



Issue no: 01 | Vol no: 05 | February 2026: 01-08

Analysing Relationships Among Streets Through Correlation Analysis of the Dublin Pedestrian Footfall Dataset

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Received: 2025-12-24

Accepted: 2026-01-18

Published: 2026-02-27

Cite this article in APA

Koech, M. J., & Sobhani, N. (2026). Analysing relationships among streets through correlation analysis of the Dublin pedestrian footfall dataset. *Editon consortium journal of physical and applied sciences*, 5(1), 1-8. <https://doi.org/10.51317/ecjpas.v5i1.676>

Abstract

This article examines the relationships among the 15 streets in the Dublin footfall dataset. Understanding interdependencies and differences in pedestrian activity patterns across streets in Dublin City Centre is essential for informed urban planning, retail strategies, and effective management of urban spaces, yet such spatial-temporal relationships remain underexplored in available sensor-based footfall data. This study utilised pedestrian footfall data collected via PYRO-BOX Counters sensors provided by Dublin City Council and the National Transport Authority (NTA). The analysis began with careful data preprocessing, including cleaning, standardisation of street column names, handling missing values through forward-fill imputation techniques, and deletion of some columns after learning of relationships between them. Hourly pedestrian counts were aggregated to daily totals to better capture long-term movement patterns relevant to street-level comparisons. A Pearson correlation heatmap was created to examine how the streets in Dublin City Centre relate to one another. This visualisation revealed different groups of streets with comparable activity patterns, clearly emphasising the interdependence and differences among them. These groupings highlight shared temporal behaviours alongside distinct variations in pedestrian footfall across locations. The findings provide a basis for better-informed urban planning and policy decisions by shedding light on how various locations interact with one another. This analysis contributes meaningfully to urban informatics by illustrating street-level relationships and inter-dependence in footfall data, thereby supporting more responsive infrastructures, enhanced city services, retail and commercial planning, and sustainable urban growth as business will know where to locate themselves so as to get a high number of customers by choosing streets that have high footfall and urban planners will know how to plan the city in terms of green spaces and street paths depending on the number of people using the different available streets.

Keywords: Pearson correlation analysis, pedestrian footfall, street-level interdependence.



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INTRODUCTION

Understanding pedestrian movement patterns is important in the context of rapid urbanisation, smart city development and data-driven urban planning. Accurate footfall analysis provides critical insights for infrastructure design, retail optimisation, public safety management and transportation planning. Despite the availability of pedestrian data, there remains a significant challenge in extracting meaningful patterns across spatial and temporal dimensions to support evidence-based decision-making in urban environments. This research addresses this gap by analysing pedestrian movement patterns between the 15 streets using available data. Footfall, also known as foot traffic, refers to the masses of people entering a shop, an area, or a building during a particular period of time.

In Dublin City Centre, which serves as the main case study for this research, pedestrian footfall data is recorded using a network of PYRO-Box people counters. These passive infrared (PIR) pedestrian counters are widely deployed across the city to monitor and record footfall, detecting pedestrians by sensing body heat differences as they pass through the device's field of view. This enables accurate and anonymous counting without capturing personal data. The devices log count at hourly intervals and store them locally on internal memory, with data transmitted in real time or scheduled batches through wireless internet or Global System for Mobile Communications (GSM) networks to central servers overseen by Dublin City Council. Once received, the data undergoes preprocessing steps including validation, cleansing, and aggregation. Before public release on open data portals such as data.gov.ie, datasets are quality checked to correct anomalies or sensor gaps (Dublin City Council, n.d.). Although captured hourly, data is published monthly to ensure accuracy and consistency, providing a reliable, privacy-compliant, and scalable approach to monitoring pedestrian activity across multiple streets in real time. For example, on Grafton Street, a two-sided PYRO-Box with a 20m/65' range allows monitoring of pedestrian traffic on Dublin's most used shopping street (Traffic Technology International, n.d.).

Predicting and understanding foot traffic is essential for enhancing operations, allocating resources effectively, and making informed decisions in sectors like retail, transportation, and urban development (Komar & James, 2024). The multi-location nature of the dataset covering diverse streets with varying spatial characteristics offers

potential to reveal interdependencies and differences in pedestrian activity patterns among locations. Despite advancements in data availability, there remains a gap in localised analyses that account for urban spatial characteristics and how pedestrian volumes relate across different streets in the same city Centre. This study addresses aspects of that gap by examining pedestrian footfall data in Dublin City Centre to identify relationships between streets, providing insights into shared temporal behaviours, groupings of comparable activity patterns, and distinct variations that can inform urban planning and policy decisions.

The objective of this study is to identify relationships between streets in the Dublin footfall dataset, establishing the context for analysing street-level interdependencies and similarities in pedestrian activity across Dublin City Centre.

LITERATURE REVIEW

Estimating pedestrian foot traffic has gained increasing focus due to its applications in retail management, transportation planning, and urban design. Accurate insights into movement patterns support business optimisation and inform infrastructure planning and public safety. However, pedestrian dynamics are complex, shaped by weather, events, and other temporal factors, which complicate comparisons across locations and limit model transferability. Early research relied on observational studies and manual data collection. Foundational work, such as Whyte (1980), demonstrated how micro-scale environmental factors, such as seating availability and sunlight, influence pedestrian presence. While influential, these studies were descriptive and context-specific, offering limited methodological tools for quantifying interdependence across multiple streets or supporting predictive, multi-location urban analytics, but their applicability to network-level planning remained constrained.

Advances in sensing technologies (e.g. infrared counters) and data analytics have enabled large-scale, high-frequency pedestrian datasets spanning multiple sites. Time-series approaches are widely used to identify temporal trends, but recent research recognises that footfall data exhibit non-linear and spatiotemporal dependencies that require more sophisticated analytics techniques. Correlation analysis has been used to compare pedestrian counts between retail streets and nearby transport, revealing weekday patterns and shared seasonal effects (Murcio & Wang, 2025). However,

reliance solely on Pearson correlation assumes linear relationships and sensitivity to outliers; some studies therefore employ Spearman's rank correlation to capture monotonic relationships when distributions are influenced by irregular events. Despite these applications, comparative evaluations of correlation metrics in pedestrian contexts remain limited, and few studies explicitly discuss methodological trade-offs.

Although multi-sensor pedestrian studies exist internationally, evidence specific to Dublin is limited in scope and methodological depth. Existing Irish research and municipal reports primarily focus on descriptive counts at individual locations, tourism movement patterns or transport demand estimation rather than analysing interdependencies across multiple streets using statistical similarity or clustering techniques. A targeted review of academic databases and literature reveals no comprehensive peer-reviewed studies that systematically examine correlations, clusters or network relationships among Dublin city-centre pedestrian sensor locations. This absence indicates a clear empirical and methodological gap. Demonstrating inter-street relationships within Dublin is therefore necessary to understand whether patterns observed in other cities generalise in this context and to provide relevant evidence for planning and policy.

This review establishes the need for a more integrated analytical approach by critically identifying limitations in prior literature: overreliance on descriptive methods, limited comparison of correlation techniques, underuse of clustering and lack of Dublin-specific multi-location analysis. Addressing these gaps, the study examines pedestrian footfall data across Dublin city-centre streets to identify temporal interdependence and spatial variations that can inform urban planning and decision making. Despite these developments, comprehensive analyses of street-level interdependencies in city centres, such as Dublin, remain limited, especially studies that use sensor-based datasets to uncover clusters of similar activity patterns, common behaviours, and notable differences.

METHODOLOGY

This study adopted a quantitative, descriptive-correlational research design, drawing exclusively on secondary open data to identify and characterise interdependencies, similarities, and differences in pedestrian footfall patterns across streets in Dublin City Centre. The primary data source was the Dublin City

Centre Footfall Counters dataset, Available as an open-access resource on data.gov.ie. The dataset was compiled by Dublin City Council together with the National Transport Authority (Dublin City Council, n.d.). The dataset consists of hourly pedestrian counts captured by a network of PYRO-Box passive infrared sensors installed at multiple locations throughout the city centre. For this analysis, the complete raw CSV files covering the full calendar years 2022, 2023, and 2024 were downloaded and processed without any sampling, ensuring comprehensive inclusion of all available street-level time series.

All preprocessing and analysis were conducted in Python, primarily using the pandas and seaborn libraries. The workflow began by importing the annual files and merging them into a single Data Frame while adding a 'Year' column to preserve temporal traceability. Column names were standardised by removing extraneous parentheses, redundant descriptors such as 'Pedestrian', and unnecessary whitespace to eliminate inconsistencies arising from varying export formats. Completely empty columns and those with more than 5 per cent missing values were removed to maintain data reliability. A (5%) threshold was chosen to minimise bias while preserving sufficient temporal coverage across street sensors, as higher levels of missingness could weaken spatial comparability and introduce correlations through imputation. For streets recorded with directional components ('IN' and 'OUT'), it was verified that the aggregated total equalled the sum of the directional counts; the directional columns were then discarded, retaining only the total footfall per street. Remaining missing values were imputed using forward-fill, a method suitable for maintaining continuity in sequential time-series data (Kamalov & Sulieman, 2021). Timestamps were converted to datetime format, set as the index, and hourly counts were aggregated to daily totals by summing values within each day, a transformation chosen to emphasise longer-term movement patterns relevant to street-to-street comparisons. This process yielded a clean, structured dataset comprising daily total footfall time series for 15 streets.

The primary analysis involved computing Pearson correlation coefficients for the daily footfall series of the 15 streets, resulting in a correlation matrix that reflected the magnitude and direction of linear relationships in their activity patterns over time. This matrix was visualised as a heatmap to highlight clusters of streets exhibiting comparable behaviour (strong positive

correlations) and those displaying distinct or independent patterns (weak or near-zero correlations). To provide additional spatial and temporal context, average footfall was calculated for each street across the three years and ranked to reveal variation in overall activity levels. All data processing and visualisations were performed reproducibly using pandas for data handling, and seaborn and matplotlib for creating the heatmap and supplementary plots. This methodological approach ensured transparency, rigour, and direct alignment with

the objective of uncovering street-level interdependencies within the Dublin footfall dataset.

FINDINGS AND DISCUSSION

Street-level relationship summary of Pedestrian Footfall using correlation Analysis

The correlation heatmap (Figure 1) illustrates a visual summary of pedestrian footfall patterns with respect to their relationship on different streets. Several key insights emerge from the analysis:

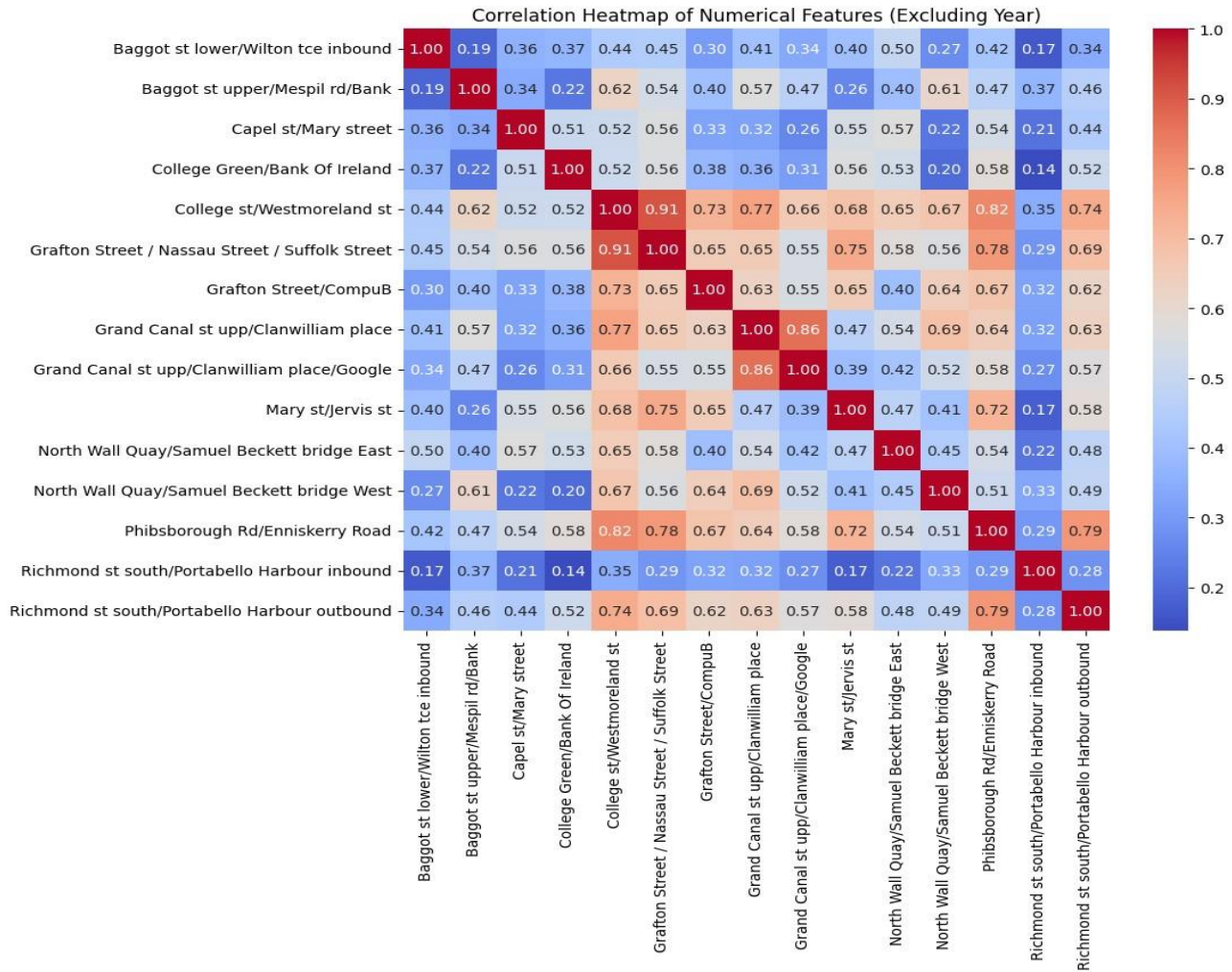


Figure 1: Correlation Map of Streets

Strong Positive Correlations (High Similarity in Patterns)

College Street/Westmoreland St exhibits a very high correlation with Grafton Street/Nassau Street/Suffolk

Street ($r = 0.91$) and College Green/Bank of Ireland ($r = 0.90$), indicating these areas experience similar pedestrian traffic patterns. This is expected as these locations are central and likely experience shared

commercial and tourist footfall. Correlation coefficients above 0.90 suggest strong linear movement. These strong relationships are consistent with the spatial proximity and functional connectivity of these streets, which form part of Dublin's primary commercial door.

Grand Canal Street Upper/Clanwilliam Place shows a strong correlation with its Google-specific point (Grand Canal Street Upper/Clanwilliam Place/Google) at $r = 0.86$, reflecting consistent patterns in that localised area. Given the geographic closeness of the sensors, this result reflects spatial autocorrelation rather than broader network interdependence.

Phibsborough Road/Enniskerry Road and Grafton Street/CompuB display moderately strong correlations with other key pedestrian areas. Correlation coefficients in the range of 0.60 – 0.80 suggest meaningful but not identical temporal dynamics, indicating these areas share broader citywide behaviour like weekday commuting patterns while retaining their local variability.

Weak or Low Correlations (Distinct Patterns)

Locations such as North Wall Quay/Samuel Beckett Bridge East and Richmond St South/Portabello Harbour exhibit a lower correlation value at $r = 0.33$. Lower coefficients ($r < 0.40$) suggest distinct temporal structures with central pedestrian flows, and a coefficient of determination at $r = 0.33$ indicates that their pedestrian patterns differ from those of the major city centres.

Baggot St Lower/Wilton Tce Inbound consistently shows weak correlations across most other locations, implying

relatively independent temporal behaviour compared with the main pedestrian clusters.

Conclusion

The correlation analysis reveals that pedestrian footfall patterns are highly interconnected in central commercial and tourist areas, while peripheral or specialised locations demonstrate more distinct and independent behaviours. However, correlation coefficients alone describe association rather than causation and interpretations regarding underlying influences should be supported by additional data. Incorporating inferential statistics like hypothesis testing and confidence intervals would improve the analytical depth and allow stronger conclusions regarding the strength and reliability of inter-location relationships. Understanding these relationships is key to effective planning of urban areas and resource allocation, particularly in managing pedestrian flows and optimising commercial opportunities in key zones. This analysis provides an initial quantitative foundation for understanding spatial interdependencies in Dublin pedestrian activity and can inform subsequent modelling stages, such as clustering or predictive forecasting, to support evidence-based urban planning and resource allocation.

Average Footfall Trends by Location and Year

The analysis of average pedestrian footfall across various locations for the years 2022, 2023, and 2024 (Figure 2) reveals both spatial and temporal dynamics in pedestrian movement patterns. These trends offer insights into the evolving commercial, social, and infrastructural landscape of Dublin city.

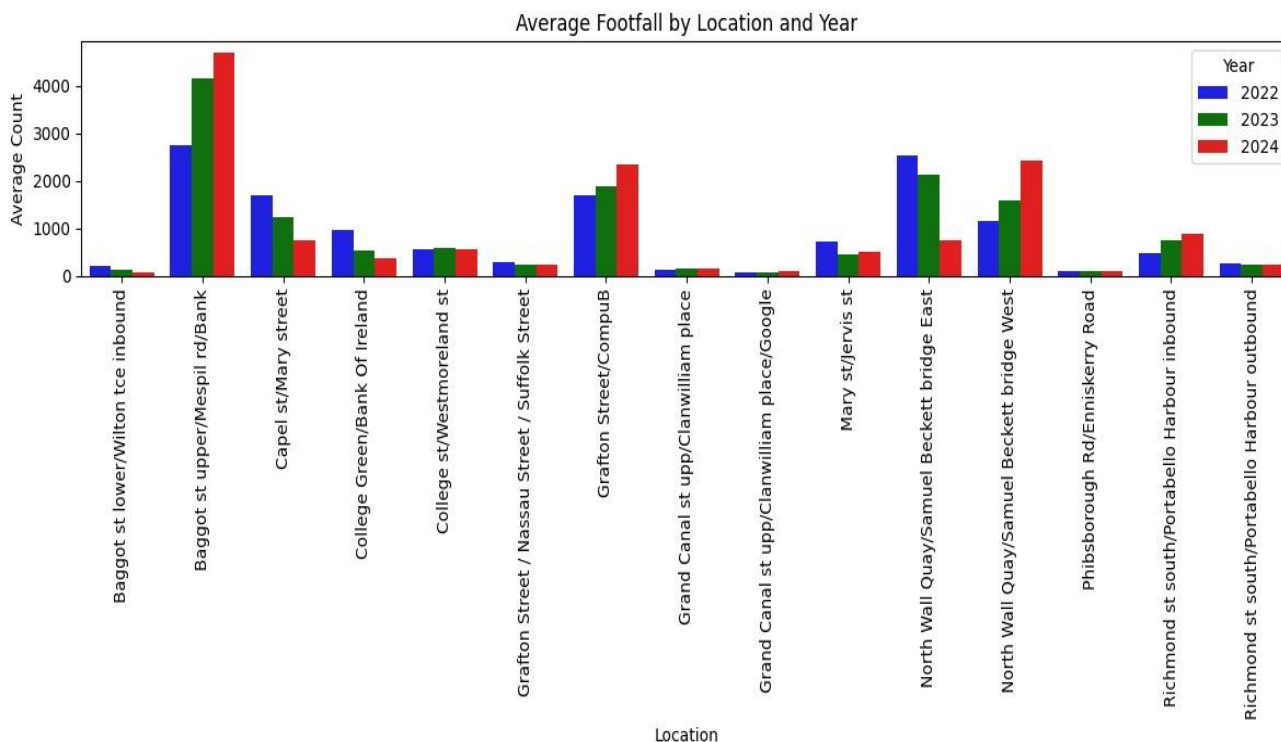


Figure 2: Footfall Distribution

High Footfall Locations

Baggot Street Upper/Mespil Road/Bank consistently recorded the highest pedestrian counts across all three years, with a significant increase observed in 2024. This sustained and growing activity suggests that the area remains a vital commercial and transit hub.

Grafton Street/CompuB similarly maintained high footfall levels, with a noticeable rise in 2024. As a well-known shopping and leisure destination, this growth reflects increased economic activity and the return of tourism and public events.

North Wall Quay/Samuel Beckett Bridge East also experienced a notable surge in footfall in 2024, surpassing previous years. This pattern is attributed to ongoing developments in the Docklands area and improved pedestrian connectivity to key attractions and business centres.

Moderate Footfall Locations

Locations such as College Street/Westmoreland Street and Mary Street/Jervis Street maintained moderate but stable pedestrian activity. Mary Street/Jervis Street experienced a marked increase in 2024, which suggests

recent urban revitalisation projects and the introduction of new retail and entertainment spaces.

Low Footfall Locations

Areas including Baggot Street Lower/Wilton Tce Inbound, Grand Canal Street Upper/Clanwilliam Place/Google, and Phibsborough Road/Enniskerry Road consistently showed lower pedestrian volumes across all years. These locations are less commercially oriented or primarily serve as transitional zones for commuters rather than pedestrian destinations.

Despite low historical footfall, Richmond Street South/Portobello Harbour Inbound saw a sharp increase in 2024, which indicates the growing popularity of the Portobello area, possibly driven by urban renewal initiatives, increased residential development, or cultural events attracting foot traffic.

Temporal Trends

Across most locations, 2024 exhibited an upward trend in average footfall, suggesting a broader recovery and normalisation of pedestrian movement post-pandemic. This trend was driven by improved urban mobility strategies, the return of public events, and increased economic activity.

The variation in year-on-year changes across locations highlights how localised factors, such as new infrastructure, commercial developments, and urban policies, play critical roles in shaping pedestrian movement.

Conclusion

The year-on-year analysis of pedestrian footfall underscores both the resilience and adaptability of urban environments. While some areas remain established pedestrian hotspots, others are emerging as significant zones of activity, driven by targeted development efforts. Understanding these evolving patterns is essential for effective urban planning, commercial investment strategies, and the design of pedestrian-friendly public spaces.

CONCLUSION AND RECOMMENDATIONS

Conclusion: This study examined pedestrian footfall patterns across multiple streets in Dublin City Centre to identify spatial-temporal interdependence using correlation-based analysis. Rather than focusing only on the descriptive relationships between the locations, the analysis contributes methodologically by demonstrating how simple statistical techniques, such as correlation coefficient and heatmap visualisation, can provide meaningful insights into urban pedestrian systems when applied to multi-sensor datasets. These findings illustrate the potential of correlation analysis as an exploratory tool within urban informatics, particularly for identifying synchronised activity structures and distinguishing locations that operate with greater temporal independence.

From a theoretical perspective, the study supports the view that urban pedestrian movement exhibits network-

like characteristics where streets function as interconnected components influenced by shared temporal drivers rather than isolated entities. The identification of synchronised clusters reinforces concepts from urban systems theory and spatial interaction research, suggesting that pedestrian dynamics can reflect functional urban zones shaped by land use intensity, accessibility and socio-economic activity. It highlights how empirical data can be used to test theoretical ideas in practical planning contexts.

The research demonstrates the applicability of correlation-based approaches for preliminary urban diagnostics, particularly when more complex modelling frameworks may not be feasible. It also highlights the importance of integrating inferential considerations such as statistical significance and robustness of relationships when interpreting correlations in spatiotemporal datasets, and this provides a foundation for future analytical extensions, positioning correlation analysis as a gateway method rather than an endpoint.

The analysis relied primarily on univariate pedestrian counts without incorporating explanatory variables such as weather conditions and event schedules, which limit causal interpretation. Correlation analysis captures association rather than directionality, and spatial proximity may influence observed relationships.

Recommendations: Future work should extend this work by integrating geospatial variables and urban data to better explain the mechanisms underlying observed interdependencies. Such developments would strengthen the evidence base for adaptive, data-driven urban planning and contribute to more sustainable and human-centred city development strategies.

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