ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 09, pp.7166-7172, September, 2019

DOI: https://doi.org/10.24941/ijcr.36643.09.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

SAFETY BENEFITS AND CONCERNS ABOUT EFFICIENT PUBLIC LIGHTING INVESTMENT: LOURES COUNTY AS A CASE STUDY

***José Bustorff and Nuno Soares Domingues**

Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal

ARTICLE INFO

Article History:
Received 17th June, 2019
Received in revised form
19th July, 2019
Accepted 20th August, 2019
Published online 30st September, 2019

Key Words:
Public Lighting,
Public Roads,
Road Accidents,
Fatalities.

ABSTRACT

Public road lighting during night-time is essential in citizens' daily lives. In recent years, investments in efficiency of street lighting have been done at all levels: European, national, regional and local. A switch to LED technology is taking place as pilot projects. It is expected to provide the same lighting quality, reduction of costs and increasing energy efficiency. In this investigation, the relationship between illumination during the daytimedarkness period and the number of road accidents resulting in fatalitieswas studied for the Loures County. It was found that the largest number of fatalities occurred during the darkness period. Fatalities decreased between 2000 and 2015. The energy efficiency of Loures increased and at the same time, there was a decrease in the number of accidents resulting in fatalities. It is concluded that the quality of public light may contribute to reducing loss of human life in road accidents.

Citation: José Bustorff and Nuno Soares Domingues. **2019.** "Safety benefits and concerns about efficient public lighting investment: Loures County as a case study", *International Journal of Current Research*, 11, (09), 7166-7172.

INTRODUCTION

Public roads lighting (PL) is seen as a necessity for modern societies because the illumination during daytime darkness period influences pedestrians and driverssafety. But PLinvolves costs, energy consumption and environmental pollution problems. Therefore, PL efficiency has been much debated in recent decades. PLefficiency is being addressed replacing light equipment with Light Emitting Diode (LED) technology. However,PL efficiency depends on several factors. For example, if outdoor lighting is projected incorrectly, light shines tounnecessary directions wasting energy, whichresults inthe lack of light in target areas and objects(Narisada& Kawakami, 1998). Main issue is to know the influence of the quality of illumination during daytime darkness period for reduction of road accidents fatalities. The importance of night illumination has been debated in several scientific works in relation to pedestrians, drivers and the way in which they circulate(Adams & Zuckerman, 1991; Dubois et al., 2016; Fotios, Yang, &Uttley, 2015; Fotios& Castleton, 2016; Fotios, Castleton, Lin & Yang, 2016; Gentile et al., 2016; Jägerbrand, 2016; Kruisselbrink, van Duijnhoven, Dangol & Rosemann, 2018; Narisada & Kawakami, 1998a; Perko, Topić & Šljivac, 2016; Pun, So, Leung & Wong, 2014).

Corresponding author:* **José Bustorff,
Rua Conselheiro Emidio Navarro, 1, 1959-007 Lisbon, Portugal.

This paper aims to contribute to the knowledge of PL efficiency, having Loures Countyas case study. This research intends to demonstrate that the increase of energy efficiency in the last decades is related to the reduction of the number of road accident fatalities during the daytime darkness period.

Review

There are publications about night illumination,and people safety and goods security. We mention some of them: Fotios et al. (2015); Fotios &Castleton (2016); Gentile et al. (2016); Marty et al. (2003); Peña-García et al. (2015); Pollard (1997); Willis, Arnold & Brock (2002). Light emitting diode (LED) technology is replacing conventional lighting, allowing significant energy savings up to 40% (Perko et al., 2016; Rugeles, Garzón, & Osorio, 2010). Limitations of LED technology are the initial costs of implantation and the heat emitted (Castañeda, Sáenz, & Cárdenas, 2012; Saavedra, Rey, & Luyo, 2016). The public lighting system is usually managed by the Local Administration, and consumes part of its budget (Perko et al., 2016). Since tax collection finances PL (Milan & Creutzig, 2016, Milan, Kapfer, & Creutzig, 2016), installing more efficient technology is necessary. The need for lighting is different for each type of urban circulation infrastructure (Newman, Kosonen, & Kenworthy, 2016). The real LED revolution happened in the 1990s with the discovery of Indium Gallium Nitride (InGan) technology. The possibility of obtaining light with smaller wavelengths in the blue, green and cyan colours was discovered, and later all the colour spectra

were added(Bustorff&Domingues, 2018; Da Luz, Scheffer, Krzyzaniak, & Cadore, 2015). Kruisselbrink, van Duijnhoven, Dangol & Rosemann also agree that the quality of illumination had a significant development in the 90's, as confirmed in several conferences and scientific publications. Improvements in lighting quality were also confirmed by other studies, namely Dubois et al. (2016); Gentile et al. (2016); Veitch & Newsham (1996). Outdoor PL is installed in several places: vehicles and pedestrian roads, metro line, parking lots, outdoor constructions, etc. (Saavedra et al., 2016). The same researchers believe that street lighting creates a sense of security and draws corporate attention to illuminated spaces. According to Peña-García, Hurtado, & Aguilar-Luzón (2015), the function of road PL is to guarantee people and goods safety.Up to a certain limit, what is happening is that as the amount of light increases, the lighting becomes more pleasant, more comfortable, clearer, more stimulating, brighter, more colourful, more natural, more friendly, warmer and more uniform (Gentile et al., 2016).PL quality is in terms of: lights quantity, lights distribution, brightness, spectral energy distribution, daytime lighting, light direction and dynamics (Kruisselbrink et al., 2018; Kruisselbrink et al., 2018).

Night-time PL facilitates mobility for citizens safety, either on foot or by car (Murray & Feng, 2016). Therefore, during the night time, more illuminance is needed to increase safety until a threshold of light for the pedestrian to be identified (Steve Fotios & Castleton, 2016; Steve Fotios et al., 2016). The distance to feel safe between unknown pedestrians is 30 m according to Fotios et al.(2015). The distance between pedestrians under low light comfort 1.5 lux is around 1.17 m, while with more illumination it is around 0.53 m (Adams & Zuckerman, 1991). However, sighting a person at a distance of 15 m, the duration of the fixation time is around 500 milliseconds (Fotios et al., 2015, Willis et al., 2002). In general, luminaires have a system for precise optical control. Then, there is a need to meet the technical and visual requirements of light to illuminate roads. At the same time, the upward flow emission is carefully controlled to avoid energy waste (Narisada & Kawakami, 1998). During daily darkness hours, the light source is the only equipment common to all forms of illumination. The light source technology aims to get as close to daylight as possible (Pollard, 1997). The indicators for the distribution of illumination are: the uniformity of illuminance, and the distribution of luminance (Gentile et al., 2016). Excessive street lighting or inadequate projection can adversely affect the natural environment, as well as causing energy waste (Pun et al., 2014). It should be noted that the luminance is directly related to the illuminance in the retina and to the human visual perception of brightness (Marty et al., 2003). In addition, luminaires protect the lamps and control the light emitted (Pollard, 1997).

LED lighting must comply with road safety regulations. It must meet the requirements of pedestrians and cyclists. If possible, it is expected to improve energy efficiency without affecting visual performance and traffic safety (Jägerbrand, 2016). An advantage of LED is that its driver has a lifetime of at least 50.000 to 65.000 hours, coupled perfectly with current lifetime of LED lamps (EDP, 2016; Saavedra et al., 2016). LED technology complies with the European Union Ecodesign Regulations (Jägerbrand, 2016). It also complies with the requirements of the European standard EN13201 Road Lighting developed by the European Committee for Standardization.

The Energy Efficiency Index (IEE) for roadways is classified according to the width of the road (EDP, 2016). Also, planning lighting schedule for dark hours needs to be tailored to traffic intensity while minimizing the risk of affecting safety and keeping energy efficiency criteria (Jägerbrand, 2016).

MATERIALS AND METHODS

This research is based on literature review on public road lighting and its efficiency. A review was made about the effects of lighting on public roads during daily darkness period. The case study was carried out in Loures County. The information is organized according to the census county division. Figure 1 and Figure 2 show the methodology of this research.

Case study – Loures County: Loures County is part of the metropolitan area of Lisbon. It is located on the northernpart of the Tejo River. Loures has an area of 167.24 km². In this county, the number of inhabitants has undergone some variations: from 1970 to 1980 the population increased, between 1980 and 2011 the population decreased. According to the INE Census, in 2011 there were 205.054 inhabitants (Figure 4). Loures is divided into 10 census divisions (Figure 5). Loures County has a road network of approximately 185.251 km; 55% (Table 1) of the roads are Primary Routes type, that is, main and complementary. The remaining 45% are national and municipal roads (Leão, 2013). Leão identified a blackspotwhere fatalities are registered in Loures County; it is in the A1 highway between km 3 + 600 and km 3 + 800.

According to INECensus 2011 of Loures County, the most populated divisions are located to the South, while those located to the North have less population (Figure 5). It was also observed that the population growth rate was negative infour of them (Table 2): Moscavide-Portela,Camarate-Unhos-Apelação,Lousa,and Bucelas. The analysis of energy consumption in the Municipality of Loures during the period 1970/2015 showed a pick value in 2011 (26500434 kWh / year). However, as of 2011 the values began to decrease (Figure 6). It seems that some measures were applied for this decrease to occur and could coincide with the beginning of the replacement of traditional lamps by LED lamps. The increase of population resulted in the increase of routes. The need of traveling resulted in the increase of thevehicle fleet. In the period 1974/2014 the increase of the car fleet in Portugal was 580%;the maximum value was reached in 2013 (5.873.000 vehicles) (Figure 7). These figures suggest that the number of road accidents has decreased, although the number of vehicles has increased, in addition to the public lighting factor. The total number of light vehicles inContinental Portugal was 5.391.652 in 12/31/2014. At the same date, the District of Lisbon had 1.244.216 cars (Autoinforma, 2018).

RESULTS

It was found that the number of road accidentfatalities decreased both in Loures County and Lisbon District (Figure 8). Figure 9 shows the number of road accident fatalities per administrative division in 2013. Santa Iria de Azoian-São João da Talha-Bobadela , and Loures are the most populated and have more fatalities. The number of road accident fatalities is shown in Table 3. It can be seen that a larger area did not mean a greater number of fatalities.

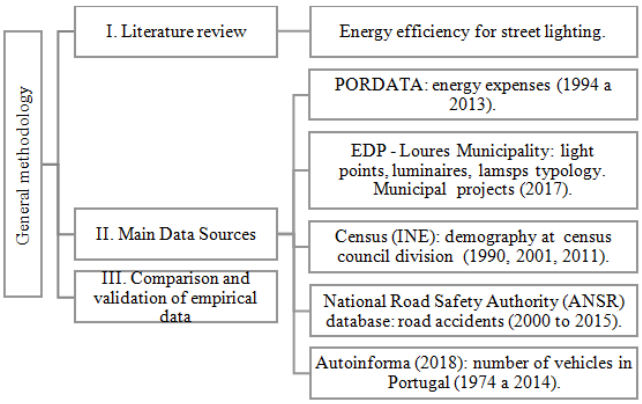

Figure 1. Methodology

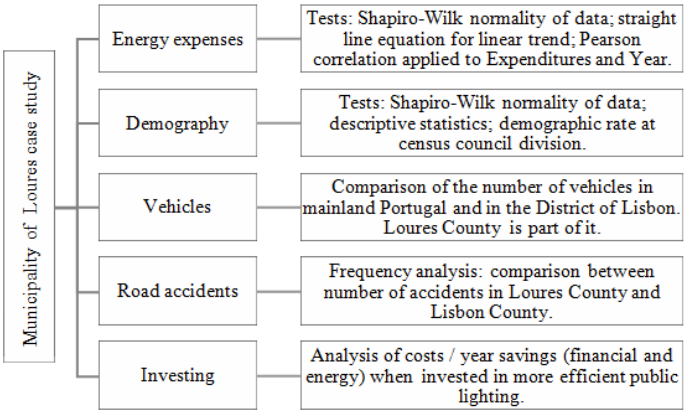

Figure 2. Case study

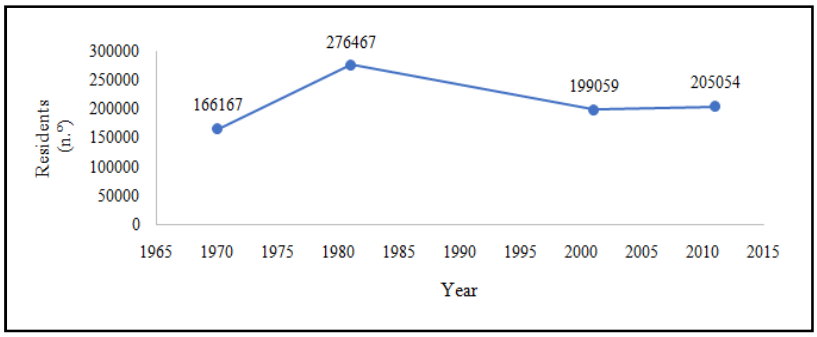

Figure 4. Evolution of the number of inhabitants living in the Loures County between 1970 and 2011 (INE, 1970/2011).

Table 1. Road typology of Loures County(Leão, 2013)

Roads typology	Percentage (%)
Primary routes: Main and Complementary	55
Secondary routes: National and Municipal roads	31
Tertiary roads: Municipal roads	14

Table 2. Population growth rate 2000/2011 (INE, 2001; 2011)

Loures County divisions	Year 2001 (n.º)	Year 2011 (n.º)	Population density 2011 (inh./km^2)	Growth rate
Moscavide-Portela	26335	25035	15081,3	-0,05
Sacavém-Prior Velho	23653	24563	6314,4	0,04
Santo António dos Cavaleiros-Frielas	23266	26561	2887,1	0,14
Camarate-Unhos-Apelação	34232	33597	2903,8	-0,02
Santa Iria de Azoia,-São João da Talha-Bobadela	42068	42608	2422,3	0,01
Loures	23160	26242	799,6	0,13
Santo Antão-São Julião do Tojal	7659	7757	273,0	0,01
Fanhões	2696	2735	235,2	0,01
Lousa	3305	3062	185,4	-0,07
Bucelas	4634	4522	133,1	-0,02

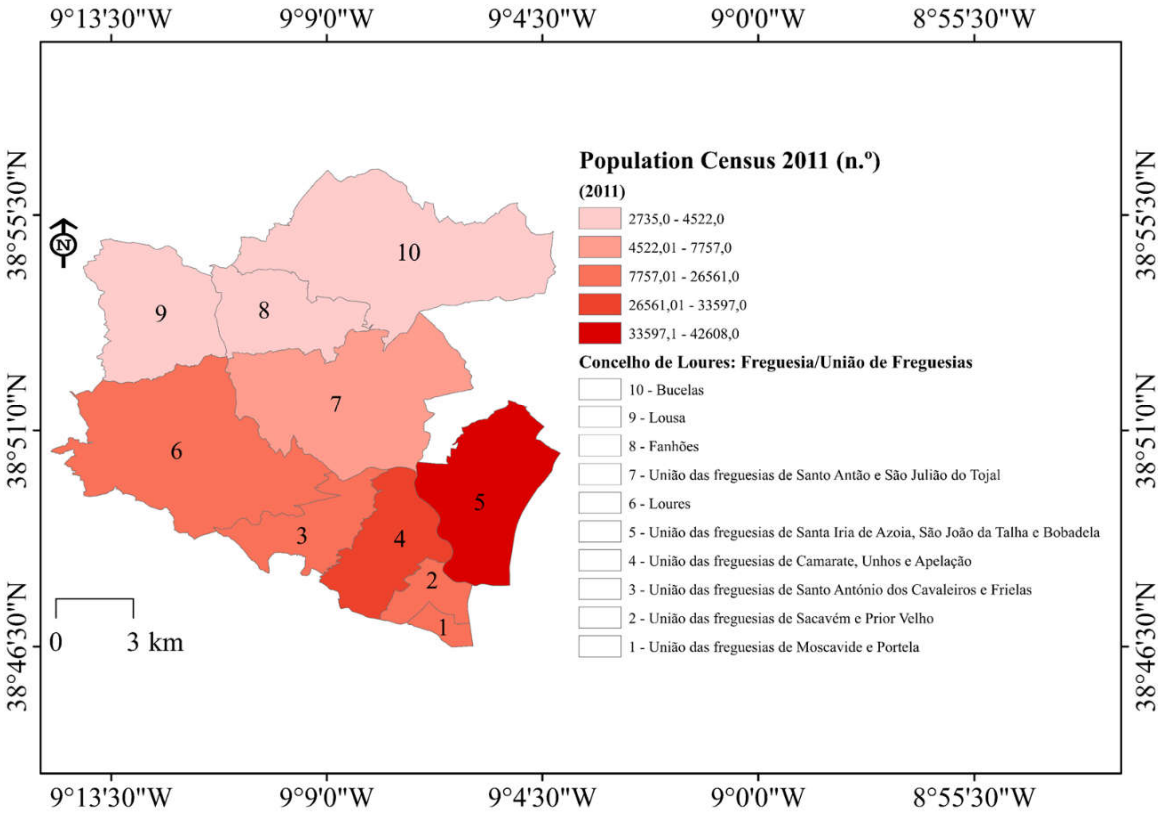

Figure 5. Loures County demography

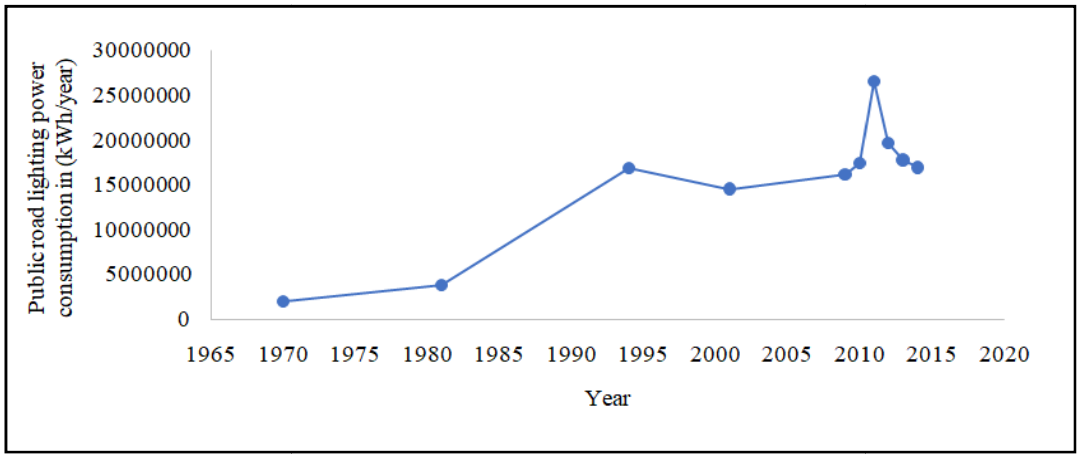

Figure 6. Public outdoor lightening consumption (kWh) between 1970 and 2014, Loures (PORDATA, 2016)

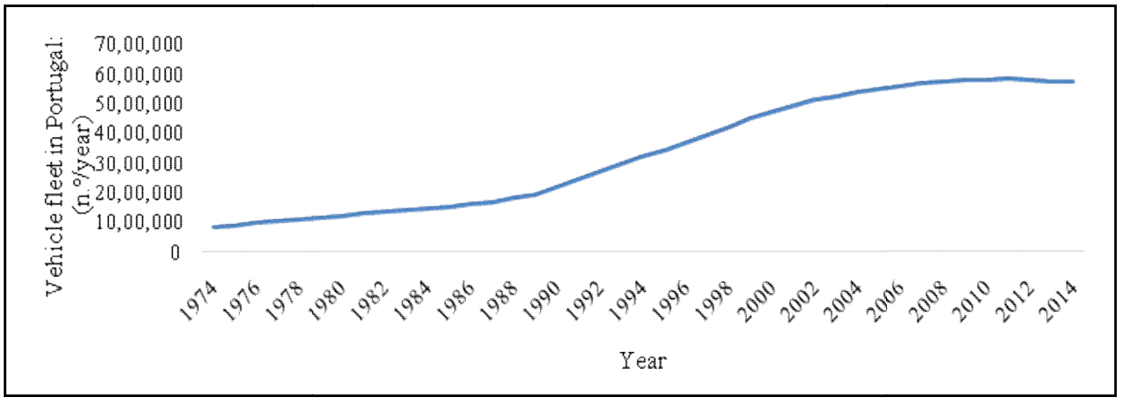

Figure 7. Car fleet in Portugal, passenger lightcars; light commercial vehicles; heavy vehicles Between 1974 and 2014 (Autoinforma, 2018)

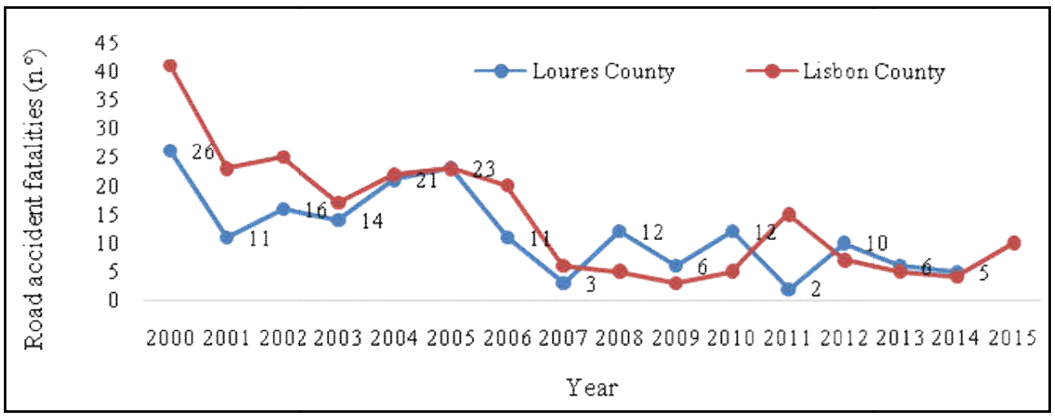

Figure 8. Road accident fatalities per year in daily darkness period in Loures County between 2000 and 2015 (ANSR, 2015)

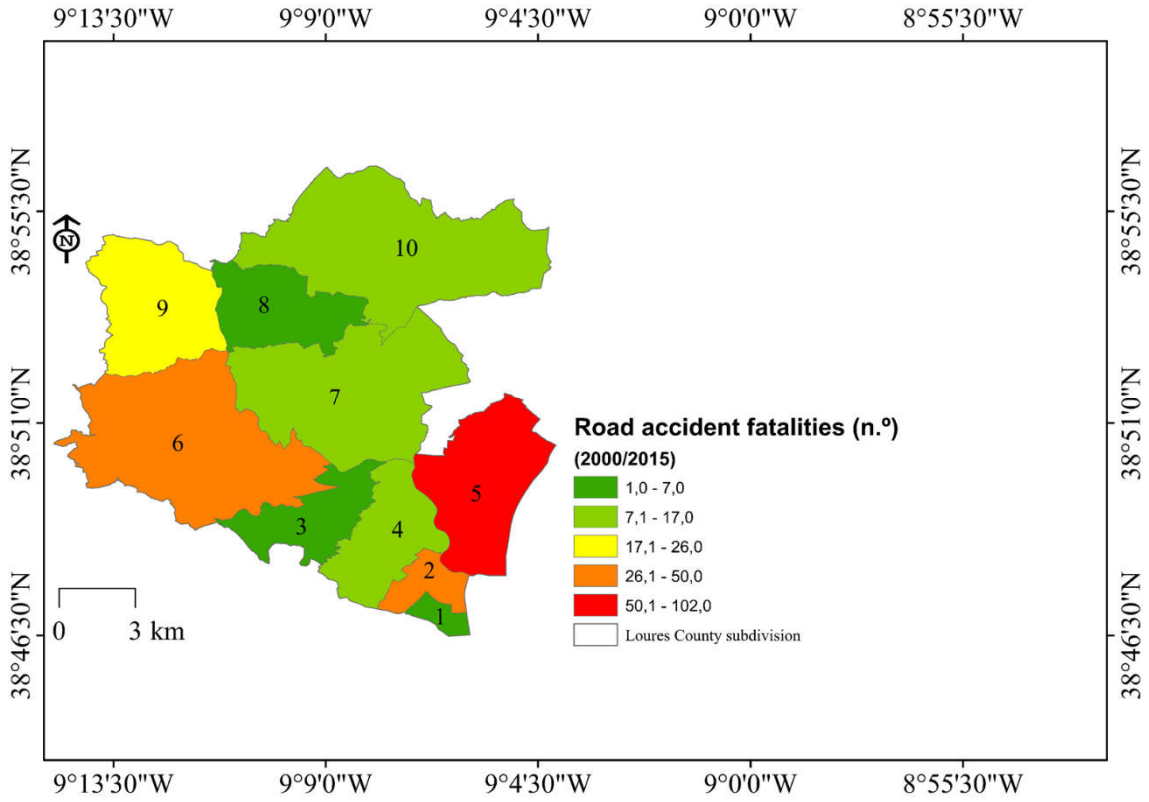

Figure 9. Road accident fatalities in Loures County, between 2001/2015 (ANSR, 2015; CAOP, 2015)

Table 3. Number of Loures road fatalities in Loures County divisions, between 2001/2015 (ANSR, 2015; CAOP, 2015)

Name of Parish (P) /Cluster of Parishes (CP)	Fatalities (n.º)	Area (km^2)
Moscavide-Portela	7	1,7
Sacavém- Prior Velho	45	3,89
Santo António dos Cavaleiros- Frielas	7	9,2
Camarate-Unhos-Apelação	14	11,57
Santa Iria de Azoia-São João da Talha-Bobadela	102	17,59
Loures	50	32,82
Santo Antão-São Julião do Tojal	12	28,41
Fanhões	1	11,63
Lousa	26	16,52
Bucelas	17	33,97

Table 4. Relation between driver age and fatalities for a sample of 280 individuals, between 2000 and 2015 (ANSR, 2015)

	Minimum (years)	Maximum (years)	Total	Average (years)	Standard deviation	Asymmetry	Default error
Age	18	85	10530	37,61	16,13	0,41	0,15
Fatalities	1	2	308	1,10	0,30	2,76	0,15

Table 5. Pilot project: replacement of ballasts in Loures County: financial overview (values excluding VAT), CML (2017)

Ferromagnetic ballasts									
Luminaries (n.º)	Power (W)	Reactance (W)	Consumption (W)	Hours/day	Days/year	Hours/year	kWh year	€/kWh	Total/year (€)
830	150	15	165	11	365	4015	549854	0,1266	69611,55
Electronic ballasts									
Luminaires (n.º)	Power (W)	Reactance (W)	Consumption (W)	Hours/day	Days/year	Hours/year	kWh year	€/kWh	Total/year (€)
830	150		90	11	365	4015	299921	0,1266	37.969,94
								Energy annual saving (kWh):	249.934
								Financial annual saving (€/year):	31.641,61
								Investment (€):	74.700
								Payback period (years):	2,4

Table 6. Relation between population and fatalities in Loures County divisions (ANSR, 2015; CAOP, 2015)

Divisions	Year 2001 Inhabitants	Year 2011 Inhabitants	Fatalities (n/year)	Area (km^2)
Moscavide- Portela	26335	25035	7	1,66
Loures	23160	26242	50	32,82
Fanhões	2696	2735	1	11,63

Between 2001 and 2015, 280 fatalities were registered (a record was without this data - fault). Regarding drivers age, the minimum was 18 years old, and the maximum was 85 years old (Table 4). It should also be noted that most of accidents involving deaths the drivers were men (217 fatalities).It was also verified that the road accident fatalities occurred undernormal conditions, that is, the vehicle was within the speed limits defined in Portuguese law. The Municipal Council of Loures (2017) developed an economic analysis of changes in public lighting. Table 5 shows that the replacement of electronic ballasts instead of ferromagnetic ballasts required an investment of 74.700 € to obtain a saving of 31.641,61 €/year, and a return in 2.4 years. This data is in line with the study carried out by Salvador (2016). He estimated that the placement of 1000 luminaires to replace the traditional ones would contribute to an annual energy reduction of 240 MWh / year, corresponding to a saving of € 38.000,00 / year. Savings are both in energy and financial. Salvador goes further; heis convinced that the payback period could be 1 year.

DISCUSSION

We found some evidence in the literature that shows that the relationship between public lighting points and the number of accidents in the dark period can be significant. However, this research did not confirm the relation because the georeferentiation of the light points was not available. It was found that the vast majority of road accidents between 2000 and 2015were overnight.

This fact deserved our attention regarding approaches to the quality of roadway lighting. Road PL could be an issue to be taken in account to avoid loss of life. It was in Fanhões (2.735 inhabitants)that there was the minimum number of fatalities, 1; Moscavide-Portela (25.035inhabitants) was in second place registering 7 fatalities. Comparatively, in Loures (26.242inhabitants)occurred 50 fatalities (Table 6). It should be noted that registered deaths do not mean that they are residents, what was recorded is the place where the accident occurred. On the other hand, we consider that there are other variables besides lighting that must be considered for the debate on what has influenced the decrease in road traffic fatalities.

We consider as influencing factors the increase of road infrastructures, the introduction of LED technology, and the traffic increasing.

Conclusion

The number of fatalities in road accidents has been in the decreasing for the period 2000 to 2015. The majority of road traffic fatalities occurred during the "dark" period between 6 pm and 9 am. This brings to recognize that there may be some influence of lighting. Energy efficiency has increased with the introduction of LED technology. The Loures County made PL technology changes and verified improvements in energy efficiency: they replaced traditional lamps with LED technology; the infrastructure and equipment were adapted to the current technology. The replacement of ferromagnetic and electronic ballasts pilot project led to predict an economic saving of 31.641,61 €/; it was consequence of energy efficiency. The results obtained from the relationship between road accident fatalities, and PL during the daily darkness period are not conclusive. It needs further research tests to study how illumination can prevent accidents and fatalities (for example, number of vehicles, age of drivers, number of light points and its georeferentiation). Next stage will be the deepening into LED technology and its contribution to the road accident reduction to contribute to avoid loss of human lives, while contributing to energy efficiency.

REFERENCES

Adams, L. and Zuckerman, D. (1991). The Effect of Lighting Conditions on Personal Space Requirements. *The Journal of General Psychology*, *118*(4), 335–340. https://doi.org/10.1080/00221309.1991.9917794.

Bustorff, J. and Domingues, N. S. (2018). Public Lighting in Portugal: Standardization and Results. *Energy Research,2*(3), 158–169. https://doi.org/10.31058/j.er.2018.23009.

Castañeda, D., Sáenz, G. and Cárdenas, H. (2012). Estudio comparativo de características eléctricas y fotométricas de LEDs de iluminación de estado sólido y CFLs para iluminación interior. *Tekhnê*, *9*, 79–90.http://revistas.udistrital.edu.co/ojs/index.php/tekhne/article/view/8930/10302. Accessed 10 September 2018.

Da Luz, A., Scheffer, C., Krzyzaniak, P., & Cadore, W. (2015). A evolução da eluminação: O LED. *III Semana das Engenharias 3ª Mostra Científica*, 26–31.http://www.fw.uri.br/NewArquivos/publicacoes/publicacoesarquivos/205.pdf#page=26. Accessed 7 September 2018.

Dubois, M.-C., Gentile, N., Amorim, C. N. D., Osterhaus, W., Stoffer, S., Jakobiak, R., Tetri, E. 2016. Performance evaluation of lighting and daylighting retrofits: Results from IEA SHC task 50. *Energy Procedia*, *91*, 926–937.doi: 10.1016/j.egypro.2016.06.259.

EDP, D. 2016. Manual de Iluminação Pública 2016.https://www.edpdistribuicao.pt/pt/profissionais/EDP%20Documents/Manual%20Ilumina%C3%A7%C3%A3o%20P%C3%BAblica.pdf. Accessed7September 2018.

Fotios, S, Yang, B. and Uttley, J. 2015. Observing other pedestrians: Investigating the typical distance and duration of fixation. *Lighting Research & Technology*, *47*(5), 548–564.https://doi.org/10.1177/1477153514529299.

Fotios, Steve, & Castleton, H. 2016. Specifying enough light to feel reassured on pedestrian footpaths. *Leukos*, *12*(4), 235–243.https://doi.org/10.1080/15502724.2016.1169931.

Fotios, Steve, Castleton, H., Lin, Y. and Yang, B. 2016. Varying facial expressions in studies of interpersonal judgements and pedestrian lighting (pp. 275–282). Proceedings of CIE 2014 Lighting Quality and Energy Efficiency, Commission Internationale de L'Eclairage.http://eprints.whiterose.ac.uk/96645/. Accessed 5 September 2018.

Gentile, N., Dubois, M.-C., Osterhaus, W., Stoffer, S., Amorim, C. N. D., Geisler-Moroder, D. and Jakobiak, R. 2016. A toolbox to evaluate non-residential lighting and daylighting retrofit in practice. *Energy and Buildings*, *123*, 151–161.https://doi.org/10.1016/j.enbuild.2016.04.026.

Jägerbrand, A. K. (2016). LED (Light-emitting diode) road lighting in practice: An evaluation of compliance with regulations and improvements for further energy savings. *Energies*, *9*(5), 357.doi:10.3390/en9050357.

Kruisselbrink, T., van Duijnhoven, J., Dangol, R. and Rosemann, A. 2018. Improving Lighting Quality by Practical Measurements of the Luminance Distribution (pp. 190–198). Congress of the International Ergonomics Association, *Springer*.https://link.springer.com/chapter/10.1007/978-3-319-96059-3_21.

Leão, M. de F. F. 2013. Análise da sinistralidade rodoviária no concelho de Loures em meio interurban. (Analysis of the road accidents in the municipality of Loures in the interurban environment). (Master Thesis). ISEL - Eng. Civil. http://hdl.handle.net/10400.21/3409. Accessed 15 September 2018.

Marty, C., Fontoynont, M., Christoffersen, J., Dubois, M.-C., Wienold, J., Osterhaus, W., Carco, R. F. 2003. *User assessement of visual comfort: review of existing methods*. Technical report, Ingelux, Lyon.https:// www.researchgate.net/profile/Jens_Christoffersen/publication/283497394_User_assessment_of_visual_comfort_Review_of_existing_methods/links/563b29af08ae337ef2988a61.pdf. Accessed 5 October 2018.

Milan, B. F. and Creutzig, F. 2016. Municipal policies accelerated urban sprawl and public debts in Spain. *Land Use Policy*, *54*, 103–115.https://doi.org/10.1016/j.landusepol.2016.01.009.

Milan, B. F., Kapfer, D. and Creutzig, F. 2016. A systematic framework of location value taxes reveals dismal policy design in most European countries. *Land Use Policy*, *51*, 335–349.https://doi.org/10.1016/j.landusepol.2015.11.022.

Murray, A. T. and Feng, X. 2016. Public street lighting service standard assessment and achievement. *Socio-Economic Planning Sciences*, *53*, 14–22.https://doi.org/10.1016/j.seps.2015.12.001.

Narisada, K. and Kawakami, K. 1998a. 5. Field Survey of Outdoor Lighting in Japan. *Highlights of Astronomy, Volume 11A: As presented at the XXIIIrd General Assembly of the IAU, 1997*, *11*, 209.

Narisada, K. and Kawakami, K. 1998b. Field survey of outdoor lighting in Japan (Vol. 139, p. 21). Apresentado na Preserving The Astronomical Windows.http://adsabs.harvard.edu/full/1998aspc..139...21n. Accessed 15October 2018.

Newman, P., Kosonen, L. and Kenworthy, J. 2016. Theory of urban fabrics: planning the walking, transit/public transport and automobile/motor car cities for reduced car dependency. *Town Planning Review*, *87*(4), 429–458.https://doi.org/10.3828/tpr.2016.28.

Peña-García, A., Hurtado, A. and Aguilar-Luzón, M. 2015. Impact of public lighting on pedestrians' perception of safety and well-being. *Safety science*, *78*, 142–148.https://doi.org/10.1016/j.ssci.2015.04.009.

Perko, J., Topić, D. and Šljivac, D. 2016. Exploitation of public lighting infrastructural possibilities (pp. 55–59). Apresentado na Smart Systems and Technologies (SST), International Conference on, IEEE.**DOI:** 10.1109/SST.2016.7765632.

Pollard, N. 1997. Techniques and limitations of outdoor lighting. *The Observatory*, *117*, 31–33.http://adsabs.harvard.edu/full/1997Obs...117...31P. Accessed 25 Aug 2018.

Pun, C. S. J., So, C. W., Leung, W. Y. and Wong, C. F. 2014. Contributions of artificial lighting sources on light pollution in Hong Kong measured through a night sky brightness monitoring network. *Journal of Quantitative Spectroscopy and Radiative Transfer*, *139*, 90–108.https://doi.org/10.1016/j.jqsrt.2013.12.014.

Rugeles, V. H. F., Garzón, H. B. C. and Osorio, J. A. C. 2010. Aplicaciones de iluminación con LEDs. *Scientia et technica*, *2*(45).http://dx.doi.org/10.22517/23447214.297.

Saavedra, E., Rey, F. J. and Luyo, J. 2016. Sistemas de Iluminación, situación actual y perspectivas. *Revista Cientifica TECNIA*, *26*(2), 44. http://dx.doi.org/10.21754/tecnia.v26i2.57

Salvador, J. A. F. 2016. *Plano de ação para a energia sustentável do município de Loures: análise de progressos*. [Sustainable energy action plan for the municipality of Loures: progress analysis.] Universidade de Lisboa. http://repositorio.ul.pt/bitstream/10451/32756/1/ulfc124130_tm_J%C3%A9ssica_Salvador.pdf. Accessed 20 October 2018.

Veitch, J. A. and Newsham, G. R. 1996. Determinants of Lighting Quality II: Research and Recommendations. https://eric.ed.gov/?id=ED408543. Accessed 20 Aug 2018.

Willis, I. C., Arnold, N. S. and Brock, B. W. 2002. Effect of snowpack removal on energy balance, melt and runoff in a small supraglacial catchment. *Hydrological Processes*, *16*(14), 2721–2749.https://doi.org/10.1002/hyp.1067.

****