Institution: Loughborough University

Unit of Assessment: C13 Architecture, Built Environment and Planning

Title of case study: EN 17037: The First Major Upgrade to National/European Daylighting Standards Since the 1950s

Period when the underpinning research was undertaken: 2012 – 2017

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
John Mardaljevic	Professor of Building Daylight Modelling	2012 – Present

Period when the claimed impact occurred: 2017 - 2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact (indicative maximum 100 words)

Indoor daylight is crucial to health and well-being. Research at Loughborough University led to the formulation of the daylight performance basis of the European CEN Standard for Daylight in Buildings (EN17037). This first significant upgrade to national daylight standards in over half a century led to the following impacts: 1) Adopted by all 34 CEN member states with conflicting national standards withdrawn; 2) Adopted by the International WELL Building Standard to demonstrate adequate levels of daylight for health and wellbeing of occupants; 3) Transformed the design evaluation of new buildings for architects and 'day light' designers which is now founded on annual profiles of absolute quantities of daylight illumination, and promotes higher levels of illumination than previous standards; 4) Underpinned a major upgrade of practitioner software tools for daylight modelling across the EU and beyond; and, 5) Shaped legal decisions in civil litigation (Sweden) and UK High Court 'Right to Light' cases.

2. Underpinning research (indicative maximum 500 words)

In the last two decades the role of good daylighting design for buildings has achieved a new importance due to considerations regarding the long-term health/well-being and productivity of building occupants. It is now well understood that absolute measures of illumination received at the eye is responsible for a number of effects on the human body that are unrelated in any direct sense to vision: light has measurable neuroendocrine and neurobehavioral effects on the human body. There is also evidence for strong links between daylight illumination and alertness, productivity, and academic achievement **[R2].**

For over half a century, daylight provision has been determined at the design stage using a relative measure called the daylight factor (DF); that is, the percentage ratio of daylight inside to outside under a single, static overcast sky (without sun). With the increased recognition of the importance of daylight, the desire to deliver "good daylighting" often resulted in crudely designing to higher daylight factors – a schema which took no account of the sun or prevailing climate. Thus, the designs of many buildings, in particular schools were heavily criticized for being overglazed and so overheated in summer **[R5].**

In 2000 Prof Mardaljevic first published his work on what became known as Climate-Based Daylight Modelling (CBDM) **[R1]**. CBDM predicts annual profiles of absolute levels of daylight illumination using sun and sky conditions derived from weather files. He subsequently proved the concept and demonstrated its application in several landmark projects, e.g., New York Times Building, Hermitage (St. Petersburg) and Central Park Tower (NYC). CBDM has transformed the way daylight in buildings is determined and has a profound impact on the design/evaluation of glazing systems for daylighting. Mardaljevic has

been the driving force behind the CBDM concept and, in this REF-cycle has, finally completed the research **[R2-R6]** to enable the major international daylight standards to adopt the CBDM approach.

The research to provide the basis for what eventually became the CEN 17037 Standard comprised multiple strands. Key was the development of a transitional methodology to allow for 'climate connectivity', and importantly, a frictionless path to full CBDM (pioneered by Mardaljevic). This was an ambitious aim since many key players serving on the Technical Committee (TC) were seeking a 'light touch' revision that preserved the daylight factor (DF) basis of existing national standards. When the TC first convened, the traditional DF approach was widely perceived as 'fit for purpose'. There was (in 2012) nothing in the research literature to indicate how it might be possible to transition from daylight factors to more absolute measures of daylight provision. The necessary research comprised first a forensic critique of existing standards exposing fundamental shortcomings (e.g., reliance on measures that make no account of the spatial distribution of daylight **[R3]**); opportunities for gameplaying targets (e.g., BREEAM Daylight **[R4]**); and critically flawed previous attempts at upgrading daylight recommendations (e.g., LEED 2.2 and ASHRAE 189.1 **[R5]**). Next, a transitional method to CBDM was needed which allowed existing approaches, in the short-term, to be applicable to the standard with modest modification. This was achieved with a new way to process and categorize the illuminance data in weather files **[R6]**. Importantly, the standard strongly encouraged both the uptake of CBDM and the achievement of better levels of daylight in accord with recommendations to promote health and well-being.

3. References to the research (indicative maximum of six references)

R1. Simulation of annual daylighting profiles for internal illuminance. *Lighting Research and Technology*, 32(3):111–118, 1 2000 doi.org/10.1177/096032710003200302

R2. J. Mardaljevic, M. Andersen, N. Roy, and J. Christoffersen. A framework for predicting the non-visual effects of daylight – Part II: The simulation model. *Lighting Research and Technology*, 46(4):388–406, 2014 doi.org/10.1177/1477153513491873

R3. J. Mardaljevic and J. Christoffersen. A Roadmap for Upgrading National/EU Standards for Daylight in Buildings. CIE Midterm conference – Towards a new century of Light, Paris, France 12-19 April, 2013.

R4. J. Mardaljevic, J. Christoffersen, and P. Raynham. A Proposal for a European Standard for Daylight in Buildings. Lux Europa, Krakow, Poland, 17–19 September, 2013.

R5. J. Mardaljevic. Climate-Based Daylight Modelling And Its Discontents. CIBSE Technical Symposium, London, UK, 16-17 April, 2015.

R6. J. Mardaljevic and J. Christoffersen. 'Climate connectivity' in the daylight factor basis of building standards. Building and Environment, 113:200–209, 2 2017. doi.org/10.1016/j.buildenv.2016.08.009

The research was published in international leading journals following rigorous peer review. The CIE and Lux Europa conferences are major quadrennial events, and, like CIBSE, papers are peer reviewed and the acceptance rate is competitive (i.e., low).

4. Details of the impact (indicative maximum 750 words)

Pathway to Impact

To gain widespread uptake of climate-based daylight modelling (CBDM) outside of academia required winning the 'hearts and minds' of practitioner and wider-stakeholder communities, including policy makers and advisors. Key to achieving this in the UK were the many CBDM-themed invited presentations given by Prof Mardaljevic at CIBSE Daylight Group meetings (he has been Chair since 2014); invited presentations at Society of Light and Light Masterclasses (six venues across the UK); and numerous invitations to CIBSE Regional Events. Additionally, Prof Mardaljevic presented at 18 international events (between 2012-2018) in Europe, the US and South America which focussed on daylighting, CBDM and daylight metrics. Together, these activities laid the groundwork for influencing the practitioner and policy-making community (in the UK and beyond) to recognise CBDM as a necessary and important advance and, consequently, leading to acceptance for the proposal which became the EU standard. As noted by Paul Rogers, [Head of Daylight / Agency for Architecture & Urbanism, Stockholm]:

> *"In addition to his many influential lectures and papers on the subject over this time, specific mention must be given to* [Prof Mardaljevic's] *work in advancing the calculation methods of the European daylight standard"*. **[S1]**

The wide-ranging impacts from the research that culminated in the European Standard are as follows.

Impact 1: EN 17037 and Impact on National Standards, Legislation and Rating Schemes

All 34 EU/CEN member countries have implemented the standard on a national level. In the UK, the standard was adopted by the UK in May 2019. **[S3]** Publication of the standard has achieved impact far beyond implementation at the national level. It has been incorporated into national legislation (Denmark) with a legal requirement to demonstrate adherence. The United States Green Building Council have approved a version of the influential LEED (Leadership in Energy and Environmental Design) rating system for high latitude countries (>55°N) called 'Nordic LEED' where the default (US) daylight credit has been replaced with the EN 17037 formulation:

> *"… after working together with Sweden Green Building Council, our American counterparts at USGBC have approved our proposal. Amongst other things, LEED projects using this path will be able to prove compliance by exclusively using the methods of the new European Daylight Standard (EN 17037:2018)."* **[S1]**

Other rating schemes which have adopted the standard include the Danish Green Building Council **[S3]** and the Irish Green Building Council 'Home Performance Index (Well Being)'.

Impact 2: Adopted by the International WELL Building Standard

The internationally used WELL Building Standard is the first to focus *"solely on the health and wellness of building occupants"* **[S6]**. Based in the US, the WELL Standard is applied worldwide – the International WELL Building Institute website (Dec 2020) claims: *"5,118 projects with 741 MILLION SQ FT [~70M m^2] in 66 countries"*. Version 2 of the standard (Q4/2020) adopted the performance evaluation methodology and recommended daylight levels of EN 17037 as an option to demonstrate compliance in 'Concept L06: Daylight Simulation', thus requiring for compliance the higher daylight illumination levels necessary for health and well-being than any previous standard. The EU 17037 daylight performance standard is approved to demonstrate compliance with the WELL Standard for buildings anywhere in the world, including the US **[S6]**. Consequently, Mardaljevic's research, underpinning the EN 17037 standard, has global reach.

Impact 3: Transformed the Basis of Design Evaluation for Architects and 'Daylight Designers'

For architect/designers the research has transformed the basis for the evaluation of new buildings which is now founded on annual profiles of daylight illumination instead of the single overcast sky used in previous standards.

In the UK, the recent revision of the 'CIBSE/SLL LG2 (2019): Lighting for Healthcare Premises' evidences this transformation:

> *"BS [EN] 17037: Daylight of buildings (BSI, 2019) requires the use of climate-based daylight modelling (CBDM), which takes account of the quality and quantity of sunlight and daylight. The introduction of these new metrics is leading to daylight design becoming a fundamental part of the architectural design. As such, daylight designers need to be consulted on massing, orientation and façade optimisation at the earliest stages of design even before detailed analyses are carried out."* **[S2]**

Impact 4: Major Upgrade of Practitioner Tools to align with EN 17037

The most commonly used software tools for daylight modelling were significantly upgraded to be able to carry out CBDM in order to compute the metrics required for EN 17037. These include the following leading developers/vendors of building simulation tools:

- DIAL+ https://www.dialplus.ch (Swiss based) **[S8]**
- LightStanza http://lightstanza.com (US based) **[S8]**
- MBS software https://www.mbs-software.co.uk (UK based) **[S8]**
- Climate Studio (Diva4Rhino) https://www.solemma.com (US based) **[S8]**

Practitioner engagement during the public consultation phase of the standard was vital to ensure that stakeholders were prepared for and understood the new requirements for more advanced daylight modelling tools. In response to increasing awareness of the upcoming standard **[S3] [S4]**, various professional and industry bodies across the CEN member countries have hosted/supported numerous training events where EN 17037 and the tools to predict the new metrics were the focus. In the period between September 2018 and May 2019, a list compiled by the CEN/TC 169/WG 11 Secretariat records eight events in various countries (including France, Germany, UK, Switzerland) with at least 1000 participants in total. **[S3]** Notable in the UK was the Daylight Group event 30th January 2019, demand was such that two back-to-back sessions were ran on the same day to cope with the capacity (~150 in total). Following stakeholder presentations (including from the developers of DIAL+), the attendees (mostly practitioners) rejected overwhelmingly (by 15 to 1) the draft Annex proposed by the BRE (a 'daylight brexit' keeping the existing British Standard and daylight factors) and voted instead to adopt the EU standard with only minor modifications in a heavily revised Annex. **[S4]**

Impact 5: Shaped Legal Decisions in Civil Litigation (Sweden) UK High Court Right to Light Cases

Although not intentionally formulated to quantify loss of light for planning disputes, the daylight performance basis of EN 17037 (requiring CBDM) has been used in high-profile Rights to Light (RTL) cases. Outcomes from RTL disputes have considerable influence over design/planning decisions, e.g., an injunction will either prevent a development occurring, or result in a 'cut back' to the design. The cases where CBDM/EN 17037 were used achieved settlement prior to hearings scheduled for the High Court, and so the details are not public.

[redacted]

[redacted] **[S7].** Reflecting on this outcome, a partner of law firm Pinsent Masons LLP stated that:

> *"Professor Mardaljevic's work in researching and developing alternative methods of measuring and assessing light loss such as Climate Based Daylight Modelling is ground breaking and enormously important to support the establishment of an alternative to the Waldram Method, which I am certain will assist the proper and fair resolution of rights of light disputes in the future."* **[S5]**

Further reach of this impact is evidenced by a Civil Litigation case in Sweden, in which EN 17037 was, according to Paul Rogers of BAU Architects,

> "*successfully used… to support the plaintiff's argument of [daylight] sufficiency*". **[S1]**

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Paul Rogers (BAU Architects in Stockholm, Sweden) [TESTIMONIAL]
[S2] 'CIBSE/SLL LG2 (2019): Lighting for healthcare premises [BUILDING GUIDELINES]
[S3] CEN/TC 169/WG 11 Secretariat: DS (Denmark) [TESTIMONIAL]
[S4] David McNair, CIBSE Daylight Group Secretary (2015-2020) [TESTIMONIAL]
[S5] Matthew Baker, Partner - Pinsent Masons LLP, Leeds. [TESTIMONIAL]
[S6] WELL Building Standard v2 (September 2020). Concept L06: Daylight Simulation. [BUILDING STANDARD]
[S7] Will Densham, Partner - Eversheds Sutherland (International) LLP [TESTIMONIAL]
[S8] Evidence from software providers' websites (collected 17/11/20) [SOFTWARE TOOLS]