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Lighting is arguably the single most important element in retail design. Among retail environments, grocery stores are important for their potential contribution to sustainable community. More than a mundane place for running errands, the grocery store is increasingly a “third place” that sits at the nexus of healthy lifestyles and community gathering. This study explores the ways that lighting helps to enhance these larger goals and advances an approach to lighting design that considers not just the environmental, but also the economic and social impacts of lighting.

This study developed two key resources for practitioners involved in the lighting design of grocery stores. The first resource is a sustainable lighting design process and the second product is evidence-based design guidelines for sustainable lighting design in grocery stores. The “sustainable lighting design process” is the result of combining major elements in lighting design with the 3-E framework for sustainability that encourages consideration of environment, economy, and equity. The second resource, and the major undertaking of this thesis, is a systematic review of existing scholarly literature that results in a comprehensive matrix of sustainable lighting guidelines for the grocery store environment. The matrix of guidelines additionally reveals how each guideline relates to the 3 major goals of sustainability. Hence, each study was examined

for its contribution to ecological, social, and economic sustainability goals, and sustainability themes were mapped accordingly into the guidelines.

The final guidelines can be selected to fit unique applications and contexts by store owners and retail designers. The use of the guidelines, even in part, can improve the sustainability of lighting solutions across numerous dimensions – from reducing the carbon footprint of the building to increasing sales to fostering positive social interactions among customers. These guidelines can also be used by scholars to find gaps in the research field by looking across the matrix and the mapping of sustainability themes. The hope is that future researchers will help to improve the matrix by continuing important research on sustainable lighting strategies.

EVIDENCE-BASED STRATEGIES FOR

SUSTAINABLE LIGHTING DESIGN

IN GROCERY STORES

by

Majedeh Modarres Nezhad

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Approved by

_____
Committee Chair

Dedicated to my husband, the love of my life, Farhad,

and my beloved parents Mehri and Mohammad.

APPROVAL PAGE

This thesis written by Majedeh Modarres Nezhad has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

Lighting accounts for about one third of the total energy consumption in the US, most of which is produced from fossil fuels (Russell, 2012). This means that we are burning an immense amount of natural resources to light up houses, neighborhoods, and cities. This energy consumption also has an impact on environmental health. Energy-efficient lighting can help mitigate the rapid depletion of fossil fuels and bring us closer to maintaining ecological balance. However, the key to successful lighting design is to consider not just the environmental factors but also the economic and social impacts of lighting. Lighting can address social dimensions of sustainability by affecting the way people feel, react, and function in various settings (Steffy, 2008, Horská & Berčík, 2014). Lighting significantly influences how people experience interior environments and respond to certain tasks and to each other (Quartier et al., 2014). Also, lighting design can affect economic factors since appropriate lighting design solutions can help reduce operating costs, improve workforce productivity, and increase customer satisfaction leading to a net increase in revenue (Kliment & Barr, 2004; Yudelson, 2009). Hence, given the multifaceted impact of lighting on interior environments, one shouldn't merely focus on energy consumption when discussing lighting design but should also consider the economic and social influences of lighting

design. These three aspects, however, can have various degrees of importance in the lighting design of different spaces.

Retail accounts for the largest energy costs among commercial spaces, and lighting is using almost 50 percent of this energy (EIA, 2003). Besides the energy related roles, lighting is arguably the single most important element in retail design. A retail space lives and breathes by the success of its lighting plan (Kliment & Barr, 2004; Horská & Berčík, 2014). Among retail environments, grocery stores were chosen as the focus of this study for their importance in sustainable communities. The first grocery stores were public markets, and one of the main things that was happening in these spaces was social interaction. They were the core of the community, but throughout time this role diminished. The point is that grocery stores have the potential fill the part of society that is lacking because of modern life styles. Lighting, one of the elements of the space, can help grocery stores to enhance a sense of community in urban spaces, which results in lasting social and economic values (Kliment & Barr, 2004).

In addition to this role grocery stores can affect other non-retail and more human centered roles. For instance the studies that focused on food deserts can be considered as participating in social equity. All of these emphasize the importance of grocery stores and demonstrate how fully the goals of sustainability are in line with the roles of grocery stores in society. This shows grocery stores are not a normal retail space and that they have a large effect on the city and community.

Problem Definition

Many researchers and theorists address sustainable development by breaking it down into the three categories of ecological, social, and economic, generally referred to as the three dimensions of sustainability (Aplet, 1993; Goodland & Daly, 1996; Rogers & Boyd, 2008; Trzyna & Osborn, 1995; McDonough & Braungart, 2002). Although sustainability is a trend in lighting design, most of the previous studies have covered more economic and ecological dimensions of sustainability. However, as discussed before, sustainable lighting design must cover and integrate the ecological, social, and economic aspects in order to achieve desirable results. There are studies that support sustainable lighting but they either address just one aspect of sustainability, or they cover sustainable lighting design in an environment other than grocery stores. Therefore there is a need to develop a study that holistically covers all three dimensions of sustainability related to lighting. This holistic study offers a set of design guidelines that cover the ecological, social, and economic needs of lighting for the grocery store environment.

Significance of Study

Lighting design is a process that needs to be adjusted to include sustainable design criteria in order to create sustainable lighting. This study provides a sustainable design process (for more information refer to in Chapter II) for the lighting of grocery stores by integrating the lighting design and sustainable design processes to cover the

three dimensions of sustainability. Lighting design starts with design considerations which are followed by lighting design criteria and tools. In this process, the lighting codes and third parties' rules are considered to control the whole process. The results of this study should help both grocery store owners and designers in design and implementation phases. It should provide a guide to create a lighting design solution to reduce environmental impacts, to reduce business costs, to improve productivity, to encourage favorable customer behavior, and to support the well-being of customers in the space.

The methodology that has been chosen to develop the sustainable design guidelines is a systematic review of scholarly studies. The systematic review of previous scholarly resources helps to establish these guidelines on the basis of evidence.

Organization of Thesis

The organization of this thesis is as follows. Chapter II is broken down into two subsections. In the first subsection, the relevant literature is reviewed in order to clarify the lighting needs in grocery stores. Then a sustainable lighting design process is developed that covers these needs. The second subsection of Chapter II focuses on sustainability and the effects of lighting design on each of the three dimensions of sustainability. This subsection helps to better understand the aspects of lighting design and sustainability that interact with each other and should better position the sustainability concept within lighting design. The major contribution of Chapter II is a

"sustainable lighting design process" (Figure 1). Within this process, the lighting design criteria become the foundation of the lighting design guidelines.

In Chapter III, the methodology used to develop guidelines for sustainable lighting design in grocery stores is introduced. The reasoning for adopting the systematic review of literature, which is used in healthcare studies, is also presented in this chapter. This chapter concludes with the applications and limitations of this methodology.

Chapter IV covers design guidelines for sustainable lighting in grocery stores. As mentioned before, these guidelines are evidence-based suggestions that may be used by grocers or lighting designers. Each guideline is explained and expanded in this chapter by using evidence from empirical studies.

The final chapter sums up all the findings of this study. Also the limitations that the author faced with throughout this study are covered in this chapter. At the end there are suggestions for future studies based on the findings of this study.

At the end the first appendix includes the matrix of sustainable lighting design strategies. These designing guidelines is demonstrated for different areas in grocery stores in Appendix B. Appendices C and D include two design projects that helped to shape these guidelines and had influence in developing of the guidelines.

CHAPTER II

LITERATURE REVIEW

Sustainability in lighting design is a relatively new practice and interior designers have recently started to consider sustainability broadly in their design and practice. There are several resources that discuss design solutions in order to create sustainable environments, but there is not a holistic resource that addresses sustainable lighting design in interior environments, and specifically grocery stores. Based on the definition of sustainability, which covers ecological, social, and economic aspects, this research reviews scholarly sources to identify best practices for sustainable lighting design specifically for the grocery store environment.

This chapter is divided into two sections: “Lighting Design in Grocery Stores” explains general lighting design needs and considerations of a grocery store, and “Sustainable Lighting Design in Grocery Stores” discusses these lighting design needs and considerations through the lens of sustainability. This section is divided into three categories based on the three major dimensions of sustainability: ecological sustainability, social sustainability, and economic sustainability. In each category, lighting design considerations were discussed related to their effects on ecological, social, and economic issues.

This literature review helps to better understand different aspects of sustainability. Sustainable lighting design is not just about ecological issues but needs to cover social and economic aspects of sustainability as well. Also, this study will demonstrate how sustainable criteria can be added to the current process of lighting design in order to change it into a process that leads to sustainable outcomes in practice.

Lighting Design in Grocery Stores

In this study, the lighting design process that is proposed in E-Light (Sarawgi, 2013) was used in conjunction with two other sources: one by Rea (2000), and the other one by Karlen & Benya (2004). These resources do not cover all three dimensions of sustainability. Therefore, another resource by Marshall-Baker & Tucker (2012) was used to cover the deficiencies. Marshall-Baker & Tucker's book is not directly about lighting design, but the design process that is suggested by them covers three dimensions of sustainability. Using all of these resources helped to develop the lighting design process used in this study, which can be seen in Figure 1. This process is divided into three main sections: design considerations, lighting design criteria, and lighting design tools and techniques.

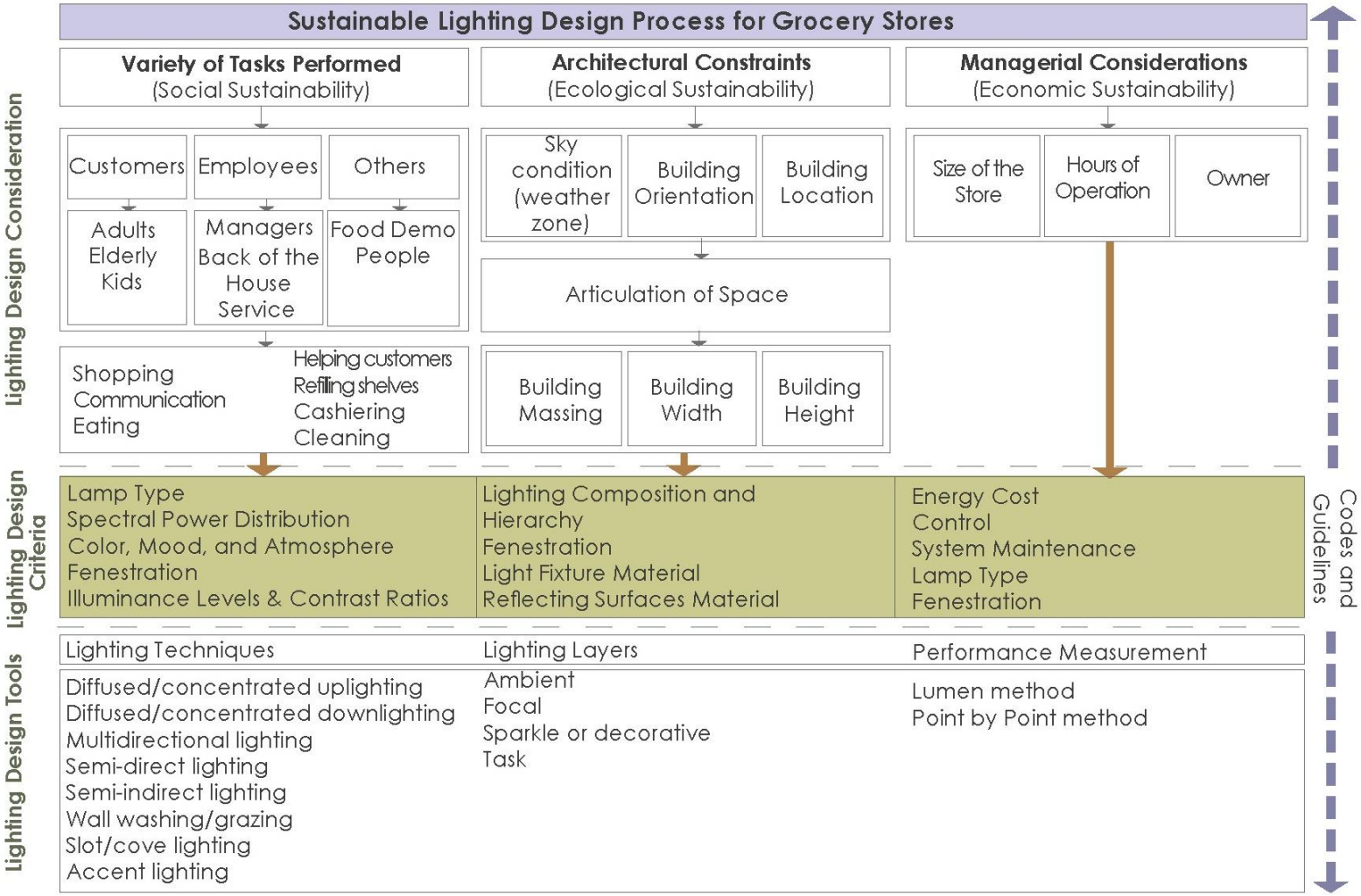


Figure 1. Lighting Design Process Proposed by This Study

Lighting Design Considerations

Lighting design in grocery stores is based on three considerations: variety of tasks performed, architectural constraints, and managerial considerations.

First, successful lighting design begins with recognizing visual functions and tasks (Karlen & Benya, 2004). The users of the space can help to identify tasks that are accomplished in that space and based on that, lighting design suggestions can be developed to satisfy visual needs. Generally, in a grocery store there are two main groups of users: customers (who can be categorized based on their ages and abilities) and employees. Employees of a grocery store vary based on the size of the store, but overall there are management, service, clerk, and back of house employees. Also, there are other groups that cannot be fit into these two categories, which include food demo people, drivers, and so on, who are not working in the store regularly. Based on these groups of users, different tasks are happening in most grocery stores: shopping, communication, eating, refilling shelves, helping customers, cashiering, and cleaning. Occupations in grocery stores that may change depending on the scale and type of stores: management, business, and financial occupations; professional and related occupations; service occupations; sales and related occupations; office and administrative support occupations; production occupations; and transportation and material moving occupations (Grocery Stores, 2010).

The second phase is considering architectural constraints, which include orientation, location, climate, and latitude (Nabil & Mardaljevic, 2005). Identifying these

issues before developing the lighting design in new or existing buildings helps to achieve the appropriate amount of daylight in desired spaces of a grocery store.

The third phase of lighting design consideration is identifying managerial considerations, which play an important role in defining and affecting the other two phases. Some of the points that can be addressed as managerial considerations are scale and type of store, hours of operation, owners' expectations, and so on. Grocery stores are retail units and, similar to other businesses, profit and cost play an important role in every aspect of design and especially lighting design ("SIC 5411 Grocery Stores," 2008).

Lighting Design Criteria

In grocery stores, similar to any other retail store, attracting customers, providing adequate light for evaluating products by customers, and facilitating the completion of the sale are the goal of lighting design (M. S. Rea, 2000). But in addition to these, lighting design in grocery stores needs to promote social interactions and conserve energy. Based on these goals there are several lighting design criteria: Illuminance Levels and Contrast Ratios; Lamp Type; Spectral Power Distribution, Color, and Mood; Lighting Composition and Hierarchy; Lighting and Materials; Fenestration; positively. And a lighting that reflect these changes are more desirable for office workers.

Energy Cost; Control; and System Maintenance (Sarawgi, 2013; Karlen & Benya, 2004; Marshall-Baker & Tucker, 2012). All of these points are described in Chapter IV in detail with best practices for each category based on evidence from research. The goal of this process is to help designers and grocers to develop a lighting design plan which is both functional and sustainable.

Lighting Design Tools

In the lighting design process, there are tools that help to develop the design. These tools are lighting layers, lighting techniques, and performance measurement. Some of the lighting techniques are diffuse uplighting, concentrated uplighting, diffuse downlighting, concentrated downlighting, multidirectional lighting, semi-direct lighting, semi-indirect lighting, wall washing, wall grazing, slot lighting, accent lighting, and cove lighting. These lighting techniques can be used in the space to create different light layers of ambient, focal, decorative, and task (Sarawgi, 2013).

In the design process designers can use calculation techniques in order to measure the performance of the lighting system. There are two methods to calculate the desired illumination level for a specific space; one is the lumen method and the other one is the point by point method (Sarawgi, 2013; Karlen & Benya, 2004).

In lighting design, codes, regulations, and third parties such as LEED are consulted to guide each step of the whole process. The main resources of codes and regulations for interior lighting are ASHRAEH, International Code Council (IECC), and

National Fire Protection Agency (NFPA) (Sarawgi, 2013). The Green Construction Code (IgCC) has a set of codes that are addressing sustainable practices in building construction, including lighting. Also, LEED, as a third party that evaluates buildings for their environmentally friendly performances, has some credits that cover sustainable lighting practices. But it needs to be considered that the LEED guidelines are covering mostly ecological and economic dimensions of sustainability, rather than social dimensions. Based on the study by Athens (2007), just 28% of LEED's credits cover social sustainability, and few of the socially oriented credits related to lighting.

Summary

Designing based on the proposed process for lighting design of a grocery store can offer lighting design options that have the least environmental impact, heighten customer satisfaction, and promote better economic outcomes. The resources that have been used to develop lighting design processes in the past considered sustainability a micro subject or, if they considered sustainability, usually it was related to economic issues and energy consumption. As mentioned before, the lighting design process proposed here offers a sustainable version of the lighting design process that addresses three aspects of sustainability (ecological, social, and economic). In the next section, the relationship between these three dimensions of sustainability and the lighting design process is clarified.

Sustainable Lighting Design in Grocery Stores

The concept of sustainability covers three areas of ecology, equity, and economy (McDonough & Braungart, 2002). Therefore, sustainable lighting design suggestions must cover all of these aspects of sustainability. In this section of this literature review, the three dimensions of sustainability (ecological, social, and economic) have been used as a framework. The lighting effects on each of these areas shaped the subheadings. Each subheading, by clarifying the lighting effects on sustainable development, explains the importance of finding a sustainable solution for lighting design.

Each section follows the same pattern: first, a description of that specific dimension of sustainability in lighting design in general and in grocery stores specifically; second, the effects of lighting in relation to that dimension of sustainability; and finally, a review of literature that address that issue. Resources about sustainability and sustainable development in design were used as models to define the categories and subheadings (Thorpe, 2007; McDonough & Braungart, 2002; McLennan, 2004; Jones, 2008). The results of literature review are discussed in detail in Chapter IV.

Ecological Sustainability and Lighting Design of Grocery Stores

Ecological sustainability and sustainability are terms that are usually used interchangeably. One of the probable reasons for this is that unsustainable ecological practices are easier to see because of the direct effects on the environment. The other reason is that the effects can be quantified easier (Athens, 2007). These reasons show

why ecological sustainability has been addressed more often compared to other aspects of sustainability both in scholarly sources and practice.

Effect on energy and fossil fuel usage and climate. In studying ecologically sustainable lighting design, the first point that should be addressed is energy usage, which has a direct relationship to burning fossil fuel to produce this energy. This process has an impact on global warming and consequently on the level of a building's carbon footprint (Loe, 2003).

Environmental Protection Agency (EPA) reported that lighting consumes approximately 23 percent of the electricity used in buildings. In addition, 20 percent of the electricity required for air-conditioning results from the heat generated by lamps. This portion in commercial buildings is different. They use half of their electricity for lighting (Winchip, 2005). It is more serious when considering that fossil based sources, which are finite, are used to produce electricity. This process doesn't just deplete resources but also causes air pollution.

Sustainable lighting design is a response to these effects and tries to reduce the impact of lighting on nature by replacing the current electrical lighting sources with more efficient ones and integrating electrical lighting with daylight in interior spaces (Loe, 2003).

Effect on material and product life cycle. The natural environment is the main focus of ecological sustainability. Ecological sustainability addresses Earth and the atmosphere surrounding it. Nature is shaped from four systems or layers: atmosphere,

biosphere, lithosphere, and hydrosphere (Thorpe, 2007). There are cycles of life in each sphere and in the system as a whole. In a sustainable ecosystem, each material that is taken from one sphere to make a product needs to return to its original sphere. It is necessary for nature to sustain this cycle and balance (Thorpe, 2007). This is one of the points that sustainable development emphasizes when considering products' life cycles.

Another concept about the life cycle of materials is the one that McDonough & Braungart (2002) proposed in their book. The "cradle to cradle" concept explains the fact that materials need to stay in a natural cycle in order to have sustainable development. This sustainable cycle includes all the production steps, from providing raw materials, to manufacture, delivery, use, and disposal practices (Winchip, 2005). In order to have sustainable lighting, careful attention must be paid to the life cycle of bulbs, luminaires, and the surfaces that receive light.

Social Sustainability and Lighting Design of Grocery Stores

Social sustainability addresses the strategies in design that promote human quality of life (Bay, 2010). Sometimes it is called restorative design, which is part of the biophilic hypothesis. The biophilic hypothesis is about the tendency that human beings have towards nature. According to this theory, designing green buildings which are ecologically sustainable, is not enough to create a sustainable environment. In addition to that, buildings need to be accepted by people by responding to users' psychological, social, and cultural needs (Kellert, 2005). Thus, paying attention to social criteria is

necessary if the purpose is creating a sustainable environment. Among the three dimensions of sustainability, it is usually harder to address this aspect (Athens, 2007). Based on the study by Athens (2007), socially related credits of LEED only account for 28% of all the credits.

This limitation should encourage people to put more effort into addressing social issues. For instance designers can consider these concepts: users' needs, demography, behavior of users, users' wellbeing and health, and so on (Kellert et al., 2008; Bay, 2010).

Socially sustainable lighting design criteria in a grocery store are mostly found in consumer behavior studies. Mainly the purpose of these studies is increasing sales rather than creating a sustainable environment. The results of these studies were used to develop socially sustainable lighting solutions without considering that the studies were originally intended to increase sales. For instance the study by Bellizzi & Hite (1992) is published in the journal of *Psychology and Marketing* which is in favor of the economical aspect of sustainability.

In the following sections, among all the socially related effects of lighting, only the three that were the most related to grocery stores are reviewed. The main purpose was to clarify how design considerations in grocery stores relates to socially sustainable design. These three criteria are: lighting design and social interactions in grocery stores, impact of lighting on employee well-being and job satisfaction, and lighting design needs for elderly customers.

Effect on social interactions. Grocery stores are part of the retail environment and are similar to any other retail space; they are not just a place to shop; they can be a communal space for social interaction (Kliment & Barr, 2004). With the evolution of the suburbs in America, a desire for memorable communal experiences has become more obvious. The mass-produced aspect of suburban sprawl has left many people without a public sense of belonging. They lack communal identity and social memory, which are the ingredients of “a sense of place” (Kliment & Barr, 2004). Based on the original role of grocery stores in American society, they can become one of the places that create a sense of belonging. When a grocery store is designed “well and properly, it enhances a sense of community in urban spaces and results in lasting social and economic value” (Kliment & Barr, 2004, pp. 3-4).

There is a theory that names communal spaces the “third place.” A “third place” is a place that exists outside the home and beyond the "work lots." They are places where people gather primarily to enjoy each other's company. According to Oldenburg and Brissett (1982):

> It is argued that participation in these third places provides people with a large measure of their sense of wholeness and distinctiveness. Such experiences can help the development of meaningful interaction at home and work. (Oldenburg & Brissett, 1982; p. 265)

Grocery stores have the potential of becoming a third place, which, as mentioned before, was one of their original roles (Mayo, 1993). Lighting design in

grocery stores as one of the elements that helps to create space can have an effect on encouraging social communication in grocery stores. Gifford (1988) concluded that brighter lighting levels stimulate general and intimate communication, and lower lighting levels encourage more intimate communication.

It needs to be considered that encouraging a sense of place by creating an opportunity for conversation doesn't negate one of the main services of grocery stores which is fast service. A grocery store environment with appropriate lighting design should provide both of these spaces: one that encourages communication through inviting lighting at the deli or store café, and one that offers fast service, by providing adequate lighting for selecting products (Karlen & Benya, 2004).

Effect on employee well-being and job satisfaction. Offices in grocery stores can be considered workplaces. Since there isn't a specific study that addresses lighting design in offices at grocery stores and they are similar to other offices, results of studies about workplaces can be applicable for this study. There are several behavioral studies that investigated the effect of light in the workplace, and some of them specifically address daylight in office spaces.

Galasiu & Veitch (2006) reviewed literature about daylit offices between 1965 and 2004. Their study covers two main subjects of occupant preferences and control systems in daylit offices. One of the main achievements of this study is the fact that daylight is a desirable light source in office spaces. Another study about the effect of windows for wellbeing in a workplace is the study of Leather et al. (1998). They

investigated the effect of windows in workplaces considering these three points: level of illumination, sunlight penetration, and view. The result of this study emphasizes the direct relation of sunlight and view to natural scene on wellbeing. Day et al. (2012) investigate the possibility of accessing blind controls and the importance of an integrated design process between different members of a design team in order to get a better result. There are other studies that cover the effect of sunlight on mood by Wang & Boubekri (2011) and Butler & Biner (1989) in office space. Another study by Bommel & Beld (2004) proves the effect of bright light in work space on increasing productivity. Other studies by Webb (2006), and Rea et al. (2002) explains the effect of light sources on wellbeing in the buildings.

Effects on elderly customers. One of the aspects of socially sustainable design is considering the specific needs of people using the space. One criteria is different vision needs based on age (Figueiro, 2008; Stern & Ander, 2008). While there are few studies that address lighting for the elderly specifically in grocery stores, there is much we can learn from research in other environments or studies specifically about elderly people. Kolanowski (1990) studied the effect of color of light on activity level of aged people. Boyce (2003) in his study listed lighting design guidelines for elderly people. Charness & Dijkstra (1999) in a field study found out that adding light improves the performance of older users of spaces. Park & Farr's (2007) study is one of the few studies that investigates lighting design needs for elderly costumers in retail. They studied differences in perception of color temperature and color-rendering index based on age.

Economic Sustainability and Lighting Design of Grocery Stores

Defining economic sustainability and providing an economic doctrine that respects the environment and nature is hard, even harder than defining social sustainability. Unfortunately, nature has not been addressed completely and properly in commonly followed economic forms. Hawken (2010) wrote in his book that "because commerce lacks ecological principles, what is good for business is almost always bad for nature" (p.65).

Another issue is the paradox of having a sustainable store that respects the environment when the nature of retail is to encourage people to consume more. There are some studies that address this issue (Stern & Ander, 2008) but it is not the purpose of this study to explain these conflicts.

Considering all of these debates about economic sustainability and the concept of sustainability in retail, lighting design in grocery stores can affect economic sustainability through energy costs, building and luminaire material selection, and presentation of products.

Effects on cost of energy. Sustainable projects generally require more investment during the design and construction phases. Such extra costs, however, can be paid off during the project life via, for example, reduction in waste and energy consumption. This will eventually motivate owners and businesses to practice sustainability. Some of the economic related benefits of sustainable lighting design in retail environment are:

> reduced energy costs, increased use of utility and tax incentives for energy conservation, increased building value, through higher net operating income, improved productivity and reduced health impacts of building operations, improved sales and lease-up of properties, growing evidence of increased sales from daylighting, marketing benefits, public relations benefits, recruitment and retention of key people, greater funding availability from institutional sources, increased interest by investors in a company's long-term sustainability program, corporate social responsibility exemplified in green buildings, especially with concern over global warming and carbon emission mounting each year. (Yudelson, 2009; p.22)

As listed above, and based on the study by Leach et al. (2011), energy consumption in grocery stores can be reduced by 50% by adopting sustainable lighting practices. The main factors in lighting design that help reduce energy costs are integrating daylight into design and combining it with artificial light, and using energy efficient lamps.

Effect on local luminaire and building materials. One movement that started recently and ties sustainability and grocery stores together is the new tendency towards eating healthier and organic foods, and ideally those foods are manufactured in or harvested by local companies and farms (Shwaluk, 2010; Carolyn & Greene, 2002). This new tendency toward these types of products is because they perceive the products to be healthier, and more environmentally friendly, because they need less costly transportation, and to be more supportive of small scale agriculture and local rural communities (Darby et al., 2006; Stern & Ander, 2008). The same approach can be applied while selecting material or light sources by buying from locally owned

businesses. But it needs to be considered the possibility of application of this approach in selection of luminaires and materials for the interiors.

Effect on presentation of products. Another subject that has an effect on economic sustainability is the effect of light on live and fresh products in store displays. These studies address the relationship between quality of these products and different light sources. Effective product lighting can contribute to economic sustainability by increasing sales and customers' wellbeing and consequently their satisfaction. For instance, one of the studies about meat displays in grocery stores shows that meats last longer and look fresher under light sources that have UV protection (Saenz, 2005; Djenane et al., 2001).

Summary

All three dimensions of sustainability (ecological, social, and economic) are intertwined and synergistic. For instance, the idea of using energy efficient lighting sources, such as LED, reduces energy costs, while providing higher CRI, which is not only more pleasing and better for wellbeing, but also increases sales. Also, since LED lamps have a long life, it reduces the amount of bulbs that need to be produced and therefore it helps to offer a better life cycle for light sources, and lower maintenance costs. Also, LEDs are dimmable so they can be adjusted based on different needs, one of which is creating suitable light to encourage social interaction. As it can be seen, separating sustainability into smaller pieces makes it more approachable and finding solutions for

achieving sustainable design can be easier. In this study by separating sustainability into three sections it helped to clarify the main lighting design considerations.

Conclusion

The purposes of this chapter are two-fold. First this literature review organizes the critical needs for lighting design in grocery stores and develops a sustainable lighting design process. Second, three dimensions of sustainable lighting (ecological, social, and economic) are examined in detail. The frameworks explored in this section are the foundation for the matrix of sustainable lighting guidelines presented in this thesis (Appendix A).

CHAPTER III

METHODOLOGY

The objective of this study is to develop guidelines for sustainable lighting design in grocery stores which will be used by designers and owners to create lighting systems that have minimal environmental impact, that improve employees' productivity, that promote social interactions in the space, and that reduce costs. Thus, this study aspires to guide the design of lighting with a more holistic array of sustainability concerns.

In order to develop design strategies in this study, sustainability has been integrated into the lighting design process discussed in E-Light (Sarawgi, 2013) and other studies (Karlen & Benya, 2004; Rea, 2000). For this purpose the sustainable design process that has been proposed by Marshall-Baker & Tucker (2012) was used. In their book, they considered three dimensions of sustainability for developing programming for the Cradle to Cradle home design competition. Although their focus is not directly on lighting design, the programming section used by them covers all three dimensions of sustainability and is applicable for the purpose of this study. This sustainable lighting design process has been discussed in Chapter II and will be discussed in Chapter IV.

This chapter will describe the methodology for arriving at evidence-based guidelines for lighting design in grocery stores. It will unpack the research process step-by-step and conclude by discussing the application and limitations of this research.

Approach

The method used in this study was a systematic review of existing scholarly literature on lighting design and its environmental, social, and financial impacts. Systematic design is a method of reviewing literature through a structured process and is common in healthcare studies (Cook & Murlow, 1997). “A systematic review involves the application of scientific strategies, in ways that limit bias, to the assembly, critical appraisal, and synthesis of all relevant studies that address a specific … question” (Cook & Murlow, 1997). Systematic reviews have been compared to narrative reviews; the differences can be found in the process and the result. Table 1, adapted from Cook & Murlow (1997), highlights these differences and explains different stages of the systematic literature review process.

Table 1. Narrative Reviews versus Systematic Reviews

Feature	Narrative Review	Systematic Review
Question	Often broad in scope	Often a focused question
Sources and search	Not usually specified, potentially biased	Comprehensive sources and explicit search strategy
Selection	Not usually specified, potentially biased	Criterion-based selection, uniformly applied
Appraisal	Variable	Rigorous critical appraisal
Synthesis	Often a qualitative summary	Quantitative summary*
inferences	Sometimes evidence-based	Usually evidence-based

*A quantitative summary that includes a statistical synthesis is a meta-analysis.

One reason for adapting the systematic review method for this study is that there are several vantage points for understanding sustainable lighting design and it is useful to combine multiple frameworks in a systematic review process. Further,

although there are studies on the subject of sustainable lighting, there is no significant study that holistically addresses all three dimensions of sustainability (ecological, social, and economic). In addition, by rigorously and objectively evaluating evidence, the systematic review helps to create a credible and trustworthy picture of the problem (Evans & Kowanko, 2000). The other advantages of this methodology is that it can identify the questions that need to be answered in future studies more accurately since it systematically summarizes existing data, refines hypotheses, and estimates sample sizes (Egger et al., 2001; Cook & Murlow, 1997).

There are several studies on lighting design that used the systematic review method. Figueiro (2008) used evidence from previous studies to create socially sustainable lighting guidelines for healthcare environments. Her study focuses on the effect of hospital light on the wellbeing of the elderly. Galasiu & Veitch (2006) studied occupant preferences and satisfaction with the luminous environment and control systems in daylit offices. They noted that recent developments in automated control systems and novel materials and technologies required new investigative directions from the scientific literature and therefore adopted the systematic review method to address this need.

The methodology that has been used for developing sustainable lighting design guidelines in this project was developed based on the six-step process proposed by Cook & Murlow (Table 1): Question, strategy and search, selection, appraisal, synthesis, and inferences and applications.

Question

A systematic review starts with a specific and well defined question. Defining a focused versus broad question for the study is one of the things that differentiates systematic review from narrative review. The main question that shaped the base of this study is: What are evidence-based strategies for sustainable lighting in grocery stores that can be used to guide design decisions?

This question clarifies the different aspects of this study: the types of literature that were reviewed, the purpose of study, and the main focus of the study (sustainable lighting design). In order to cover all of these issues, a systematic review was needed to filter and define the best way of solving them. After defining the research question, the next step in this process is selecting the right strategy to start searching for evidence, which is explained in next section.

Strategy and Search

Having a specific question leads to a holistic and focused search of the literature. As explained before, there needs to be a well-defined strategy to get the best results out of this holistic search. Therefore, this process depends on developing the right keywords which generates more accurate and relevant evidence for the study.

The keywords of this study were developed by combining the three dimensions of sustainability with lighting design criteria in different contexts (Figure 2). In order to look for each dimension of sustainability, the definition of sustainability was used for

each category. For instance, in looking for evidence related to social sustainability, since authors rarely use the term “social sustainability” explicitly, keywords such as aging, comfort, and behavior were used to identify studies about social factors related to lighting design. For economic sustainability, keywords such as energy cost and employee productivity were used. The keywords used for the different lighting design criteria (such as illuminance, task planes, etc.) were based on the Sustainable Lighting Design Process chart in Chapter II, Figure 1. For the context of the study, the two keywords of “supermarket” and “grocery store” were used interchangeably. Also, based on the activities that take place in a grocery store, parallel searches in related fields such as workplace and retail environments were performed. It was necessary to broaden the search to contexts beyond grocery stores because in some areas there were not enough studies that addressed that specific issue in grocery stores. For instance there was not a specific study that explained the lighting design of grocery store workplaces. Therefore, in this case, studies related to lighting in workplaces and offices were used.

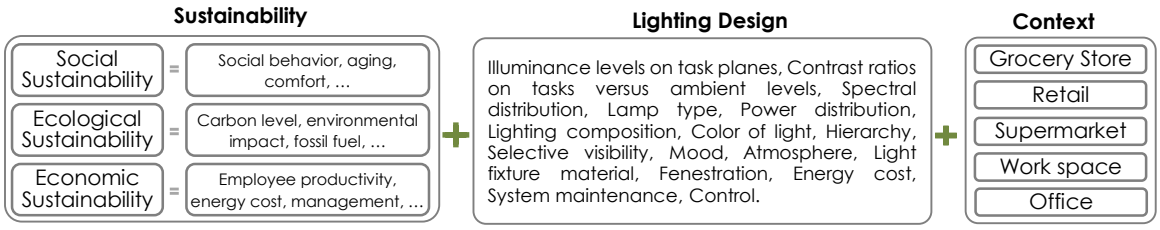


Figure 2. Keywords for Literature Search

The primary search methods for literature included online databases such as Google Scholar and ProQuest, as well as the library of The University of North Carolina at Greensboro. Based on the articles and papers found through this process, further studies were identified by consulting each study's citations and recommended references. This research method helped to extend the depth of research available for use in this study.

Selection

After finding the related studies through the above keyword search, the next step was defining some filters to identify successful and reliable studies to use as evidence. The main criteria for selecting studies was to choose research that was empirical in nature or included a summary or meta-analysis of empirical studies. The articles selected for inclusion were published in peer-reviewed journals. In addition to these articles, the IESNA Lighting Handbooks (ninth and tenth editions) were used to generate these guidelines. The IESNA Lighting Handbook is recognized as one of the main sources that most professional lighting designers consult. To fill in the gaps of the IESNA Lighting Handbook, the Advanced Lighting Guidelines (ALG) (both the latest online edition and the 2003 edition) were also used.

The other factor in selecting articles was publication date. Limiting the referenced articles' date of publication to the last ten years assured the most up-to-date information. This was especially important for this topic because the improvement of

lighting design as a technology is happening very fast and every day new products are introduced to the market that change previous calculations in lighting design. Also, as mentioned before, sustainability is a relatively new concept in lighting design and the suggested solutions for sustainable lighting design change over time. Because of these reasons and also to narrow down the study, a period of ten years was chosen for the selection of studies. The studies cited here that are older than 10 years are either key studies or the only study found in a specific subject.

Appraisal

The generated keywords and defined filters helped to identify credible research from which the author could extract design strategies for the different categories of the lighting design process. This method provides more than one design strategy for each category of the lighting design process. In selecting and organizing the design strategies, specific attention was paid to ones that offered design guidelines that could be used by the audience of this study and were clear enough about the reason for the suggested guideline.

The next layer of consideration was how each study related to the goals of sustainability. Each study was examined for its contribution to ecological, social, and economic sustainability goals (as described in Chapter II). The rating in the final matrix was based on the framing and interpretation provided by the individual author of each study. The main reason was that this way of rating reduced errors and

misunderstandings. This rating helped to better identify guidelines that best addressed sustainability while giving an overview of the studies and clarifying the areas that need further study. For example, although the study on color of light by Park et al. (2007) can be considered as contributing to both economic and social aspects of sustainability, it was rated only as social in the matrix because the article was published in a social journal.

There is another layer of coding for rating the guidelines which is based on the author's evaluation of each guideline. The definitions and descriptions about each dimension of sustainability related to lighting design in previous chapter were used in this rating. This second layer of rating was shown with yellow in the matrix. This additional level of rating helps to better recognize the guidelines that address all aspects of sustainability without considering the initial purposes of the original studies.

Synthesis

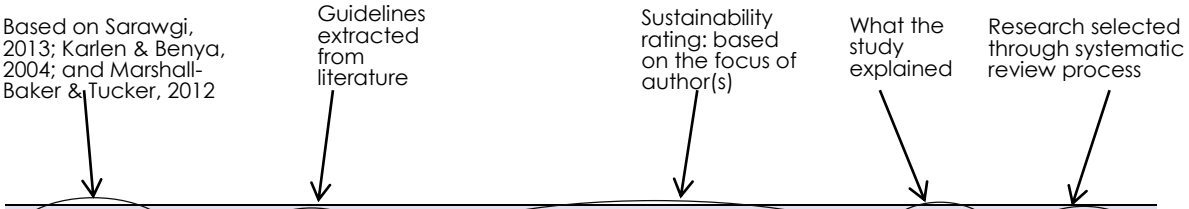
The next step in the systematic literature review process proposed by Cook & Murlow (Table 1) is a synthesis of research. As they described, there are two methods for synthesizing the results of a literature review: "When the results of primary studies are summarized but not statistically combined, the review may be called a qualitative systematic review. A quantitative systematic review, or meta-analysis, is a systematic review that uses statistical methods to combine the results of two or more studies" (Cook & Murlow, 1997). Based on this definition, this study will offer a qualitative

systematic review. The summary of the results is a matrix of evidence-based guidelines (Table 2).

Application and Inference

Design guidelines for each lighting design criteria produced by the matrix can be used by designers and owners. As described before, the sustainable rating of each lighting design guideline offers a map that shows how strategies connect to particular aspects of sustainability. Also, this rating helps to recognize optimized lighting design solutions; that is, the solutions that have been rated for all three dimensions of sustainability.

Table 2. Sample of Matrix of Evidence-based Guidelines



Lighting Design Categories	Guidelines	Sustainability: Ecological	Sustainability: Social	Sustainability: Economic	Context of Study	Evidence
a. Illuminance Levels and Contrast Ratios						
a.1	To increase the amount of time customers spend in the store and make them check more items at the store's displays, **increase the level of lighting** in the store displays. Use **accent lighting** to create contrasts between display units and the area surrounding them.				Retail, Work-place, Grocery store	Summers & Hebert, 2001; Bommel & Beld, 2004; Gifford, 1988; Ejhed et al., 2011
b. Lamp Types						
b.1	**LEDs** are one of the best lamp types, because they consume less energy, they have a long life, they have higher CRI, and they do not emit UV radiation.				Lighting studies	Karlen & Benya, 2004

Limitations

The progressive production of peer-reviewed lighting studies has reached a point of maturity where reviewing them in order to detect trends and potential research opportunities is possible. One limitation, however is developing the right keywords patient. Figure 2 demonstrates the plethora of keywords used in various combinations for the literature search. Despite attempts to form a comprehensive search strategy, the integration of numerous expansive themes challenges the ability to discover every piece

of relevant literature. Thus, it is likely that useful studies did not emerge in the search process and thus are not ultimately included in the matrix. Another, related limitation is that some lighting guidelines in the chapter to follow have limited evidence. The matrix (Appendix A) demonstrates the number of sources used to craft each guideline in the column labeled “evidence.”

The other issue is about rating the studies based on what their author(s) proposed about ecological, social, and/or economic sustainability. There are studies that cover some aspects of sustainability but the author(s) didn’t mention those in the study clearly or the intention was not sustainability. In this case the study was not coded for a sustainability theme, but since it still addressed some aspect of sustainability it was included in the matrix.

CHAPTER IV

GUIDELINES

This chapter presents and discusses the sustainable lighting design guidelines which were developed based on the lighting design process proposed in Chapter II. As described in the previous chapters, these guidelines are evidence-based design solutions for the sustainable lighting design of grocery stores. A systematic review of literature was used as the method for developing them (refer to Chapter III). The heading for each section in this chapter is based on lighting design criteria proposed as part of the sustainable lighting design process in Figure 1. The subheadings include: Illuminance Levels and Contrast Ratios, Lamp Types, Lighting Composition and Hierarchy, Lighting and Materials, Fenestration, Control, and System Maintenance.

In the appendix A, there is a user-friendly design matrix created to summarize these sustainable lighting design guidelines. Also, these guidelines were reorganized in Appendix B based on the areas in a grocery store. The guidelines are intended to be used by designers, grocers, retailers, or scholars. Providing a matrix similar to what is presented here helps designers, grocers, and retailers make better decisions and create an overall more sustainable lighting solution. Also, help scholars with their study of sustainable lighting.

Illuminance Levels and Contrast Ratios

Tasks in a grocery store are divided into two main categories of shopping and services; shopping is done by customers and services by the store's employees. In addition to these two main groups of tasks, there are other activities that take place in grocery stores that can be categorized separately: managing, eating, and communicating. Managing is done by employees of the store while eating and communicating can be done by anyone who uses the space (Grocery Stores, 2010).

In grocery stores, as in other environments, tasks can be classified based on the age and physical ability of users of the space. Taking into account the different tasks for different groups of people in a grocery store, this section describes the illuminance level for each task. Considering and addressing the needs of each group of user supports the design of socially-sustainable lighting in a grocery store.

Generally, studies show that in a retail environment an increased level of in-store lighting increases the amount of time customers spend in the store and viewing items in the store's displays (Summers & Hebert, 2001; Areni & Kim, 1994; Biner et al., 1989). Based on the findings of Summers & Hebert (2001), consumers pick and check out more items at the store displays under bright lighting rather than soft lighting[i]. In

[i] In the study by Areni & Kim (1994) "bright versus soft lighting was manipulated by altering the number and the wattage of the lamps". In the basic condition store had "twenty-two 50 watt bulbs lighted the merchandise and a single 75 watt bulb lighted the dining area of the wine cellar. In the soft lighting condition, the 75 watt bulb over the dining area was removed, leaving the twenty-two 50 watt

addition to the impact of bright light on purchasing decisions, lighting level has some effects on another task in the store: productivity. The study by Bommel & Beld (2004) shows the positive effect of bright light on office workers' productivity.

There are a few studies that address the suitable contrast ratio between the task level and environment. One of the examples of these studies is by Park & Farr (2007). In their study they found out that the CRI of the light source is a very important factor in readability of figure to background value contrast (CRI needs to be more than 80 to 90), especially of materials with low contrast (Park & Farr, 2007). Also, they checked the effect of aging in this study and it showed that elderly customers can see and read better in higher color temperature environment (in their study, the cool color temperature is 4100K), especially when value contrast was reduced. It needs to be considered that their study addresses retail environment in general, and it is not taking into account more specific lighting requirements of grocery stores. For instance, there are specific considerations for meat display feature lighting that are not pertinent to this study.

The study by Ejhed et al. (2011) shows that instead of increasing brightness in shops, and consequently energy consumption, it is better to design lighting with high-

bulbs to illuminate the wine cellar. In the bright lighting condition, the experimenter replaced the 75 watt bulb over the dining area, and in every third lamp over the merchandise, the 50 watt bulb was replaced by a 75 watt bulb. The intention was to create an observable difference in illumination in both the dining and merchandise areas of the wine cellar." (p.120)

contrast, which makes perception easier and heightens levels of attention. They suggest that “accent lighting that stands out positively from the surrounding homogeneous ambient lighting is a suitable way of creating contrasts” (Ejhed et al., 2011; p. 18). The study by Ejhed et al. (2011) provides a guideline that is in line with sustainable practices (the desired contrast ratios in different sections in a grocery store can be found in Table 3).

As mentioned earlier, aging is one of the critical factors that needs to be addressed in lighting. Aging can cause some limitations: reduced visual acuity, reduced contrast sensitivity, reduced color discrimination, increased time taken to adapt to large and sudden changes in luminance, and increased sensitivity to glare (Boyce, 2003). Considering these limitations, lighting should create a uniform illuminance distribution without strong shadows and also provide a gradual change in illuminance from one level to another (Boyce, 2003).

In a grocery store, there are four different areas based on different visual tasks (Karlen & Benya, 2004): first, the areas outside of the shelving/freezer section; second, shelves, checkout counters, the back of the house, and management offices; third, the specialty areas for baked goods, deli items, wine, and gourmet foods; and fourth, the entrance/exit vestibule, and the central areas. The illuminance level for each of these tasks can be seen in Table 3 as recommended by the IES Lighting Handbook’s 10th edition.

Table 3. Illuminance Levels by Application

Application		Notes	Horizontal Illuminance level (fc)			Vertical Illuminance level (fc)			Uniformity	
			Visual Years of Observers (years) Where at least half are			Visual Years of Observers (years) Where at least half are			1st Ratio E_h/2nd E_v if Different Uniformities apply	
			<25	25-65	>65	<25	25-65	>65	Max:Avg	Avg:Min
Circulation		E_h@floor, E_v@5' AFF	10	20	40	3.75	7.5	15	1.2:1	1.2:1
General Retail		E_h@ 2'6" AFF, E_v@3'-5' AFF	25	50	100	10	20	40	1.5:1/3:1	1.5:1/3:1
Feature Displays	Dazzle	Apply strategically to _<10% of display	10 times general E_h of adjacent retail area							
	Highlight	Apply strategically to _<25% of display	5 times general E_h of adjacent retail area							
	Total Display	Apply to entire display	Equal to general E_h of adjacent retail area							
Perimeter		E_v@5' AFF				25	50	100	2:1	2:1
Cashier		E_h@ 2'6" AFF, E_v@5' AFF	10	20	40	3.75	7.5	15	3:1	
Cafe		E_h@table plane; E_v@4' AFF	Avg = 3 times adjacent area E_h, but _< 100			Avg = 3 times adjacent area E_h, but _< 30				3:1
Office		E_h@ 2'6" AFF, E_v@4' AFF	15-25	30-40	60-80	3.75	3-7.5	15-6	2:1	1.5:1
Services, Storage		E_h and E_v@ 2'6" AFF	10	10	10	1.5	3	6	3:1	
Food preparation		E_h and E_v@ preparation table	50	50	50	10	20	40	2:1	
Toilet Rooms		E_h and E_v@ 2'6" AFF	20	20	20	5	10	20	3:1	

Summary of Guidelines for Illuminance Levels and Contrast Ratios

- To increase the amount of time customers spend in the store and encourage them to view more items at the store's displays, **increase the level of lighting** in the store displays. Use **accent lighting** to create contrasts between display units and the areas surrounding them. (Refer to Table 3 for in-detail illuminance levels and contrast ratios.)
- **Signs,** especially ones made up of materials with low contrast, should be lit up by light sources with high CRI (≥ 80), to help with readability.
- Specific guidelines for **elderly customers**:
    - Lighting should create a uniform **illuminance distribution** without strong shadows.
    - Provide a gradual change in illuminance from one level to another.
    - Provide higher **color temperature** environment so that elderly customers can see and read better in higher color temperature environment (~4000 k) especially when value contrast reduces.
- The details of vertical and horizontal illuminance levels and contrast ratios for different areas in a grocery store can be found in Table 3.

Lamp Type

Each lamp creates a different quality of light with different intensity, which consequently affects mood (Horská & Berčík, 2014). Selecting a suitable lamp type

should be based on the following factors: the effect of light on the quality and freshness of product, energy costs, maintenance costs, and color rendering index (Saenz, 2005; Benya et al., 2003). For each of the layers of light in grocery stores that were discussed in the last section, designers can use different types of lamps. The preference for lamp type was examined by Horská & Berčík (2014). The finding of their study shows that, subconsciously, fluorescent lamps are more desirable while halogens are more attractive. However, desirability or attractiveness should not be the only factors for decision making about lamp type; energy consumption needs to be considered as well.

In grocery stores, generally there is a shift from using T12 to T8 and more recently to T5 and very recently light emitting diodes (LEDs). To name a few of the benefits, LEDs consume less energy to produce the same amount of output, are dimmable, have the ability to turn on and off frequently, have high CRI, and they have a very long life (Godwin & Chijindu, 2012; Madireddi et al., 2010). One of LEDs disadvantages is their higher initial costs, but it needs to be considered that their operating costs are low due to lower energy consumption. The lamp type selections for different areas in grocery stores are moving towards LEDs because of the reasons mentioned here.

In selecting lamps for the grocery stores, temperature of the environment is a critical factor that needs to be considered. For instance, the performance of LEDs declines in higher temperatures, which is the opposite of fluorescent lamps, which declines in cold temperatures. The design suggestion based on this characteristic of

lamps is using LEDs for refrigerators and freezer displays instead of fluorescent lamps. Also, it is recommended to avoid using LEDs in bakeries or areas with need for high temperatures and use fluorescent lamps instead (Benya et al., 2014).

Other factors that need to be considered when selecting lamp types are the warm up time and the lamp's ability to be dimmed. For instance, metal halide is not a good choice for areas with control sensors since this type of lamp needs enough time to cool down after switching off (Benya et al., 2014). Also, while dimming can help reduce the consumption of energy for lighting, it needs to be considered that the color of light usually changes while the lamp is dimmed. Hence, while selecting lamps, consider dimmability of light and the changes in the color of light.

Lighting for meat and produce storage and display is critical in a grocery store. To display or store fresh produce and meats specific electrical light sources need to be used in order to keep them fresh and to look fresh for a longer period of time. Studies suggest that in display units the types of lamps used should either not emit UV radiation or, in case they radiate UV, the lamps or the luminaires should use UV filters. UV radiation is one of the characteristics of fluorescent lamps and if used, can be eliminated by using polycarbonate UV filters. These lamp selection considerations help to extend the meat life from 12 to 22 days (Djenane et al., 2001).

Another concept that is related to lamps is that lamp output decreases over time, which is called Lamp Lumen Depreciation (LLD). This factor differs based on the type of lamps and manufacturers. LLD is an important factor that needs to be

considered while selecting a lamp since it can affect maintenance (relamping) (DiLaura et al., 2011). For instance, currently LEDs don't have very good lifetime lumen maintenance compared to fluorescent lamps, which have a good to excellent lifetime lumen maintenance (DiLaura et al., 2011).

Summary of Guidelines for Lamp Types

- **LEDs** are one of the best lamp types, because they consume less energy, they have a long life, they have higher CRI, and they do not emit UV radiation.
- Don't use **metal halide** lamps for areas with control sensors, since they need enough time to cool down after switching off.
- Use LEDs for refrigerators and freezer displays instead of fluorescent lamps, and avoid using LEDs in bakery or other high temperature environments, since the performance of LEDs declines in **higher temperatures**, which is the opposite of fluorescent lamps, which declines in **cold temperatures**.
- In display units, use lamps that either do not emit **UV radiation** or, in case they radiate UV, use UV filters, in order to keep meat and produce fresh and to look fresh for a longer period of time.
- Lamp output decreases over time, this concept is called Lamp Lumen Depreciation (LLD). LLD is an important factor that needs to be considered while selecting a lamp since it can negatively affect maintenance (relamping), which increases cost and amount of waste.

Spectral Power Distribution, Color, and Mood

The color of light is a critical factor in the lighting design of a grocery store, since it affects consumer behavior and consequently the rate of sale. Light and color are interdependent; the color of space can be generated or emphasized by light sources. Also, since colors convey emotions and influence the acceptability of a space in a store interior, changing the color of light can create a different mood and atmosphere (Barlı et al., 2012). This section covers the effect of color in space in general, and color of light specifically. Also, different colors of light and the mood and atmosphere that they create are addressed.

Color and Retail

There are two separate concepts in studying the effect of color on customers: "approach orientation and physical attraction" (Bellizzi et al., 1983). It is important in retail design to attract customers and bring them into the store (approach orientation) and create a situation so they feel comfortable and spend more time in the store (physical attraction). Based on this, Bellizzi et al. (1983) showed in their study that in the lighting design of a grocery store, warm and bright colors can be used to attract customers but they are generally unpleasant in the long term. The same approach is true for a bright and colorful environment; customers find these spaces less pleasant than cool-color spaces (Bellizzi et al., 1983; Crowley, 1993; Bellizzi & Hite, 1992). Based on the result of these studies and the attraction concept, the suggestion is to use warm

color on the exterior and signage to attract customers, and cool color for the interior to create a pleasant environment. Also, a warm color palette is suitable for the sections inside the store where grocers want to encourage unplanned buying (Bellizzi et al., 1983). Another color for interior that has a positive effect on sales because it increases the time customers spend in the store is green which is the complimentary color to red (Barlı et al., 2012).

Color Temperature

A study by Zumtobel (Ejhed et al., 2011) showed that "cool color temperatures, such as cool-white, make areas appear more spacious whereas warm color temperatures create an impression of smallness and familiarity. White light with intermediate color temperature (neutral white which is not cool or warm) extends the amount of time customers spend in a shop and improves their sense of well-being, and it is suggested to be used for general lighting" (p. 18). Also this study suggests using light sources with various color temperatures within a single lighting concept so that they create a balance between warm color temperature and cool color temperature (Ejhed et al., 2011).

Color of Light and Age, Sex, Geographical Region, and Culture

In addition to studies that address the effect of color and color of light in an interior space, it needs to be considered that color preference could be based on the differences in age, sex, geographical region, culture, and life style. One of the studies

that addresses these factors is a study by Saito (1996). He found that white is the most favorable color in Japan, China, and Korea. Related to this concept, there is another study that indicates Anglo-Canadians perceive products to be higher quality in cool color temperature, whereas French-Canadians tend to rate products as higher quality in warm-color environments (Chebat & Morrin, 2007).

Guidelines by the New Buildings Institute (Benya et al. 2003) indicate that preference of color temperature has a relationship with latitude and thermal comfort. For the US they suggest using lighting sources with 4100 K in the south, 3500 K in the majority of the country, and warmer color temperature (3000K) in the north for commercial spaces.

Aging is another factor that affects the perception of the color of light. In their study, Park & Farr (2007) showed that older adults perceive higher color temperature light sources as less cool than younger adults. Also, older customers are more comfortable under light with cool color temperature. Therefore, cooler color light sources should be used for grocery stores where the demographic of customers is older. This study also indicates that light sources with higher CRI provide better readability (e.g., of store signage), and that the color temperature of light sources has some effect on the readability. The study by Park & Farr (2007) shows older adults have more difficulty reading the signs under warmer lighting sources when value contrast between sign and background decreases.

Color of Light and Mood

There are several studies that show that the color of light and the color of the interior environment in general have psychological and physiological effects (Knez, 2001; Knez, 1995; Küller et al., 2009; Quartier et al., 2014; McCloughan et al., 1999). For example, Küller et al. (2009) showed the psychological and physiological effects of color of space. Their results indicate that color has the potential to improve mood and the wellbeing of users of a space. In their study, they compared the effects of a gray room versus a colored room, and a blue versus a red room on the people who used the space. While the context of their study is general interior space, these findings are still applicable to grocery stores. This study shows that color of the space affects the perception of the room; also the color of the room affects the emotion of the person who stays in the room. For instance, "strong, especially red, colors and patterns put the brain into a more excited state, sometimes to such an extent as to cause a paradoxical slowing of the heart rate. Introvert persons, as well as those already in a negative mood, became more affected than others, which caused severe changes in their performance" (p. 141).

A study by Partonen & Jouko (2000) describes the positive effect of bright light on increasing mood in office spaces during winter. Also, the study by French et al. (1990) shows the same results and indicates that bright lights have positive effects on performance. The main application of these studies for sustainable lighting design of a grocery store is that it can help with branding and the mood that the designer wants to

create. Knowing about different effects of color and light on the mood can help with social sustainability, as well as economic sustainability. Having a good design can raise the mood and wellbeing of the users of the space, and therefore, in a retail environment like a grocery store, can increase the sales.

Summary of Guidelines for Spectral Power Distribution, Color, and Mood

- Light sources that are bluish (with cool-color temperature, such as cool-white) are suitable for **general lighting** of the store, since these cooler color temperatures make the space feel bigger and over time and is more comfortable for the eyes. Furthermore, older customers are more comfortable under light sources with cool color temperature.
- **Warm, colorful, and bright colors** can be used to attract customers but they are generally unpleasant over time. Hence they can be used on the exterior, vestibule, and the areas of the store that aim to encourage **unplanned shopping**.
- Reddish light (warm color temperatures) can be used in areas such as the café since it creates an impression of coziness and familiarity, which encourages **social interactions**.
- The **color of light** in the store can be soft green because it increases the time customers spend in the store, and therefore it has positive effect on sales (this finding is based on studies about color of interior).

- Use **intermediate white** light (neutral white which is neither bluish (cool) nor reddish (warm)) for **general lighting** because it extends the amount of time customers spend in a shop and improves their sense of well-being.
- Using light sources with **various color temperatures** within a single lighting concept so that they create a lighting design with better color distribution. This will help customers see **the colors of products** better.
- Consider using light sources that match the **color and mood** preferences of people living in different latitudes (for the US, 4100 K in the south states, 3000 K in the north, and 3500 K in the majority of the rest of the country).
- **Bright light** can improve increase employee mood in **office** spaces during winter.

Lighting Composition and Hierarchy

In general, luminaires can create different light textures with different photometric characteristics based on the shape of the luminaire and their location in the interior space: direct lighting, indirect lighting, direct-indirect lighting, and diffuse lighting. Each of these categories can provide ambient lighting, accent lighting, and decorative lighting, which can be used for different purposes in grocery stores (Benya et al., 2003).

Pendent direct and/or indirect downlight with glare control are suitable for general lighting. The recommended direction of linear pendant luminaires is perpendicular to the row of shelves, so that it doesn't create shadow and lighting layout

is independent of store layout. In grocery stores, signs and shelves at both ends of aisles can be emphasized by accent track lighting. The main lighting layer in the cashier section is downlight for the cashier counter. Rows of luminaires should be parallel to the cashier counters. In the produce section the ambient light can be mainly pendent uplight, in order to create diffuse light; the produce should be accented (Benya et al., 2014).

The study for Zumtobel (Ejhed et al., 2011) showed that "vertical illuminance makes orientation easier in a room. The easier it is for customers to find their way around, the more likely they are to walk around a shop. Efforts must therefore be made to use vertical lighting to delimit the periphery of a space" (p. 18). The main application of this study in grocery stores is the use of vertical surfaces such as end of aisles, to encourage movement in the store. This effect is based on the fact that human being is attracted to light (Russell, 2012).

Ambient lighting of specialty departments, such as the bakery, deli, florist, wine section, etc., can be created through pendent or recessed downlight. The critical point in the lighting of this section of the store is lighting task surfaces. Also decorative lighting by wall washing, accent lighting of signs, and decorative pendent luminaires is a good solution to draw attention to these sections of a grocery store. It is also critical for the café to have decorative lights with a lower level of ambient light which creates intimate space that may encourage intimate conversations (Benya et al., 2014).

Summary of Guidelines for Lighting Composition and Hierarchy

- Pendent direct and/or indirect downlight with glare control are suitable for **general lighting**.
- The recommended direction of linear **pendant luminaires** in the merchant area is perpendicular to the row of shelves, so that it doesn't create shadow and lighting layout is independent of store **shelving** layout.
- **Signs and shelves** at both ends of aisles can be emphasized by **accent** track lighting.
- Illuminance of vertical surfaces, such as accent walls, helps to make **orientation** easier in the space. The easier it is for customers to find their way around, the more likely they are to walk around the store. This effect is based on the fact that human being is attracted to light.
- The main lighting layer in the **cashier section** is downlight for the cashier counter. Rows of luminaires should be parallel to the cashier counters.
- In the **produce section** the ambient light can be mainly pendent uplighting, in order to create diffuse light; the produce should be accented.
- Ambient lighting of **specialty departments**, such as the bakery, deli, florist, wine section, etc., can be created through pendent or recessed downlight. The critical point in the lighting of this section of the store is lighting up task surfaces by direct downlight. Also decorative lighting by wall washing, accent lighting of

signs, and decorative pendent luminaires is a good solution to draw attention to these sections of a grocery store.

- It is desirable for the **café** to have decorative lights with a lower level of ambient light which creates intimate space which encourages intimate conversations.

Lighting and Materials

Material selection in the lighting design process for a grocery store can be divided into two main categories: lighting fixture material and material of reflecting surfaces in the space (Russell, 2012). Critical materials related to luminaires are diffusers, reflectors, refractors, and shielding materials. Their job is to collect the light from the light source and refract it into more useful zones, in order to control glare plus direct the light as in lensed fixtures. Shielding materials are suitable to control the direct glare from the light source (Benya et al., 2003). Selecting luminaires with desired and suitable materials is critical to get the best output from the light sources. Properly selected luminaires will help to meet design purposes and energy consumption goals. For instance, in order to have “uniform light distribution” it is recommended to use “high-reflectance matte finishes diffuse light” to avoid creating “harsh shadows” for elderly customers (Yeager & Halloin, 2007; p. 16). The reflectance value of the surfaces which receive and reflect light is also important. Based on the IESNA Lighting Handbook, the ceiling has to have 90% reflectance, walls 60%, and floors 20% in most sections of grocery stores (DiLaura et al., 2011). Having high reflectance materials helps to increase

daylight penetration and consequently reduce the need for electrical lighting, which in turn can help conserve energy.

One often neglected factor in the selection of light fixture assemblies is the consideration of where products will go at the end of their life. In selecting both luminaires and surfaces, Life Cycle Assessment (LCA) of the materials provides a framework for examining product sustainability. LCA is "a technique to assess the environmental aspects and potential impacts associated with a product, process, or service" (US EPA, 2006). Therefore, the LCA of materials related to grocery store lighting needs to be considered while selecting luminaires or other materials. For instance, some of the common materials in luminaires are steel, aluminum, glass, and plastic. Most of these materials are recyclable but for some of them such as steel and aluminum the main issue is with the manufacturing process which is highly energy intensive (Benya et al., 2014). Software tools do exist to help with LCA for building materials, but there is not one that specifically calculates LCA for lighting systems (DiLaura et al., 2011; p. 19.9).

While selecting the materials for luminaires and surfaces that receive light, because of maintenance issues, it is necessary to consider the location of the light fixture. In areas with higher amounts of dirt, the luminaires and surfaces will become covered with dirt and will not have their best output. These concepts are called Luminaire Dirt Depreciation (LDD), and Room Surface Dirt Depreciation (RSDD). LDD is from dirt accumulation on lamps, reflectors and lenses. RSDD considers the effect of dirt

on room surfaces since they become less reflective with time. Using luminaires and surfaces made out of materials that have some sort of resistance to dirt or having a consistent schedule for cleaning those surfaces and fixtures will help alleviate these factors. These concepts are maintenance issues and they need to be considered when calculating the quantity of light in grocery stores (Benya et al., 2014; DiLaura et al., 2011).

Summary of Guidelines for Materials

- In order to have **uniform light distribution** it is recommended to use high-reflectance matte finishes to diffuse light to avoid creating harsh shadows for **elderly customers**.
- In the selection of light fixture assemblies and interior materials, it is necessary to consider where these material/ products come from and where they will go at the end of their life. The factor that covers this concept is **Life Cycle Assessment** (LCA). **LCA** is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service.
- In all areas of grocery stores, the **reflectance of surfaces** is important for the comfort of the users of the space. The ceiling has to have 90% reflectance, walls 60%, and floors 20% in most of the sections in grocery stores. Having high reflectance materials helps to increase daylight penetration and consequently reduce the need for electrical lighting.

- Because of maintenance issues, it is necessary to consider the location of the light fixture for selection of materials. In areas with higher amounts of dirt, the luminaires and surfaces will become covered with dirt and will not have their best output. The concepts of Luminaire Dirt Depreciation (**LDD**) and Room Surface Dirt Depreciation (**RSDD**) address this issue. Using luminaires and surfaces made out of materials that have some sort of **resistance to dirt** or having a **consistent schedule for cleaning** those surfaces and fixtures will help alleviate these factors.

Fenestration

In order to integrate daylight into the lighting design of grocery stores, in-depth consideration of the following factors are needed: building orientation, building latitude, time of day, thermal comfort, energy consumption, and product freshness. As indicated by Lawrence et al. (2008) these are some of the challenges of integrating daylight into the design: “The cost of windows/skylights and lighting control systems; added design complexity to ensure siting and interior space facilitates daylighting; glare (large intensity variations) management; and implementation of effective lighting controls” (p. 92).

In the history of grocery store architecture, the very first stores had windows and window displays. With the replacement of these stores with big-box stores, daylight has often been deleted from the design of the retail environment (Mayo, 1993). Recently

there is a new tendency towards bringing daylight through skylights to these big-box retail stores.

Bringing daylight into the building helps to reduce the amount of electricity to be used and consequently the energy costs. But without considering the type of the glazing, and the location of the fenestration, integrating daylight can cause an increase in energy consumption (Heschong et al., 2002). When planning windows for grocery stores, location, orientation, height, glazing, and total amount of windows are critical to control heat gain and glare. Calculating the amount of fenestration areas and their location and other technical characteristics of fenestration needs to be done by referring to the information from the manufacturer as well as detailed simulation of the effects of light on the interior.

In grocery stores, daylight could be brought into the space through fenestration, such as windows, skylights, or reflectors. A study by Okura et al. (2000) demonstrated the positive effect of skylights on sales in retail environments. Their study shows that the existence of skylights has positive effects on increasing sales up to 40%. The potential reasons for this increase can be the fact that the stores look cleaner, the customers feel more relaxed, there is better visibility, the products look more attractive, and employees have better morale (Okura et al., 2000). The recommended areas in a grocery store for windows are offices and the store café, and skylights can be used throughout the store. But, skylights should not be located above the cashier sections so that sunlight doesn't interfere with the cashier system (Benya et al., 2003).

There are some rules of thumbs such as suggested the ratio of window (side lighting) area to floor area be approximately 15% to 20%, or the ratio of toplighting (skylights, monitors, and sawtooths) area to the floor area be 2% to 5%. But all of these need to be calculated based on the critical points related to daylight such as building orientation, building latitude, time of day, thermal comfort, energy consumption, and so on as mentioned earlier (Lawrence et al., 2008).

The main characteristic of daylight is the fact that it changes frequently throughout the day and in different seasons. The key approach is to consider all of these changes in design. For instance, for an area such as an office "the changes in lighting conditions can affect office worker's performances" (Benya et al., 2003; p. 2-19). Begemann et al. (1997) showed in their study that office workers prefer a lighting design that creates "a daylight cycle instead of a constant level" of lighting in office spaces (p. 231).

Summary of Guidelines for Fenestration

- In order to **integrate daylight** into the lighting design of grocery stores, in-depth consideration of the following factors are needed: building orientation, building latitude, time of day, thermal comfort, energy consumption, and product freshness.

- The recommended areas for **windows** are offices, the store café, and **skylights** can be used through out of the store. But, there shouldn't be skylights above the cashier sections so the sunlight doesn't interfere with the cashier system.
- To **control heat gain and glare**, pay attention to location, orientation, height, glazing, and total amount of windows and skylights. Calculating the **amount of fenestration areas** and other technical characteristics of fenestration needs to be done by referring to the information from the manufacturer as well as detailed simulation of the effects of light on the interior.
- Consider the additional importance of daylight since providing **changes in levels of light across a season and a day** impacts workers' performances positively. And a lighting that reflect these changes are more desirable for office workers.

Energy Cost

Energy-efficient lighting in grocery stores can be accomplished by considering these factors: lighting equipment, lighting installation design (task illuminance, installation maintenance, and illuminance distribution), electric lighting considering daylight, user occupancy, and lighting control (Loe, 2003; Loe, 2009). These factors have been so far addressed in this chapter, and in this section they will be reviewed again based on the suggestions by Leach et al. (2009). In this report, they showed that energy consumption can be reduced by up to 50% in grocery stores. Their suggested solutions include both lighting relevant and irrelevant solutions, but for the purpose of this study

only lighting relevant solutions are addressed. The study by Leach et al. (2009) is "the only study that provides an analysis on the whole-building energy consumption in the grocery store" (Mukhopadhyay & Haberl, 2014; p. 416). The result of a study by Mukhopadhyay & Haberl (2014) confirm part of these results. In this study, they reduced lighting power and equipment power density and implemented daylighting and occupancy sensors, and concluded that these changes can help to reduce the energy consumption the most when compared to other solutions. The following suggestions are adopted from[i] Leach et al. (2009):

- "**Reduce lighting power density** to 0.8 w/ft^2 and install **occupancy/vacancy sensors** in the active storage, mechanical room, restroom, and office zones"(Leach et al., 2011; p. 4).
- "Install **daylighting sensors** tuned to a 46.5 fc (500 lux) set point" (the authors set this baseline for their study based on feedbacks from retailers) (Leach et al., 2011; p. 4).

[i] The building that was selected for the Leach et al. (2009, 2011) study is a one-story, 45,000-ft^2 building with a 1.5 aspect ratio and 20-ft ceiling height. The façade contains 1,400 ft^2 of glazing, giving a 27% window-to-wall ratio on the south wall and 8% window-to-wall ratio overall. The grocery store contains 13 thermal zones, dominated by main sales (~55%), produce (17%), deli (5.4%), bakery (5%), and storage (10%). The remaining floor area is taken up by restrooms, meeting rooms, offices, and electrical/mechanical areas. Plug and process loads were taken from Deru et al. (2010), totaling 0.884 W/ft^2 and 0.384 W/ft2 for electrical and gas loads, respectively. Operating hours (6:00 a.m. to 10:00 p.m. 7 days/week) and occupancy were taken from ASHRAE 90.1-1989 (ASHRAE 1989).

- "Reduce south façade **window-to-wall ratio** from 50% to 13.5% on the south wall." (Leach et al., 2011; p. 4) This change can help to reduce gain heat in summer and therefore reduce energy consumption for air conditioning.
- "**Skylight** can be in any area in grocery stores except the perimeter sales area and the vestibule." (Leach et al., 2011; p. 4) In Leach et al.'s study, skylights were selected for grocery stores in warm and hot climates where there is ample sunlight for daylighting. Their study suggests to have 2% skylight to roof area for climate zone 1A, 2B, 3B-CA (California), and 4B; for climate zone 2A, 3A, 3B-NV (Nevada), and 3C, 3%; area zone 4C, 4%; and area zones 4A, 5A, 6A, 5B, 6B, 7, and 8 no skylights (retrieved from Leach et al., (2009) tables on p. 78 to 83). These findings about skylights are partially addressed in a study by Nemri & Krarti (2005). They showed in their study that a "skylight to floor ratio more than 0.3 does not affect significantly the lighting energy savings, and the optimum value of skylight to floor area ratio was found to be 0.2 to minimize the annual total building energy use" (p. 51).

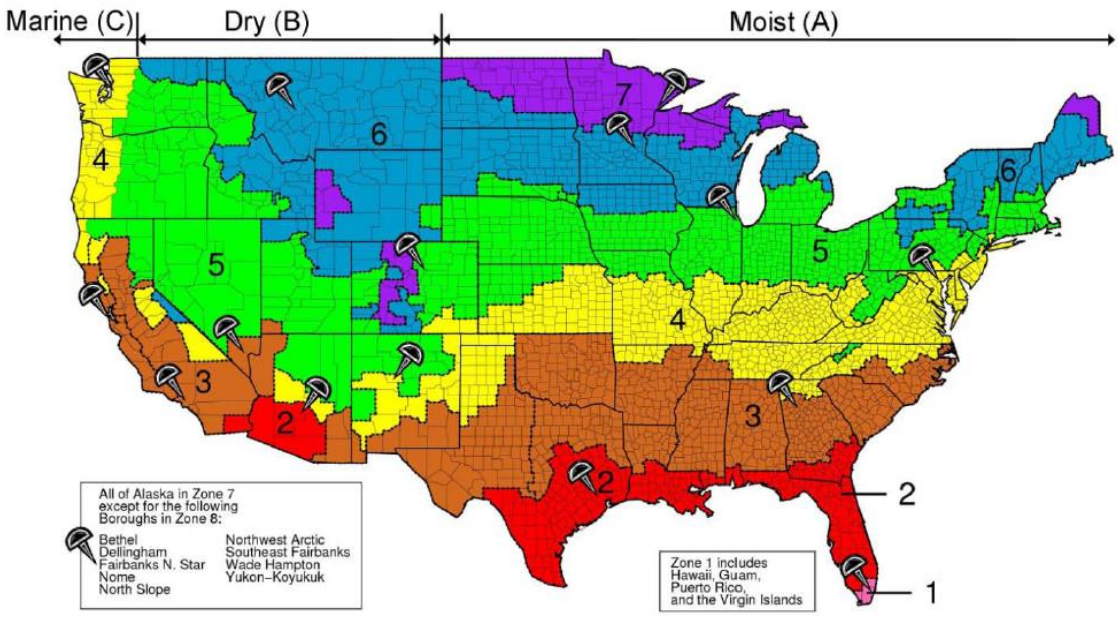


Figure 3. Climate Zones Defined in the Study by Leach et al. (2009)

Control

Lighting controls are the main tools to reduce the energy usage in interior spaces. In addition to this, they can help to increase the comfort level in interiors such as offices. Based on work by Benya et al. (2003), there are several types of control technologies: switches and dimmers, occupancy sensors, daylighting control, building level controls, and other control technologies. All of these types of technologies are applicable in grocery stores. The study by Williams et al. (2012) shows the importance of using multiple methods of control in order to increase the energy savings. The total energy savings can be nearly 40 percent (Williams et al., 2012). The use of controls in grocery stores depends on the hours of operation (this includes maintenance and

cleaning time). In general, having occupant sensors or daylight sensors helps to reduce the overall energy consumption.

The recommended control options for grocery stores are multi-level manual or timer-activated switching (different light levels can be used for different times of the day). This method suggests that lower level light be used during night or stocking and cleaning. Another method is daylight zone dimming (a method that dims the electric light based on the intensity of daylight). In this method, lower level light can be used because the eye can adapt itself to lower light at night. The optimal control system for grocery stores are the combination of multi-level manual or timer-activated switching with daylight zone dimming. In this case it can save over 50% in energy consumption (Benya et al., 2003, p.5-45).

Summary of Guidelines for Control

- The optimal **control system** is a combination of **multi-level manual or timer-activated switching** with **daylight zone dimming**. In this case it can save over 50% in energy consumption.
- A lower level light can be used during night or **stocking and cleaning** to save energy, since eyes can **adapt** to darker conditions.

System Maintenance

The maintenance of lighting systems needs to address both daylight and electrical lighting components and/or surfaces. For instance, a maintenance strategy

relating to daylight is cleaning and keeping any type of fenestration in the building dust free in order to fully benefit from the windows. It is the same for electrical lighting systems: it is necessary to keep the light-reflecting surfaces clean, it is important to clean light fixtures once a year, it is beneficial to replace light bulbs in groups according to their organized specifications, and it is recommended to check controls frequently (O'Connor et al., 1997). In addition to all of these, Lumen Lamp Depreciation (for more information about these concepts refer to section about Lamp Type and Material in this Chapter) is a an important factor that needs special consideration in the maintenance scheduling (Benya et al., 2003).

The other component of lighting systems is the control. Control systems need maintenance at least once a year. Photoelectric controls require cleaning of the photosensitive surface almost every six months. Well-designed control systems can also reduce lighting maintenance costs. For example, it reduces the frequency of relamping since one of the advantages of lighting controls is their effect on increasing the life of lamps. This also can help to reduce the labor costs for relamping (Benya et al., 2003).

Summary of Guidelines for System Maintenance

- The maintenance of lighting systems needs to address both **daylight and electrical** lighting components and/or surfaces.
- A maintenance strategy relating to daylight is **cleaning** and keeping any type of fenestration in the building **dust free** in order to fully benefit from the windows.

- **Electrical lighting systems** need maintenance strategies: it is necessary to keep the light-reflecting surfaces clean, it is important to clean light fixtures once a year, it is beneficial to replace light bulbs in groups according to their organized specifications, and it is recommended to check controls frequently.
- **Control systems** need maintenance at least once a year. **Photoelectric controls** require cleaning of the photosensitive surface almost every six months.

Conclusion

This chapter covered the empirical studies and lighting guidelines that together comprise a sustainable approach to the lighting design of grocery stores. The sections of this chapter provide a set of evidence-based guidelines that summarizes these studies. The explanation for each section in this chapter is an attempt to reveal the background of each guideline in detail. This summary of guidelines aims to make these guidelines more comprehensible for designers, retailers, and grocers. The complete list of guidelines with the sustainable coding map can be found in Appendix A.

CHAPTER V

CONCLUSION

Given the imperative for environmental sustainability and the importance of lighting for cost savings, energy savings, and psychological and social factors, it is clear that the approach to lighting design in grocery stores needs to be a sustainable one. It is evident that the main focus of retail is to encourage customers to buy more and consequently consume more. Here we can see a big paradox between what sustainability advocates and the retailers' goals. However, grocery stores are somewhat unique among retail establishments in that the products they offer are often vital to customers. Grocery store products are essential household purchases, and recent trends suggest that even big box grocery retailers are beginning to offer local and organic food options. Furthermore, grocery stores have the potential to encourage social interactions and community bonds among the tenants of an urban neighborhood. More than a mundane place for running errands, the grocery store is increasingly a "third place" that sits at the nexus of healthy lifestyles and community gathering.

Lighting is one of the main elements that shapes and defines interior spaces. The criteria of sustainability can be well defined related to lighting. Lighting consumes energy which connects it to the economic and environmental dimensions of sustainability. Also the existence of lighting has the potential to encourage social

interactions and individual well-being. In order to have a sustainable lighting design the process of lighting design needs to be adjusted to consider all the aspects of sustainability.

Relevance of Guidelines

Approaches to sustainable lighting are typically focused on environmental impacts. One of the examples of this is lighting handbooks. They are considered one of the main sources for lighting design by lighting designers (the handbook that has been published by IESNA is the most notable resource). They offer thorough and in-detail design guidelines about lighting. Usually the subject of sustainable lighting is summarized in a section/chapter, and mostly covers the environmental aspects of sustainability. The same approach can be seen by LEED. Most of the credits about lighting address environmental aspects of sustainability, such as energy savings to reduce carbon footprint.

Due to this gap in current lighting guidelines, there was a need to introduce an approach to sustainability and lighting that covers all three aspects of ecological, social, and economic. This study is an attempt to fill in this gap in the context of grocery store lighting. The result of this approach is a matrix of guidelines that addresses all three aspects for each guideline presented. By looking across the matrix, the gaps in knowledge in relation to sustainability can be ascertained for each of the critical subjects related to lighting design.

Limitations

A matter of particular concern to this study is the possibility of missing relevant literature. In spite of a systematic method for finding literature, still there might be studies that couldn't be found in the online sources that were accessible to the author. Similarly, there were some categories of sustainable lighting, such as the materiality of lighting assemblies (pp. 52), where empirical resources were scarce. In this case the lighting handbooks were used as a reference.

The main limitations of this study were the limited resources in some areas related to lighting design and also areas specifically related to sustainability. The lack of information about lighting design mostly pertains to the materials related to lighting: the material of luminaires and the material of reflecting surfaces, and the life cycle analyses of materials such as these. The limitations in sustainability resources can be found in the matrix of guidelines in Appendix A by reviewing the sustainability coding map. The other limitation that the author faced was the lack of an organized and well-developed sustainable lighting design process. In order to solve this issue, thorough work was done to review lighting design processes and sustainable design processes in other areas. These processes were then combined to create a process for sustainable lighting design that addresses all the issues related to lighting and sustainability (Figure 1).

Summary of Findings

Beyond outlining lighting guidelines for environmentally friendly grocery stores, a second key purpose for creating this matrix was revealing how each guideline relates to the goals of sustainability. Hence, each study was examined for its contribution to ecological, social, and economic sustainability goals. There are two levels of coding shown on the Appendix A matrix. The first level of coding was done according to the explicit intent of the author(s) who informed each guideline. This strategy was employed to reduce research bias and potential misunderstanding. That said, there are some guidelines that potentially address more domains of sustainability than indicated on the matrix due to this coding strategy. For example, the study about the light level in a café addresses the social and psychological effects of lighting for the users of the space. Therefore, this guideline is rated for social sustainability, but it also can be categorized as economic and environmental aspects. This guideline recommends lowering the level of lighting to help reduce the energy usage and consequently have a positive impact on the economy. In order to cover this issue, a second level of coding was used to rate the guidelines based on the researcher's assessment of each study across the three dimensions of sustainability. This second layer offers an overall more complete story of how each guideline contributes to the major goals of sustainability.

Based on the coding of sustainability themes in the matrix, there are twenty three guidelines that address all three aspects of sustainability (Appendix A). The other point that the matrix reveals is that the majority of studies address economic aspects of

sustainability (studies that show both economic and social or studies that show both economic and ecological). The possible reason for this is the financial incentive for pursuing environmentally and socially respectable practices is one of the key incentives for decision makers.

Table 4. The Summary of Findings from Matrix of Guidelines

Sustainability aspects	Number of Guidelines
All three aspects of ecological, social, and economic	23
Economic and social	18
Ecological and economic	2
Social	1
Economic	1
Ecological and social	0
Ecological	0

Analyzing the matrix to identify areas that need more investigation is one approach to these guidelines. Another way to apply this matrix is to use the guidelines in lighting design of a grocery store in order to have a sustainable lighting system that is environmentally, socially, and economically sustainable. But it needs to be noted that following these guidelines is not enough, since some of these guidelines conflict, and users' judgment is needed to choose the guidelines that best suit the project. In that way, these guidelines are not absolutes, but can be considered a toolkit or pattern book for piecing together sensible lighting solutions for unique applications and contexts. An example of application of these guidelines can be found in the studio IAR 602 design project (Appendix C).

Future Research

Categorizing sustainable lighting into three separate areas of environment, social, and economic helps to address sustainability holistically. The suggestion for future studies about lighting or other subjects related to sustainability in design is to follow this pattern and acknowledge the fact that sustainability has three aspects, and is not just about environment. This concept is the main reason for creating the matrix of guidelines and having a rating system for different aspects of sustainability. The rating system created a pattern that can be used to recognize the areas that need more attention and highlight the gaps in the body of knowledge. Using an approach similar to what was proposed in this study can be a solution to promote holistic approaches to sustainability. The findings in the matrix indicate the need to conduct empirical research about the lighting guidelines suggested by lighting handbooks. Empirical studies, with special attention to the three aspects of sustainability, help to adjust the lighting guidelines suggested by lighting handbooks to more sustainable ones.

The method that has been used for this study is a relatively new approach in lighting design. Although this method of systematic literature review is popular in healthcare, it can be used in other areas of knowledge. It is an appropriate method for the creation of evidence-based guidelines, such as those created here for sustainable lighting in grocery stores. The method further created the foundation from which the current author was able to identify which aspects of sustainability are and are not being addressed in the literature.

The next step for someone who wants to continue this specific study can be the use and evaluation of the developed guidelines by professionals of both lighting and grocery stores. A team including lighting designers, lighting manufacturers, grocery store designers, grocers, and other related professionals can evaluate the results of this study and suggest refinements to the Design Guideline Matrix (Appendix A).

The guidelines offered here are a first step towards the much larger project of creating regulations, measurement tools, and certifications to encourage the application of sustainable guidelines in the lighting design of grocery stores. The guidelines here can act as a supplement to the LEED Rating System, which encourages energy conservation but does not offer the specificity needed for making the many decisions related to lighting systems. As noted previously, the guidelines presented here also go beyond the offerings of LEED by making recommendations for social sustainability.

Although sustainability has been long considered in many aspects of interior architecture including lighting design, there is yet much to do for the sustainable approach to become the one and the only approach in design. As McDonough & Braungart (2002) mentioned in Cradle to Cradle that “being less bad is not good,” it should be noted that ecologically-sustainable approaches is not adequate per se. The future must be built on sustainable environment efforts that are holistic and simultaneously address all three aspects of sustainability in design.

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APPENDIX A

MATRIX OF GUIDELINES

Lighting Design Categories	Guidelines	Sustainability			Context of Study	Evidence
		Ecological	Social	Economic		
a. Illuminance Levels and Contrast Ratios						
	a.1 To increase the amount of time customers spend in the store and make them check more items at the store's displays, **increase the level of lighting** in the store displays. Use **accent lighting** to create contrasts between display units and the area surrounding them Refer to Table 3 for in-detail illuminance levels and contrast ratios).				Retail, Work-place, Grocery store	Summers & Hebert, 2001; Bommel & Beld, 2004; Gifford, 1988; Ejhed et al., 2011; Areni & Kim, 1994
	a.2 **Signs,** especially ones made up of materials with low contrast, should be lit up by light sources with high CRI (more than 80), to help with readability.				Retail	Park & Farr, 2007
	Specific guidelines for **elderly customers**: a.3 Lighting should create a uniform **illuminance distribution** without strong shadows. a.4 Provide a gradual change in illuminance from one level to another.				psychology, Retail	Boyce, 2003
	a.5 Provide higher **color temperature** environment so that elderly customers can see and read better in higher color temperature environment (~4000 k) especially when value contrast reduces.					

Lighting Design Categories	Guidelines	Sustainability			Context of Study	Evidence
		Ecological	Social	Economic		
	a.6 The details of vertical and horizontal illuminance levels and contrast ratios for different areas in a grocery store can be found in Table 3.					
b. Lamp Types						
	b.1 **LEDs** are one of the best lamp types, because they consume less energy, they have a long life, they have higher CRI, and they do not emit UV radiation.				Lighting studies	Karlen & Benya, 2004
	b.2 Don't use **metal halide** lamps for areas with control sensors, since they need enough time to cool down after switching off.				Lighting studies	Benya et al., 2014
	b.3 Lamp output decreases over time, this concept is called Lamp Lumen Depreciation (LLD). **LLD** is an important factor that needs to be considered while selecting a lamp since it can negatively affect maintenance (relamping), which increases cost and amount of waste.				Lighting studies	DiLaura et al., 2011
	b.4 Use LEDs for refrigerators and freezer displays instead of florescent lamps, and avoid using LEDs in bakery or other high temperature environments, since the performance of LEDs declines in **higher temperatures**, which is the opposite of fluorescent lamps, which declines in **cold temperatures**.				Grocery store	Benya et al., 2014
	b.5 In display units, use lamps that either do not emit **UV radiation** or, in case they radiate UV, use UV filters, in order to keep meat and produce fresh and to look fresh for a longer period of time.				Grocery store	Benya et al., 2014

Lighting Design Categories	Guidelines	Sustainability			Context of Study	Evidence
		Ecological	Social	Economic		
c. Spectral Power Distribution, Color, and Mood						
	c.1 Light sources that are bluish (with cool-color temperature, such as cool-white) are suitable for **general lighting** of the store, since these cooler color temperatures make the space feel bigger and over time and is more comfortable for the eyes. Furthermore, older customers are more comfortable under light sources with cool color temperature.				Retail, Lighting study, Psychology	Bellizzi et al., 1983; Crowley, 1993; Bellizzi & Hite, 1992
	c.2 **Warm, colorful, and bright colors** can be used to attract customers but they are generally unpleasant over time. Hence they can be used on the exterior, vestibule, and the areas of the store that aim to encourage **unplanned shopping**.				Retail	Bellizzi et al., 1983
	c.3 Reddish light (warm color temperatures) can be used in areas such as the café since it creates an impression of coziness and familiarity, which encourages **social interactions**.				Retail	Bellizzi et al., 1983
	c.4 The **color of light** in the store can be soft green because it increases the time customers spend in the store, and therefore it has positive effect on sales (this finding is based on the study about color of interior).				Retail	Barlı et al., 2012
	c.5 Use **intermediate white** light (neutral white which is neither bluish (cool) nor reddish (warm)) for **general lighting** because it extends the amount of time customers spend in a shop and improves their sense of well-being.				Retail	Ejhed et al., 2011

Lighting Design Categories		Guidelines	Sustainability			Context of Study	Evidence
			Ecological	Social	Economic		
	c.6	Using light sources with **various color temperatures** within a single lighting concept so that they create a lighting design with better **color distribution**. This will help customers see the colors of products better.				Retail	Ejhed et al., 2011
	c.7	Consider using light sources that match the **color and mood** preferences of people living in different latitudes (for the US, 4100 K in the south states, 3000 K in the north, and 3500 K in the majority of the rest of the country).				Lighting study	Benya et al., 2003
	c.8	**Bright light** can increase mood in **office** spaces during winter.				Work-place, Healthcare	Partonen & Jouko, 2000; French et al., 1990
d. Lighting Composition and Hierarchy							
	d.1	Pendent direct and/or indirect downlight with glare control are suitable for **general lighting**.				Grocery stores	Benya et al., 2014
	d.2	The recommended direction of linear **pendant luminaires** in the merchant area is perpendicular to the row of shelves, so that it doesn't create shadow and lighting layout is independent of store **shelving** layout.				Grocery store	Benya et al., 2014
	d.3	**Signs and shelves** at both ends of aisles can be emphasized by **accent** track lighting.				Grocery store	Benya et al., 2014
	d.4	Illuminance of vertical surfaces, such as accent walls, helps to make **orientation** easier in the space. The easier it is for customers to find their way around, the more likely they are to walk around the store. This effect is based on the fact that human being is attracted to light.				Retail	Ejhed et al., 2011; Russell, 2012

Lighting Design Categories		Guidelines	Sustainability			Context of Study	Evidence
			Ecological	Social	Economic		
	d.5	The main lighting layer in the **cashier section** is downlight for the cashier counter. Rows of luminaires should be parallel to the cashier counters.				Grocery store	Benya et al., 2014
	d.6	In the **produce section** the ambient light can be mainly pendent uplighting, in order to create diffuse light; the produce should be accented.				Grocery store	Benya et al., 2014
	d.7	Ambient lighting of **specialty departments**, such as the bakery, deli, florist, wine section, etc., can be created through pendent or recessed downlight. The critical point in the lighting of this section of the store is lighting up task surfaces by direct downlight. Also decorative lighting by wall washing, accent lighting of signs, and decorative pendent luminaires is a good solution to draw attention to these sections of a grocery store.				Grocery store	Benya et al., 2014
	d.8	It is desirable for the **café** to have decorative lights with a lower level of ambient light which creates intimate space which encourages intimate conversations.				Hospitality	Benya et al., 2014
e. Lighting and Materials							
	e.1	In order to **uniform light distribution** it is recommended to use high-reflectance matte finishes to diffuse light to avoid creating harsh shadows for **elderly customers**.				Gerontology	Yeager & Halloin, 2007

Lighting Design Categories	Guidelines	Sustainability			Context of Study	Evidence
		Ecological	Social	Economic		
	e.2 In all areas of grocery stores, the **reflectance of surfaces** is important for the comfort of the users of the space. The ceiling has to have 90% reflectance, walls 60%, and floors 20% in most of the sections in grocery stores. Having **high reflectance materials** helps to increase daylight penetration and consequently reduce the need for electrical lighting.				Lighting studies	DiLaura et al., 2011
	e.3 In the selection of light fixture assemblies and interior materials, it is necessary to consider where these material/ products come from and where they will go at the end of their life. The factor that covers this concept is **Life Cycle Assessment (LCA).** LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service.				Lighting studies	Benya et al., 2014; US EPA, 2006
	e.4 Because of maintenance issues, it is necessary to consider the location of the light fixture for selection of materials. In areas with higher amounts of dirt, the luminaires and surfaces will become covered with dirt and will not have their best output. The concepts of **Luminaire Dirt Depreciation (LDD)** and **Room Surface Dirt Depreciation (RSDD)** address this issue. Using luminaires and surfaces made out of materials that have some sort of resistance to dirt or having a consistent schedule for cleaning those surfaces and fixtures will help alleviate these factors.				Lighting studies	Benya et al., 2014; Dilaura et al., 2011

Lighting Design Categories		Guidelines	Sustainability			Context of Study	Evidence
			Ecological	Social	Economic		
f. Fenestration							
	f.1	The recommended areas for **windows** are offices, the store café, and **skylight** can be used through out of the store. But, there shouldn't be skylights above the cashier sections so the sunlight doesn't interfere with the cashier system.				Grocery store	Benya et al., 2003; Okura et al., 2000
	f.2	To **control heat gain and glare**, pay attention to location, orientation, height, glazing, and total amount of windows and skylights. Calculating the **amount of fenestration areas** and other technical characteristics of fenestration needs to be done by referring to the information from the manufacturer as well as detailed simulation of the effects of light on the interior.				Retail	Heschong et al., 2002
	f.3	Consider the additional importance of daylight since providing **changes in levels of light across a season and a day** impacts workers' performances positively. And a lighting that reflect these changes are more desirable for office workers.				Work-place	Benya et al., 2003; Begemann et al., 1997
	f.4	In order to integrate daylight into the lighting design of grocery stores, in-depth consideration of the following factors are needed: building orientation, building latitude, time of day, thermal comfort, energy consumption, and product freshness.				Energy study	Lawrence et al., 2008
g. Energy Cost							
	g.1	"**Reduce lighting power density** to 0.8 w/ft^2 and install **occupancy/vacancy sensors** in the active storage, mechanical room, restroom, and office zones."				Grocery store	Leach et al., 2011

Lighting Design Categories		Guidelines	Sustainability			Context of Study	Evidence
			Ecological	Social	Economic		
	g.2	"Install **daylighting sensors** tuned to a 46.5 fc (500 lux) set point" (the authors set this baseline for their study based on feedbacks from retailers).				Grocery store	Leach et al., 2011; Deru et al., 2010
	g.3	"Reduce south façade **window-to-wall ratio** form 50% to 13.5% on the south wall." This change can help to reduce gain heat in summer and therefore reduce energy consumption for air conditioning.				Grocery store	Leach et al., 2011
	g.4	"**Skylight** can be in any area in grocery stores except the perimeter sales area and the vestibule." The suggestion is to have 2%-4% skylight to roof area in different climate zones.				Grocery store	Leach et al., 2011
h. Control							
	h.1	The optimal **control system** is a combination of **multi-level manual or timer-activated switching** with **daylight zone dimming**. In this case it can save over 50% in energy consumption.				Grocery store	Benya et al., 2003
	h.2	A lower level light can be used during night or **stocking and cleaning** to save energy, since eyes can **adapt** to dark.				Retail	Williams et al., 2012
i. System Maintenance							
	i.1	The maintenance of lighting systems needs to address both **daylight and electrical** lighting components and/or surfaces.				Retail	O'Connor et al., 1997
	i.2	A maintenance strategy relating to daylight is **cleaning** and keeping any type of fenestration in the building **dust free** in order to fully benefit from the windows.				Grocery store	Benya et al., 2003

Lighting Design Categories		Guidelines	Sustainability			Context of Study	Evidence
			Ecological	Social	Economic		
	i.3	**Electrical lighting systems** need maintenance strategies: it is necessary to keep the light-reflecting surfaces clean, it is important to clean light fixtures once a year, it is beneficial to replace light bulbs in groups according to their organized specifications, and it is recommended to check controls frequently.				Retail	O'Connor et al., 1997
	i.4	**Control systems** need maintenance at least once a year. **Photoelectric controls** require cleaning of the photosensitive surface almost every six months.				Retail	O'Connor et al., 1997

Matrix Legend

Sustainability coding based on the researcher's assessment of effects of each guideline

Sustainability coding based on the stated contribution to sustainability by the cited author(s) of each study

Explanatory Photos of the Guidelines


a.1


a.2
BULK
save


a.3
TRAIL MIX


a.4
ON YOUR


a.5


c.1

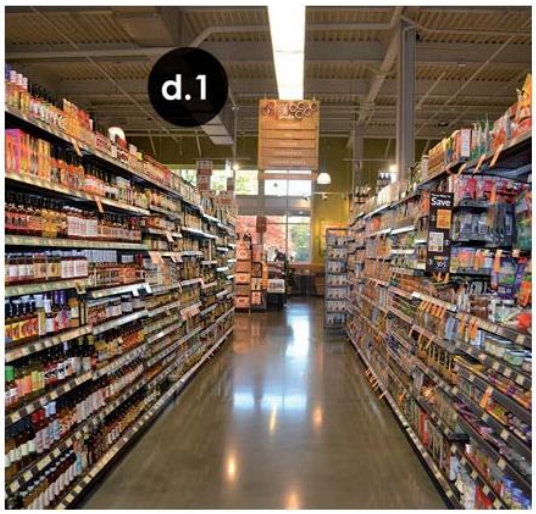

c.2
HEARTH BREADS
Baked Fresh Daily

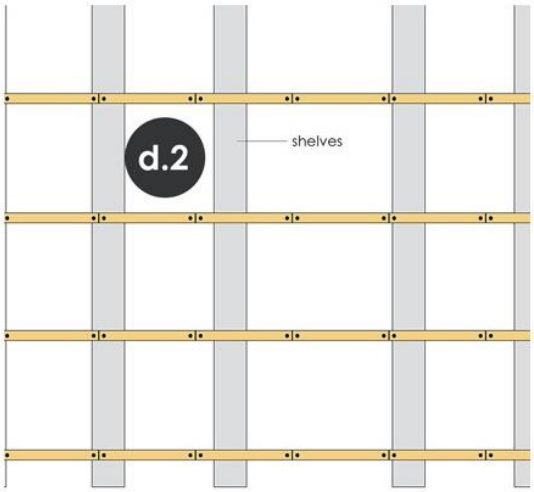

c.3


c.4
Ask our TEAM MEMBERS
FOR THEIR TOP
PRODUCE PICKS


c.5
EXIT


c.6


d.1


d.2
shelves


d.3
5/$5


d.3
the TABLE


d.4


d.5
f.1
Hot
Cold


d.6
LOCAL

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APPENDIX B

GUIDELINES BY LOCATION

The findings of the systematic literature review conducted for this study helped to define the guidelines for lighting design in a grocery store. Considering different areas in a grocery store (Main Sales, Perimeter Sales, Produce, Deli, Bakery, Enclosed Office, Meeting Room, Dining Room, Restroom, Mechanical Room, Corridor, Vestibule, and Active Storage [retrieved from Leach et al., (2009)]), the guidelines generated by this study cover sustainable lighting suggestions for four areas: sales, café, specialty department, and office. Where the guidelines outlined in Chapter IV were organized by lighting issues, it is useful to now examine the findings by area within the store. The evidence base for the following guidelines can be located in the Design Guideline Matrix (Appendix A).

Sales

The following guidelines pertain to lighting required for store merchandise.

- To increase the amount of time customers spend in the store and make them check more items at the store's displays, **increase the level of lighting** in the store displays. Use **accent lighting** to create contrasts between display units and the area surrounding them (Refer to Table 3 for in-detail illuminance levels and contrast ratios).

- **Signs,** especially ones made up of materials with low contrast, should be lit up by light sources with high CRI (more than 80), to help with readability.
- Specific guidelines for **elderly customers**:
    - Lighting should create a uniform **illuminance distribution** without strong shadows.
    - Provide a gradual change in illuminance from one level to another.
    - Provide higher **color temperature** environment so that elderly customers can see and read better in higher color temperature environment (~4000 k) especially when value contrast reduces.
- The details of vertical and horizontal illuminance levels and contrast ratios for different areas in a grocery store can be found in Table 3.
- **LEDs** are one of the best lamp types, because they consume less energy, they have a long life, they have higher CRI, and they do not emit UV radiation.
- Don't use **metal halide** lamps for areas with control sensors, since they need enough time to cool down after switching off.
- Use LEDs for refrigerators and freezer displays instead of fluorescent lamps, and avoid using LEDs in bakery or other high temperature environments, since the performance of LEDs declines in **higher temperatures**, which is the opposite of fluorescent lamps, which declines in **cold temperatures**.

- In display units, use lamps that either do not emit **UV radiation** or, in case they radiate UV, use UV filters, in order to keep meat and produce fresh and to look fresh for a longer period of time.
- Lamp output decreases over time, this concept is called **Lamp Lumen Depreciation (LLD).** LLD is an important factor that needs to be considered while selecting a lamp since it can affect negatively maintenance (relamping), which increases cost and amount of waste.
- Light sources that are bluish (with cool-color temperature, such as cool-white) are suitable for **general lighting** of the store, since these cooler color temperatures make the space feel bigger and over time and is more comfortable for the eyes. Furthermore, older customers are more comfortable under light sources with cool color temperature.
- **Warm, colorful, and bright colors** can be used to attract customers but they are generally unpleasant over time. Hence they can be used on the exterior, vestibule, and the areas of the store that aim to encourage **unplanned shopping**.
- The **color of light** in the store can be soft green because it increases the time customers spend in the store, and therefore it has positive effect on sales (this finding is based on the study about color of interior).

- Use **intermediate white** light (neutral white which is neither bluish (cool) nor reddish (warm)) for **general lighting** because it extends the amount of time customers spend in a shop and improves their sense of well-being.
- Using light sources with **various color temperatures** within a single lighting concept so that they create a lighting design with better color distribution. This will help customers see **the colors of products** better.
- Consider using light sources that match the **color and mood** preferences of people living in different latitudes (for the US, 4100 K in the south states, 3000 K in the north, and 3500 K in the majority of the rest of the country).
- Pendent direct and/or indirect downlight with glare control are suitable for **general lighting**.
- The recommended direction of linear pendant luminaires in the merchant area is perpendicular to the row of shelves, so that it doesn't create shadow and lighting layout is independent of store shelving layout.
- **Signs and shelves** at both ends of aisles can be emphasized by **accent** track lighting.
- Illuminance of vertical surfaces, such as accent walls, helps to make **orientation** easier in the space. The easier it is for customers to find their way around, the more likely they are to walk around the store. This effect is based on the fact that human being is attracted to light.

- The main lighting layer in the **cashier section** is downlight for the cashier counter. Rows of luminaires should be parallel to the cashier counters.
- In the **produce section** the ambient light can be mainly pendent uplighting, in order to create diffuse light; the produce should be accented by track-lights.
- In order to have **uniform light distribution** it is recommended to use high-reflectance matte finishes to diffuse light to avoid creating harsh shadows for **elderly customers**.
- In the selection of light fixture assemblies and interior materials, it is necessary to consider where these material/ products come from and where they will go at the end of their life. The factor that covers this concept is **Life Cycle Assessment** (LCA). **LCA** is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service.
- In all areas of grocery stores, the **reflectance of surfaces** is important for the comfort of the users of the space. The ceiling has to have 90% reflectance, walls 60%, and floors 20% in most of the sections in grocery stores. Having high reflectance materials helps to increase daylight penetration and consequently reduce the need for electrical lighting.
- Because of maintenance issues, it is necessary to consider the location of the light fixture for selection of materials. In areas with higher amounts of dirt, the luminaires and surfaces will become covered with dirt and will not have their best output. The concepts of Luminaire Dirt Depreciation (**LDD**) and

Room Surface Dirt Depreciation (**RSDD**) address this issue. Using luminaires and surfaces made out of materials that have some sort of **resistance to dirt** or having a **consistent schedule for cleaning** those surfaces and fixtures will help alleviate these factors.

- In order to **integrate daylight** into the lighting design of grocery stores, in-depth consideration of the following factors are needed: building orientation, building latitude, time of day, thermal comfort, energy consumption, and product freshness.
- To **control heat gain and glare**, pay attention to location, orientation, height, glazing, and total amount of windows and skylights. Calculating the **amount of fenestration areas** and other technical characteristics of fenestration needs to be done by referring to the information from the manufacturer as well as detailed simulation of the effects of light on the interior.
- "Install **daylighting sensors** tuned to a 46.5 fc (500 lux) set point" (the authors set this baseline for their study based on feedbacks from retailers) (Leach et al., 2011; p. 4).
- "Reduce south façade **window-to-wall ratio** form 50% to 13.5% on the south wall." (Leach et al., 2011; p. 4)
- "**Skylight** can be in any area in grocery stores except the perimeter sales area and the vestibule." (Leach et al., 2011; p. 4)

- The optimal **control system** is a combination of **multi-level manual or timer-activated switching** with **daylight zone dimming**. In this case it can save over 50% in energy consumption.
- A lower level light can be used during night or **stocking and cleaning** to save energy, since eyes can **adapt** to dark.
- The maintenance of lighting systems needs to address both **daylight and electrical** lighting components and/or surfaces.
- A maintenance strategy relating to daylight is **cleaning** and keeping any type of fenestration in the building **dust free** in order to fully benefit from the windows.
- **Electrical lighting systems** need maintenance strategies: it is necessary to keep the light-reflecting surfaces clean, it is important to clean light fixtures once a year, it is beneficial to replace light bulbs in groups according to their organized specifications, and it is recommended to check controls frequently.
- **Control systems** need maintenance at least once a year. **Photoelectric controls** require cleaning of the photosensitive surface almost every six months.

Café

The following guidelines address lighting issues for in-store cafes.

- Use lower lighting levels to encourage more **intimate communication** in the café.
- Reddish light (warm color temperatures) can be used in areas such as the café since it creates an impression of coziness and familiarity, which encourages **social interactions**.
- It is desirable for the **café** to have decorative lights with a lower level of ambient light which creates intimate space which encourages intimate conversations.

Specialty Departments

The following guidelines address lighting issues for specialty departments such as bakery, florist, wine section, etc.

- Ambient lighting of **specialty departments**, such as the bakery, deli, florist, wine section, etc., can be created through pendent or recessed downlight. The critical point in the lighting of this section of the store is lighting up task surfaces by direct downlight. Also decorative lighting by wall washing, accent lighting of signs, and decorative pendent luminaires is a good solution to draw attention to these sections of a grocery store.

Offices

The following guidelines address lighting issues for office spaces in a grocery store.

- **Bright light** can increase mood in **office** spaces during winter.
- Consider the additional importance of daylight since providing **changes in levels of light across a season and a day** impacts workers' performances positively. And a lighting that reflect these changes are more desirable for office workers.
- "**Reduce lighting power density** to 0.8 w/ft^2 and install **occupancy/vacancy sensors** in the active storage, mechanical room, restroom, and office zones."(Leach et al., 2011; p. 4)
- The recommended areas for **windows** are offices, the store café, and **skylight** can be used through out of the store. But, there shouldn't be skylights above the cashier sections so the sunlight doesn't interfere with the cashier system.

APPENDIX C

DESIGN PROJECTS

Studio IAR 502

- Introduction
- Concept
- Programming
- Schematic Design
- Design Development I
- Design Development II
- Design Proposal
- References

Studio IAR 602

- Introduction
- Programming
- Lighting Analysis
- Concept
- Design Proposal
- References

Studio IAR 502

Introduction

Design opportunity. This project was for a 2013 international competition held by the Retail Design Institute, which required the design of an American Fare restaurant. The objective was to design a new U.S. prototype for an existing building in Columbus, Ohio. The store was a freestanding 600 m^2 (6500 ft^2) building on one level.

Project goal. I was asked to consider the following criteria in my design: demonstrate an understanding of the retail practices of a restaurant and use that understanding to design a new prototype building and a brand development concept that meet the company's retail expectations and use innovative thinking when designing the building interior, planning, seating layout, lighting, millwork, and interior signage/graphics.

Users. American fare restaurants are casual dining facilities that serve the middle class and upper middle-class public. American fare restaurants are considered fast casual dining restaurants. Fast casual dining became mainstream by the beginning of the 2010s. Most fast casual diners are 18 to 34 years old. These customers usually have limited discretionary meal spending and tend to use it on dining perceived as healthier. This demographic is close to the median age (39.3) of the Columbus Ohio population (City Data, 2013; Jargon, 2010; Retail Design Institute, 2013).

Concept

Hearth, an eco-eatery. In recent years, the phrase "You are what you eat" has been used to address the emerging trend of eating local and organic foods. The appearance of casual dining restaurants with a focus on serving local foods seems to be in response to this societal tendency to lead a healthier life.

In today's fast-paced society, people have less time to spend on cooking at home. In addition, people go to restaurants when they are travelling or gathering for social occasions. In brief, today's lifestyle encourages people to dine in places other than the home and hence, people are spending increasing portions of their lifetime in restaurants. Accordingly, restaurants are inadvertently being required to assume more responsibility than just providing food by being warm and inviting.

The place that conveys this feeling is one's home. A restaurant may be a public version of one's home, a place that inspires familiarity, security, and a sense of reassurance. The restaurant as an extended version of home fits the definition of casual dining; that is, somewhere in the vast gap between fast food and fine dining. The menu of a casual dining restaurant is more varied and often of a higher quality than fast food diners. Furthermore, the atmosphere is laid-back and more relaxed than a fine restaurant.

Borrowing the concept of "home", the proposed design does not simply embed the physical elements of home (such as fireplace, dining rooms, etc.) but more

importantly reflects the spirit of home and the essence of home which include familiarity, intimacy, and security.

Lighting. Daylight has an important role in this home-like restaurant; it characterizes the layout of the restaurant. The openings on the four sides of the building give patrons a chance to experience different quality of light during day. The suspended ceiling reflects daylight, leading a generous amount of daylight into the space, hence expanding the visual space. Changing lighting quality is achieved through flexible and mobile lighting systems that respond to lighting needs for individual spaces during lunch and dinner.

Family. Based on the demography of customers that involves patrons in the age range of 18 to 40 years old, families with children should also be contained in the design. The proposed restaurant has a dining area to let such patrons come together and order food on platters (family style). Family-style dining is a style of serving shared food on platters, similar to home environment. The advantages of this style include increased choices, improved socialization, and improved quality of life. Therefore, this service is in line with the concept of the proposed home restaurant.

Locality. A sustainable restaurant and design will not be achieved just through a local, sustainable menu. Similar to the menu, furniture and light fixtures are designed by local artists, and sustainable or down-cycled materials are used to produce them locally. As a result, this design approach also supports local businesses. In addition, use of local

materials in design creates familiarity and makes patrons feel more connected to the space.

Another concept to support locality is the opportunity for local bands to perform in the restaurant outdoor area. Local bands performing in the restaurant not only entertain patrons but also accentuates the sense of locality and hence, the sense of belonging to restaurant. It also supports local performing-art businesses.

The sense of belonging to the space is also created when patrons see an object that relates to them. In the proposed design, children have a chance to draw paintings and hang them in the waiting area. Not only are patrons entertained but pleasant memories are created for the family for its subsequent visits. Belongings that create sense of familiarity are important characteristics of home, making patrons feel that the restaurant is an extension of their home.

Sustainability (energy saving). According to the Green Restaurant Association bulletin, restaurants evaluate in 7 categories of energy, food, water, waste, disposables, chemical and pollution reduction, and furnishing and building materials, in order to be recognized as sustainable and green restaurants. Not only does the proposed restaurant address sustainability in its design but also it respects sustainability in its operations; used cooking oil is collected and delivered to recycling companies that convert it to renewable fuel, herbs and vegetables harvested from the local urban fields are consumed, solar panels for heating is used if possible, and rainwater is collected for watering plants,...

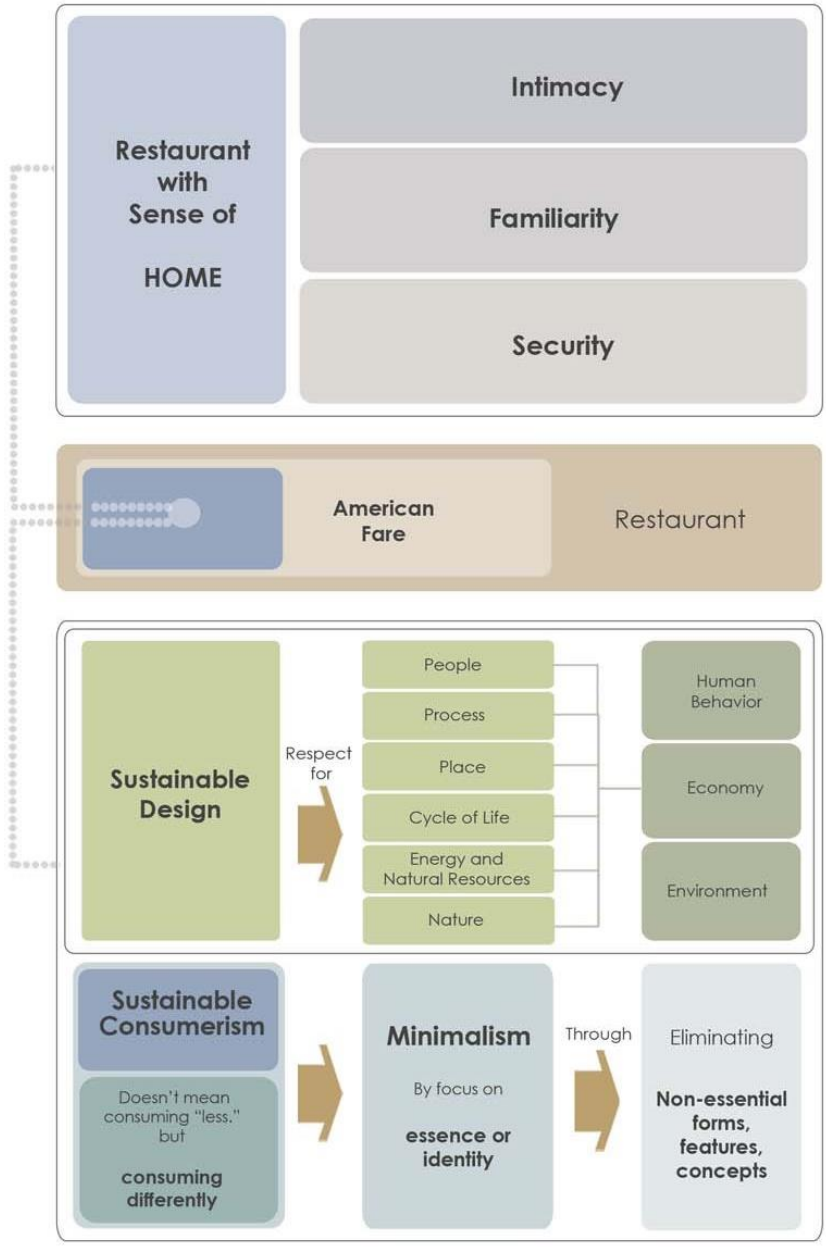


Figure 4. Theoretical Frameworks

Programming

Space allocation. *Entrance*. The green walls at the entrance invites patrons to a space with a sense of home. The entrance acts as a threshold where patrons are

welcomed by a host who guides them to couches for sitting and relaxing while waiting or to their tables. In this area there is a board on which community members can post announcements and advertisements of local products. Also, a wall made of picture frames separates the entrance from the rest of the restaurant. The pictures in these frames are paintings drawn by younger patrons. Painting helps the children to enjoy their time while in the restaurant and also creates a sense of familiarity and belonging for the families.

***Community Table/Bar/Bar Lounge*.** The restaurant environment focuses on the central area which is a casual gathering area where one can hang out while having food individually or with other patrons from the community. This area enjoys a view of the preparation area of the kitchen, similar to today's homes with open kitchens. The community table and the wall between the bar and the kitchen is made from reclaimed wood which can be purchased from local stores.

Dining Area. The dining area is a place to relax, to come together for a quick drink or snack, or to linger over a hearty meal. The layout of the whole restaurant is based on the idea of "space within space." The aim is to create varied experiences ranging from private to public.

Blurring Boundaries. Translucent uplit glass panels physically define the boundaries between these spaces, while maintaining a visual connection. The glass walls

combined with the neutral yet bright color palette of the space imparts a simple and elegant feeling to the whole restaurant.

Sunken Dining Area. Another element in the dining area is the sunken area with a fireplace. The sunken dining area is an intimate space which is visually connected to the rest of the restaurant.

Day-Room. The day-room in the restaurant provides a unique experience to the patrons with its changing light quality throughout the day. At night the glowing windows in the day-room invite passers-by into the restaurant. The special seating furniture in this area, the hanging chairs and window couches, help to turn it into an enclosed porch acting as a transition area between inside and the open porch.

Table 5. Space Allocation

	Entrance	Dining Area	Community Table Bar/Bar Lounge	Day Room	Kitchen	Pick up Area	Sunken Dining
Activity Requirements	Greeting Waiting	Lounging Dining	Entertaining Lounging Dining	Lounging Dining	Food Service Food Preparation	Greeting Waiting Sitting	Entertaining Dining Lounging
Furniture Requirements	Counter Sofa Bench	Dining Chair Table Booth Outside furniture Serving Table	Stool Community Table Cocktail Table Bar Table Chair Sofa	Table By Window Chair Hanging Chair Book Shelves Serving Table	Equipment Storage Cabinet Refrigerator Freezer Dishwasher	Counter Refrigerator	Bench Chair Table Serving Table
Specified Users	Host Patrons	Wait Staff Patrons	Wait Staff Patrons	Wait Staff Patrons	Manager Cook Wait Staff	Wait Staff Patrons	Wait Staff Patrons
Psychological Requirement	Inviting	Warm Inviting Nourishment Open Space Flexible	Casual Nourishment Lively	Warm Inviting Nourishment Open Space Flexible Casual	Collaborative Safe	Inviting	Warm Inviting Nourishment Open Space Flexible

Table 6. Physical Programming

Space	Requested SF	Notes
Front of the House		
Dining Room(s)	3000	Minimum 150 Seats
Bar	450	50 Linear Minimum/20 Stools Minimum
Bar Lounge	750	50 Seats Minimum
Vestibule	100	Entrance can Relocate
Wait Staff Station (2)	100	Include Fountain Station
Hostess Session/Waiting	150	10 Seats for Waiting Customers Minimum
Restrooms	600	Verify Code Requirements
Pick Counter/Waiting	200	Maintain Separate Entrance
Total Front of House	5350	Include Seat Counts on Final Concept Plan
Back of the House		
Kitchen	500	
Walk-in Freezer	150	
Walk-in Refrigerator	100	
Dry Storage	150	
Prep Area	100	
Clean-up Area	100	
Office Area	50	
Total Back of House	1150	
Total		
Total Net	6500	Usable Area
Total Gross Area	6650	Includes Building Walls

Schematic Design

This stage of the project is about developing concepts based on the previous studies, and theoretical frameworks through sketches and precedent studies.

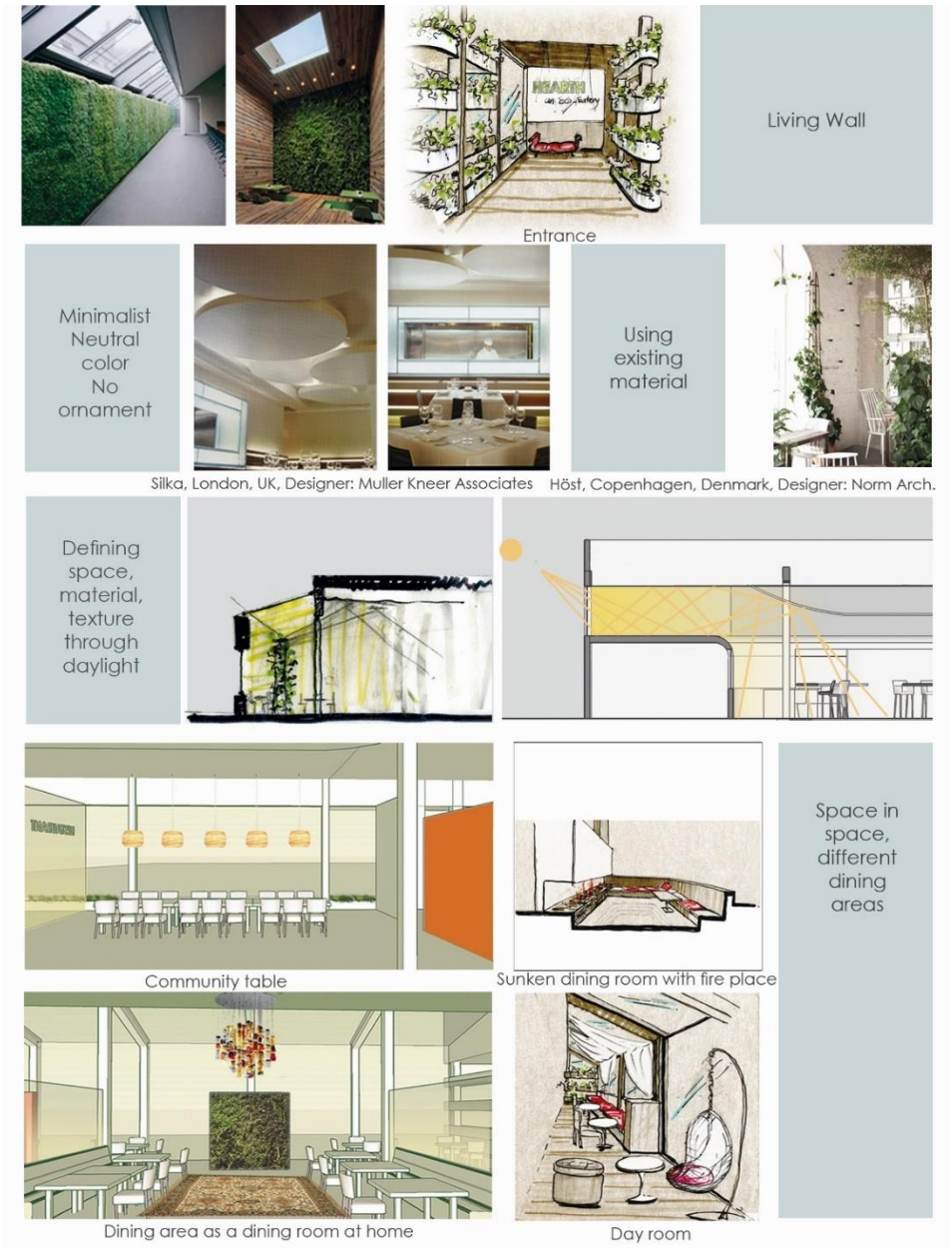


Figure 5. Schematic Design

Design Development I

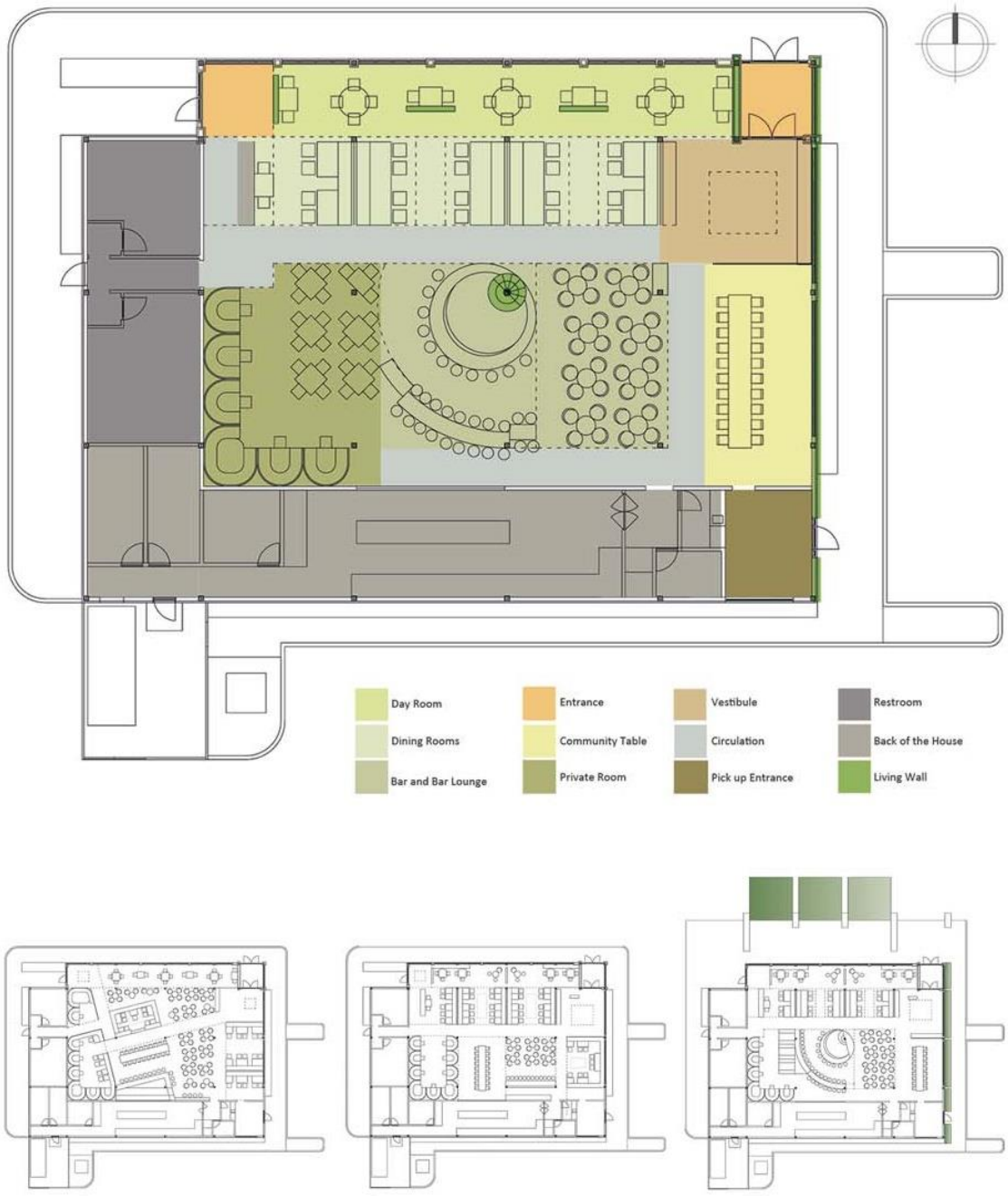


Figure 6. Developing Floor Plans

Design Development II

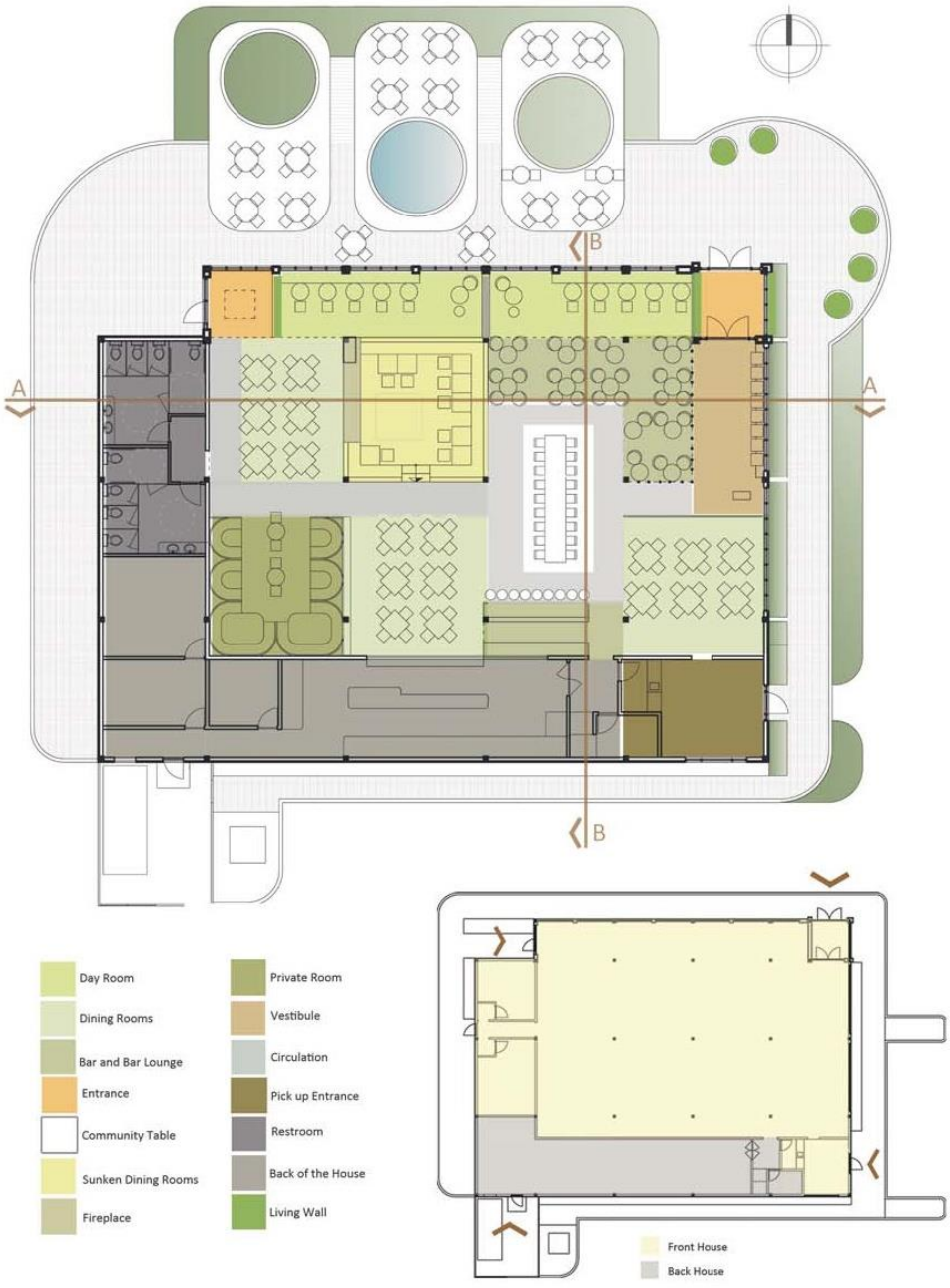


Figure 7. Floor Plan

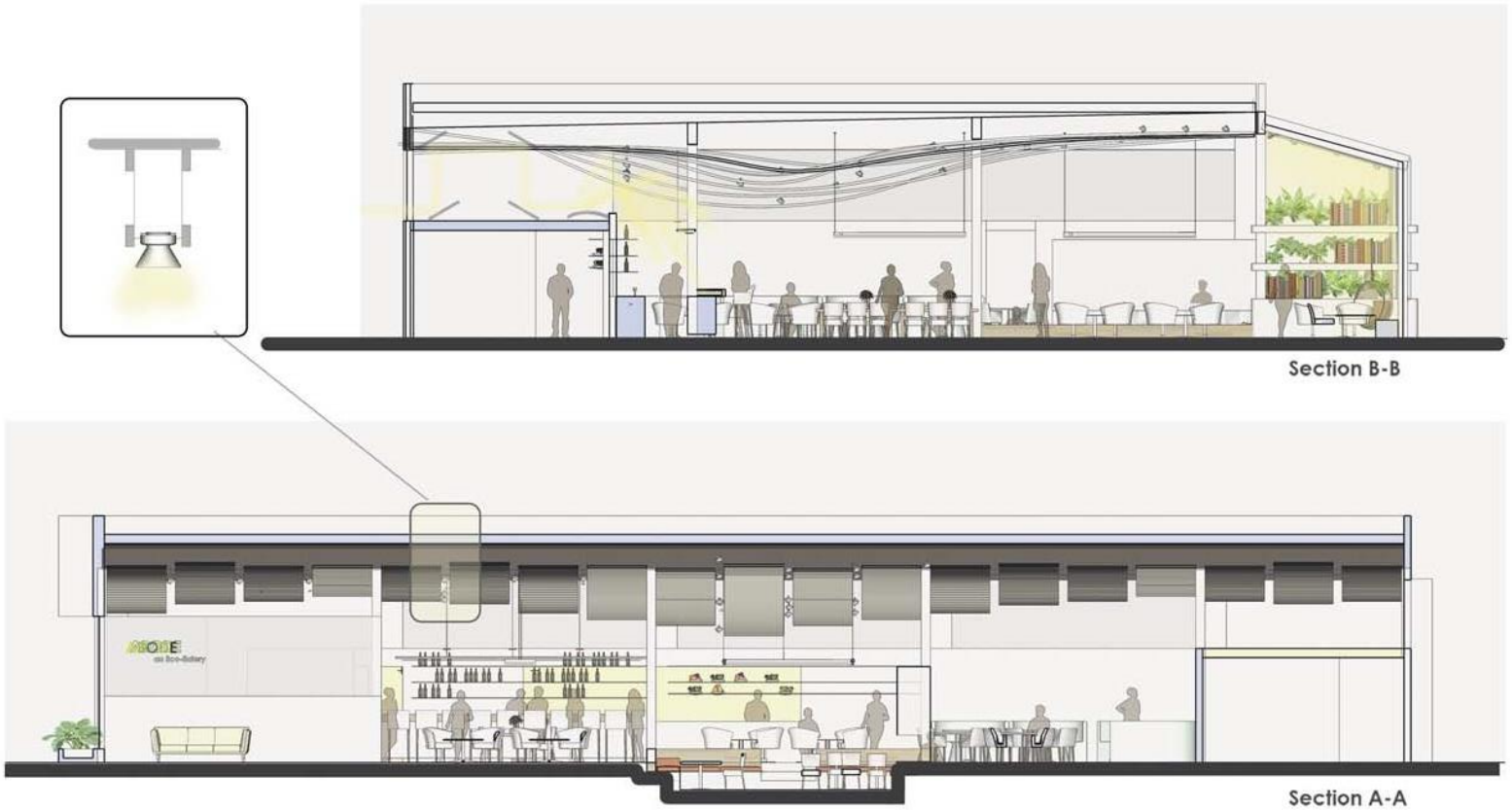
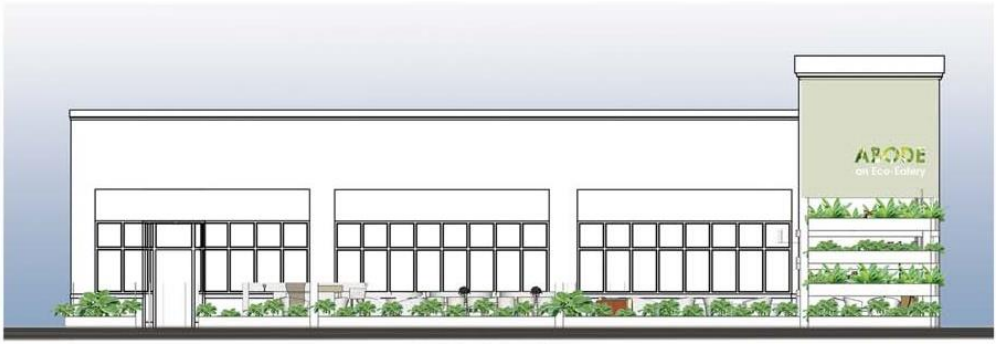


Figure 8. Interior Elevations



East Elevation

Entrance

Figure 9. Perspective and Elevation

Figure 10. Perspectives

Design Proposal

Figure 11. Floor Plan

Figure 12. Interior Elevations

Figure 13. Elevations

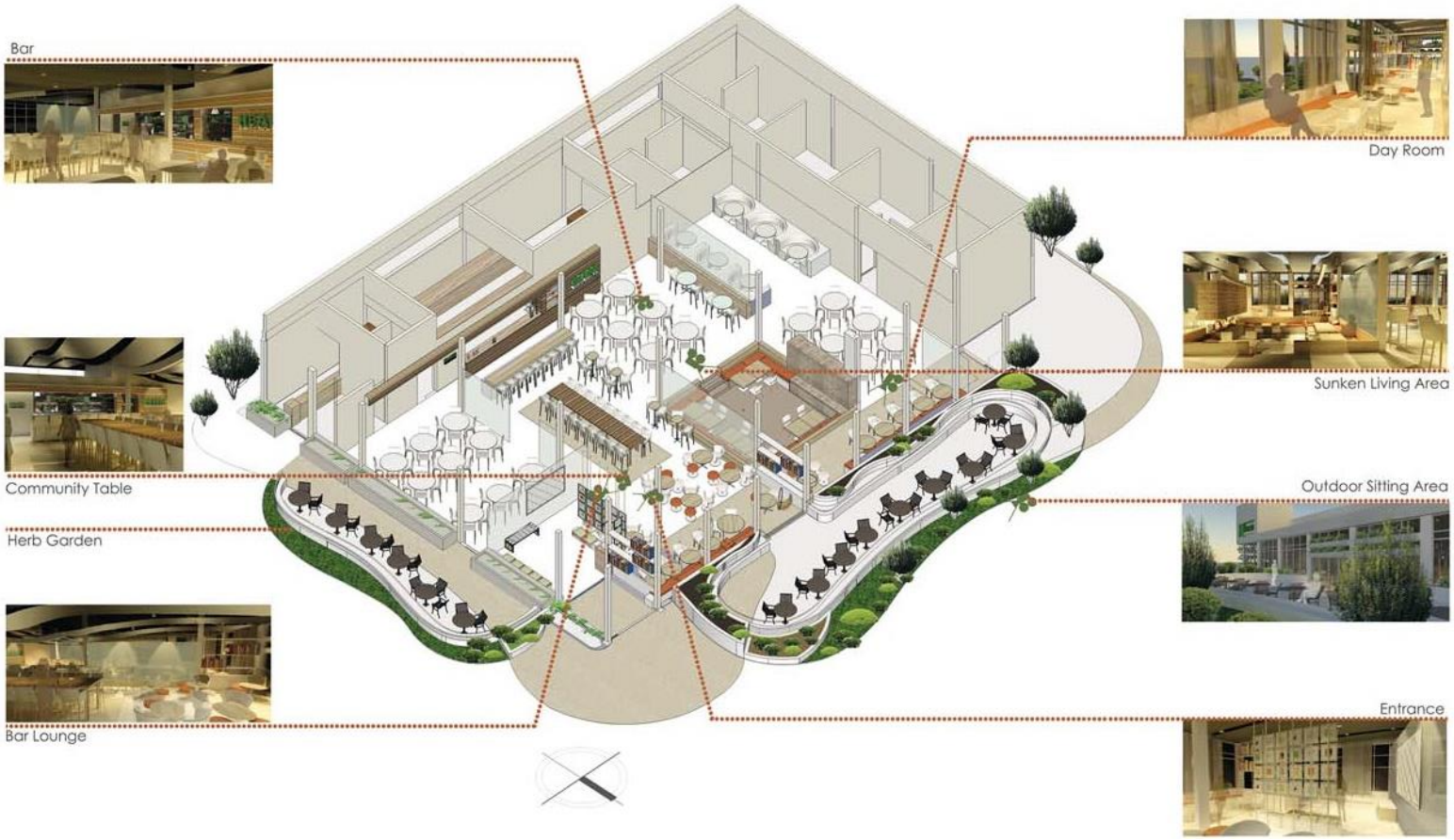


Figure 14. Axonometric and Perspectives

Figure 15. Sunken Dining Area

Figure 16. Community Table/Bar

Figure 17. Bar Lounge

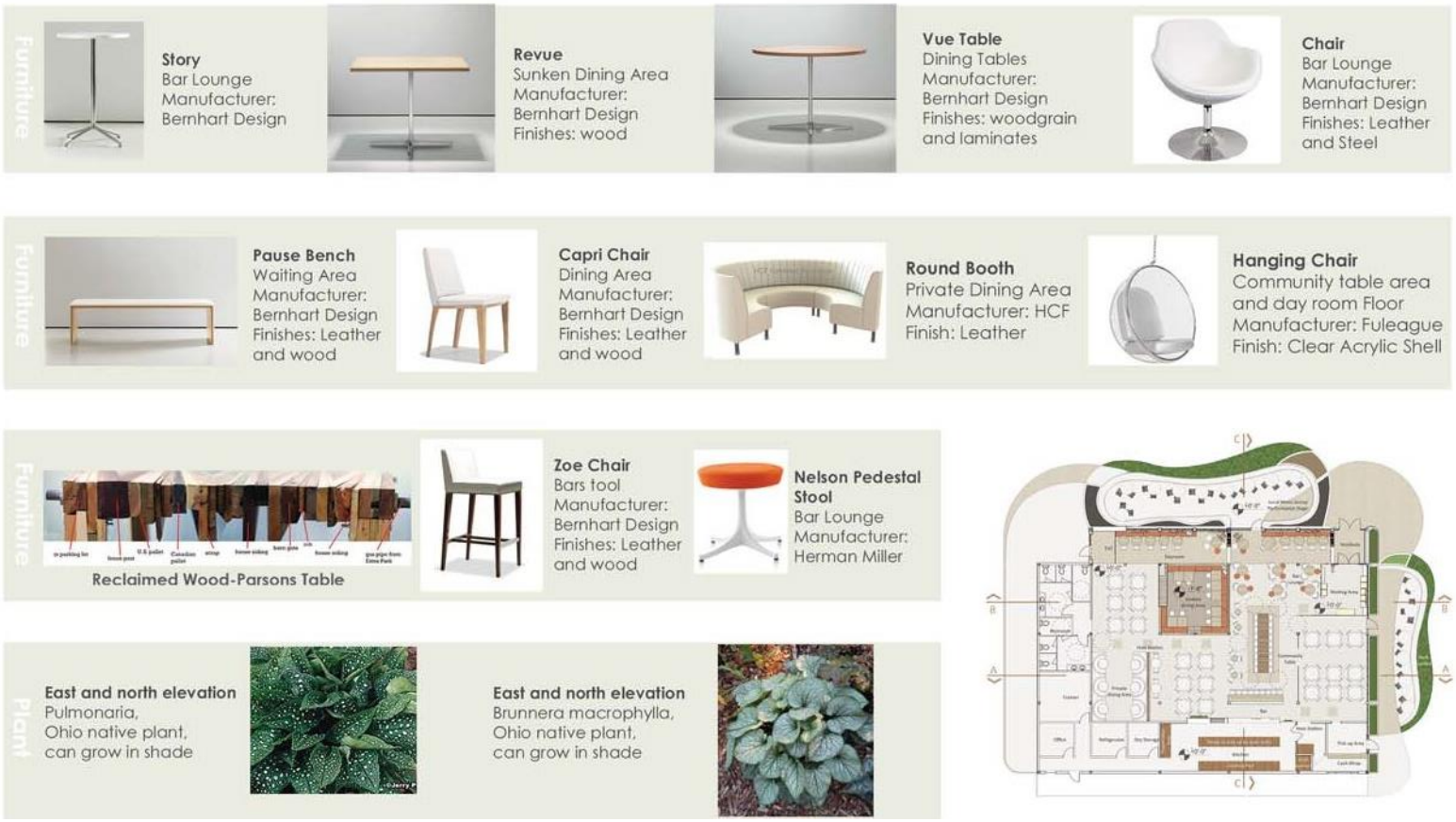


Figure 18. Materials, Finishes, and Furniture (1)

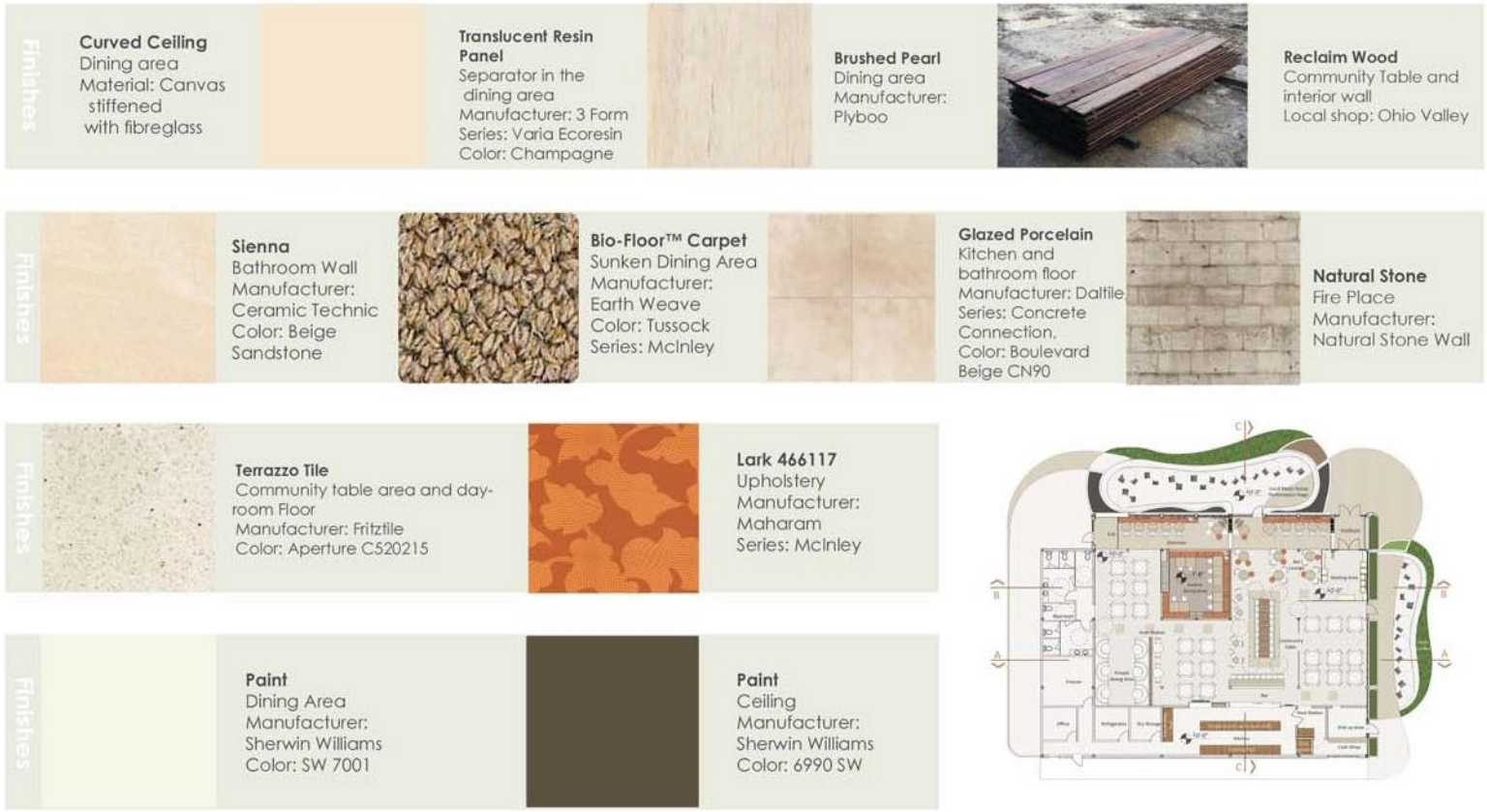


Figure 19. Materials, Finishes, and Furniture (2)

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Studio IAR 602

Introduction

This project focused on the redesign of the lighting design of a grocery store in order to create sustainable lighting for an existing grocery store in Greensboro (Deep Roots Market). This project was one of the steps towards developing a set of guidelines for the sustainable lighting design of grocery stores. This helped me to develop the guidelines for my thesis. The findings of my thesis about sustainable lighting design process were applied to the lighting design of this store.

Table 7. Introduction

Project description		
Integrating sustainable lighting design in grocery store consider: How can daylight affect designing of a grocery store? How can lighting become one of the elements of the design that shape the space? How can the concept of sustainable lighting affect the interior design of the grocery store?		
Lighting requirements based on the different areas in the grocery store		
Spaces and Tasks	Daylight	Artificial Lighting
Shopping area: grocery and non-grocery merchandise shelves, refrigerator area	Yes/No	Ambient, and task light
Independent Departments: wine department, backer, butchery, floral	Yes/No	Decorative, wall washing, ambient, and task lighting
Cashier area: Card corner, cashiers tables	Yes	Task lighting, ambient lighting
Management area: Manager office, offices	Yes	Ambient, and task light
Storage: Dry merchandise storage, refrigerators, loading and uploading area	No	Ambient
Eating area: Coffee shop, salad bar	Yes	Focal, and ambient lighting
Miscellaneous: Food demonstration, restroom	Yes/No	Ambient, wall washing, and task lighting
Users		
Grocery shoppers' demographics in the US (Carpenter & Moore, 2006): Gender: 73% female, 27% male Age: 18 and higher, median: 56 Race: Caucasian		
Critical issues		
Incorporate daylight in the design of the grocery store Reduce energy by using up-to-date and sustainable lighting techniques Follow codes and regulation and yet create a sustainable building Focus attention on specific lighting design needs of users		

Programming

Table 8. Social Dimensions

Region Demographics (Fisher Park Neighborhood)					
Education	%	Age (yrs)	Year old	Population: 1,194	
High School diploma	23.9	Median Female age	47.3	Median Household Income: $39422	
Bachelor's Degree +	46.1	Median male age	39.7	Household Size: 1.6 people	
Sex	Quantity	Ethnicity	%		
Female	605	**Euro-American**	92		
Male	589	African-American	5		
		Asian	2		
		Other	1		
Management and Workers Demographics					
Education (workers over the age of 25)	%	Age (yrs)	%	Ethnicity	%
less than high school	12	16-24	23	**White**	68
high school graduate	38	25-44	39	Hispanic/Latino	15
attend some college	20	45-64	33	African-American	11
associate degree	30	over 65	5	Asian	5
Sex: Female, and male are equal, female slightly higher.		**Median age: 38**		other	1

Users			
	Cultural Values		Physical and Psychological Needs
Shoppers and workers	high activity levels, multi-tasking achievement and money individualism and independence efficiency and practicality materiality and consumerism	majority rules informal and direct moralists but humanitarians self-fulfillment time viewed as a commodity	areas that promote efficiency and activity space that promotes independence space for productive work environment

Table 9. Space Criteria Based on Social Dimensions

User activity and corresponding lighting need chart				
User	Actions	Interactions	Details of Actions	Lighting Needs
shoppers	Enter	alone, with someone, or in a group	walking taking a cart checking the announcements sanitizing the cart	attractive lighting and signage ambient lighting appropriate for transition
shoppers	Exit	alone, with someone, or in a group	walking leaving the cart waiting checking the announcements	ambient lighting appropriate for transition
shoppers workers	Paying	with the cashier and bagger	walking/waiting check out bagging	task lighting ambient lighting daylight
shoppers workers	shopping	alone, with someone, or in a group With other shoppers with the store representative	walking/waiting talking weighing	ambient lighting decorative lighting accent lighting for displaying products daylight
shoppers workers	returning or asking questions	with the store representative With other shoppers	standing waiting talking	task lighting ambient lighting
shoppers	eating	alone, with someone, or in a group	selecting food paying having food	ambient light daylight track and dimmable light

User activity and corresponding lighting need chart				
User	Actions	Interactions	Details of Actions	Lighting Needs
shoppers	resting	alone, with someone, or in a group	sitting using bathroom	ambient light accent lighting
workers	working	alone with logistic team with product providers with client over phone with colleagues	Sitting talking writing	ambient lighting task lighting daylight
workers	cleaning	alone	not known	task lighting ambient lighting
workers	resting	alone with colleagues	sitting having food reading	ambient lighting daylight
workers	storing	alone with colleagues	not known	ambient lighting
workers	preparation	alone with colleagues	shelving loading or unloading the products	ambient lighting task lighting

Conclusion. Aging needs to be considered in lighting design decisions making.

Also, since the majority of the customers and workers of the store are Euro-American, lighting design can be focused on this group and their lighting preferences.

Environmental dimensions.

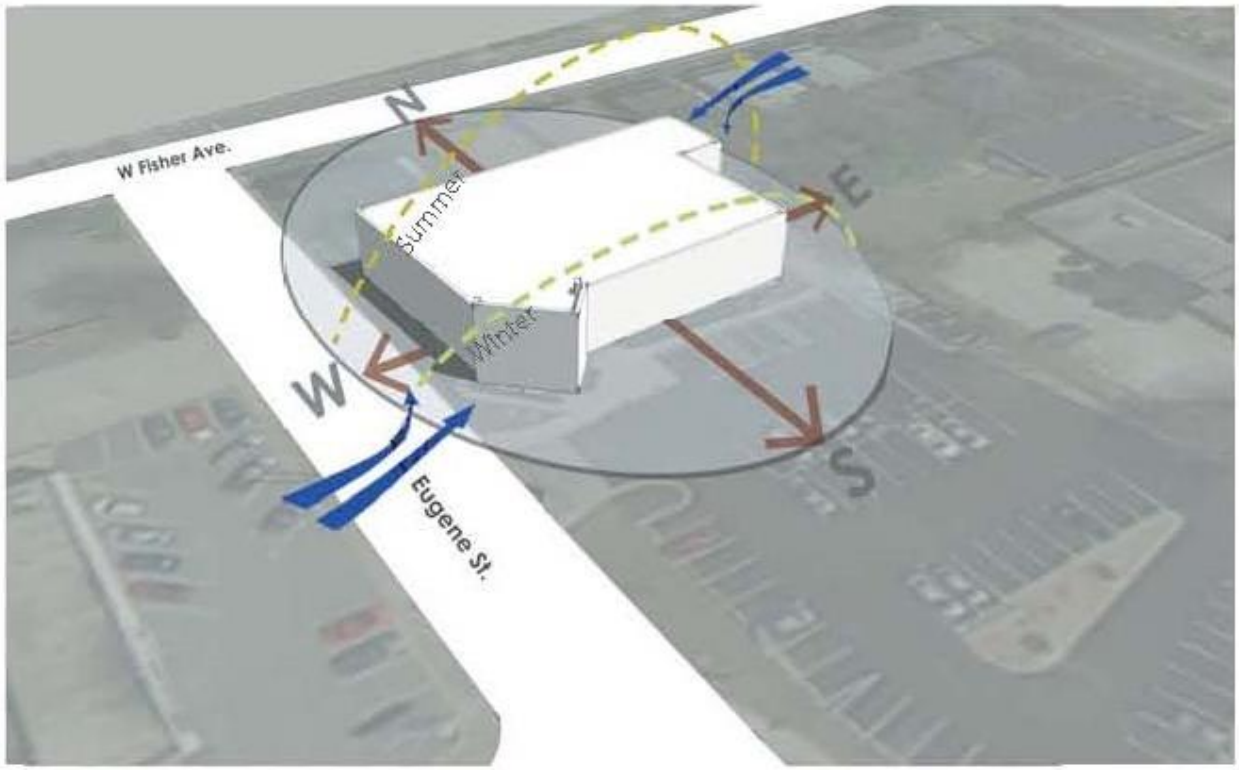


Figure 20. Sun Path Diagram and Prevailing Winds

Table 10. Environmental Dimensions

Physical Conditions: Geography and Climate	
Location	Geography
Located in the northern Piedmont section of NC Elevation: 897 feet above sea level Latitude: 36.08 N, Longitude: 79.82 W	Near the headwaters of the Haw and Deep rivers Mountains at the north and west of the city
Energy	
geothermal water wind solar	The dominant wind direction for Greensboro is from the southwest. warming up water saving thermal energy for warming up spaces daylight indirectly by creating biothermal energy
Weather and Climate	
Average Temperatures: January, 38.1° F; July, 77.9° F; annual average, 57.8° F Average Annual Precipitation: 50.24 inches (3.8 inches of snow) Greensboro has a relatively mild climate Freezing temperatures occur on more than half the winter days Snowfall can range from trace amounts to as much as 15 or 20 inches in a single season. Summer temperatures vary depending on cloud cover and thundershower activity, which itself varies greatly from year to year.	

Table 11. Lighting Criteria

Space Allocation, Space Description, Needs Assessment, Square Footage			Illuminance Level	
			Hor. (fc)	Ver. (fc)
sanitizer stand wall or panel for announcements and coupons cart storage attractive lighting and signage ambient lighting appropriate for transition	foyer	a small stand wall surface and the space in front of it	40	15
wall or panel for announcements and coupons waiting area cart storage ambient lighting appropriate for transition	exit		40	15
counter space for the line and waiting enough space for the shopper's cart task lighting and ambient lighting fixtures storage	cashier		40	15
product departments shelves refrigerators counter for scale	shopping area		100	40
counter storage space for the line and waiting enough space for the shopper's cart sitting space display	customer service	cabinet surface cabinets floor area floor area chair shelves	30-50	
dining set	coffee shop	chair and tables	15	50

Space Allocation, Space Description, Needs Assessment, Square Footage			Illuminance Level	
			Hor. (fc)	Ver. (fc)
table or counter for dining ware place for carts		one big counter floor area		
track and dimmable light				
restrooms sitting space	restrooms		20	20
working area, video conference task lighting acoustical privacy storage and shelves for papers or office supplies	office	desk and table file cabinet and library for documents	60	15
refrigerators and shelves	storage		10	6
shelving loading or unloading the products	preparation		50	40
storage for cleaning products sink for washing clearing cart storage	supportive	cabinet surface cabinet	10	6

Economic dimensions.

Table 12. Economic Dimensions

Employment			
Primary Businesses			
maximum male occupation:			
31.70%	education, training, and library occupations		
maximum female occupation:			
21.30%	service occupations		
Individuals and Families			
Median Household Income		$39,422	
(Fisher Park Neighborhood)			
Population below poverty line		23.90%	
Regional Materials (within 500 miles)			
Poplar	Red Oak	Hard Maple	
White Oak	Basswood	Granite	
White Ash	Soft Maple	Brick	
Neighborhood			
Green Hill Cemetery		Fisher Park	businesses in downtown
historical museum		Latham Park	other commercial
central library		Downtown Greenway	offices
			mostly single family residential

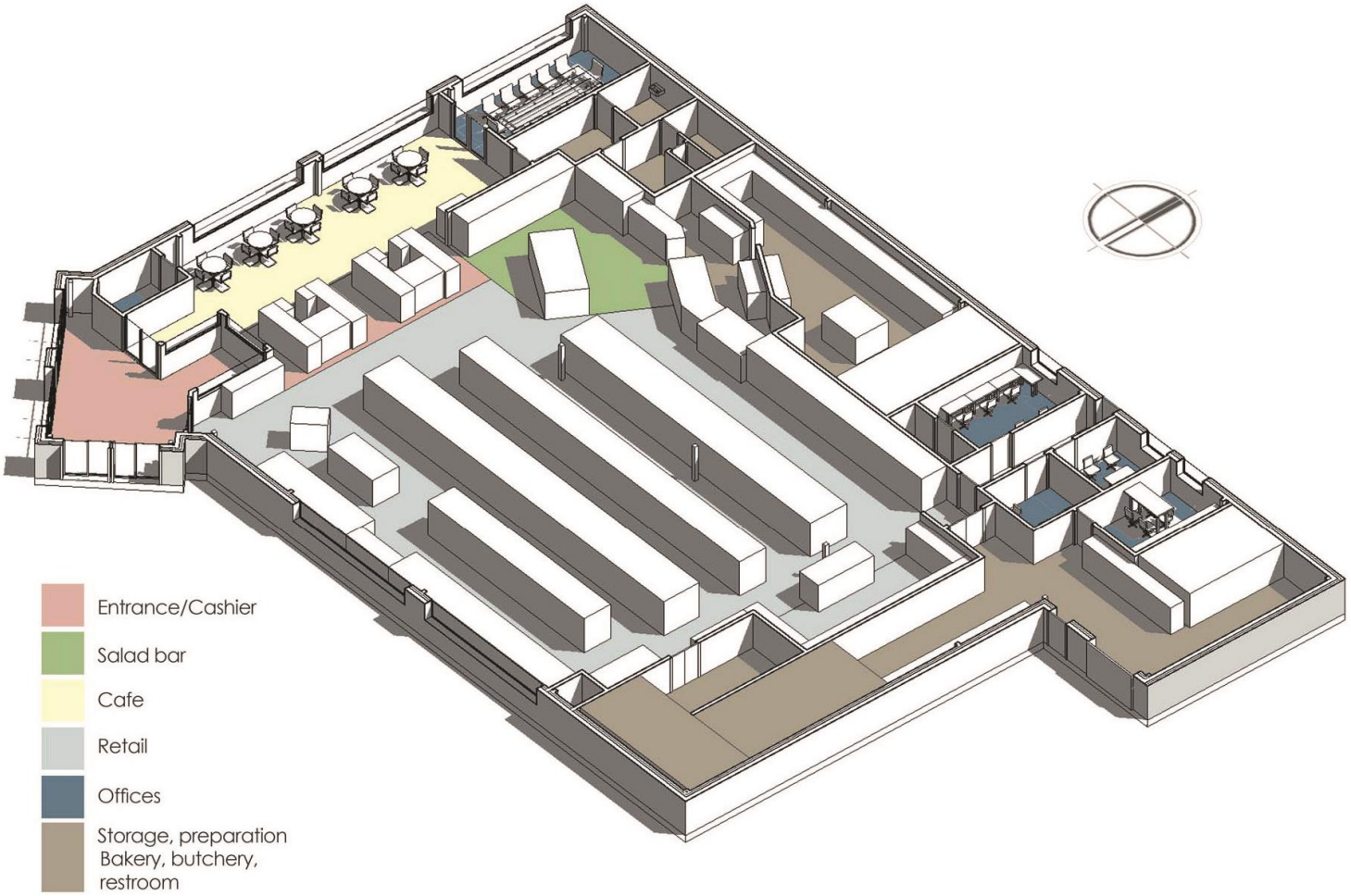


Figure 21. Existing Store Layout

Lighting Analysis.

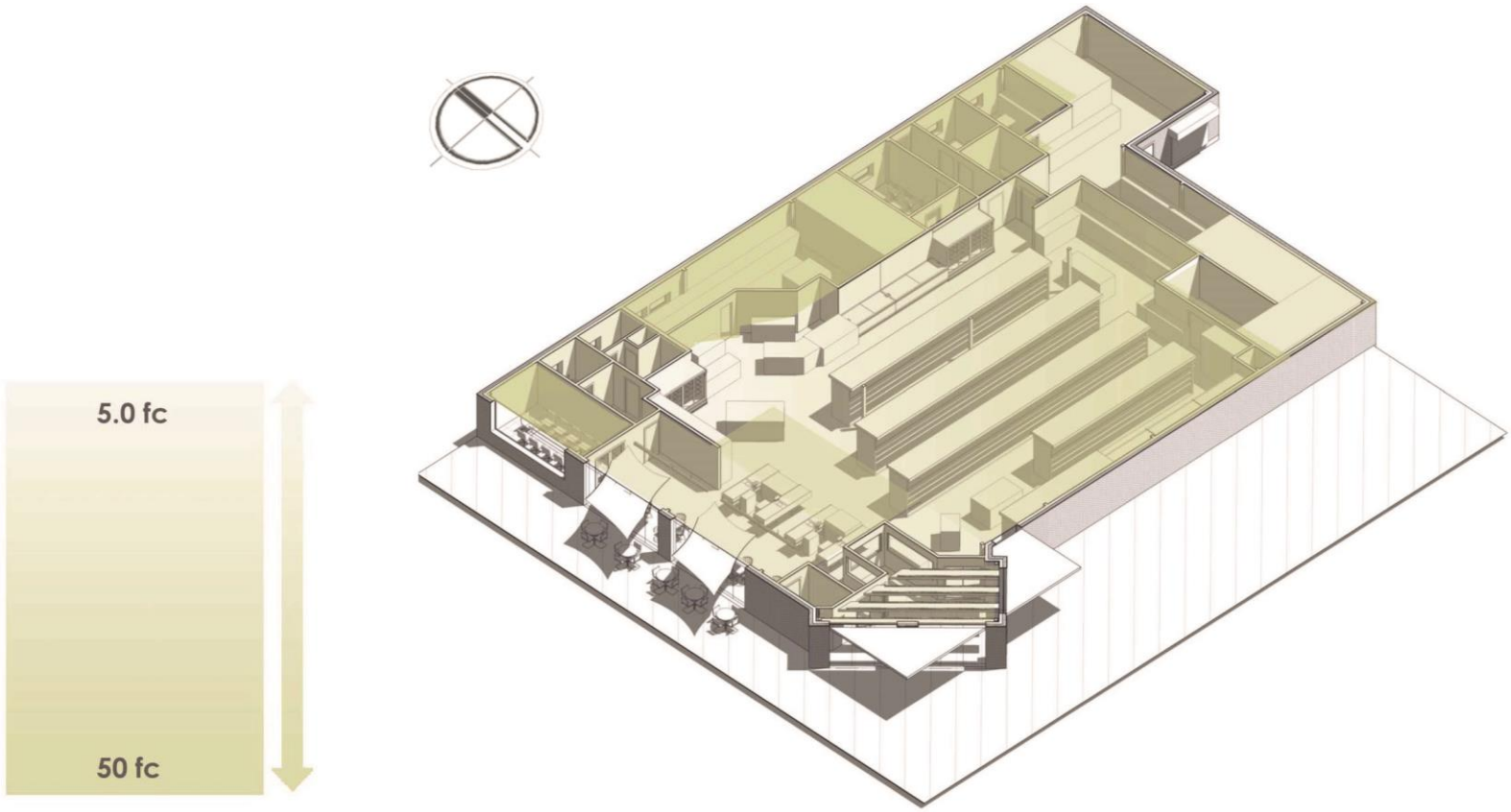


Figure 22. Desired Illuminance Level

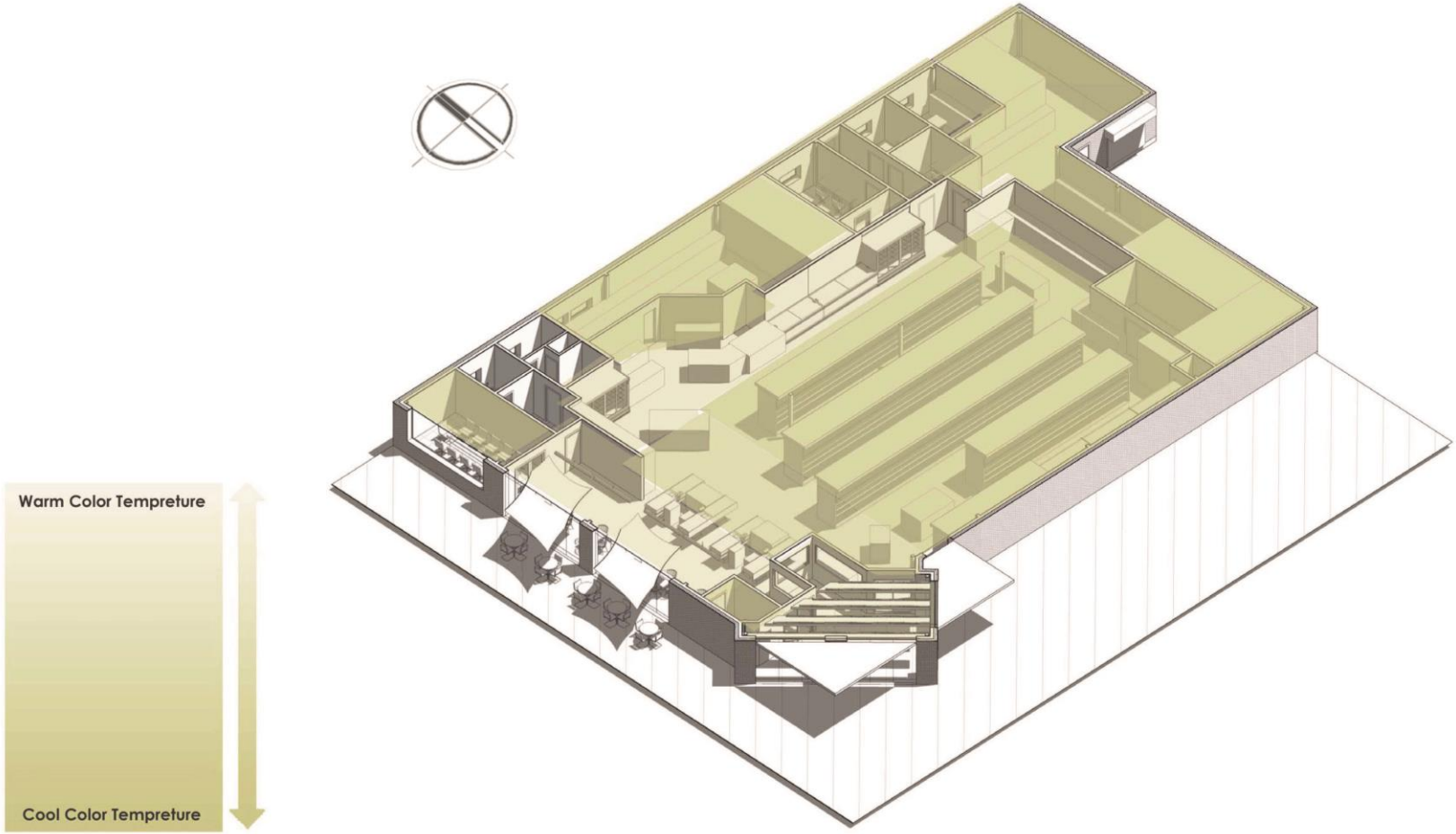


Figure 23. Desired Color Temperature

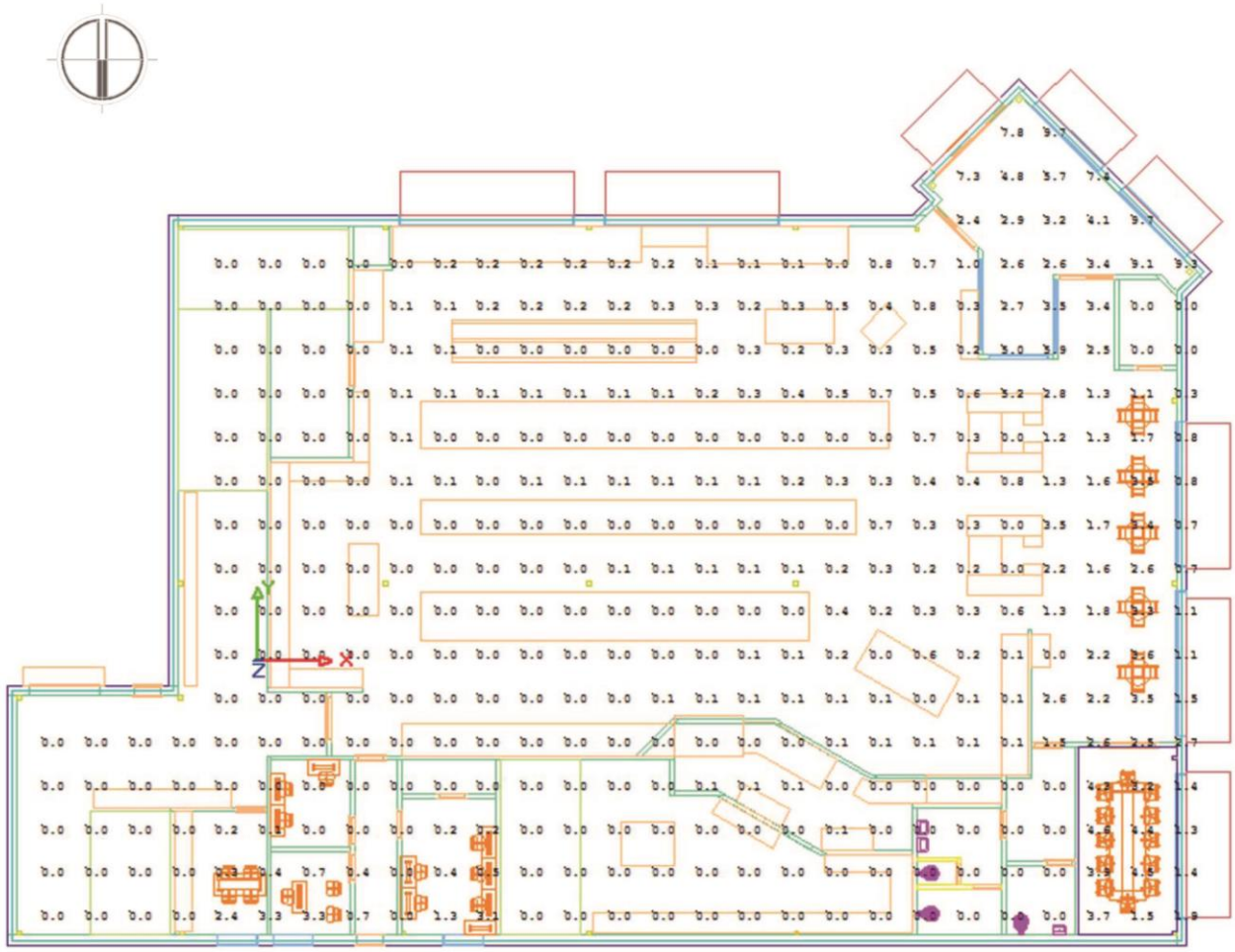


Figure 24. Daylight Factor-Exist. Building

Min 0, Avg 0.7, Max 9.7, 12% over 2%

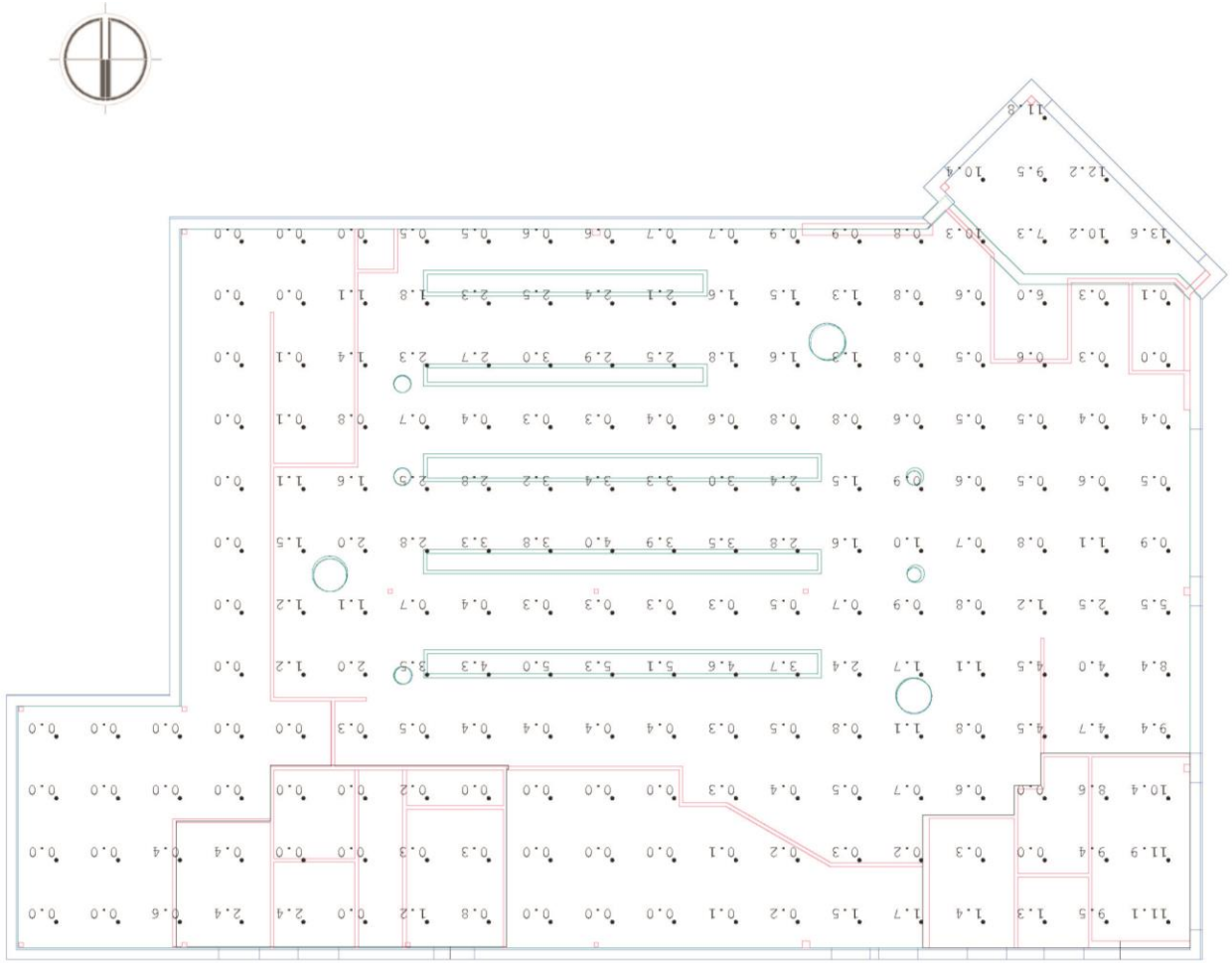


Figure 25. Daylight Factor-New Building

Min 0, Avg 11.4, Max 25.3, 65% over 2%

Table 13. Constraints

User Lighting Wants and Needs
Design the lighting layout of the store suitable for different types of shoppers with different shopping style
Reduce energy consumption by integrating daylight into the space
Help the grocery store to revitalize one its old functions, which was the core of neighborhood community
Constraints
Egress Lighting Typically range from .1 to 1 fc (1.1 to 11 lx) minimum, maintained on the path of egress, as well as exit signs of appropriate size, luminance, and color located at paths and egress ways. The codes generally require emergency lighting to be provided at all exits and any aisles, corridors, passageways, ramps, and lobbies leading to an exit. Both general exit lighting and exit and area of refuge signs must be lit at all times a building is in use. The intensity of emergency lighting should not be less than 1 fc at any point and not less than 0.1 fc measured at the floor level on the path of egress. Exit signs must be illuminated by not less than 5 fc at the illuminated surface. A contrast level of not less than 0.5 must be provided as well. Exit lighting must be connected to an emergency power source that will assure illumination for at least 1 ½ hours in case of power failure. **Type of Luminaire:** Only luminaires should be used in interior spaces that are accepted by the Nationally Recognized Testing Laboratories (NRTL) Program in the US and (UL) internationally. **Luminaire Thermal Protection:** In commercial construction, "thermal breaks" around the luminaires are designed to keep the insulation at least 3" from any component of the luminaire. In addition, if the lighting fixture is used in an enclosed space, ventilation to prevent excess heat buildup may be required. **ADA-compliance:** Wall sconces should not protrude more than 4" beyond the face of the wall and the bottom of the wall sconce should be least 6'-8" AFF. If they protrude more than 4", they should be mounted at least 80" from the finish floor level. An illuminance level of 5fc (50lx) is required at elevator thresholds. The height of switches should be between 15" and 48" for wheel chair users. The outlets should not be above 15" above the finish floor level. **Lighting Related LEED Credits (NC):** Illuminance level of minimum 25 fc daylight for 75% of regularly occupied spaces. Or minimum of 2% glazing for 75% of regularly occupied spaces. **Lighting Power Density:** Dining: Cafeteria 1.4w/ft2; Office 1w/ft2; Retail 1.5w/ft2

Concept

A main street in an urban neighborhood. One of the main factors that distinguishes Deep Roots Market from other grocery stores is the operation and management system. Deep Roots Market is a co-op which makes it a community oriented retail store and gives the neighborhood community the opportunity to be involved in the management of the store. This also means that the community can have the chance to manage the products that they purchase and eat. Also, being a co-op encourages community based activities and actions that provide benefits to the whole community in the Fisher Park neighborhood (the neighborhood that Deep Roots Market is located in) and downtown Greensboro. In addition to this operational aspect of Deep Roots Market, it has a main mission which is summarized in four words: “fresh, local, healthy, and delicious”. Each of these words is expressing one characteristic of the store, its products, its services, and the management system.

The proposed concept for lighting design of this store is coming from the community-based aspect of Deep Roots Market. The lighting design of the store recreates the feeling of being in a main street in an urban neighborhood. Streets are the element of cities that connect the whole city together. A good street provides orientation to its users, connects well to the larger pattern of streets, encourages human contact and social activities, has a memorable character, contains a vast range of activities, and is a source of diversity. The reference for the concept of this grocery store is old and historical streets that reference the era when streets showcased as well as

encouraging social bonds and interactions. Referring to the past helps to evoke a sense of belonging since it is addressing something familiar for the customers.

Kevin Lynch's elements of legibility for urban spaces (paths, edges, districts, and landmarks) are used in the lighting design of the store. For the lighting design of the store, these elements, which were originally developed for urban design, were used as a guide to shape the overall layout of the lighting. The paths and edges are aisles in between two rows of shelves and refrigerators; the land marks are the focal points that differentiate each department; and the districts are each department and area in the grocery store. The goal of the lighting design is to supports two different types of activities in the grocery store which are based on what happens in the urban main streets: reflective activities and dynamism.

Café-Store Front-Traditional Awning. Since the cafe in the grocery store was facing west, an awning system was used to control the daylight in the evening. The awning system was inspired by traditional awning system.

Aisles and Shelves. Walking in the aisles conveys the freshness of walking under trees in the street. The ambient light is dim and in high contrast with the shelves that have cove lighting.

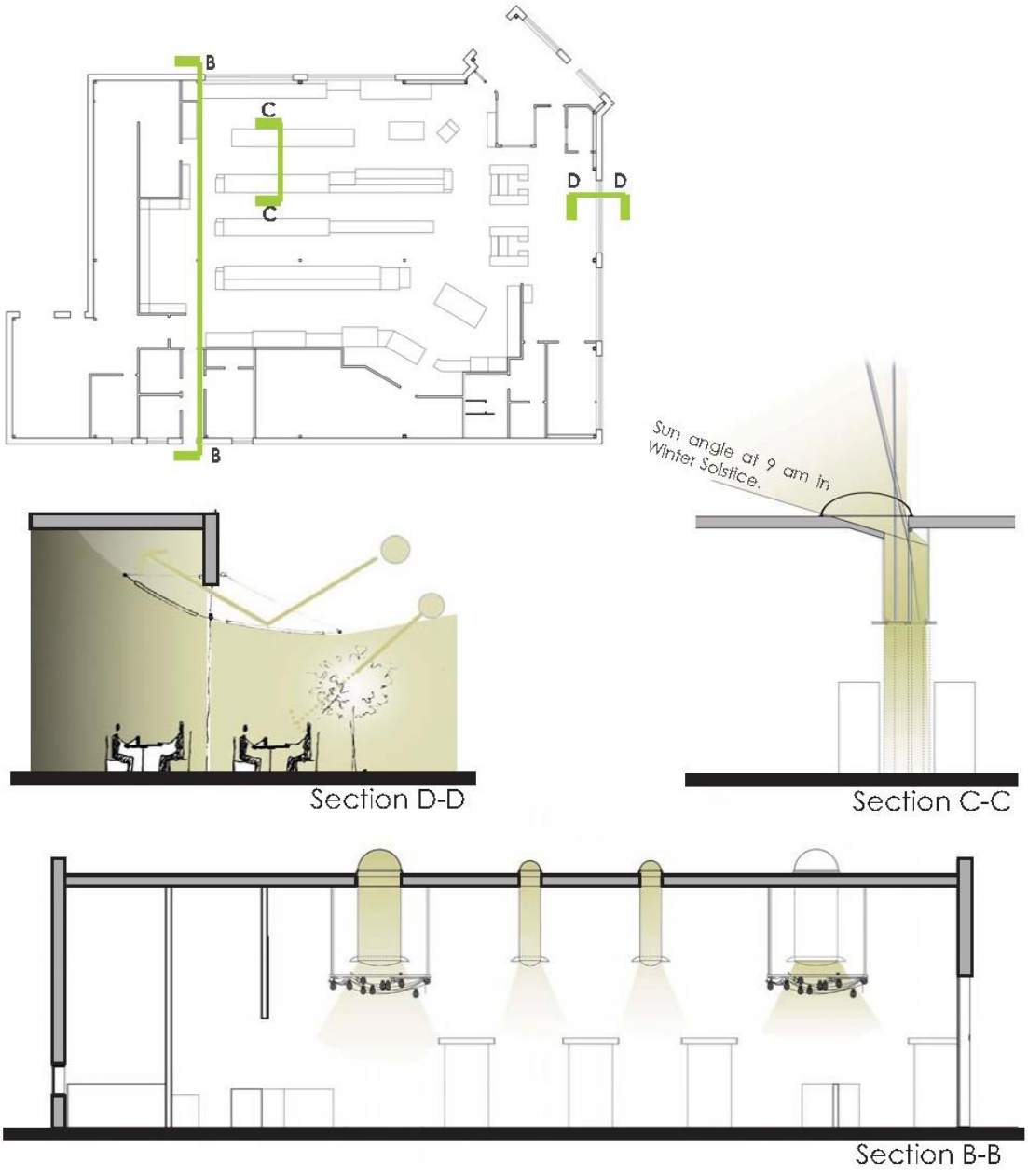


Figure 26. Schematic Design

Specialty Departments. The last aisle is the place for the specialty departments. The colorful panels for each section, with graphics that show the name of each

department, give the sense of walking in the old streets in this region. And the brighter light at the bottom of the refrigerators resemble traditional store front windows.

Street Lights. Street lights inspired both the artificial and natural light in the grocery store to recreate an urban feel. The luminaire selection and the quality of light resemble street lights. For instance, the tubular downlights and the quality of light that they create is similar to street lights. Also, the string lights in the produce section mimic street string lights used during holidays.

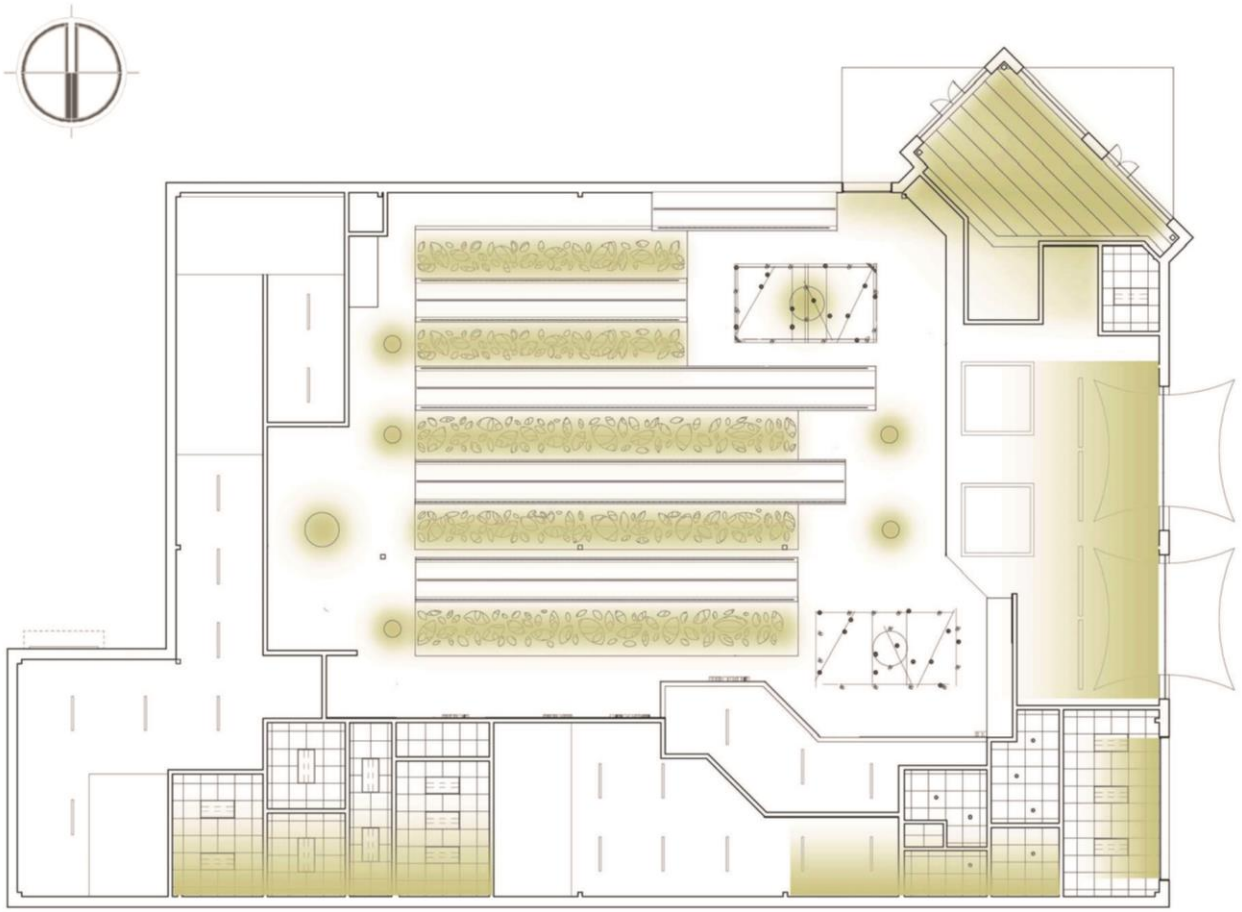


Figure 27. Reflected Ceiling Plan - Daylight

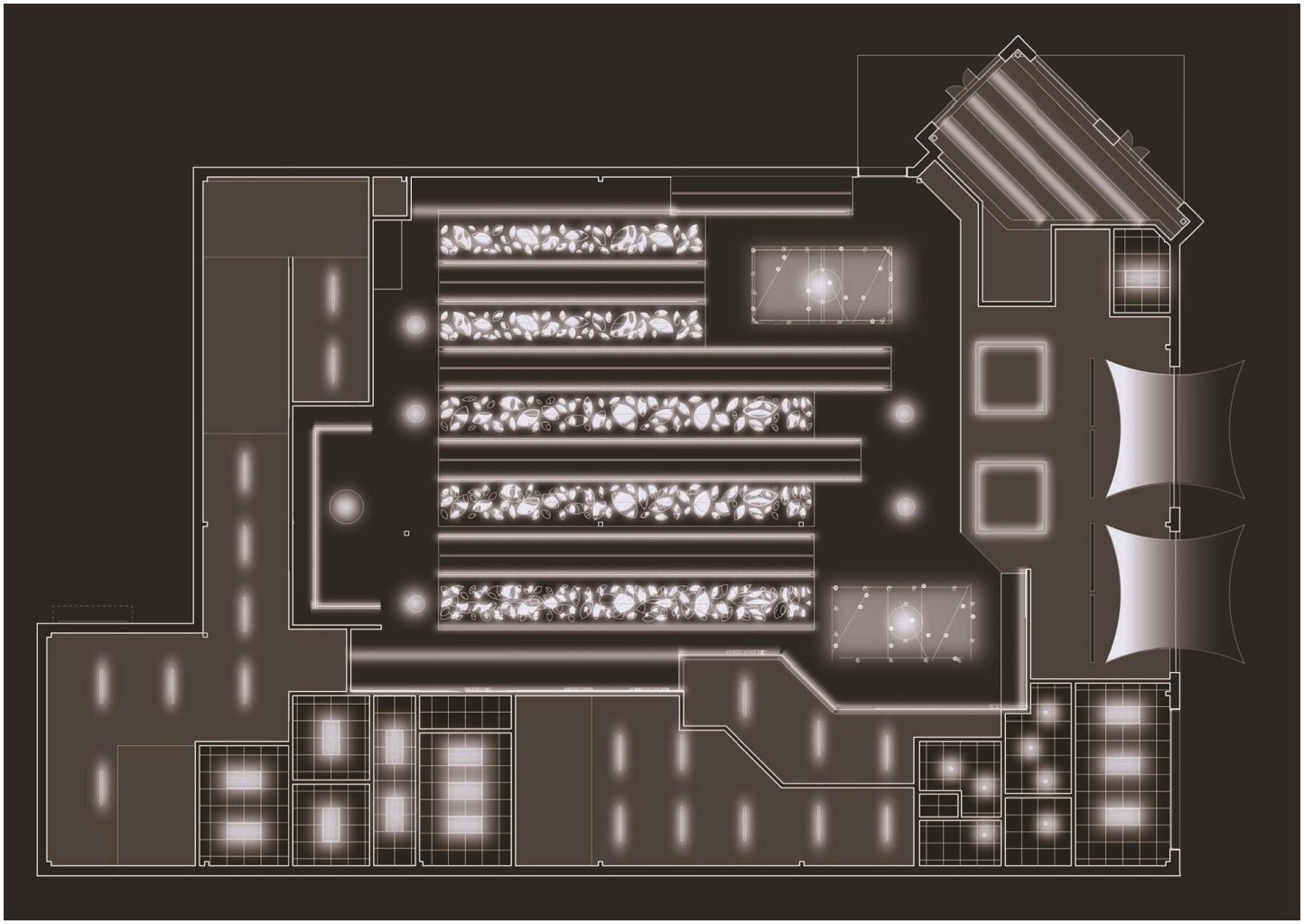
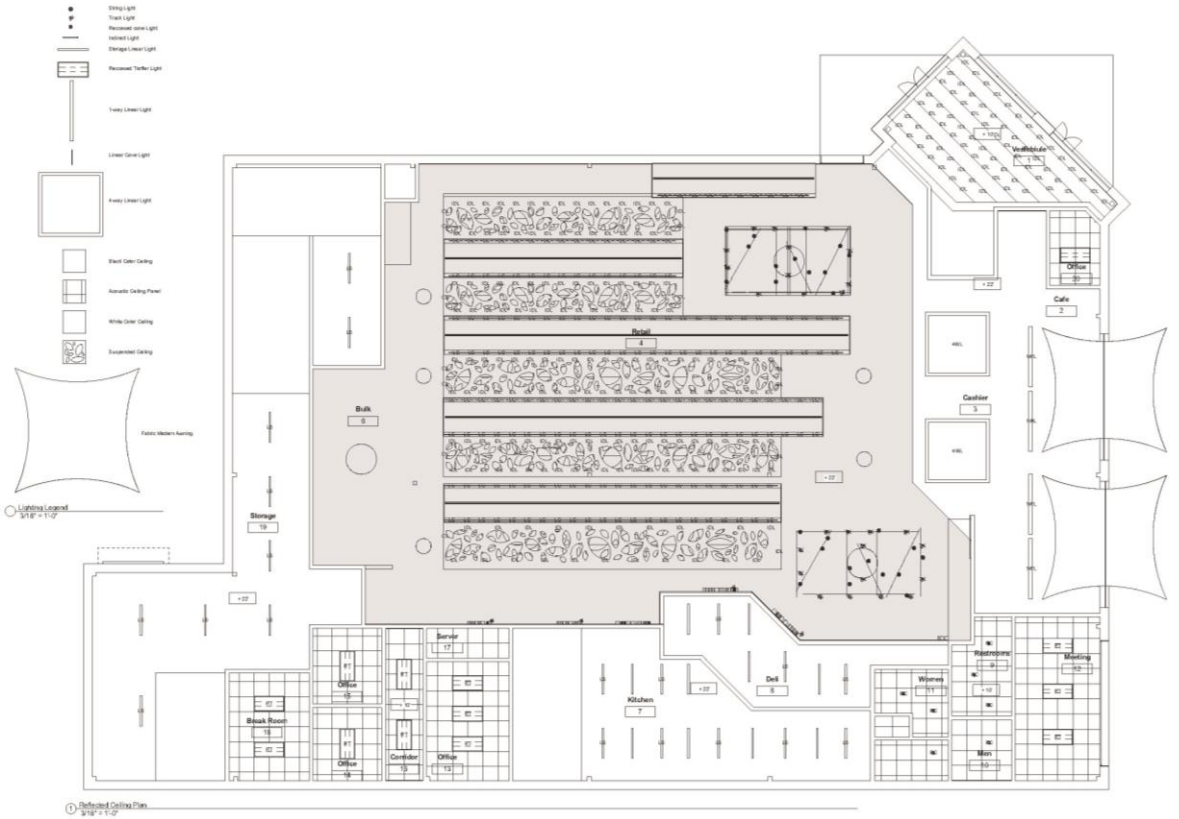


Figure 28. Reflected Ceiling Plan - Electrical Light



LIGHTING FIXTURE SCHEDULE

Mark	Manufacturer	Description	Type	Model	Count	Lamp	Efficacy	Color Rendering Index	Color Tempreture
TK	Cooper Industries, Inc.	Track Light	Architectural_Cooper_Halo_L805MED	Model	26	LED	7 lm/W	85	3000
RC	Cooper Industries, Inc.	Recsed Cone	Downlight_Recessed_Cooper_Halo_LED_4 Inch_H456ICAT120D	H456ICAT120D - H4 LED Gen1 Housing	7	LED	149 lm/W	80	4000
LS	Cooper Lighting	Narrow Design - Lensed and Reflector	Lighting-Striplight-Cooper-Metalux-SNLED	SNLED	19	LED	149 lm/W	85	4000
	Cooper Lighting	Recessed - LED	Lighting-Troffer-Cooper-Corelite-Class-R3-2X2-2X4-LED	Class R3	13	LED	149 lm/W	85	4000
LC	Cooper Industries, Inc.	Linear Cove	Linear_Cooper_Io-LED_Line .75 Asymmetric	line .75 Asymmetric	186	LED	149 lm/W	80	4000
IDL	Acuity Brands Lighting	Indirect Linear	Refer to Type Catalog	ZL1N	255	LED	149 lm/W	80	4000
ST	Novelty Lights	String Decorative	String Light	commercial grade light strings	26	LED	149 lm/W	80	3000
1WL	Cooper Industries, Inc.	1 Way Linear	Suspended_Cooper_Ametrix_Arrowlinear Individual Linear LED (1-Way)	Arrowlinear Linear LED	4	LED	149 lm/W	-	3000
4WL	Cooper Industries, Inc.	4 Way Linear	Suspended_Cooper_Ametrix_Arrowlinear Individual Linear LED (4-Way)	Arrowlinear Linear LED	2	LED	149 lm/W	-	3000

Figure 29. Lighting Plan

Figure 30. Interior Elevation

The luminaire selection is based on these factors: the desired color temperature, illuminance level, energy efficiency, Color Rendering Index, and mood. This information can be found in the programming section.

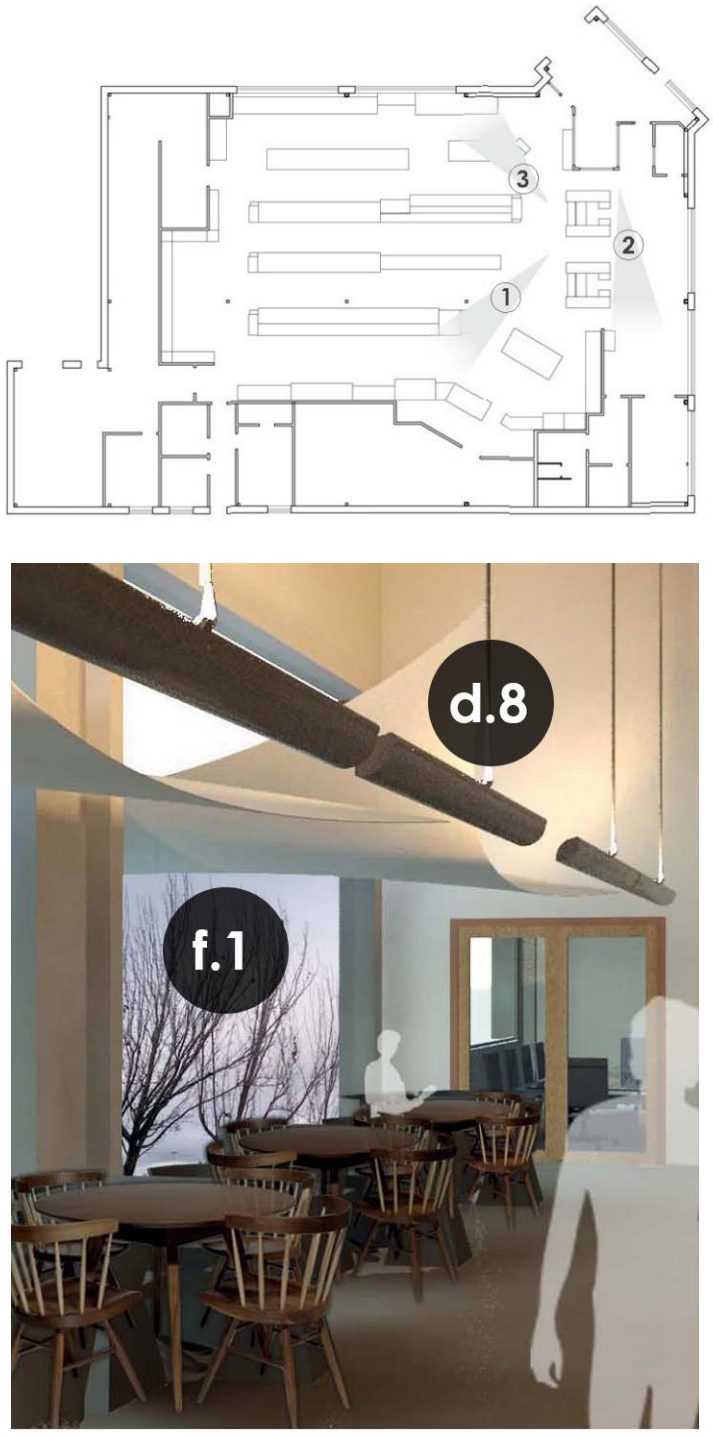


Figure 31. Rendering Cafe (2)

Figure 32. Departmental Section: Bakery (1)

Figure 33. Produce Section (3)

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