# Does lighting affect pedestrian flows? A pilot study in Lund, Market Harborough and Dublin.

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***Abstract*—A study records pedestrian footfalls in Lund, Dublin and Market Harborough during the day and after dark, either side of the Autumn 2016 clock change, using the change of end of civil twilight time to measure the effect of different lighting levels at the same clock time on footfall rates. Examination of total footfalls on weekdays and at weekends found significant decreases in counts after the clock change, on 5/6 sites on weekdays and half the sites at weekends. Further analysis found that the percentage decrease in the counts in the test period (same time/day of the week, light one week, dark the next) was more than in the control period (same time/day of the week, light both weeks), in 79% of counting sessions. The findings demonstrate higher reduction in footfalls on weekdays in mixed use areas, such as the sites selected in Dublin, and on Sundays in non-central locations.**

***Index Terms*--Accessibility, footfalls, lighting, routes, streets.**

## I. Introduction

Well connected, accessible environments encourage usage, which in turn improves the social and physical health of people in cities [1] [2]. Lighting contributes to the accessibility of streets because it helps pedestrians see their surroundings and other people which informs decision making including routes choices. Route choices are informed by environmental conditions including lighting. City wide street lighting changes tend to be implemented without consideration of the impact on street users. For example, upgrades to LED street lighting luminaires change the night time appearance of many cities due to changes in the distribution and spectrum of light. Lighting control systems which are easy to embed in LED luminaires, permit unprecedented flexibility and have potential to reduce energy consumption at a large scale. Local Authorities must decide when to dim street lighting, without compromising comfort and accessibility.

Whether street lighting changes compromise pedestrian comfort and street accessibility is difficult to prove when pedestrians tread the same familiar daily routes. External lighting may influence route choices [3], [4], as could other physical characteristics such as space configuration, for example how narrow a street is or how many escape routes are visible [5], [6]. Focusing on the details of optimum electric lighting conditions could be premature if familiarity with an environment reassures pedestrians to the extent that other parameters do not matter. Therefore, the aim of this study is to establish whether a change in large scale ambient lighting conditions influences pedestrian flows measured by footfalls. The clock change provides an opportunity to do this, as the same clock time offers daylight and after dark conditions in subsequent weeks. Footfall counts are a simple, quantitative measure of how many pedestrians are using a street. If an overall effect is found, then further research into the effect of electric lighting conditions on pedestrian behaviour after dark, is relevant.

## II. Method

### *A. Procedure*

Pedestrian movement flow is recorded by counting pedestrians passing through notional “gates” at locations in Lund, Market Harborough and Dublin during five minute intervals. The surveys were completed either side of the clock change in Autumn 2016, so that different lighting conditions at the same time of day could be compared. Footfall sites are sampled on the basis of relative illumination conditions and whether they provide direct or indirect routes to a destination. Two sets of footfalls are compared; (1) Changes in count rates for all footfall data before and after the clock change and (2) changes in count rates before and after civil twilight on specific days. The collection dates and site characteristics are provided in Table 1.

TABEL1 FOOTFALL DATA COLLECTION INFORMATION

| ***City*** | ***Route*** | ***Abbreviation*** | ***Route info.*** | ***Building type on route*** | ***Minimum illuminance*** [a] | ***Maximum illuminance*** [a] | ***Pre-Clock Change Dates 2016*** | ***Approximate time street lighting switched on*** | ***Post-Clock Change Dates 2016*** | ***Approximate time street lighting switched on*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Dublin | Kilmainham Rd | D-KL | Indirect & lighter | Housing blocks and shops. | 11 lux | 25 lux | 25/10<br>26/10<br>29/10<br>23/10 | 18.10hrs<br>18.10hrs<br>18.10hrs<br>18.10hrs | 1/11<br>2/11<br>12/11<br>13/11 | 16.55hrs<br>16.55hrs<br>16.40hrs<br>16.20hrs |
| | Kilmainham Rd | D-KD | Direct & darker | | 2 lux | 5 lux | | | | |
| Lund | Monument Park (left) | LL | Lighter | None, green area in residential area. | 2 lux | 7.8 lux | 25/10<br>26/10<br>29/10<br>23/10 | 18:06<br>18:04<br>17:57<br>18:10 | 1/11<br>2/11<br>12/11<br>13/11 | 16:51<br>16:49<br>16:32<br>16:30 |
| | Monument Park (right) | LD | Darker | | No lighting. | | | | | |
| Market Harborough | High Street | MH-HS | Indirect & lighter | Mainly shops. | 8.7 lux | 41.8 lux | 23/10<br>24/10<br>26/10<br>29/10 | 18:15<br>18:10<br>17.55hrs<br>17.30hrs | 6/11<br>7/11<br>2/11<br>19/11 | 16.30hrs<br>16.20hrs<br>16:45hrs<br>16.15hrs |
| | Adam and Eve Street | MH-AES | Direct & darker | | 4.2 lux | 35 lux | | | | |

a. Horizontal Iilluminance at gate

## *B. Sites*

Footfall data collection sites were selected in pairs in each city, based on local knowledge of common routes and shortcuts. Each pair is comprised of a lighter longer route and a darker shorter route, except Lund where parallel paths are the same length (270m). Illuminance levels are recorded in Table 1. A visual appraisal of relative lighting conditions was supported by photometric measurements along the routes. Figure 1 shows the gate locations and possible routes pedestrians were walking when they were identified as a count through the gate. In Dublin the two routes provided options for walking between the train station and a residential area. The ratio of one route length to the other was 1.3 (Gate 1 route: 1640m, Gate 2 route 1290m). The Market Harborough site also captured pedestrian flows between a train station and a residential area, however in this case both sites were in the town centre, High Street is a main thoroughfare and Adam and Eve Street, a pedestrianized shortcut. Assuming the same start and end points, the ratio of the longer route (168 meters) to the shorter one (108 meters) was 1.6. In Lund, one path was lit the other was not, in a green area in a residential district. Street lighting switch on times are listed in Table 1.

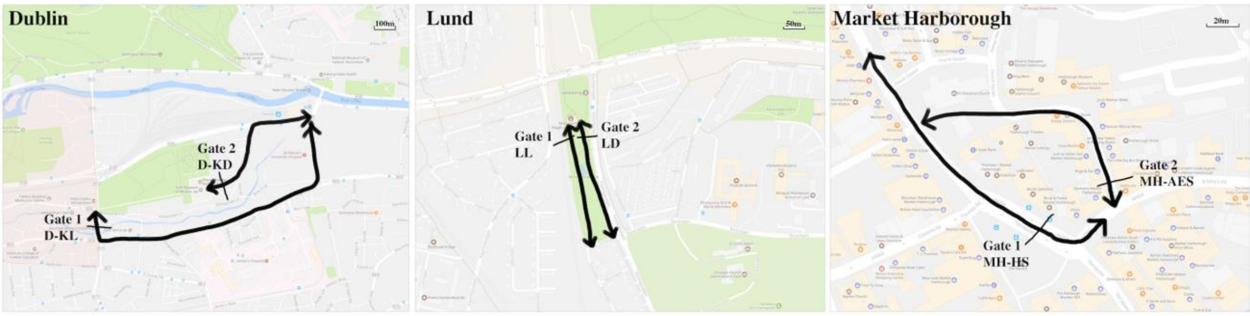


Figure 1. Routes selected for gate locations in Dublin, Lund and Market Harborough. Map data ©2017 Google.

## *C. Statistical Analysis of footfall data*

The count rate (i.e. the total number of pedestrian taking a route per unit time) for a particular survey period (typically 3:30pm-6:30pm) were compared before and after the clock change on the same day of the week, for example, Tuesday before and Tuesday after the clock change. The statistical significance in the count rate ratios recorded before and after the clock change were determined by calculating 95% confidence intervals. A comparison was made between the overall footfall rate before and after the clock change. Then count rates for different time periods were compared. The time period of particular interest is the period of time where it was light before the clock change and dark afterwards defined as t2. This is the time after the civil twilight on the survey date after the clock change. The time period where it was light both before and after the clock change was used for control purposes (t1). Figure 2 shows how these time periods are divided.

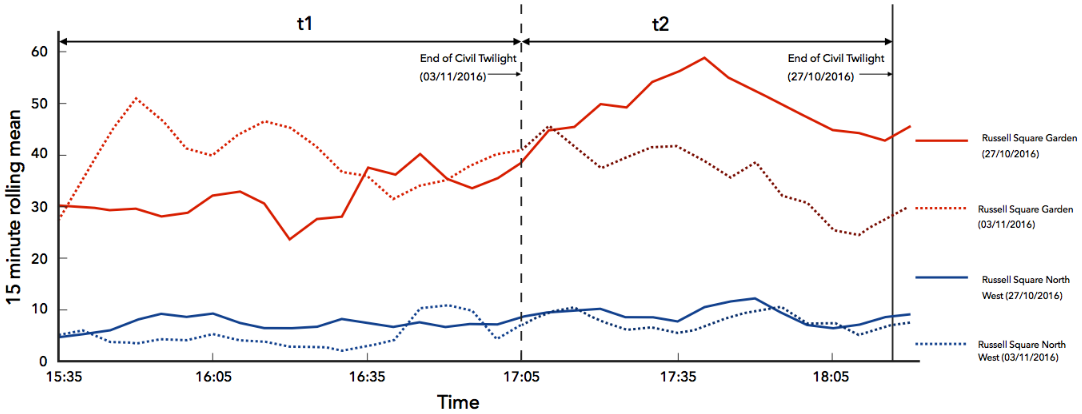


Figure 2. Example of t1 and t2 time split on a pre pilot study site in London.

## III. Results

### A. Count rates

Figure 3 shows the mean counts per 5-minute interval measured in the afternoon/evening (3:30-6:30pm) for all of the routes reported in this paper. Table 2 shows the number of occurrences in which there were statistical changes in the rates of footfall after the clock change. Rate ratio plots are also shown which includes the 95% confidence interval on these values. This enables us to determine if the rate change is statistically significant. Results are shown for weekdays and weekends for both pre- and post-clock change. The results indicate that, in general, there was a decrease in pedestrian footfall counts after the clock change. On weekdays, 5 of the 6 sites recorded statistically significant reductions (at the 95% confidence level) in the number of pedestrians passing through the gate. The exception was High Street, the busy thoroughfare in Market Harborough. On weekends, reductions in footfall count rates after the clock change were also observed. All the relatively darker route options (Gate 2 at each site) saw statistically significant reductions in footfall counts.

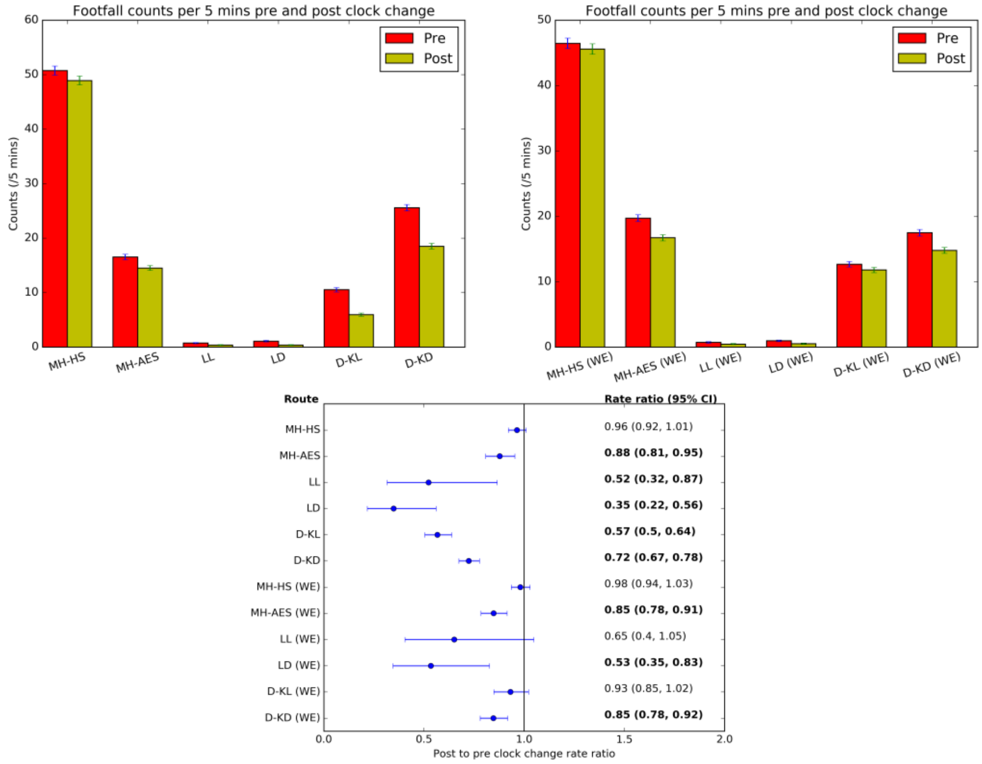


Figure 3. Bar charts showing the mean counts per 5 minutes across all locations pre and post clock change on weekdays (top left) and weekends (top right). Error bars represent the statistical (1σ) error on the count rate. The bottom plot show the ratios of pre- to post- footfall rates for all routes with 95% confidence interval error bars shown.

### B. Count rates before and after civil twilight on specific days

This section looks at the count rates for different routes on particular matched days. The time periods, t1 and t2, have been defined in section IIC. Figure 4 plots rate ratios of post to pre clock change in footfalls in t1 and t2 for 24 days across six sites. Sites showing a difference in change rate ratio between t1 and t2, indicate a change in pedestrian behaviour expressed in footfalls, possibly due to lighting conditions. The results indicate that there were statistically significant reductions in footfall count rates after the clock change for 23/48 time periods including both t1 and t2. Data are summarised in Table 2 which reveals that on weekdays there are slightly more statistically significant reductions in footfall counts observed after the clock change in t1 (8/12) compared to t2 (7/12). At weekends, this behaviour changes with fewer footfall reductions in t1 (2/12) compared to t2 (6/12). On closer examination of t1 and t2 at each site, on 18/24 days the post to pre clock change rate ratio is lower in t2 compared to t1, indicating a trend for higher footfall reductions in t2 compared to t1, even if reductions in both t1 and t2 were significant.

TABLE II ROUTES WITH RATE CHANGE AFTER THE CLOCK CHANGE

| Number of routes with statistically significant (at 95% confidence interval) rate change after the clock change | | |
|---|---|---|
| ***Time period of counts*** | ***decrease*** | ***increase*** |
| All weekday | 5/6 | 1/6 (MH-HS) |
| All weekend | 3/6 (All Gate 2) | 3/6 (All Gate 1) |
| Weekday t1 | 8/12 | 3/12 |
| Weekday t2 | 7/12 | 5/12 |
| Weekend t1 | 2/12 | 9/12 |
| Weekend t2 | 6/12 | 6/12 |

Market Harborough had the highest footfalls of the three locations, with mean counts per five minutes ranging from 6 to 112 pedestrians. High Street was the busiest street in this study (Figure 2). Comparisons of post to pre clock change rate ratios in t1 and t2 (Figure 4) shows no effect of lighting conditions at the two sites in Market Harborough on weekdays or weekends, because significant change rate ratios in t2, are almost always matched by significant changes in t1. On Wednesdays (26/10), t1 shows more decrease than t2 at both sites. The Market Harborough routes were centrally located thoroughfares, the darker street was pedestrianized with cafes and small shops. New LED street lighting was installed on Adam and Eve Street before data collection on the 19.11.17., which may have influenced the results. A shop launch on Adam and Eve Street on 2.11.16. between 17-20hrs explains the anomaly in the change rates in t2 MH-AES (26/10 02/11). The inconclusive findings in Market Harborough imply that activities in busy urban environments continue regardless of the lighting conditions on the streets selected for study.

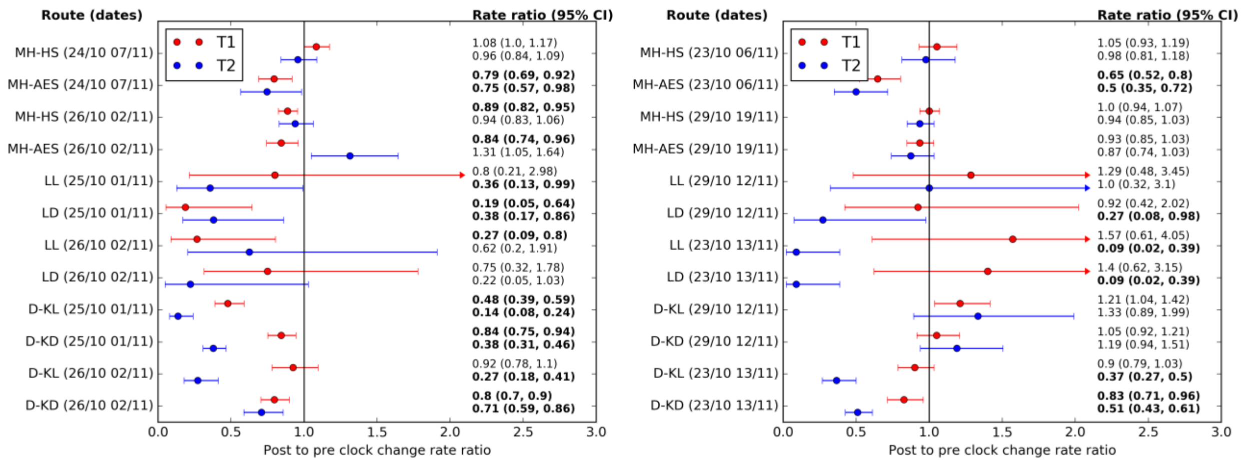


Figure 4. Rate ratios of post to pre footfall during time intervals t1 and t2 for the routes on weekdays (left) and weekends (right). The 95% confidence intervals are indicated. Bold denotes significant decrease results.

The error bars for Lund are long because the counts were low, at mean counts per five minutes of less than two pedestrians. On weekdays, the findings are inconsistent. On Tuesday (25/10/2011), the lighter side of the path shows no change in t1 and a significant reduction in t2. This could indicate the effect of lighting conditions, however on the dark side of the path there was a significant reduction in both t1 and t2, indicating that less people use this side of the path after the clock change regardless of the lighting condition. Wednesdays however, showed no significant change rate except for for t1 on the lighter side of the path. Therefore on week days the effect of lighting conditions on pedestrian flows is inconclusive. Behaviour at the weekend appears different, as on three out of four counting sessions there was no significant change in t1 however in t2 there were significantly less pedestrians. If it is assumed that weekend journeys are more likely to be optional, as less people work at the weekend, then this suggests that the lighting conditions have more of an effect on optional journeys in areas of low pedestrian flows. Optional use of the external environment is more likely to be recreational and recreational use of the environment, particularly green spaces, may influence health and well-being [1].

In Dublin, the change rate is consistently higher in t2 compared to t1, with the exception of Saturdays. Figure 3 shows that the error bars do not overlap for most counting sessions. This implies that the post to pre clock change ratio expressing more of a reduction in pedestrian footfalls in t2 compared to t1, is significant. External lighting conditions could partially explain this behaviour change as could other site characteristics such as the stretches of impermeable wall found on both routes in Dublin. The illumination conditions recorded were slightly lower than the sites in Market Harborough (Table 1).

To summarise, pedestrian behaviour is both location and site specific, and pedestrian route taking decisions can not be isolated from their physical and social context. The study found that there is no effect of the change from light to dark ambient conditions on pedestrian behaviour in centrally located busy areas of Market Harborough, entirely pedestrianised or with wide pavements and where minimum horizontal illuminance is no less than 4 lux. At the other extreme, on quiet paths with few people, external lighting conditions seemed to influence only weekend journeys, perhaps recreational in nature. Mixed use urban areas such as those in Dublin, with a combination of residential blocks and shops along the routes and pedestrian flows of less than a mean of 30 per 5 minutes were the only areas where weekday pedestrian flow patterns could have been affected by ambient lighting conditions.

## IV. CONCLUSION

Overall there are less people walking outside after the clock change, regardless of the lighting condition. This could imply that the fact the days are shorter deters people from going out, even before sunset. This study demonstrates that the relationship between lighting conditions and pedestrian behaviour is not easy to predict, however the following would be worth further investigation:

- Minimum acceptability in busy areas. As pedestrian may be reassured by hustle and bustle, explore how lighting load can be reduced in these areas, without compromising comfort and accessibility.
- Whether green spaces in quiet residential areas would be used more, if they were lit. Or whether the effect of shorter days, and the fact that people seem less willing to out after dark, would render this as energy wastage.
- The influence of spatial characteristics and land usage, for example the change in perception of mixed use areas after dark and the effect of long walls and wide roads on pedestrians' perceptions. The presence of other people in the environment, may matter to reassurance than illumination conditions alone, which means that lighting environments which reveal people may be important.

To answer the question which forms the title of this paper, external lighting conditions seem to affect pedestrian flows in some places and at some times in the weeks before and after the clock change on the selected sites between 15:30-18:30hrs. Further work should compare dark conditions before and after the clock change to each other, as it may be that later on, when in most areas there are less pedestrians overall, change rates are more variable. This paper reported a pilot study. Further work can take these findings to design studies to explore specific conditions in which lighting conditions can improve accessibility and comfort. This can be used to inform Local authority decisions on when dimming is acceptable and how to light environments efficiently without compromising on comfort.

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