SDAR* Journal of Sustainable Design & Applied Research

Volume 1 | Issue 1 Article 6

2012

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Recommended Citation
Doyle, Bernard (2012) "An Investigation Into Why Lighting Controls Fail in Buildings," *SDAR* Journal of Sustainable Design & Applied Research*: Vol. 1: Iss. 1, Article 6.
doi:https://doi.org/10.21427/D7JB10
Available at: https://arrow.tudublin.ie/sdar/vol1/iss1/6

An investigation into why lighting controls fail in buildings

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Abstract

The project began as a post-occupancy evaluation of lighting controls installed in a range of buildings, including a public office building, a shopping centre and a primary school. Actual controlled lighting consumption was to be compared against past billing or simulated energy consumption. However, when the research began it was found that the controls had been removed from two out of the three buildings. Further research proved that it was not unusual for lighting controls to be disconnected following installation.

This raised a much bigger research question – why were the controls disconnected and what were the factors governing success or failure of these systems? To answer this new question a new methodology to that first envisaged had to be established. Investigating the reasons for disconnection could only be achieved by discussion with those involved. To find out what people know, or think, it is necessary to ask them. Interviewing was used to address the new research question.

It was found that little research exists on long-term performance analysis of lighting controls. A framework was created to determine if there is correlation between past findings and the reasons for failure in the case studies. It should be noted that there were minimal findings into the failure of lighting controls systems in buildings in Ireland, which prompted possible additional reasons for the failure of these systems, e.g. differing usage patterns, availability of useful daylight.

The research that followed posed many challenges requiring the use of qualitative data in an engineering environment. In order to answer the research question, a clearly-defined and well-structured methodology was required. It was concluded from the research that the conceptual framework used was appropriate and that the methods were fit for purpose.

Some of the findings included:

- Maintenance costs are comparitively high
- Misinterpretation of commissioning processes
- Incomplete analysis prior to installation
- The requirement for post-occupancy evaluation in current engineering practices

Key Words:
Daylight controls, daylight harvesting, problematic controls.

1. Introduction

1.1 Basis for studies

This project began as a post-occupancy evaluation of existing lighting control systems in an office space to determine the installed financial savings and CO_2 emission reduction. Three buildings were chosen as case studies. It was intended to compare the actual consumption of energy and greenhouse gas emissions due to lighting with automated controls to previous manually-switched systems or simulated systems. However, during the initial stages of data acquisition it became apparent that a large number of developments had significant problems with such controls.

The research question then evolved to a much bigger one, i.e. why were the controls disconnected and what were the factors governing success or failure of these systems? It became apparent that disconnection was not untypical and although considerable research has been conducted into a comparison of control types, little information was available as to the reasons for failure of systems within Ireland. Documented evidence of failed systems is also a rarity. Galasiu et al[1] highlights the lack of availability of information for long-term performance studies of daylight control systems. However, the use of lighting control systems is becoming more relevant as energy consumption, energy costs and greenhouse emissions are pushed to the agenda forefront.

This research attempts to address the issues that result in the disconnection of lighting controls systems in day-to-day use within buildings. The research questions investigate why controls were disconnected from the public office and the shopping centre, but were successfully deployed in the school.

1.2 How will the research be conducted?

As no recordings had been taken of the operating system, no quantitative data existed. The reasons for disconnection can only be established by discussions with those involved during the design stages and at times when problems arise. A qualitative methodology was adapted to address the new research question. Interviewing the parties involved was the method proposed to investigate how the supplier, designer and end user felt about the reasons for disconnection.

2. Research methods

A new approach was required for gathering data and the reasons as to why daylight harvesting systems succeed or fail. Several approaches were considered and the methods used are explained below.

2.1 Research questions

The methodology and methods in any research will be determined by the research questions posed. In this research the questions are:

- Why were controls removed from building A?
- Why were controls removed from Building B?
- What are the reasons for the success of the controls in Building C?
- Are the findings of this research in line with past studies?
- Have faults outside the conceptual framework of this research been discovered?

2.2 Methods

2.2.1 Qualitative research

For the buildings chosen the problems arising were not very well documented. Little quantitative data was available for any of the selected case studies and information is therefore only accessible through survey or discussion with those involved. The research method chosen is to be a combination of qualitative data and case study review or post occupancy evaluation analsysis. According to Hancock and Algozzine,[2] these research traditions are generally classed separately. However, for the case studies chosen, a combination of both approaches seemed more fitting.

Engineering usually involves mathematical processes to provide a solution to a given problem. Engineers therefore prefer a quantitative approach. It is noted that the use of a qualitative approach means that the researcher must ...

- have an understanding of the research area
- establish a participant's knowledge of the subject area
- be aware of any hidden agenda by the participant
- be impartial to information obtained
- be aware of their own feelings on the subject.

2.2.2 Interviews

Individual interviews were chosen as the main method for data acquisition. Interviewing offers the greatest return on answering of questions as there are numerous techniques such as probes and prompts to induce more information from the interviewee, than simple yes or no answers. This can be one of the downfalls of surveying. Several structures or formats of interview may be employed. Robson[3] describes the relevance of structured versus unstructured interviews and the applications of each.

Semi-structured interview

Pre-determined questions are prepared, but the order can be modified based upon the interviewer's perception of what seems most appropriate. Question wording can be changed and explanations given, particular questions which seem inappropriate with a particular interviewee can be omitted, or additional ones included.[3, p.270]

Powney and Watts[4] suggest a different approach, i.e. respondent interviews and informant interviews. A respondent type approach is where the interviewer maintains control for the duration of the interview, i.e. questions are somewhat structured and guided towards the interviewer's research or interests. The open question style allows for structuring of the interview but will afford the opportunity to analyse the interviewee's true knowledge of the systems and design processes. Face to face interviewing with open style questioning allows probing or any questions to be asked that had not previously been considered.

During the literature review it became apparent that the Weidt Group's study into daylight harvesting, as conducted by Ejadi and Vaidya's,[5] appears to be extremely relevant in this field and it is for this reason that the findings formed the conceptual framework of the research in this document.

2.2.3 Interview transcription

Transcribing as close to the interview session as possible enabled inclusion of emotions or any significant other findings that arose during the interview, in the transcipts. The main benefits of transcribing to text were that important findings in the data was flagged and grouped for further analysis. This is referred to as coding.

2.2.4 Coding of data

Data was analysed following the logic of coding, i.e. categorised under the conceptual framework of Eijadi and Vaidya's[6]. Interviewees' responses were analysed under the headings below:

- Lack of coordination or understanding between the design disciplines concerning the daylighting control system;
- Improper location of daylighting controls;
- Inadequate specification of the controls systems, component parameters and sequence of operations;
- Shop drawings made by contractors that detail the system are not checked, or the lighting designer does not know what to check;
- Field changes to tune a system are not documented and taken back to the designer to complete the feedback loop;
- Findings outside of the conceptual framework.

This template approach will make the analysis of the data more simplistic as questions were specifically created in a template manner to receive answers relating to each of the recommendations of Eijadi and Vaidya. An example of which might be asking the supplier, designer, facilities manager and client about the specific input of a client or client representative during the design stage of the lighting installation. The answers can then be compared under the *"Lack of coordination or understanding between the design disciplines concerning the daylighting control system"* heading.

2.2.5 Reliability and validity of data

It must be noted that any collectable data was based on the expressed opinions and knowledge of the participant on the given subject and, as a result, can only be addressed as qualitative data. In order to provide a fair argument similar questioning was purposefully created for supplier, designer, client and end user of the different case studies. This process, known as a template approach as defined by a study by Crabtree and Miller,[7] also aides coding.

2.3 Addressing the research questions

2.3.1 RQ 1 – Why were controls removed from building A?

Building A is a public office located in South Dublin. Daylighting controls, presence detection and timed controls were installed throughout the building. However, due to several problems some of the control features were disconnected. Interviews were conducted with the facilities manager and the electrical services engineer who carried out the design of building A.

2.3.2 RQ 2 – Why were controls removed from building B?

Building B is a shopping centre located in Co Tipperary. Some of the lighting controls were disconnected after a relatively short period of time following installation. Interviews took place with the centre manager and the electrical services engineer responsible for the design.

2.3.3 RQ 3 – Why were controls successful in building C?

Building C is a primary school located in Co Waterford. In contrast to the other post occupancy evaluations carried out in this research, the daylight controls in Building C remain intact. However, the approach used in Research Questions 1 and 2 above was applied to Building C also. The aim was to determine if similar design methods and installation techniques were used as in Buildings A and B.

Interviews were conducted with the school caretaker to determine if any problems arose and how they were dealt with. Questioning followed the same format as that used in Research Questions 1 and 2.

2.3.4 RQ 4 – Are findings in line with the research?

Once all interviews had been conducted and transcribed they were categorised under the findings of the Weidt Group 2004-2005 Dimming Study. This allowed for a comparison of successes of the case studies against the recommendations of the Weidt Group studies.

2.3.5 RQ 5 – Have faults outside the framework been discovered?

Any other factors of relevance outside the boundaries of this framework were highlighted and may create a path to further research areas.

The three buildings used for the case studies included a public office building, a shopping centre and a school, all of which are located in southern Ireland. Items such as maintenance costs, feasibility studies and weather patterns do not fall under the conceptual framework and shall be addressed in this research.

3 Data presentation and results

Having conducted the interviews with all parties involved, data was initially transcribed and then coded under the common headings listed previously. As discussed in the Research Methods section above, each building was initially analysed separately, under the conceptual framework of this document. This allowed comparisons to be made between what was stated by the client and what was stated by the designer. The findings of each case study were then grouped under the framework headings for further analysis.

3.1 Lack of coordination or understanding between the different design disciplines concerning the day-lighting control system.

3.1.1 Summary of results on coordination between design groups

Although the "lack of coordination or understanding between the different design disciplines concerning the daylight controls system" is a significant factor, it is felt that the role of the end user is overlooked. In order to increase the satisfaction with the installed system, the end user should be one of the leading members of the design team.

For Building B, the Shopping Centre, it is felt that some of the problems may have escalated as the final end user, i.e. the general manager, was not directly involved during the design stage. As the project progressed changes were made from tendered drawings through to construction stage, resulting in discrepancies between schematics, narrative reports, etc. In some instances the supplier does not directly provide training to the end user allowing for misinterpretation, with a possible snowball effect.

For Building C, the primary school, the end user had little input into the switching arrangements. Details were agreed between the electrical services designer and the architect. Having fewer people involved would decrease the opportunity for changes to be made, or misunderstandings to arise.

Di Louie[6] discusses the importance of taking measurements of incoming daylight and creating zones for lighting control systems. When asked about readings being taken prior to installation, the shopping centre general manager stated that he assumed a simulation or readings had been carried out. The designer stated that he assumed such measurements are the responsibility of the lighting controls specialist. On the other hand, the controls supplier laid that responsibility with the design engineer. It would appear that there is no standard format for the design methods, and there is a lack of coordination between those involved.

3.2 Improper location of controls

3.2.1 Summary of results on location of controls

Without the correct analysis of natural daylight, installation of a photocell for the purpose of controlling internal lighting seems irrational. Placing the photocell on the roof to control the internal mall lighting makes little sense.

The design team on the other hand were confident that locating the photocells on the roof was the correct choice. However, on review of Figure 1 *Internal versus External Illuminance* it is quite clear that levels outside the mall area are much greater than natural lighting levels internally.

The ideal location of the sensor should be determined, to ensure that the level being read by the sensor is the same location as where the artificial lighting was used. The importance of the PIR location was also noted, i.e. possibility of injury through improper location. The location process may not always be correct during design stages as room layouts can change and new obstacles may arise.

Fig. 1: Internal versus external illuminance

3.3 Inadequate specification of the controls systems, component parameters, and sequence of operations.

3.3.1 Summary of results on specification

To safeguard against future problems it is concluded from this research that the installed system must be well defined and documented for future users. This can be achieved through adequate labelling and reference manuals. This could however increase the capital cost of supply, installation and commissioning. Expensive maintenance contracts can act as a major deterrent for the installation of such control systems as it is highly probable that payback periods would be significantly increased by purchasing such contracts.

Dimming systems with no override create problems. One would assume that conflicts between devices and overriding facilities should be recognised during commissioning. Failure to recognise such problems in Building A meant having to arrange meetings in certain rooms rather than having full flexibility to use any office available. Override problems found in Building B meant the total disconnection of the daylight controls. Any possible energy and financial savings via this feature were removed.

It seems that lighting control system problems or complete failure can be due to ...

- Inadequate documentation
- Inadequate labelling of components
- Inadequate end user training
- Improper use of controller/sensor type
- End user fear of unknown system
- Existing commissioning techniques

3.4 Shop drawings made by contractors that detail the system are not checked, or the lighting designer does not know what to check.

3.4.1 Summary of results of shop drawing analysis

For Building A the lighting designer was of the opinion that the lighting controls were installed and still in use. This implies that shop drawings, or as constructed layouts, were not verified with the finished project. Snagging works may not have been part of the initial scope of works.

In Building B, many differences were found between lighting controls descriptive documents, drawings and installations on site. This again implies that no verification was made between what was proposed and what was installed. It is not clear whose responsibility this task was.

Commissioning seems to be a problem area with the controls systems. There seems to be a lack of boundary lines around each party's responsibilities and no certification verifying complete system operation.

3.5 Field changes to tune a system are not documented and taken back to the designer to complete the feedback loop.

3.5.1 Summary of results of the communication feedback loop

It was stated for Building A, the Public Office Building, that there were "issues with the design not matching the needs when the offices were occupied". One of the problems discussed for example was the use of remote controls in an office. Several steps were taken by the facilities manager to rectify this problem. However, without the knowledge of any problems it would not be surprising if the designer assumed the project a success and specified remote controls on future builds.

Another highlighted problem was the use of PIR's in stairwells. This situation was not conveyed to the designer so could occur again in a similar project.

3.6 Findings outside the conceptual framework

3.6.1 Summary of results outside the conceptual framework

The surprisingly high costs of maintenance contracts is a huge negative drawback on the possible savings achievable through the installation of daylight controls systems. No feasibility study was conducted for any of the buildings used in the case studies above. Had they been performed, and the maintenance contracts been included, it is very likely that the payback period would render the controls as unfeasible.

4 Conclusion

The case studies used in this research were random selections that consisted of two buildings with disconnected lighting controls and one building with a control system that remains in use. The research can therefore be construed as a critical analysis of a sample section and not a selective sample of successful projects, that can often be used for marketing purposes.

It is clear from the summaries of the Data Presentation and Results chapter that there are a vast amount of variables that can lead to the failure of the lighting control systems. Although all three case studies were completely different buildings, i.e. different construction elements, constructed throughout different parts of Ireland and had different end user requirements, the framework allowed for the data from all three case studies to be analysed under similar headings. This helps the reader to understand that the proposed reasons for failure or success are common among differing projects across Ireland. The findings outside of the conceptual framework section allowed for more local analysis of the problems associated with lighting controls. An example would be the high cost of maintenance contracts discovered during the interview with Building A Facilities Manager.

Investigation into the failure of the controls in the case studies, under the framework, found that some of the reasons for disconnection included

Coordination

- no standardised communication channels from supplier to end user
- information lost in translation from supplier to end user
- lack of coordination between design parties
- changing design team persons
- the end user role in the design process

Location of controls

- daylight analysis and zoning required for sensor location
- PIR location at construction stage
- inadequate as constructed layouts
- location of manual controls for override

Specification of control systems

- inadequate specification of installed system
- conflict between installed devices
- improper use of sensor type

As constructed analysis

- lack of commissioning knowledge or coordination
- lack of contracts for engineer to review installed controls

Communication feedback

- lack of feedback of field changes to designer
- lack of post occupancy evaluations by designers

A substantial finding was the misinterpretation of the commissioning process. It would appear that all parties have their own opinions as to what exactly occurs during commissioning, i.e. the supplier feels that commissioning should be performed by the contractor and the designer feels that commissioning should be performed by the lighting specialist. Hence it would appear that there is currently no commissioning process that ensures that the controls had been installed and operate as per the original designs and narrative reports.

Engineers are often sceptical about qualitative research as described in the methodology. However, for this research it was the only way to find out why people made decisions to disconnect controls. The limitations of qualitative research were also discovered during the research process. As an engineer, it is always preferable to see a problem defined clearly and calculated, with appropriate data to prove

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DOI: https://doi.org/10.21427/D7JB10

a theorem. Without sufficient data a different approach is required. Qualitative data is not conclusive and often needs to be formally supported by quantitative data. It must also be recognised that in order to explore what happened, and to establish personal opinions and feelings in a given situation, a qualitative approach offers the possibility of rich and insightful findings.

It is concluded from this research that the framework used was appropriate with methods fit for purpose. It was found that most faults or problems fit within the confines of the headings used within the conceptual framework. Coding was made easier through use of the headings, and data could be easily categorised and evaluated.

Post occupancy evaluation is not a common process in the construction industry and one would imagine that through adequate feedback channels most of the existing problems in current developments could be overcome in future builds by using accumulated data from post occupancy evaluations..

It is hoped that this research can be used as an aid to designers, installers and future research studies to increase the amount of data available on lighting control systems and eradicate minor problems that sometimes end up resulting in the total disconnection of controls. Solving these problems may increase the uptake of lighting controls on a national level and so help to reduce energy consumption and CO2 emissions as per government targets. Studies into a facility for feedback of realtime savings to the end user, along with further long-term assessment performance studies, could also have a substantial impact on the uptake of daylight controls systems.

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The Chartered Institution of Building Services Engineers Republic of Ireland Branch and The Society of Light and Lighting present the

Irish Young Lighter & Irish Lighter Awards

These awards – jointly promoted by CIBSE, SLL and ILP – are an annual event with the finals and presentation of prizes being held each September in DIT Kevin St. Typically, the programme of events is as follows:

2.00pm	Young Lighter final begins
4.40pm	Announcement of winners and presention of prizes
5.30pm	Tea/coffee, sandwiches served
6.30pm	Irish Lighter final begins
8.25pm	Announcement of winners and presention of prizes
8.30pm	Wine and finger food reception in Kevin Street penthouse
10.00pm	Close

Young Irish Lighter & Irish Lighter Awards 2011	
Irish Young Lighter	**Irish Lighter**
First Prize €1000 presented by ILP	**First Prize €1000 presented by Enlighten**
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DOI: https://doi.org/10.21427/D7JB10