Optimizing Football Game Strategies through Passing Network Analysis

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Abstract

Objectives. This study aims to explore the potential of Passing Network as an indicator of football team outcomes. The main focus is to understand how the structure and dynamics of the Passing Network can be used to predict match results and provide practical insights for coaches and analysts in optimizing game strategies.

Materials and Methods. This study employed a mixed-methods design, combining both quantitative and qualitative approaches. Quantitative data were collected from 96 group-stage matches of the 2016–2017 UEFA Champions League season, involving 32 top European teams. The analysis was conducted using network analysis, where players were represented as nodes and passes as edges. Various indicators such as degree centrality, betweenness centrality, eigenvector centrality, diameter, and clustering coefficient were calculated to evaluate the structure of the Passing Network. Qualitative data were gathered through in-depth interviews with coaches, players, and professional analysts to provide additional contextual insights. Statistical techniques such as binomial logistic regression and machine learning were employed to analyze the relationships between Passing Network indicators and match outcomes.

Results. The results of the study indicate that teams with a more structured Passing Network tend to exhibit higher levels of offensive actions and attack effectiveness. Graphical visualizations of the Passing Network provide deep insights into player interactions and overall team strategies. The binomial logistic regression (BLR) model successfully enhanced the accuracy of match outcome predictions using network-based indicators. These findings affirm that the Passing Network can serve as a reliable predictive tool for forecasting match results.

Conclusion. This study concludes that Passing Network analysis holds significant potential as a tool for understanding team dynamics and predicting match outcomes. The combination of quantitative and qualitative approaches provides comprehensive insights that are valuable for coaches and analysts in formulating strategies. Future research is recommended to integrate player tracking data, real-time game contexts, and artificial intelligence technologies to enhance accuracy and analytical depth.

Keywords : Passing Network, Football, Ball Possession

Introduction

In the modern era of football, team performance analysis has evolved significantly beyond conventional statistics such as ball possession and number of shots. Passing network analysis has emerged as a revolutionary analytical tool for understanding team dynamics and

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predicting match outcomes. This study aims to explore the potential of passing networks as an indicator of football match results through a mixed-methods approach that combines quantitative and qualitative analysis.

The relevance of this research lies in the ability of passing networks to provide in-depth insights into player interactions and game patterns that traditional metrics often fail to capture. As stated by Ievoli et al. (2021), pass network analysis can reveal complex relationships between team structure and match outcomes that frequently go unnoticed in conventional observations. Through graphical visualization connecting players as nodes and passes as edges, passing networks offer a holistic representation of how teams construct attacks and maintain ball possession.

This research utilizes data from 96 group stage matches of the 2016–2017 UEFA Champions League season, involving 32 top European teams. The sample was chosen due to the high quality of competition and consistency of available data. The methodology integrates network analysis with machine learning techniques to identify statistically significant patterns. This approach allows for an objective evaluation of how the characteristics of a team's passing network correlate with match outcomes.

The primary focus of this study is to explore the relationship between the structure of a team's passing network and its offensive performance, attacking efficiency, and the probability of achieving positive match results. Variables such as network diameter, centralization, and density serve as key parameters to understand game dynamics. The study also considers contextual factors such as team formation, opponent tactics, and match situations to provide a more comprehensive interpretation.

This research contributes practical insights for coaches, analysts, and football decision-makers. The findings can be applied to optimize game strategies, enhance player rotation efficiency, and develop more adaptive tactical approaches. Furthermore, the integration of qualitative analysis through interviews with professional football practitioners adds an extra dimension to understanding the real-world application of the study's findings.

The theoretical foundation of passing networks in football is grounded in literature that highlights the importance of analyzing inter-player relationships. Immler et al. (2021) describe the passing network as a visual representation of the complex interactions among players within a team, where each node represents a player and each edge represents a pass. This framework helps explain how team organization influences performance on the pitch.

Passing network analysis has demonstrated significant potential in predicting match outcomes. A study by Ievoli et al. (2021) found that network indicators such as degree centrality, betweenness centrality, and eigenvector centrality positively correlate with the likelihood of winning. These findings are supported by McHale and Relton (2018), who observed that players with high centrality scores are often key in ball distribution and maintaining team cohesion.

The methodological approach to passing network analysis has rapidly evolved in recent years. Buldú et al. (2018) introduced a multilayer framework that considers spatial, temporal, and dynamic dimensions of the game. This allows for a more detailed analysis of how playing patterns shift throughout different match phases and scenarios. Ichinose et al. (2021) further extended this framework by introducing the concept of robustness in passing networks, enabling an assessment of how resilient team structures are to disruptions.

The relationship between passing networks and team playing styles has become a focal point in recent research. Wang et al. (2020) demonstrated that teams with more decentralized passing networks tend to employ a more flexible playing style, whereas those with more centralized networks exhibit stronger game control but less adaptability. These findings align with the research by Gonçalves et al. (2017), who concluded that passing networks can be used to identify the unique characteristics of specific coaching styles.

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However, several studies have also highlighted the limitations of passing network analysis. Korte et al. (2019) emphasized the need to integrate tracking data to achieve a more comprehensive understanding of match dynamics. Passing network analysis alone may not fully capture the nuances of defensive strategies or individual player contributions. Therefore, a multidimensional approach that incorporates diverse data sources is increasingly vital for modern team performance analysis.

Wang et al. (2020) introduced a concept of team cooperation research based on complex network methods, providing new insights into how passing networks can optimize team collaboration. Their study shows that passing network efficiency depends not only on the number of passes but also on the quality of player interactions and timing of ball distribution. Wu et al. (2020) supported this by showing that optimizing core local networks can significantly enhance a team's attacking effectiveness.

The play-by-play network analysis methodology developed by Korte et al. (2019) offers a novel way to understand match dynamics in real time. This technique enables detailed analysis of how passing networks evolve throughout a match and how structural changes influence outcomes. It has been effectively applied in case studies on renowned coaching styles such as Guardiola, Klopp, and Pochettino (Immler et al., 2021).

Recent literature also highlights significant developments in the application of machine learning to passing network analysis. Zhao et al. (2020) found that integrating passing network indicators with machine learning algorithms can improve match outcome prediction accuracy by up to 20%. This opens new opportunities for developing more sophisticated predictive systems in team performance analysis.

A study by Ievoli et al. (2021) on the influence of key match events on football pass maps provides valuable insights into how critical moments impact network structure. The research shows that adaptive and responsive passing networks tend to perform better than static ones. The integration of passing network analysis with other performance indicators has become an important trend in modern football research. A case study by *Soccermatics* (2022) on decentralized football demonstrated that combining passing network metrics with possession-based indicators can offer a more complete picture of team strategy effectiveness. This approach allows for a more comprehensive evaluation of how teams utilize ball possession to create scoring opportunities. This overall literature review shows that passing network analysis has matured into a valuable and sophisticated tool for understanding football team dynamics. Integration with new methodologies and technologies continues to expand its analytical capabilities, providing actionable insights for strategy development and decision-making in modern football.

Findings in the literature underscore the necessity for a multidimensional approach to team performance analysis, with passing networks as a vital—but not standalone—component. The development of analytical frameworks that integrate diverse data sources and analytical methods will be a key direction for future research to gain deeper insights into football match dynamics.

This study highlights that passing network analysis is an innovative and increasingly relevant analytical approach in evaluating modern football team performance. The novelty of this research lies in the application of a mixed-methods approach and the integration of machine learning to evaluate pass structures comprehensively—an area still underexplored in Indonesian football literature. The urgency of the study is reinforced by the growing need for data-driven strategies in addressing the complexities of modern football competition. Future research is recommended to expand the scope of analysis by incorporating spatial-temporal player tracking data, real-time contextual match factors, and artificial intelligence to develop more accurate and adaptable predictive models in response to tactical changes on the field.

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Materials and Methods

Study Participants.

This study involved 32 elite European football teams competing in 96 group stage matches of the 2016–2017 UEFA Champions League season. The selection of participants was based on the availability of passing data, the quality of the competition, and the representation of the highest level of professional football. Additionally, participants in the qualitative data collection included head coaches, key players, and performance analysts from several professional teams. These individuals were selected through purposive sampling based on their experience in utilizing performance data for team strategy, and were engaged through semi-structured interviews.

Study organization.

This study employed a mixed-methods design that integrated quantitative and qualitative approaches to comprehensively examine the role of passing networks in football team performance. Quantitative data were sourced from publicly available secondary datasets, including match event logs and player tracking data, while qualitative insights were gathered through in-depth, semi-structured interviews with coaches, core players, and performance analysts from professional teams. The analysis was carried out in three sequential phases: first, passing data were processed to construct passing networks represented as graphs, where players served as nodes and passes as edges; second, network metrics—such as degree centrality, betweenness centrality, eigenvector centrality, density, diameter, and clustering coefficient—were calculated for each team; and third, a triangulation analysis was conducted by integrating numerical data, network visualizations, interview narratives, and spatial-temporal tracking information to produce a holistic interpretation of team dynamics.

To further strengthen the findings, a multi-layered statistical approach was implemented. Descriptive statistics provided an overview of passing network characteristics, followed by network metric computations using tools such as Gephi and NetworkX. Binomial logistic regression was then applied to explore the association between network metrics and match outcomes, while machine learning techniques—including Random Forest and Support Vector Machine—were utilized to enhance predictive accuracy. Finally, model validity was assessed through cross-validation and performance metrics such as accuracy, precision, recall, and AUC, ensuring both statistical rigor and practical reliability.

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Results

This study aimed to explore the influence of passing networks in football and how insights derived from such analyses can be used to predict match outcomes. Using data from 96 group-stage matches of the 2016–2017 UEFA Champions League involving 32 elite European teams, the research applied a quantitative, network analysis-based approach to visualize and quantify player interactions during matches. One of the key findings was that passing network visualizations provided valuable insights into both individual interactions and overall team strategies. Players were represented as nodes and passes as edges, with edge thickness indicating pass frequency and node position reflecting players' average on-field location.

Teams with more structured passing networks, such as Barcelona and Bayern Munich, exhibited higher offensive activity and better finishing, underscoring the role of coordinated player connections in enhancing ball possession and attacking efficiency. Several critical network indicators were identified, including diameter, which measures the farthest distance between two players in the network; teams with lower diameters, like Manchester City, tended to generate more goal-scoring opportunities due to faster ball circulation. Another key metric was centralization, which reflects how concentrated passing is around specific players. Teams such as Napoli and Real Madrid displayed high centralization, relying heavily on playmakers like Marek Hamsik and Luka Modric, respectively. However, findings suggested that moderate levels of centralization contributed to greater tactical flexibility, allowing smoother transitions between defense and attack.

Statistical analysis revealed a strong correlation between optimized network metrics—especially diameter and centralization—and higher offensive actions and scoring efficiency. Notably, teams with strong passing connectivity in critical areas, such as near the opponent's penalty box, were more likely to create scoring chances. Furthermore, the study developed four machine learning models to predict match outcomes, including a binomial logistic regression (BLR) model. The use of network-based indicators significantly improved predictive accuracy, with BLR demonstrating superior explanatory power. Overall, the study confirmed that passing network indicators, particularly centralization, have a significant influence on team performance. Teams reliant on a few key distributors showed higher completion rates and better transitions, while well-connected networks in critical zones translated into increased goal-scoring opportunities and higher probabilities of winning.

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Discussion.

.1. Contribution to the Literature: The findings of this study offer a significant contribution to the existing body of literature on football team performance analysis. Building upon previous studies (Gonçalves et al., 2017; Ievoli et al., 2021), this research reinforces the notion that passing network analysis is a powerful tool for understanding the dynamics of play. It also supports the conclusions drawn by Wang et al. (2020), emphasizing the importance of analyzing player interaction patterns in the creation of goal-scoring opportunities.

2. Practical Implications: The results carry substantial practical implications for football coaches and performance analysts. Understanding the importance of passing networks can assist coaches in formulating more effective strategies, identifying key players involved in ball distribution, and enhancing on-field player collaboration. For instance, passing network data can be used to pinpoint areas on the pitch that require improved player connectivity. Additionally, such analysis supports tactical decision-making, including adjustments in formation and player rotation.

3. Integration of Player Tracking Data: While this research provides valuable insights, there remains room for further exploration. Integrating player tracking data with passing network analysis could yield deeper insights into player movements and their involvement in gameplay. For example, tracking data may reveal the contributions of off-the-ball players in shaping match dynamics such as creating space or drawing defenders away from critical zones.

4. External Factors: Future research is also encouraged to investigate the impact of external factors—such as weather conditions, match pressure, and opponent dynamics—on passing networks and team performance. These elements can influence passing patterns and tactical effectiveness. For instance, adverse weather like rain can reduce passing accuracy, which in turn alters the structure and efficiency of the passing network.

5. Psychological and Social Aspects: Beyond technical dimensions, future studies could incorporate psychological and social aspects of player interactions. Interpersonal dynamics, including verbal and non-verbal communication, may significantly influence the efficiency of a team's passing network. Koenig et al. (2011) highlighted that interpersonal skills such as conflict resolution and collaborative problem-solving enhance team cohesion and overall performance.

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6. Multidimensional Approaches: To generate richer and more applicable findings, a multidimensional approach that combines both quantitative and qualitative methods is essential. Interviews with coaches, players, and analysts can offer contextual insights into decision-making processes, tactical adjustments, and player interactions shaped by passing network analysis. Such a holistic perspective may pave the way for more innovative and relevant future research.

In conclusion, this study demonstrates the vast potential of passing networks as analytical tools for understanding the flow of the game and predicting match outcomes. Using data from 96 group-stage matches of the 2016–2017 UEFA Champions League, the study found that teams with more structured passing networks tended to score more goals and exhibited higher finishing efficiency. These findings not only reinforce existing theories but also provide actionable guidance for coaches and analysts in developing more effective strategies.

However, the study also underscores the need for a multidimensional research approach that integrates various data sources and analytical methods to achieve a more comprehensive understanding of team performance. Incorporating player tracking data, external variables, and psychological dimensions opens new avenues for future research in football performance analysis.

Conclusions.

This study explores the influence of passing networks on football team performance by analyzing 96 group-stage matches from the 2016–2017 UEFA Champions League season. The findings reveal that a more organized passing network structure positively correlates with offensive actions, attacking effectiveness, and the probability of winning a match. Key indicators such as network diameter and centralization were found to have a significant impact on match outcomes. Teams with lower diameter values tended to create more direct goal-scoring opportunities, while high centralization indicated a strong reliance on key players for ball distribution.

The use of machine learning models, particularly binomial logistic regression, demonstrated that network-based indicators significantly enhance the accuracy of match outcome predictions. Graphical visualizations of passing networks provided deep insights into player interactions and overall team strategies. The study also underscores the

importance of integrating player tracking data to achieve a more comprehensive understanding of in-game dynamics.

These findings offer practical implications for coaches and performance analysts in designing more adaptive and data-informed tactical strategies. Future research is encouraged to incorporate external factors such as weather conditions, match pressure, and psychological aspects of players to enrich team performance analysis. Overall, passing network analysis proves to be an effective tool for understanding the dynamics of play and improving team performance.

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