournament structure is the most widely used format for sports competitions (Aziz et al., 2014; Connolly & Rendlemen, 2011; Groh et al., 2012; Zhong & Hong, 2022). This design is usually applied in various types of sports, such as major tennis tournaments, baseball, hockey and professional soccer. Each player or team competes head-to-head in a series of matches played in rounds. The winner of each round proceeds to the next rounds, while the losers are eliminated from the tournament (Glickman, 2008; Scarf et al., 2009; Sziklai et al., 2022). As the rounds progress, the number of competitors decrease. The last team to proceed to the final round and win the match is considered the champion of the tournament.

The RR tournament structure is a competition where a team meets all other teams a fixed number of times (Krumer et al., 2023; Li et al., 2013; Scarf et al., 2009). The collection of competitors in the RR structure is called league. In the RR structure, points are awarded for wins, losses and ties. There are different variations of the RR in sports. The single RR structure requires each team to play against every other team once. The team with the most wins at the end of the competition is declared the winner. The most popular form of RR is double RR, where a team has to play twice with its competitors: once at home and once away (Kashiwabara, 2009; van Doornmalen et al., 2023). This format provides a more balanced competition, but it requires more time and resources. The winner is the team with the highest accumulated points at the end of the tournament. The double RR structure is used in the top division of the England football league, Barclays Premier League.

The hybrid structure is based on the KO and RR tournament structures. It involves two phases. In the first phase, the RR structure is used, where each team plays against the other teams in its group. The top teams from each group advance to the second phase, which is the KO phase. In this second phase, a standard KO tournament is used until a winner is recognized in the final round. An example of this hybrid structure, i.e., the one group RR and KO structures (1GRR-KO), was described in Scarf and Yusof (2011) and Guyon (2022). In this structure, a group of competitors first plays in the RR phase, and the advancing teams then play in KO rounds until the end of the tournament. The two group RR and KO or known as 2GRR-KO was used in 1974, 1978 and 1982 of FIFA World Cup finals, while the RR structure in every round was used in 1950 (Scarf & Yusof, 2011). This shows that the hybrid design is common in the FIFA World Cup.

Another hybrid structure is the RR with elimination, combining a RR competition with an elimination format. Teams play against each other in a RR format. At each stage, teams with the lowest number of wins are eliminated until only two are left. The last two teams then compete in the final match to determine the winner. The choice of which RR structure to use often depends on relevant factors, such as the number of teams, time, and the desired level of competition and fairness. Organizers should carefully consider these factors when choosing a format for their competition.

### *Advantages and Disadvantages of Tournament Structures*

Each tournament structure has its own advantages and disadvantages. The KO structure, for instance, has been proved to be the simplest and most practical way of determining a winner in the shortest possible time (Altmann et al., 2012; Csató, 2021; Marchand, 2002). It eliminates half of the remaining teams in each round, making it efficient and practical. However, some argue that the KO structure may not be suitable for championship events as most teams are eliminated after playing only a small number of matches, resulting in a single poor performance or unlucky results (D'Souza, 2010; Scarf & Bilbao, 2006). Moreover, the KO structure does not produce a final ranking order as in the RR format (Jemson, 2013). While the KO structure is easier to understand and implement, it may not meet all the requirements of a tournament.

The RR structure provides maximum participation for all teams and produces the most valid winner (Hof et al., 2010; Kim, 2019; Rasmussen & Trick, 2008). However, this format is not ideal and consumes time and energy, especially when there are many competitors. For example, if each team plays two matches per week in a 10-team tournament, it would take 16 weeks to complete (Koning & McHale, 2012). Moreover, the RR structure does not guarantee to produce a winner since there is a probability of producing a draw result at the end of the tournament (Appleton, 1995; Scarf et al., 2009). This situation would create another problem for the tournament organizer in determining the winner, resulting in additional time. Another constraint is the carry-over effect (Carlsson et al., 2017). In general, the carry-over effect refers to the impact of each team on its opponent, which carries over to the next round. However, an earlier study by Goossens and Spieksma (2012) found no evidence to support that carry-over effects affected the result of the match.

Scarf and Bilbao (2006) and Krumer et al. (2023) found that the RR design maximizes the probability of the best team winning compared to other designs. Additionally, this design can also increase the correlation of pre to post tournament ranks, making it a more comprehensive and fair way of determining the best team in a tournament. This design is more representative of a team's ability because it uses a larger number of matches, which provides a more accurate representation compared to tournament designs that use smaller numbers of matches. In contrast, Wright (2014) discovered that as long as the KO system includes seeding and double elimination, it can be nearly as effective as the RR structure. This increases the chance of the KO system being the optimal design.

The economic advantage of the hybrid tournament structure is evident when the importance of each match increases, which can lead to a more intense demand (Csató, 2020; Csató, 2021; Noll, 2003). Moreover, the hybrid structure can capture both the benefits of the RR and KO structures (Barros et al., 2014; Sziklai et al., 2022). However, operating both formats may demand more financial resources due to preparation and arrangement. The hybrid structure is typically opposed by weak teams in a strong league as it reduces the number of matches. A weak team with a high probability of early elimination may expect to experience a double loss, which is in contrast to the RR structure that weak teams may prefer (Schokkaert & Swinnen, 2013).

### *Home Advantages*

In general, a HA is the consistent finding that home teams win over 50% of the matches played under a balanced home and away schedule (Courneya & Carron, 1992; McCarrick et al., 2021). In simpler words, a HA is the advantage that a home team has over the away team. A HA value has been shown to exist in most professional matches (Pollard & Armatas, 2017), and this factor has been considered in predicting match results, especially in soccer, for more than three decades

(Dowie, 1982; Fischer & Haucap, 2021; Leitner et al., 2022; Peeters & van Ours, 2021; Pollard & Gomez, 2015; Sors et al., 2021). A HA in sports can be influenced by various factors, such as the home stadium's altitude, crowd size and time zones crossed by the away team (Pollard & Artamas, 2017). However, the distance travelled by the away team has been found to be less significant compared to other factors.

The effect of different values of HA for each team was studied by Goumas (2015) based on participating teams in the Union of European Football Associations (UEFA). However, no significant effect was found, aside from a little variation in an increasing value of an away disadvantage. On the other hand, another study by Pollard et al. (2008) concluded that there is a visible effect of different HA values to tournament outcomes. This was observed in the increasing HA values of the teams in the north and south of Brazil during the Brazilian National Championship.

### Criteria for the Best Tournament Structure

Several factors determine the criteria for selecting the best tournament structure (Arlegi & Dimitrov, 2020; Parent & Chappelet, 2015). These include the number of teams, the length of the tournament, the level of competition and the desired outcome. The number of teams is a significant determinant in selecting the best tournament structure, as it affects the fairness to all participating teams. For small tournaments, a RR structure guarantees every team an equal number of games. For larger tournaments with a relatively small number of teams, a single KO structure quickly determines a winner. For larger tournaments with many teams, a double-elimination structure provides a second chance for teams and ensures fairness. Additionally, the number of teams can impact the tournament's duration, and organizers should consider the available time available when selecting an appropriate structure.

The length of the tournament also determines the structure to be used. As the number of participating teams increases, the length of the tournament also increases. A tournament that is too long can result in scheduling difficulties and player fatigue, while a tournament that is too short may not provide a fair assessment of the teams' abilities. To ensure the tournament length is appropriate, organizers should consider factors such as the availability of venues, players' schedules and the tournament's significance. By taking these factors into account, organizers can determine the optimal tournament length for a fair and successful competition.

The level of competition should also be considered when deciding on the best tournament structure. The level of competition can vary based on the participants' skill level, experience and training, and the tournament structure should reflect this. For example, a tournament with professional teams requires a higher level of competition than a local competition. The desired outcome will also influence the tournament structure. For some tournaments, the main objective is to determine the best team, while for others, the focus is on providing opportunities for participation and skill development. When the primary objective is to determine the best team, a KO structure can be the best choice as it provides a clear winner. In contrast, a RR structure is better suited for tournaments focused on skill development as each team plays against every other team, providing a broader range of experience.

The desired level of excitement can also impact the tournament structure. A single KO structure can provide a more exciting tournament with a high level of tension and anticipation. On the other hand, a RR structure can provide more opportunities for teams to recover from initial losses, providing a more balanced and fair competition. In summary, the level of competition, the desired outcome and the desired level of excitement are important factors to consider when deciding on the best tournament structure. Organizers must consider the participants' skill level and experience, as well as the tournament's primary objective, when determining the optimal tournament format that will result in a fair, successful and exciting competition.

## Methods

To determine which tournament structure is the best for a particular type of sports, this study developed a decision support system (DSS). The DSS simulates and forecasts the impact of various tournament structures on tournament outcomes. Soccer was chosen as the test bed because it has larger audiences, organizational structures and planning teams compared to other types of sports, such as basketball and hockey (Brook et al., 2016; Illmer & Daumann, 2022). Furthermore, soccer is the most widespread and popular sport in the world, consistently ranked among the top sports worldwide (Rodríguez et al., 2022; Wallace & Norton, 2014). This makes soccer a suitable sport to be considered in this study.

### *Data Collection*

The data used in the DSS were the Malaysia Soccer Super League 2018. The data, including scores, match venues and other information, were taken from the website http://www.soccer24.com/malaysia/super-league/. The website provides tables of match results, which can be used to calculate the attack, defence and HA strength values.

### *DSS Development*

The DSS improves decision making processes through its capability in analysing and recommending the best tournament structure. To do this, it utilizes relevant data, such as, the attack, defence and HA strength values of a team, calculated from the available raw data of previous match results. Based on the data, the model analyses and evaluates the effectiveness of various tournament structures. Thus, the DSS can be used as a decision tool for evaluating the appropriate tournament structure for a sport. Figure 1 depicts how the DSS executes its functionality.

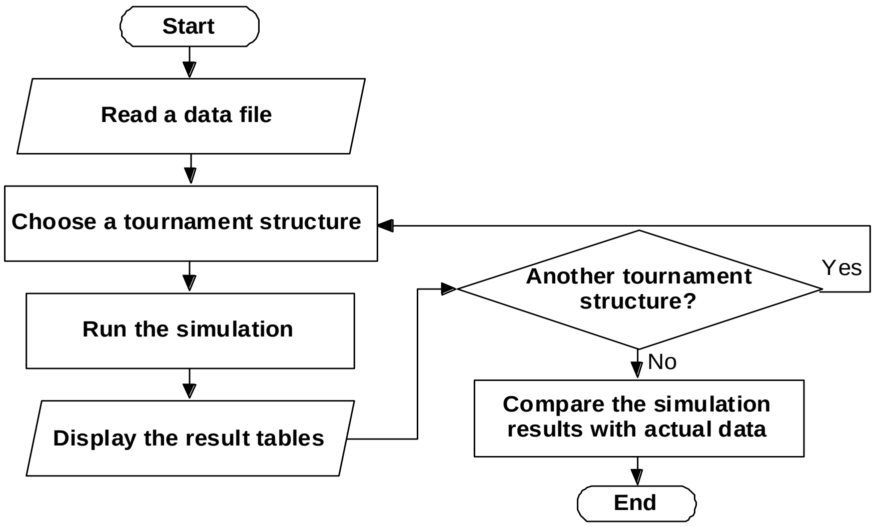



Figure 1: The Functionality of DSS

The DSS was developed using Microsoft Visual Basic and Object-Oriented Programming (OOP) paradigm to provide a clear system structure to easily maintain and modify its computer code. Briefly, the DSS first reads a data file containing information about participating teams' names, attack, defence and home advantage values. These data are utilised to simulate match outcomes and report results (e.g., win, draw and lose) based on a chosen tournament structure. These results are then used to generate the probability of teams' position numbers at the end of simulation. Using the same data, matches based on other tournament structures can be simulated. The results of each tournament structure can then be compared with the actual data results to determine the best tournament structure.

### *Home Advantage Calculation*

The ranking positions of teams are influenced by their HA values. The values are calculated based on the number of wins, draws and loses in actual match data. A win adds 3 points, a draw adds 1 point, and a loss adds no points. Based on these points, the HA value can then be determined by calculating the percentage of points collected by a team at home divided by the total points for home matches, using mathematical formula in Microsoft Excel.

## Results

### *Calculation of the Attack, Defence and Home Advantage Strength Values*

To calculate the attack and defence strength values, the following steps were followed. First, we calculated the average number of goals scored and goals conceded per team. The data on goal scored and conceded for all teams participating in the Malaysia Soccer Super League 2018 are as in Table 1. As observed, there were twelve participating teams from across the country. The average goals scored and conceded per team were both 33.5 (= 402/12). Second, we calculated the attack and defence for each team by dividing its goals scored and goals conceded with the average goal scored and goal conceded, respectively. For example, the attack strength value for Johor Darul Takzim was 1.40299 (= 47/33.5), while its defence strength value was 0.26866 (= 9/33.5). Both the attack and defence strength are variables, where higher values of attack strength indicate better attacking ability, while lower values of defence strength indicate better defensive ability.

To calculate the teams' HA values, we used the formula derived from Pollard (1986). The formula states that a team's HA is the ratio of its total points collected when playing at home to its collected home match points during the tournament. To apply this formula, we need to gather information on the total number of matches played, as well as the number of wins, losses and draws for each team. We obtained this information from Table 2, which displays the data on home matches for the Malaysia Super League 2018.

To calculate the total points collected by each team, we considered their wins, draws and losses. Each win contributed 3 points, while each draw contributed 1 point. For example, Perak won 6 matches, drew 3 matches, and lost 2 matches out of 11 home matches. Thus, we calculated Perak's total points as $[(6 \times 3) + (3 \times 1) + (2 \times 0)] = 21$.

Table 1: The Calculation of Attack and Defence Strength Values

| Team | No of Match | Goal Scored | Goal Conceded | Attack | Defense |
|---|---|---|---|---|---|
| Johor Darul Takzim | 22 | 47 | 9 | 1.40299 | 0.26866 |
| Perak | 22 | 35 | 27 | 1.04478 | 0.80597 |
| PKNS | 22 | 37 | 29 | 1.10448 | 0.86567 |
| Pahang | 22 | 35 | 21 | 1.04478 | 0.62687 |
| Terengganu | 22 | 32 | 31 | 0.95522 | 0.92537 |
| Kedah | 22 | 37 | 36 | 1.10448 | 1.07463 |
| Melaka United | 22 | 33 | 38 | 0.98507 | 1.13433 |
| Selangor | 22 | 35 | 39 | 1.04478 | 1.16418 |
| PKNP | 22 | 25 | 31 | 0.74627 | 0.92537 |
| Kuala Lumpur | 22 | 39 | 51 | 1.16418 | 1.52239 |
| Kelantan | 22 | 20 | 43 | 0.59701 | 1.28358 |
| Negeri Sembilan | 22 | 27 | 47 | 0.80597 | 1.40299 |
| | Average Goal | 33.5 | 33.5 | | |

Table 2: The Calculation of Home Advantage Values

| Team | No. of Match | No. of Win | No. of Draw | No. of Loss | Total Points | HA Value |
|---|---|---|---|---|---|---|
| Johor Darul Takzim | 11 | 11 | 0 | 0 | 33 | 1.00000 |
| Perak | 11 | 6 | 3 | 2 | 21 | 0.70000 |
| PKNS | 11 | 7 | 3 | 1 | 24 | 0.80000 |
| Pahang | 11 | 5 | 4 | 2 | 19 | 0.65517 |
| Terengganu | 11 | 7 | 2 | 2 | 23 | 0.74194 |
| Kedah | 11 | 4 | 2 | 5 | 14 | 0.45161 |
| Melaka United | 11 | 5 | 2 | 4 | 17 | 0.54839 |
| Selangor | 11 | 5 | 4 | 2 | 19 | 0.65517 |
| PKNP | 11 | 4 | 0 | 7 | 12 | 0.36364 |
| Kuala Lumpur | 11 | 6 | 2 | 3 | 20 | 0.64516 |
| Kelantan | 11 | 4 | 2 | 5 | 14 | 0.45161 |
| Negeri Sembilan | 11 | 3 | 2 | 6 | 11 | 0.35484 |

To determine the HA value for each team, we divided its total collected points by all its home match points. For instance, Perak played 11 home matches, of which it won 6 and had 3 draws, while losing the other 2 matches. Each win was awarded 3 points, and each draw was awarded 1 point to each team. Therefore, the total points allocated for Perak's home matches were calculated as $[(6 + 2) \times 3 + (3 \times 2)] = 30$. Next, we divided Perak's total collected points of 21 by the total home match points of 30 to obtain a HA value of 0.7. We used the same approach to calculate the HA values for all other teams, presented in Table 2.

Based on Table 2, Johor Darul Takzim had the highest HA value: the perfect 1. This indicates that the team has never lost in any of their home matches. The second highest was achieved by PKNS, with a HA value of 0.8, resulting from 7 wins and only 1 lost out of 11 home matches. On the other hand, Negeri Sembilan had the lowest HA value of 0.35484, as they only won 3 home matches. A higher HA value adds benefits to the team's performance on their home ground.

### *Development of a Decision Support System (DSS)*

To develop the DSS, the framework was designed as shown in Figure 2. Note that the same framework has been discussed in Yusof et al. (2016). This study updated the framework to support the inclusion of HA values. The framework handles a collection of teams and manages their relationships, such as match information and scores. Three main classes are available: Team, Match and Match Handler.

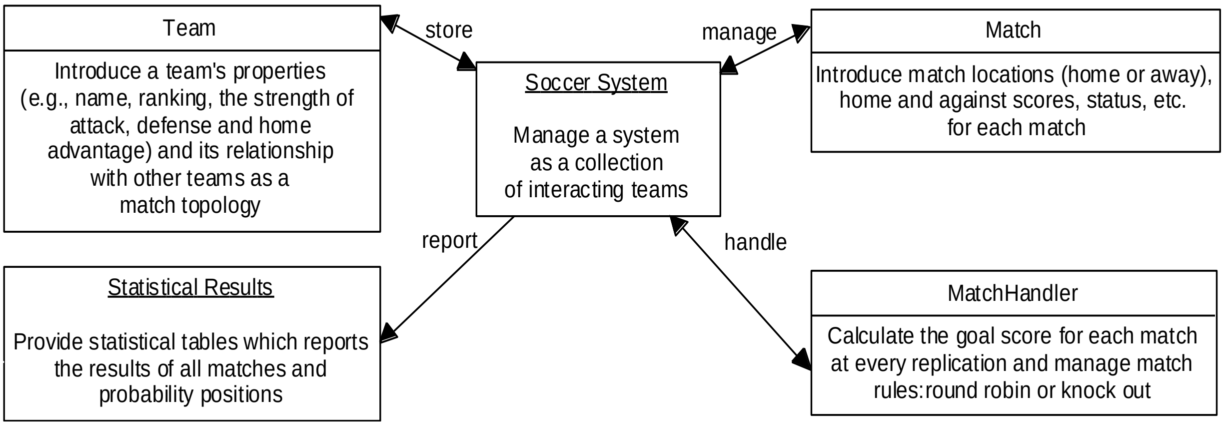



Figure 2: Framework of DSS Development

The Team class is used to collect the team’s particular properties, such as its name, number of wins, draws and loses, and ranking. This class also accumulates a list of matches with other teams, along with the scores, used to rank the teams. The Match class handles the location, score and result of each match before transferring the data to their team’s properties. The Match Handler stores the engine which calculates the total goal scored for each match at each replication, manages the type of tournament structures and analyses the match outcomes. These outcomes are simulated to observe the effect of changing tournament structures based on each team’s attack, defence and HA strength value.

The simulation process predicts the outcome of each individual match. The match prediction is based on a statistical match prediction model, called the double Poisson model (Kissell & Poserina, 2017; Siegal & Wagner, 2021). In soccer matches, many attacks occur, and each team has the opportunity to attack their opponent. However, the probability of any attack producing a goal is small. With a team’s consistent ability to score goals over time, the Poisson distribution approximation is a plausible model. For a match between the teams indexed i and j, and by letting be the number of goals scored by team i and be the number of goals scored by team j, the match outcome model is given by

$$(X_{ij}, Y_{ij}) \sim Poisson(\alpha_i \beta_j \gamma,\ \alpha_j \beta_i) \text{ for team } i \text{ playing at home against team } j \tag{1}$$

$$(X_{ij}, Y_{ij}) \sim Poisson(\alpha_i \beta_j,\ \alpha_j \beta_i \gamma) \text{ for team } i \text{ playing away against team } j \tag{2}$$

where $\alpha_i$ and $\beta_i$ are the attack and defence strength of team *i*, respectively, and $\gamma$ is the parameter that allows for a HA effect. The match prediction is based on an indirect approach that uses a match score modelling technique, as opposed to a direct approach that predicts match outcomes directly. This technique models the distribution of scores for each team separately using an independent Poisson model. The home and away team scores follow independent Poisson distributions, which are justified by the low correlation between a team’s home and away performances. Since teams tend to score more goals when playing at home, it is important to consider this when predicting match outcomes.

Our simulation results were based on an iterated Monte Carlo simulation process. The process utilized the attack, defence and HA values estimated in Table 1 and Table 2 to simulate match outcomes. By default, each tournament design was simulated 1,000 times (N=1000) to ensure the robustness of the results. This number of simulations is sufficient to obtain stable estimates of the match outcome probabilities and reduce the risk of random variation affecting the results. By using this simulation approach, reliable and accurate predictions of match outcomes can be provided. The probability mass function or PMF of the double Poisson distribution is:

$$P(Y = y) = f_{\mu,\theta}(y) = (\theta^{\frac{1}{2}} \mathrm{e}^{-\theta\mu})(\frac{\mathrm{e}^{-y} y^{y}}{y!})(\frac{\mathrm{e}\mu}{y})^{\theta y} \ , y = 0, 1, 2, ...$$

Lastly, the *Statistical Results* is the module used to display the information on analysing and evaluating the tournament design and statistical tables presenting all matches results and probability positions of participating teams.

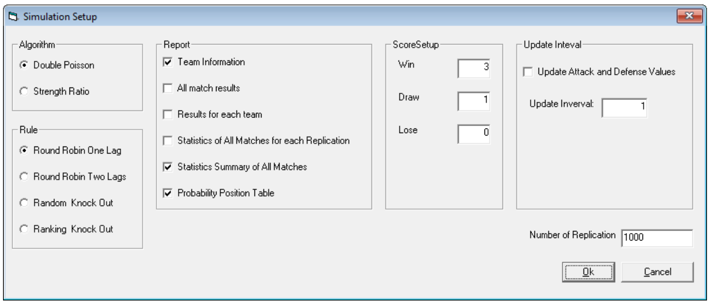
Some of the interfaces of the DSS are shown in Figure 3. The main interfaces are *input data*, which reads the strength data on attack, defence and HA values of participating teams, *simulation setup*, which accepts various simulation parameters and configurations setup by users and *statistical simulation results*, whose engine runs and generates the simulation results based on the setup parameters and configurations.

| Output Summary of All Match Results for 1000 Simulations | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| POS | TEAM | P | W | D | L | GF | GA | GD | PTS |
| 1 | Johor_Darul_Takzim | 11000 | 7574 | 2764 | 662 | 16497 | 2719 | 13778 | 25486 |
| 2 | Pahang | 11000 | 4170 | 4099 | 2731 | 8863 | 6412 | 2451 | 16609 |
| 3 | PKNS | 11000 | 3970 | 3552 | 3478 | 10247 | 9310 | 937 | 15462 |
| 4 | Kuala_Lumpur | 11000 | 3786 | 3249 | 3965 | 11226 | 11932 | -706 | 14607 |
| 5 | Selangor | 11000 | 3585 | 3525 | 3890 | 9471 | 10162 | -691 | 14280 |
| 6 | Perak | 11000 | 3321 | 3989 | 3690 | 8275 | 8927 | -652 | 13952 |
| 7 | Terengganu | 11000 | 3337 | 3839 | 3824 | 8376 | 9371 | -995 | 13850 |
| 8 | Negeri_Sembilan | 11000 | 3340 | 3555 | 4105 | 8522 | 10325 | -1803 | 13575 |
| 9 | PKNP | 11000 | 2813 | 4300 | 3887 | 6219 | 8049 | -1830 | 12739 |
| 10 | Melaka_United | 11000 | 2861 | 3713 | 4426 | 7699 | 10699 | -3000 | 12296 |
| 11 | Kedah | 11000 | 2768 | 3752 | 4480 | 7548 | 10499 | -2951 | 12056 |
| 12 | Kelantan | 11000 | 2330 | 3953 | 4717 | 5930 | 10468 | -4538 | 10943 |

| Position Number Frequency | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TEAM | Post 1 | Post 2 | Post 3 | Post 4 | Post 5 | Post 6 | Post 7 | Post 8 | Post 9 | Post 10 | Post 11 | Post 12 |
| Johor_Darul_Takzim | 887 | 84 | 19 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Perak | 10 | 103 | 102 | 102 | 122 | 99 | 107 | 77 | 77 | 82 | 60 | 59 |
| PKNS | 23 | 167 | 151 | 112 | 103 | 95 | 92 | 76 | 59 | 53 | 52 | 17 |
| Pahang | 34 | 233 | 174 | 140 | 106 | 69 | 68 | 50 | 44 | 38 | 24 | 20 |
| Terengganu | 9 | 69 | 91 | 95 | 116 | 108 | 99 | 118 | 83 | 86 | 68 | 58 |
| Kedah | 2 | 29 | 53 | 77 | 62 | 95 | 97 | 89 | 121 | 108 | 127 | 140 |
| Melaka_United | 4 | 24 | 53 | 73 | 80 | 69 | 100 | 109 | 103 | 142 | 129 | 114 |
| Selangor | 11 | 93 | 94 | 96 | 95 | 115 | 88 | 100 | 87 | 91 | 77 | 53 |
| PKNP | 3 | 36 | 62 | 62 | 82 | 86 | 91 | 116 | 123 | 99 | 131 | 109 |
| Kuala_Lumpur | 8 | 93 | 107 | 125 | 93 | 107 | 94 | 85 | 82 | 88 | 59 | 59 |
| Kelantan | 1 | 12 | 24 | 31 | 42 | 62 | 76 | 92 | 105 | 118 | 173 | 264 |
| Negeri_Sembilan | 8 | 57 | 70 | 79 | 97 | 95 | 88 | 88 | 116 | 95 | 100 | 107 |

(a) Sample of Statistical Simulation Results


(b) Input Data




(c) Simulation Setup

Figure 3: The Interfaces of the DSS

### *Comparison of Actual and Simulated Rankings*

There are three main types of tournament structures, but due to their complexity, only two structure types, i.e., RR and KO, were simulated in the DSS. Based on these two structures, four substructures were further evaluated: RR One Leg (Single RR), RR Two Legs (Double RR), Random KO and Ranking KO. Each structure yields different simulation results based on the ranking and HA value of each team.

Table 3 shows a comparison between the actual and simulated rankings. The actual ranking was based on a double RR. The simulated rankings were generated using 1000 replications. However, due to the possibility of random variation affecting the outcomes, there could be slight differences in rankings or positions with each simulation run. In the simulated single RR, some teams showed similar positions in the actual and simulated tournaments. For instance, Johor Darul Takzim emerged as the winner in both the actual and simulated tournaments. PKNS secured the third place in the simulated ranking, differing by only one place from its actual ranking. However, some teams were placed too far from their actual and simulated rankings. For example, Perak ranked the 7th place in the simulation while holding the second position in the actual ranking. Negeri Sembilan, on the other hand, occupied the last position in actual ranking but was placed 8th place in the simulation.

Table 3: Correlation for Tournament Structures

| Actual Ranking | Team's Name | Simulated Ranking | | | |
|---|---|---|---|---|---|
| | | **Single Round-robin** | **Double Round-robin** | **Random Knockout** | **Ranking Knockout** |
| 1 | Johor Darul Takzim | 1 | 1 | 1 | 1 |
| 2 | Perak | 7 | 4 | 4 | 4 |
| 3 | PKNS | 2 | 3 | 3 | 3 |
| 4 | Pahang | 3 | 2 | 2 | 2 |
| 5 | Terengganu | 4 | 5 | 5 | 7 |
| 6 | Kedah | 10 | 6 | 6 | 5 |
| 7 | Melaka United | 11 | 9 | 9 | 6 |
| 8 | Selangor | 5 | 7 | 7 | 8 |
| 9 | PKNP | 9 | 10 | 8 | 10 |
| 10 | Kuala Lumpur | 6 | 8 | 10 | 9 |
| 11 | Kelantan | 12 | 12 | 12 | 12 |
| 12 | Negeri Sembilan | 8 | 11 | 11 | 11 |
| Correlation | | **0.64336** | **0.93007** | **0.97353** | **0.95294** |

To determine the accuracy of the simulated ranking in comparison to the actual ranking, the Spearman correlation of the data was calculated. Spearman correlation measures the strength and direction of monotonic association between the actual and simulated rankings based on their ranks. The correlation value ranges from –1 to 1 and can be interpreted as follow:

- –1 = perfectly negative linear relationship
- –0.3 = weak negative linear relationship
- 0 = no linear relationship
- +0.7 = strong positive relationship
- +1 = perfectly positive linear relationship

A positive linear relationship indicates that both sets of data change in the same direction, while a negative linear relationship indicates that the data sets change in the opposite direction. Correlation is a valuable metric for evaluating the accuracy of the simulated ranking as it provides a quantitative measure of how closely the simulated ranking matches the actual ranking. When assessing the accuracy of the simulated ranking in comparison to actual ranking, correlation can serve as a goodness metric as it indicates the strength and direction of the relationship between the simulated and actual rankings. A high correlation coefficient value (closer to 1) suggests that the simulated ranking closely approximates the actual ranking, indicating a high degree of accuracy. Conversely, a low correlation coefficient value (closer to 0) indicates a weak relationship between the simulated and actual rankings, suggesting a lack of accuracy.

There are several advantages to using correlation as a goodness metric to evaluate the accuracy of simulation data in comparison to actual data (Chatterjee & Hadi, 2015). Firstly, correlation provides a standardized way of measuring the accuracy of a simulation. This eases the comparison of simulation accuracy across different datasets and scenarios, providing a uniform basis for evaluating simulation performance. Secondly, correlation is a robust statistical measure not affected by outliers or extreme values in the data. It provides a more accurate representation of the relationship between simulated and actual data, even when there are extreme values or anomalies in the data. Thirdly, correlation enables the identification of patterns and trends in the data that may not be immediately apparent from visual inspection or descriptive statistics, making it a useful tool for identifying areas where the simulation may be inaccurate or could be improved. Finally, correlation is a widely used metric in the field of data analysis and is well understood by researchers and practitioners alike. This popularity and accessibility make it a popular and useful metric for evaluating the accuracy of simulations and comparing them to actual data.

The correlation between the actual and simulated rankings of each tournament structure is represented in Table 3. For the Single RR, the correlation was 0.643357, indicating a moderate positive relationship of the actual and simulated rankings. For the Double RR, the correlation value was 0.93007, indicating a strong positive relationship of the actual and simulated rankings. Four teams—Johor Darul Takzim, PKNS, Kedah and Terengganu—maintained the same ranking in both actual and simulated rankings. The simulated rankings for the Double RR show better prediction compared to the Single RR.

In the KO structure, the data used included four dummy teams to make the number of teams participating in multiple of four. The Random KO had a high value of correlation of 0.9735, as shown in column 5 in Table 3. It had the highest value, making it the most accurate simulated ranking compared to the actual ranking. Six teams showed the same ranking in actual and simulated rankings, while the other teams only differed by one or two places in comparison.

The Ranking KO also indicated a strong positive relationship with a correlation value of 0.9529, slightly lower compared to the Random KO. As observed, the simulated ranking for certain teams, such as Johor Darul Takzim, PKNS and Selangor, showed the same results with the actual ranking.

## Discussion

The calibration data sets used to find the best parameter values for the simulation model (such as the attack, defence and home advantage values for the teams) and to train or simulate the model were collected from a secondary source of data obtained from the previously mentioned website. We did not check the authenticity of the data sets since we trusted the reputation of the source and the organization that collected and reported the data. Table 1 and Table 2 show the attack, defence and home advantage values for all the 12 teams, which range from 0.59701 to

1.40299, 0.26866 to 1.52239 and 0.35484 to 1.00000, respectively. These values were used to simulate the observed data as closely as possible. These parameters significantly affected teams' goal scored in each match, and eventually their performance and rankings in a tournament design.

The simulation model utilized these parameters and the double Poisson algorithm to simulate the actual matches under various tournament structures. The simulation generated the goal scored by each team and ranked them for every tournament structure. Thus, the DSS was used to evaluate the model's robustness and accuracy in predicting the rankings. By using both calibration and simulation data sets, we were able to study the reliability and robustness of the model in predicting the behaviour of the tournament structures.

Different tournament structures displayed varying levels of accuracy, as indicated by their correlation values. Among the structures tested, the Random KO had the highest correlation value, followed by the Ranking KO and Double RR, with the Single RR having the lowest value. The top three tournament structures had a value higher than 0.9, indicating high accuracy of prediction. However, the Single RR scored only 0.6434, indicating an average positive relationship with the actual ranking. Overall, all four tournament structures produced a positive relationship between the actual and simulated rankings.

The Single RR showed a lower correlation value for the simulated ranking compared to the Double RR, indicating that the simulated rankings for the Single RR were less accurate than the Double RR. The Double RR, where each team meets other teams twice, produced better rankings, as each team played more matches compared to the Single RR. With more matches played, more data were collected, and better predictions were produced. Hence, the Double RR is more precise in ranking teams.

Both the Random KO and Ranking KO showed highly accurate results compared to the actual ranking. Unlike the RR structures, the KO structures require fewer matches and are completed in a more efficient time frame. The KO structures eliminate weaker teams in the early stages, allowing only the stronger teams to progress. This helps to better forecast a winner, rather than having all teams play the same number of matches. While the Ranking KO structure should theoretically produce better results due to the initial ranking of the teams, the simulation showed that the Random KO produced a better ranking. This indicates that the early ranking of teams is not as important in providing a better prediction.

Based on the correlation value between the actual and simulated rankings, the Random KO proves to be the best tournament structure. This structure not only provides the closest simulated rankings to the actual rankings but also ensures a cost-effective tournament as it runs in a shorter time compared to the RR structures.

Our simulated rankings were totally based on factors that can be measured quantitatively, such as attack, defence and home advantage values. These factors have been integrated into the DSS to simulate matches and goal scored for each team. However, in real life, many other factors can significantly influence a team's chances of winning or losing, including team performance (encompassing a team's offensive and defensive tactic, teamwork, individual player performance and physical fitness) (Lago-Ballesteros et al., 2018), tactical strategies (such as the selection of team formation and player positions) (Gamble et al., 2019), injuries (caused by collisions involving kicking, full body or other factors) (Robles-Palazón et al., 2022) and refereeing decisions (which can lead to goals being disallowed or awarded unfairly and can also result in players being sent off or receiving penalties) (Sors et al., 2021). While some factors, such as team performance and tactical strategies, are within the control of the team, other factors, such as injuries and refereeing decisions, are outside of their control. All these factors are difficult to quantitatively be measured and included in the DSS.

## Conclusion

This study designs and develops a DSS to simulate and predict soccer tournament outcomes. To make better predictions, the DSS not only utilized an individual team's attack and defence strength but also its home advantage value. The outcomes, in terms of goal scored and team rankings, were simulated based on different types of tournament structures. In general, four types of tournament structures were simulated, and all the simulated results indicated a positive relationship with the actual ranking. The Single RR showed that a fewer number of matches caused insufficient data to be collected, resulting in an average ranking. However, in the KO structure, a fewer number of matches produced a better ranking because only the solid teams remained until the end, resulting in better predictions. The results indicate that ranking the participating teams before a tournament does not have much impact, as the Random KO produces better predictions than the Ranking KO.

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