Modelling Expected Threat in Gaelic Football using a Markov Chain Approach

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Abstract

This study uses Markov chain modelling to develop an expected threat model to represent the value of possession in Gaelic football for each zone in a rectangular grid. The value of actions associated with progressing possession from one zone to another are measured as the difference between these zonal values. The associated transition matrix can be used to identify patterns of play. In this way coaches and players can benefit through a quantitative understanding of structures of play and optimal actions to improve likelihood of scoring. In this study a total of 14269 observations from 14 inter-county games are analysed, with 8016 zone transitions identified and manually coded. A transition matrix is developed, and zonal threat table presented. The results indicate a preference for short kickouts and a tendency to move the ball vertically up the pitch with limited lateral movement. The expected threat values highlight the scoring potential associated with ball possession in central attacking zones close to goal and the associated action values emphasize the value of progressing the ball into these central attacking channels.

Keywords

Gaelic Football, Possession, Expected Threat, Markov Chain

1. Introduction

1.1. Gaelic Football

Gaelic football is a popular sport in Ireland that is played between two teams of 15 players on a rectangular pitch. The objective is to outscore your opponent by kicking or fisting the ball over the crossbar for one point or by kicking in to the goals for 3 points. Players use a combination of carrying, bouncing, hand-passing, kick passing and soloing to retain possession and progress the ball up the pitch. Understanding how teams score, defend and keep possession are crucial parts of Gaelic football. This work seeks to apply Markov chain models to determine the value for a team transitioning the ball from one zone on the field to another and thus to help teams and their coaches profile the value of the actions and to adapt their pattern of play to improve likely scoring output.

1.2. Markov Models and Expected Threat in Sports

Sports analytics has undergone considerable advancement in the past 15 years, with an increase in data acquisition and the implementation of sophisticated analytical methodologies. Recent progress has witnessed the emergence of machine learning techniques designed to formulate more refined player-performance metrics, which consider the contextual factors of actions occurring during soccer matches (Decroos et al., 2017).

A Markov Chain is a mathematical tool used to predict future events based on current states or current situations (KARLIN, 1968; Randall, 2003). The future state depends only on the current state and not on the sequence of events that have occurred previously. They are particularly useful in analysing the sport of soccer, where they can model the likely outcomes of game situations after several iterations of state transitions (Rudd, 2011). Markov models can evaluate the value of on-the-ball actions and the probabilities of reaching goal-scoring opportunities, effectively capturing the complexities of game dynamics (Peña, 2014; Rudd, 2011). These models can also handle arbitrary

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lengths of possessions through absorption states, allowing for a comprehensive analysis of gameplay (Peña, 2014; Rudd, 2011). The Expected Threat (*xT)* model calculates the expected scoring potential by iterating through possible actions and their outcomes, ultimately providing a numerical value that reflects the threat level associated with a given play (Poropudas, 2021; Roy et al., 2020). This approach allows for an understanding of offensive and defensive strategies, as it considers both the probability of scoring and the risk of turnovers and conceding goals (Decroos et al., 2020).

1.3. Analytics in Gaelic Football

Gaelic football, as a team invasion sport, shares physiological demands similar to those of soccer and Australian football (Florida-James & Reilly, 1995; E. Kelly et al., 2018). Research has focused on tactical behaviors critical to team performance, emphasising the importance of possession as teams work to transition the ball into scoring opportunities (G. Kelly et al., 2022; Mangan et al., 2017; McDermott et al., 2021). Possession often originates from kickouts and turnovers and its relationship with game outcomes is complex. While possession quantity alone doesn't guarantee success (McGuckin et al., 2020; McNamee et al., 2023) elite teams typically maintain longer possessions and control a greater portion of the game (Gamble et al., 2019; McGuckin et al., 2020). Winning teams also create more attacks and efficiently convert possessions into scoring chances (Allister et al., 2018; Gamble et al., 2019; McGuigan et al., 2018). However, in closely contested games (decided by six points or less), this efficiency difference is not significant (McNamee et al., 2023). Successful teams also show higher productivity, measured by the ratio of scores to possessions (Gamble et al., 2019; McGuckin et al., 2020).

The context of possession is crucial; for example, teams winning more turnovers are often more productive (McNamee et al., 2023). Kickouts that are longer tend to be more effective, though this depends on opposition positioning and timing (Daly & Donnelly, 2017; Timmons et al., 2022). Longer possession periods and more passes correlate with higher shot attempts and scores (Bradley & O'Donoghue, 2011). Shot efficiency, an important predictor of success, has improved over the years, with evidence showing an increase from 44% in 2003 to 55% in 2019 (McGuigan et al., 2022). Optimal scoring zones are identified within a 32-meter arc and a 60-degree angle from the goal (McGuigan & Collins, 2021). Contextual factors like shot type, method, and pressure significantly influence shot success (McGuigan et al., 2022). Pressure from defenders, as seen in other sports, similarly reduces shot accuracy (Corbett et al., 2018; Csataljay et al., 2013; Lago-Ballesteros et al., 2012).

The tactics adopted by a team must be flexible to capitalize on the vulnerabilities of opposition teams, highlighting the importance of strategic foresight (Mangan et al., 2022). Moreover, decision-making is shaped by an array of factors, including pre-match circumstances, present match dynamics, and individual player attributes, all of which can significantly influence performance outcomes (McLoughlin et al., 2023).

One notable constraint in Gaelic Football is the lack of data. There are currently no companies that provide event-based data. As is highlighted in previous research, this constrains the capacity of coaches to establish benchmarks and conduct thorough performance analyses across varying levels (McGuigan et al., 2018). In addition, the categorization of teams based on a sample of limited game time may result in unreliable evaluations, as previously emphasized in earlier research (Mangan & Collins, 2016). Collectively, these factors impede the advancement of comprehensive analytical frameworks within Gaelic football.

1.4. Added Value of this Research

The integration of Markov chains in sports analytics enhances tactical decision-making and player evaluation, providing a data-driven approach to understanding game dynamics (Fabrègues, 2024). This work represents the first attempt to develop a Markov chain model to evaluate the value of transitioning the ball from one zone of the field to another in Gaelic Football.

2. Methods

2.1. Research Design

The study utilises a research approach, integrating statistical modeling with a developed application for data collection to adapt the expected threat (***xT***) model to Gaelic football using a Markov chain algorithm. The research design is informed by similar applications of the *xT* model in soccer and the use of Markov chains in sports analytics (Poropudas, n.d.; Roy et al., 2020; Rudd, 2011).

The Markov model is defined by transient and absorbing states. Possession sequences in Gaelic football can start with a kickout or by gaining possession from an opponent in a zone on the field. Possessions can end with a shot for a goal or for a point or by losing possession to the opposition. Possession can also end through the referee ending the half or the game. The model is applied to possession sequences in Gaelic football by including transient states to represent a team having possession of the ball in each of 16 zones on the Gaelic football pitch as shown in Figure 1. An additional state is included to represent possession associated with a kickout. The absorbing states are given by the shot outcomes, the turnover outcome and the end of game outcome. Shots are further divided into four categories of points from open play, points from dead balls for e.g. free kicks, goals from open play and goals from dead balls.

The choice of zonal boundaries was primarily influenced by the practical challenges of data collection and the natural segmentation provided by field markings in Gaelic football. The horizontal zones align with the 20m, 45m, and 65m pitch lines, which are standard markers used in gameplay and easily identifiable during manual coding. This simplified the annotation process and reduced the likelihood of coding errors.

Moreover, the decision to increase the number of zones closer to the goal was deliberate. This granularity in attacking areas reflects the heightened strategic importance of these zones in scoring scenarios. By adding more zones in the offensive third of the pitch, we aimed to capture greater detail regarding scoring opportunities and positional advantages.

While this approach provides meaningful insights, we acknowledge the limitations of using strict boundaries between zones, which may not perfectly align with the fluidity of gameplay. Future research could address this by leveraging more advanced data collection methods, such as camera-based event tracking systems, enabling finer segmentation and continuous state definitions.

2.2. Markov Model

xT, as described by (Singh Karun, 2019), is based on a possession-driven Markov framework. This model structures Gaelic football matches as sequences of possessions, during which one team maintains ball control. Each possession is broken down into a series of sequential actions that progress the ball. The fundamental principle behind *xT* and similar models is that these actions aim to transition the game into a more favourable scoring situation. These evolving game scenarios correspond to the transient states in a Markov chain, where players alter the state by passing or carrying the ball until the sequence ends in a shot or a turnover.

Although game states can be defined with varying levels of complexity (Rudd, 2011), our representation of *xT* focusses only on the ball's position in a structured grid model.

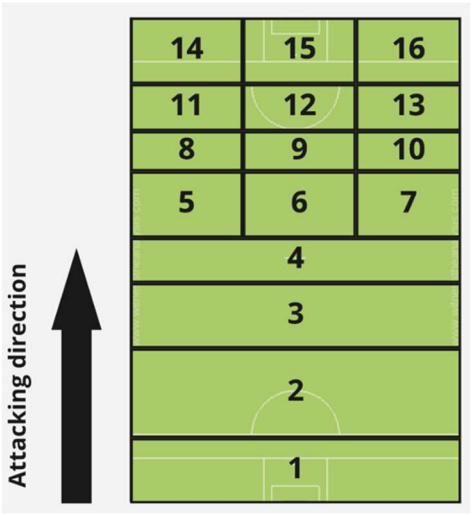

Figure 1. *Gaelic Football Pitch Zoned*

An additional state (labelled zone 0) is included to represent possession associated with a kickout. This represents the start state for many possession sequences but not all, with possessions also originating from turnovers and starts of play.

Each zone is assigned an *xT* value that indicates the scoring potential for a team in that area. This can be considered as the expected score that would result from having possession in that zone either through scoring direct from that zone or through the transition of play into other zones which then result in shots that lead to scores, either goals or points.

The possible shots that can take place are separated into four types, shots for goal (worth 3 points) from open play, shots for goal from dead ball situations, shots for points from open play and shots for points from dead ball situations. This is based on the work of (McDaid et al., 2024) who showed that there is a significant difference in outcome for shots from dead ball situations and shots from open play situations.

xT values for each zone, *xT(z)*, can then be presented through a Markov model with the following equation:

$$xT(z) = \sum_{i=1}^{4} s_z^i . xP^i(z) + m_z \sum_{z'=0}^{16} T_{z \to z'} . xT(z') \,,$$

where s^i_z is the probability that there is a shot of type *i* when in zone *z*, $xP^i(z)$ is the expected points that might result from a shot of type *i* from zone *z*, m_z is the probability that a team successfully moves the ball to a different zone when in zone *z*. Finally, *T* is the transition matrix (17 x17) that gives the probability that the ball moves to each of the other zones (***z'***), given the ball has been successfully moved to another zone.

To develop a solution for the model one can iteratively consider one zone change ahead with the expected threat of scoring in *n* actions or less from zone *z*, $xT^n(z)$, considered as the threat associated with shooting and scoring immediately added to the probability of transitioning to a new zone and then scoring in *n-1* actions or less, $xT^{n-1}(z)$. This can be expressed as follows:

$$xT^n(z) = \sum_{i=1}^{4} s_z^i . xP^i(z) + m_z \sum_{z'=0}^{16} T_{z \to z'} . xT^{n-1}(z').$$

The threat of scoring immediately with no further zone transitions is simply given as the first element of the expression. The value of actions (transition of ball from one zone to another) can then be valued as the difference in the threat value between the zone where the ball was originally and the zone where the ball was transitioned to:

$$V_{z'\to z} = xT(z) - xT(z')\,,$$

where $\mathbf{V_{z'\to z}}$ represents the value of the action where a team moves the ball from zone z' to z.

2.3. Data Collection

Given that Gaelic football does not have the advantages of soccer and other sports with the access to event-based data provided by data companies including Opta and Statsbomb, data had to be collected manually.

To facilitate systematic data collection, a custom R Shiny app was developed. R shiny is an open-source package for R that allows you to create interactive web applications (R Core Team, 2017). This process involved extensive programming, testing and updating to suit the specific data structure.

The app allowed for precise tracking of events by syncing the video with the data entry enabling the users to capture the timestamp for the action that occurred. Based on visual assessment the annotator coded each key event in a possession including the start and stop of play, passes that occurred (hand or kick), progressions of play through carrying actions, shots that occurred, including the type of shot, the pressure the person taking the shot was under and the outcome of the shot. Crucially the zone for every event was recorded as per the grid in Figure 1. It is this zone information which is of most relevance in this work although the plan is to develop more sophisticated models based on the more detailed information collected.

Annotation was performed by three different annotators which each game annotated by a single individual. Reliability between annotators was evaluated based on each annotating the same game with measures relating to individual and total events showing high consistency. It is the intention of the lead author to manage the coding of significantly more games.

2.4. Expected Value of Shots

While the data collected in this study comprised 837 shots, the authors also had access to the more substantial data set used by (McGuigan et al., 2022) which contained details of 3830 shots, 389 of which were shots for goals.

The integration involved the following steps:

- Mapping Shots to Zones: Each shot in the dataset was assigned to one of the 16 zones based on its pitch coordinates. This ensured that the external data aligned with the zonal framework used in this study.
- Shot Outcome Analysis: The dataset provided detailed information on outcomes for shots, including goals, points, and misses for both open play and dead-ball situations. By calculating the frequency of these outcomes for each zone, we derived probabilities for successful attempts by shot type.
- Calculation of Expected Points: Using these probabilities, the expected points per zone were calculated. This involved weighting the likelihood of each outcome by its associated point value (e.g., 3 points for a goal, 1 point for a point).

These expected points formed the basis of the first term in the Expected Threat (xT) equation above.

3. Results

In total 8,016 zone transitions were recorded from 14,269 observations. 837 shots were coded with 561 of those relating to shots for points from open play, 186 relating to shots for points from dead ball situations, 65 shots for goals from open play and the remainder (25) representing shots for goals from dead ball situations, mostly penalty kicks.

3.1. Transition Matrix Findings

The transition matrix, representing the probability of the ball moving between zones during a possession sequence, was derived from the 8,016 observed transitions and is shown in Figure 2.

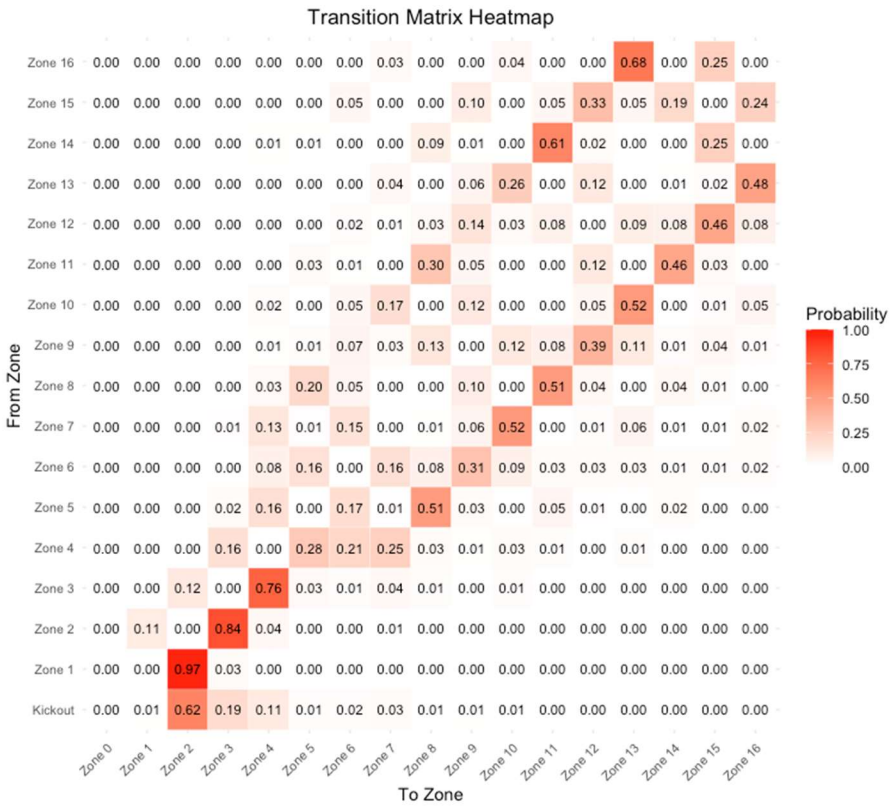

Figure 2. *Transition Matrix Probabilities*

Analysing the key transition probabilities, kickouts (from zone 0) are likely to go to zone 2 **62%** of the time, followed by zone 3 **19%** of the time. This indicates teams in our dataset favour short, and possibly uncontested, kick outs.

There is high probability of advancing the ball from defensive areas; from zone 1 to zone 2 is **97%**, zone 2 to zone 3 is **84%** and zone 3 to zone 4 is **76%.** This indicates that teams like to build up play through these zones. Zone 4 shows a varied approach to progressing the ball into attacking zones, with a slightly higher probability of going to the left **28%** of the time through zone 5, **25%** of the time to the right through zone 7, and **21%** centrally through zone 6.

Figure 3 shows the shot matrix representing the probability that a shot of each type, represented by an absorbing state, occurs when play is in each of the 17 zones. For zone 15, a shot from open play is likely 42% of the time, a point from a dead ball is likely 13% of the time, a goal from open play is likely 2% of the time, with a small percentage of the time 0.2% ending up as a goal from a dead ball. Zone 15 has the highest probability across all scoring attempts, showing its importance. When analysing shots from open play (Open Shot Point), zone 12 also scores high indicating moving the ball to central positions is significant.

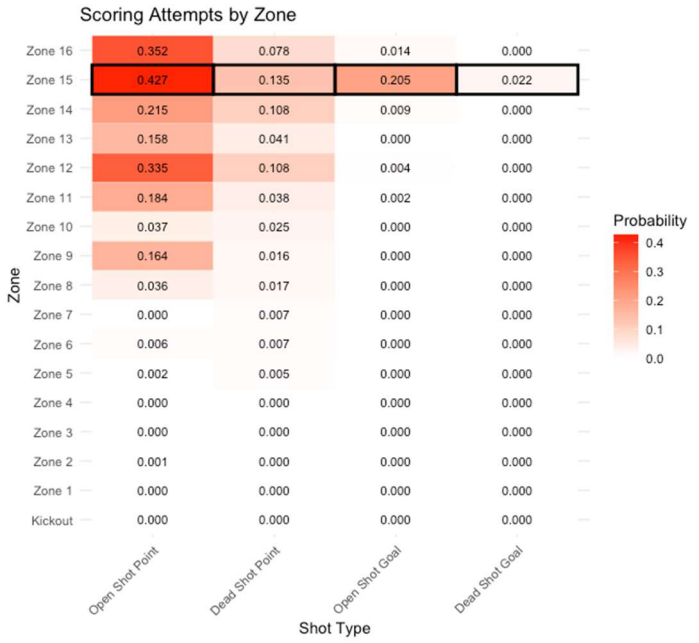

Figure 3. *Scoring Attempt Probabilities by Zone*

Analysing the turnover absorbing state as shown below in Figure 4, kickouts have the highest likelihood of a turnover. Attacking zones closest to the goal (16, 15, 14) are the next most likely to result in a turnover.

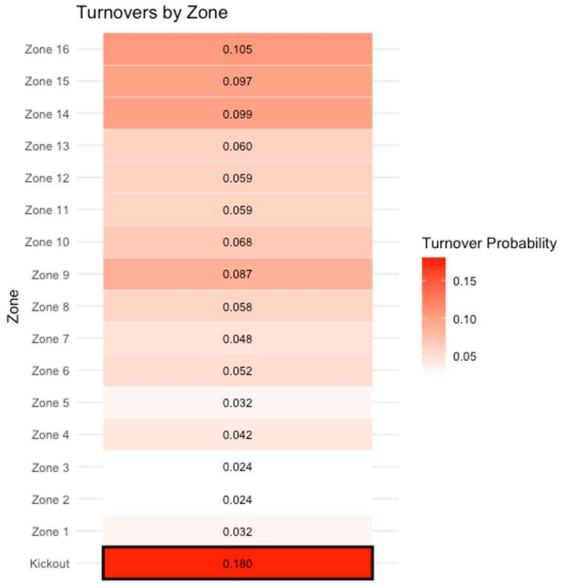

Figure 4. *Turnover Probabilities by Zone*

3.2. Expected Threat Zone Values

The *xT* model assesses the scoring potential linked to each zone/area on the pitch. By calculating the *xT* values for every zone, it becomes feasible to pinpoint regions that are most productive for scoring and understand how beneficial possession in different zones is to a team. The *xT* values were derived utilising the Markov chain model described in the Methods section. This model incorporates the probabilities associated with transitioning between distinct zones and the probability of scoring from each respective zone. Through a series of iterative calculations conducted until convergence was achieved, we obtained stable *xT* values representing the expected contribution to the team's score resulting from ball possession within each zone. The final *xT* values for each zone are shown below in Figure 5. This is the average expected points a team can achieve from possession in each zone.

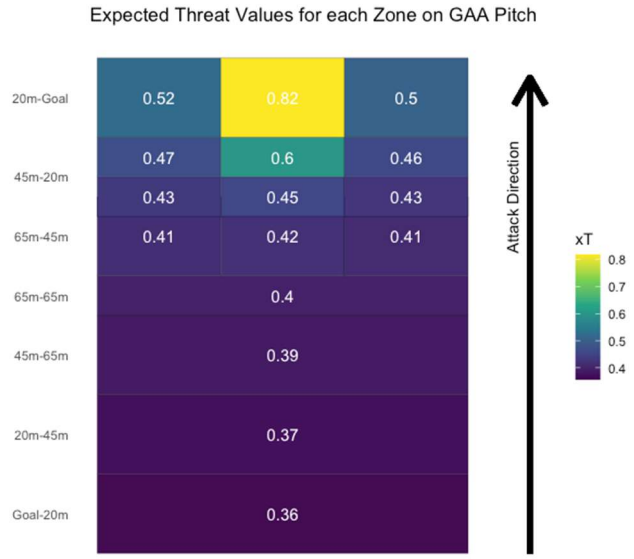

Figure 5. *Expected Threat (xT) Values by Zone*

The highest xT value is 0.82 for zone 15, this indicates that possession in this zone on average offers the highest potential for scoring it also indicates teams prefer to shoot from this zone. Zone 12 has the next highest xT value with 0.602, this zone represents areas where scoring attempts in particular dead ball are more likely. This again indicates the benefits of possession of the ball in zones 12 and 15 as they are centrally located. Moderate xT zones, zones 14 and 16 have xT values of 0.454 and 0.467, this indicates these zones are important for generating scoring attempts but to lesser extent than zone 15. Again zones 9 and 11 show moderate xT values of 0.454 and 0.467, indicating that possession in these zones still contributes meaningfully to the teams attacking potential.The symmetry of the xT map is interesting with the values for zones 5, 8, 11 and 14 similar to those for 7, 10, 13 and 16. The xT values can be used to measure the value of actions that involve the transitioning of play between zones with one particular use case to measure the risk/reward of shorter passes versus longer passes.

4. Discussion

This research extends this body of knowledge by introducing an Expected Threat (xT) model based on a Markov chain analysis to quantify the scoring potential associated with different zones on the pitch. This quantitative approach offers a novel perspective on the style of play in Gaelic football, allowing for a deeper understanding of how teams navigate the field to maximize scoring opportunities.

4.1. Current Style of Play

The analysis of the transition matrix reveals a significant preference for short kickouts, with 62% directed to Zone 2 and 19% to Zone 3. This strategy minimises the risk of turnovers, as evidenced by only 18% of kickouts leading to a turnover. This finding aligns with previous studies emphasising the importance of possession retention and efficiency in turnovers (McGuckin et al., 2020). The focus on short to medium kickouts indicates a tactical shift towards building play from the back, prioritizing control over the ball rather than contesting possession in riskier areas. While more granular data would help prove this, such as the location all players at the time of a kickout, the current data indicates a style of play centered on possession retention for kickouts.

High transition probabilities from defensive to midfield zones (Zone 1 to Zone 2 at 97%, Zone 2 to Zone 3 at 84%, and Zone 3 to Zone 4 at 76%) suggest that teams favour a gradual build-up approach. This style allows for maintaining possession while advancing the ball, reducing the likelihood of turnovers in critical areas. This sort of strategy reflects an emphasis on structured play and patience in creating scoring opportunities.

The *xT* model identifies Zones 12, 14, 15, and 16 as areas with the highest scoring potential. Possession in Zone 15, with an *xT* value of 0.82, offers the greatest expected threat. This underscores the tactical objective of advancing the ball into these zones to increase the likelihood of scoring. The recognition of these high-value zones provides a quantitative backing to the intuitive understanding of attacking strategies. As zones 12 and 15 are located centrally the findings indicate progressing the ball to a central attacking position as a beneficial strategy to improve a team's chances of scoring.

4.2. Benefits to Managers, Coaches and Players

For managers and coaches, the insights from the *xT* model facilitate more informed tactical planning. By understanding which zones contribute most significantly to scoring opportunities, coaches can devise strategies that focus on transitioning the ball into high *xT* areas. There is limited value of moving the ball vertically down the sides of the pitch. Players can now be more aware of the expected threat provided with the different zones. Teams can benchmark their performance against the expected threat values which would identify strengths and weaknesses in their playing style. Overall, it offers a data driven approach to support decision making and enables teams to track their progress over time.

4.3. Limitations

The authors recognise that the study is based on a relatively small number of games (14). It is their intention to extend this number significantly and to conduct a thorough reliability study to assess the level of difference in annotators performance and its impact on the key measures derived from the study.

The model underpinning this study is limited to zones in which possession is located. Future work based on the rich data set collected will look to include numerous other factors in the model including the duration of the attack, game state, the number of passes, both hand and foot, performed in the attack as well as the time of individual events. The potential adoption of new rules for Gaelic football will bring an interesting angle to the work with the potential to compare the pattern of play before and after any rule changes.

5. Conclusion

5.1. Summary of key findings

The highest *xT* values are clustered in zones closest to the opponent's goal (Zones 12, 14, 15, and 16), emphasising the importance of advancing the ball into these areas to maximize scoring opportunities. Actions that move the ball into high *xT* zones significantly increase the team's expected threat, underlining the value of successful plays. This will help teams with a concentration of threat.

Zone 15 stands out with an *xT* value substantially higher than other zones, suggesting that possession here is particularly valuable. Teams may benefit from strategies that focus on entering and retaining possession in this zone.

There is a consistent increase in *xT* values from defensive to attacking zones. This progression underscores the cumulative benefit of advancing the ball up the pitch. The incremental *xT* gains from moving between zones can inform decisions on risk-taking versus possession retention in different areas. The moderate *xT* values in Zones 5 to 7 highlight their role as transitional areas. While not as threatening as attacking zones, maintaining possession here is crucial for building up play. The relatively small *xT* differences between these zones suggest that horizontal movements (e.g., switching play) may offer limited increases in scoring potential compared to forward progression. Lower *xT* values in defensive zones indicate that the immediate scoring potential is low. However, turnovers in these areas can be particularly detrimental. Teams should focus on secure possession and minimizing errors in defensive zones to prevent conceding high *xT* opportunities to the opposition. Teams should also focus on practicing longer kick passes which require a higher skill but will prove to be highly rewarding.

There is significant potential for future research to enhance the current *xT* model. The addition of a richer set of contextual features will allow the development of a more practical model in line with work ongoing in other sports (Poropudas, n.d.; Roy et al., 2020).

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