An Integrated User-centered Approach to

Architectural Design for Library Study Spaces

by

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ABSTRACT

This thesis proposes a method for assessing the indoor environment of a library—more specifically, how conducive a library's indoor environment is to studying. The method involves the integration of tree analysis and the tallying heuristic function. A tree model is necessary in order to establish relationships between the primary interior architectural features and their subdivisions, as well as to provide an illustration for the research. A heuristic function, tallying, is used to count the number of times each feature is mentioned favourably. The tallies' weights for each respective feature are uniform, such that the features differ based on the number of times they are referenced in the scientific literature. In this way, the features are identified according to their respective counts, thereby allowing a greater understanding of which interior architectural features should be considered when designing a library space that is mindful of those who occupy the space for studying: primarily students. The proponent is meant to support and facilitate decision making, i.e., which features to implement based on their respective quantitative tallies. This overcomes the inherent difficulty of comparing features with qualitative differences from one another.

PREFACE

This thesis is an original work by Jad Jureidini. No part of this thesis has been previously published.

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1 INTRODUCTION

1.1 Motivation

Libraries are vital academic facilities, and thus a source of attention for renovation and retrofitting projects to extend their lifespan. This building type is commonly given special attention during the design phase prior to construction and when renovations and/or retrofits are being implemented because of how widely used they are. They undergo repairs and changes to replace damaged or aging components as well as to enhance the indoor environment users occupy. Previous research indicates that the well-being of users is increasingly being considered in relation to library renovations. It has been shown that users tend to visit libraries at a greater frequency if the buildings meet their preferences and needs. Many will consider visiting based on specific features of the facility, such as accommodation for both individuals and groups, the comfort level of the indoor environment, and the interior décor. Additionally, visitors may wish to utilize other amenities, such as cafés, seminar rooms, and/or lecture halls. Numerous studies and surveys have found that students in particular visit academic libraries more often if the facilities meet their preferences. It is thus reasonable to infer that the design of libraries, centered around users, can be regarded as a means to enhance the environment within which students learn. The background research is explained in detail in the following chapter.

People of various age groups benefit from using school libraries from elementary to university students, among others. The buildings' resources and indoor environment are intended to promote learning. The library facility is known for being a source of information, offering services to disseminate that information and provide reference materials to its occupants (Gayton, 2008). With the advent of the digital age, storing and retrieving materials has extended from the physical to the digital realm, reducing the need for visiting the facility in person to retrieve information. Similarly, space allocation for the library has changed due to the onset of digital storage technology, in that less square footage is required for shelving to hold print materials than in previous decades. The design has also been adapted to include square footage for amenities such as cafés or other spaces less associated with the library building type. However, the physical library remains significant because of its environment, which is conducive to studying and learning (Applegate, 2009). Thus, it is important to design the interior spaces of library buildings for the comfort of those who use them, namely students, to create an atmosphere conducive to studying, because "then environment can play on people's thinking and behavior" (Chen, 2010). Therefore, the factors of the physical space need to be examined.

Among the libraries on the North Campus, Cameron Library is distinct for a number of reasons. It is one of the first library to be established on the campus, its original construction dating back to 1962. Later, additional libraries were constructed as additions to preexisting structures, but Cameron Library is a separate, free-standing building; however, the building is joined to a nearby academic building by means of a pedway, which allows students to conveniently access the library facility. It should be noted that a number of buildings across the North Campus are connected in this fashion, primarily because of the prolonged periods during which the temperature is below 0°C outdoors. Another reason that Cameron Library stands out from its counterparts is its location on campus. It is in close proximity to the main quad, a central courtyard that provides walkways and open space for regular pedestrian traffic year-round and is a primary location for various events and social gatherings. This supports the argument put forth by Chen (2010) that the library is the focal point of the social, cultural, and educational institutions. The application of Chen's (2010) description of the library facility to the University of Alberta's North Campus can be observed in the illustration in Figure 1. As presented, Cameron Library is surrounded by academic buildings, and is within walking distance to dormitory buildings. Given its surroundings, the library can reasonably be considered a focal point of the campus.

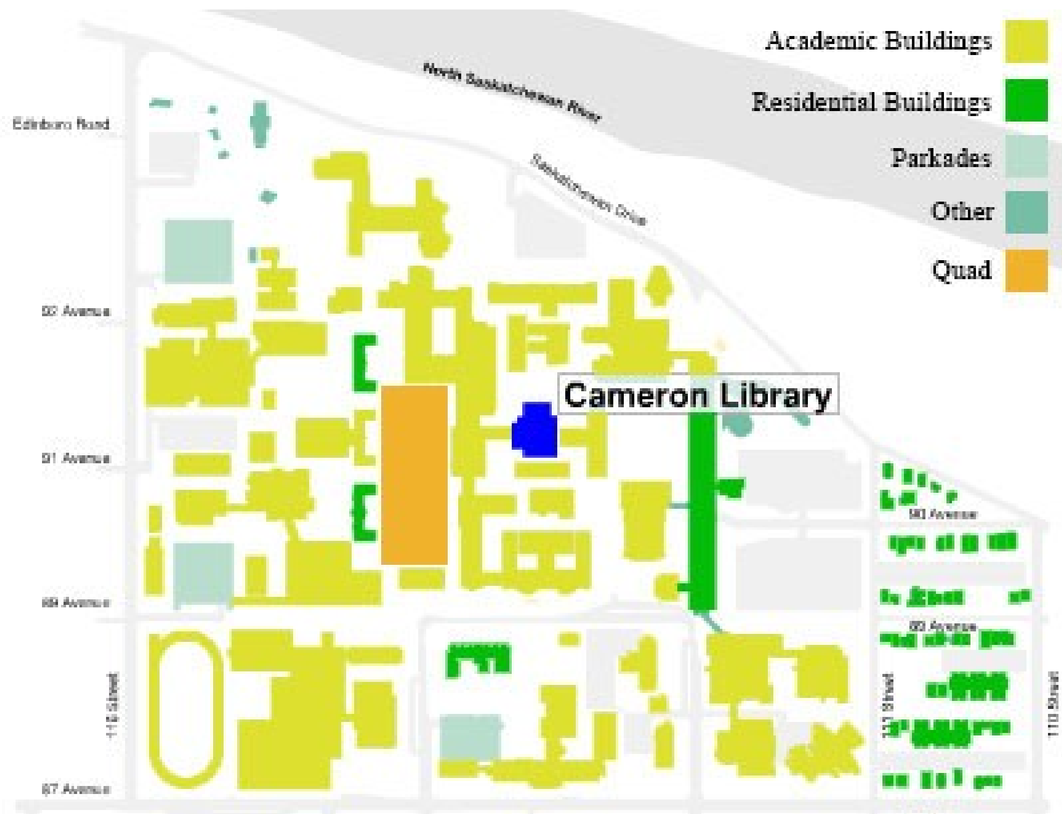

Figure 1: Map of the University of Alberta's North Campus (north of 87th Avenue)

The University of Alberta plans to retrofit one of its libraries—Cameron Library, located on the North Campus in Edmonton, Canada—with modern mechanical equipment to replace its ageing counterpart. For example, the current heating, ventilating, and air-conditioning (HVAC) system was installed three decades ago and is in the process of being upgraded. Originally built in 1962, the library has undergone numerous renovations to its façades, interiors, and building systems. Currently, the south façade, the last remaining building component from the original building construction in 1962, is being considered for renovation. This is due to the relatively high maintenance costs for repairing the façade whenever it sustains some level of damage. The same consideration is being given to the façade for the north wing, added in 1969. The intention is to reduce the annual energy consumption of the building, but this does not consider the concerns of the students who are the primary users of the building. This focus on energy consumption for the building has failed to enhance the indoor environment to conduce more effective studying, and has raised the following questions:

- How comfortable are libraries for studying?
- Is there adequate accommodation for seating and studying?
- Can better design be implemented that would enhance the indoor environment to better facilitate studying?
- What features about the building type promote learning?

These questions demand further exploration of the relationship between academic libraries and their students. In summation, this study addresses current design practices in libraries and their interior environments, and how the design of indoor spaces could be improved to better promote learning activities.

1.2 Research Objective

This research is based on the following hypothesis:

"Interior architectural features of libraries have a direct impact on attracting students to use the libraries."

This research is also conducted based on the following assumption:

"The effect of the architectural feature is measured quantitatively based on the frequency and the number of times a factor or factors is/are used and cited in the scientific literature."

Information is gathered to answer this hypothesis, and is based on the research conducted from previous case studies and experiments. To answer the questions posed in the previous section, the following specific objectives will be addressed in this study.

1) Observe current practices in renovations regarding libraries.
2) Identify the most common parts of the building interiors that could influence the students' interest to use the library, that are renovated, and for what purpose(s).
3) Develop a model to identify the major indoor environmental factors of the library affecting students' mental health and interest to use the library.
4) Quantify the effects of each factor for their contribution toward making a space conducive to studying.

1.3 Thesis Organization

This thesis consists of five chapters. Chapter 1 introduces the topic and research objectives and provides an overview of this thesis. Chapter 2 provides a review of the literature gathered and discussions on how libraries affect students to become studious. Chapter 3 presents the methodology used in this study. Tree modelling is used with subdivisions of the major factors to measure each architectural feature's contribution toward making a space conducive to studying. Chapter 4 discloses findings and analysis from the model's development. Chapter 5 presents the application of the model for Cameron Library as a case study. The results and findings from Chapters 3 and 4 are applied to the observations made from examining the building. An assessment is made based on the implementations within the library. Finally, Chapter 6 comprises recommendations, conclusions, and the future scope of research.

2 LITERATURE REVIEW

2.1 Introduction

Libraries have been and continue to be designed and built according to their purpose: to store and provide access to physical books and other sources of information. Secondary to this are the spaces in which to use these resources. Libraries are transitioning toward providing electronic services in addition to those within the physical space of the facilities. But, despite widespread access to library services via computer, the physical space occupied by users remains important (Walton, 2006). However, despite such importance, the physical space is often disregarded unless a specific emergency or extenuating circumstance is encountered which provides an opportunity to design and/or re-design the physical library study space for the benefit of the users (Simon, 1992). Examples of such emergencies include problems with the building's ventilation system, or airborne contaminants, such as allergens, being retained in the carpeting. In this sense, libraries are designed with less consideration for these possible scenarios than they are for more serious emergencies, such as fires or floods. Building codes across numerous jurisdictions account for these, and are primarily taken into account when designing a library. But more consideration can be given toward the indoor environment of the library. The physical space of the library has not lost importance as a learning space, as students continue to utilize the available study areas for extended periods of time (Applegate, 2009). Therefore, user-centric design of the academic library's interior, geared toward its primary occupants—university students—should be considered.

2.2 Evidence-based Approach

This thesis is evidence-based, and so relies on information gathered from previously conducted research, case studies, experiments, and observations. Gathering this research across a number of fields is necessary due to the nature of the research problem posed in the previous chapter, and for the following reasons.

1) There is limited knowledge that directly answers the research hypothesis.
2) There is little information regarding the productivity and well-being of students within the context of the library building.
3) There are few case studies that explore and demonstrate the use of the tallying heuristic as demonstrated in the following chapters of this thesis.

The evidence-based practice has been known to benefit users of this approach in a number of fields. Its evolution within the field of medicine can be traced back to the thirteenth century, when the idea of making a decision to treat a patient should be based not on tradition, but rather on logic derived from observations and experience (Daly & Brater, 2000). The evidence-based practice was formally introduced to the field of medicine by Guyatt et al., (1992), and has since been applied across numerous other fields, including audiology, dentistry, psychology, social work, education, and library and information science. The underlying nature of the evidence-based approach to decision making is that this approach aims to specify the way in which such decisions should be made by identifying evidence for a given circumstance and by being able to rate that evidence according to its scientific soundness. Ultimately, the goal in using this approach is to eliminate unsound or risky alternatives for those that have more favourable outcomes. Where the evidence-based approach is applied, decision makers are encouraged to use the most appropriate information available. One of the main instances this evidence-based approach can successfully be incorporated is when there is a vast amount of information available. For example, the plethora of studies linking clients' improved health outcomes and the general attitude that treatments should be based on scientific evidence helped incorporate this approach into treatment services. Within this thesis, it is proposed that linking numerous case studies of library renovations and retrofits with studies on mental health will help identify the most significant improvements to make upon an academic library for the sake of the productivity of and appeal towards university students.

The evidence-based practice is defined as research-based evidence that is used to support decision making in professional practice (Spencer, Detrich, & Slocum, 2012). The practitioner, or practitioners, involved uses the best available evidence as the basis for the decisions to be made. The available evidence is used in combination and collaboration with the experiences and judgments from the practitioner or practitioners. The three primary elements that create the foundation for the evidence-based approach to decision making are the best available evidence; the professional expertise of the user of this approach; and the values of the client and the context surrounding the circumstance. Evidence is considered "ideal" if it is deemed the most relevant to a decision that needs to be made, and if that evidence-based decision has the highest degree of certainty. Relevance depends on how closely the evidence meets the conditions for a given problem. Certainty depends on the methodological quality and the amount of research that is available. These requirements give form to the "ideal" evidence that should be used by researchers. Should such evidence be unavailable, then researchers should use the best of what is available.

This is one of the limitations of evidence-based research: when the best evidence is not necessarily available. The mandate for using the best available evidence suggests that evidence deemed imperfect, or failing to meet the "ideal" requirements, is still better than no evidence at all, because it can still be used, but must be used wisely (Spencer et al., 2012). This source identifies the second primary influence in evidence-based practice as the professional judgment of the user, or the input from the user based on professional opinion. This influence is prevalent because of the necessity for professional judgment when making a decision. Decision making cannot take place without professional judgment. Practitioners, through this judgment, refine a given number of sources of information by retaining knowledge that is relevant and disregarding the rest. Professional judgment is necessary so that practitioners, at every juncture of decision making, can weigh the best available evidence, the client values, and contextual factors involved. This sorting, filtering, and refining of given evidence occur in order to navigate the decision-making process. This professional judgment is similar to the utilization of heuristics in decision making. The application of heuristics in decision making is described in greater detail later in this chapter. However, a limitation related to practitioners using professional judgment is their need to develop skills in seeking and appraising evidence, actions which require considerable time and effort. These skills are necessary to avoid the likelihood of practitioners being prone to confirmation bias, seeing only the evidence that supports their personal experience and judgment.

Other limitations of using the evidence-based practice is the environment of the management of scientific and experiential evidence. In other words, the context of the organization of gathered data can be a potential limitation. This is because, as time passes, the context of organization may change; so much so that the data gathered under an earlier organizational context cannot be applied to the current organizational context, leaving the researcher(s) with no other choice than to use the evidence that is available, and to treat the respective organization as a prototype. In this regard, it is necessary to systematically assess the outcome of each decision through careful experimentation (Pfeffer & Sutton, 2006).

One of the benefits from the use of evidence for the basis of decision making is that scientific information can be accessed, reviewed, and applied as deemed necessary. In other words, a plethora of information from scientific and academic literature can be obtained and locally applied within a context for the purpose of making a decision, supported by evidence. An example of this is within the field of medicine. Consumers can use evidence-based information produced from outside their respective regions in order to gain insight into selecting the best medical providers, as well as make treatment decisions. This represents the local application of evidence-based scientific information (Clancy & Cronin, 2005).

Guyatt et al. (2008) describe this evidence-based approach as involving a cyclical process of inquiring about, obtaining, appraising, and applying evidence. This description parallels the development of the model proposed in this thesis. As more sources of information are gathered and retained, the model undergoes changes in its approach to identify the most significant architectural features in relation to the mental health of users of academic libraries. As more sources of information are gathered, more indoor environmental factors are identified, and those already identified are reiterated to be significant. As new indoor environmental factors are identified, the list of architectural features pertaining to those factors grows.

As such, the foundation for this approach is a thorough search of scientific literature and systematic selection as well as analysis of the literature that is reviewed. Consequently, it is necessary to become familiar with how to search through databases using relevant key words and terms. This evidence-based approach is explained in more detail in the following chapter.

2.3 Built Environment

The indoor environment influences one's abilities to concentrate, study, and learn. In this context, the "built environment" is defined as the structure and space where people live, work, and play. The relationship between designing the built environment and the health of students has become an increasingly important issue.

Currently, libraries are renovated for specific reasons: repurposing space from housing print collections to occupant use for social gatherings as well as individual activities (Weare, Jr. et al., 2016); improving accessibility to and circulation throughout the building (Tasha, 2016); addressing the issue of noise pollution in one or more areas of the facility (Lohisse & Sogno, 2008); installing modern technology and contemporary furnishings (Powelson & Vaska, 2010); renovating and updating the interior décor for a more attractive appearance (Ensor, 1996); the relocation and reorganization, as well as addition or removal of study tables and carrels (Bazillion, 2001); adding and/or installing both natural and artificial lighting (McCarthy, 2000); expanding to include a wider variety of spaces, such as cafés, group study rooms, and seminar rooms (Shill & Tonner, 2003); and improving lighting equipment for energy savings (Ganandran et al., 2014). In summary, libraries are most often renovated, retrofitted, and/or redesigned not because of concerns for the occupants, but for modernizing the building and its facilities in terms of décor and planning, as well as to address its energy consumption in order to optimize its maintenance. But, there is opportunity to consider renovating a library with regard to its relationship to the users.

2.4 Heuristics in Decision Making

With regard to decision making, heuristics play a significant role. Of Greek origin, the term means "serving to find out or discover." A heuristic is defined by Gigerenzer & Gaissmaier (2011) as "a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods." But because of this disregard for *all* information pertaining to a problem, and only utilizing *a portion* of it, heuristics are perceived as deficient or inadequate in some respects. This is because heuristics are frugal. In other words, they do not use all of the information available, but rather ignore part of it. Heuristics do not try to find the optimal, or best, solution, but find the solution that is deemed good enough. Calculating for the maximum of a function involves finding the optimal solution; selecting the first option that reaches or rises above a certain level for a function involves finding the satisfactory solution (Gigerenzer, 2008). It must be noted that the benefit of using heuristics is that they can turn complex and otherwise ill-defined problems into well-defined and manageable ones that are easier to solve. Heuristics can even be more accurate than complex strategies *despite* their processing less information. However, this accuracy depends on the structure of the environment in which the heuristic model is used.

According to Gigerenzer & Gaissmaier (2011) there are four classes of heuristics for decision making. The first class exploits recognition memory, the second ignores all reasons but one, the third "trade-off" class weighs all alternatives equally, and the fourth relies on gathering information socially. These four classes are described below, and, save for the fourth heuristic class, why they are not applied to the research presented in this thesis is explained.

First is the recognition heuristic, which follows the principle that recognition, or familiarity, appears in consciousness earlier than recollection when coming to a decision. This heuristic relies only on recognition, leading to the belief that people who rely on it will ignore strong contradicting inferences. A variation of the recognition heuristic is the fluency heuristic, which applies to a specific context: if both alternatives are recognized, but one is recognized more quickly, then it is inferred that the alternative that is recognized first has the higher value with respect to making a decision. Speed of recognition is correlated with the criterion with regard to this heuristic.

Second, whereas the recognition and fluency heuristics rely on recognition, the one-reason heuristic relies on recall. It looks for only one "clever" cue, which is the sole basis for decisions. It is not clear when such a heuristic is best applied, but it is argued to be suited for environments where the variability of cue weights and redundancy is moderate to high, and when the sample size is small. Although the nature of the context in which the one-reason heuristic is not fully understood, the nature of the heuristic itself is. The sole "clever" cue discerns among a set of alternatives when coming to a decision. A variation of this heuristic is the take-the-best heuristic model. In the event where there is more than one "clever" cue to base a decision on, in this model, multiple cues are searched for and ordered hierarchically according to their validity. Discriminating among the alternatives clearly is the cue that is selected.

The titular trade-off class makes trade-offs by weighing alternatives equally. One such model in this class is tallying, which entails simply counting how many times one alternative is favoured compared to others. The cues are searched randomly, in contrast to the one-reason model. Searching is stopped when a total number of cues has been entered and there are no remaining cues to search for, by which time a decision can be made based on which alternative has the most cues in its favour.

Fourth, the social heuristic is designed and applied almost exclusively for social information. Social intelligence is applied to this heuristic. According to the social intelligence hypothesis, species that are very social are intellectually superior to species that are less social, because the social environment is more complex, less predictable, and more intellectually challenging. In other words, individuals should be able to calculate the consequences of their own actions, as well as the actions and behaviours of others, in order to calculate the balance of advantage and loss. By this context, social intelligence can work with heuristics. One discerning feature of this class of heuristics is the involvement of social and nonsocial decision making. While all four classes can be applied to nonsocial decision making, only the social heuristic can be used in the social counterpart. The reason for this exclusiveness is that the goals of social intelligence surpass those of accuracy, speed, and frugality to include transparency, accountability, and loyalty to a group of peers.

Of these four classes, the tallying, or trade-off, heuristic is found to be most suitable, thus is chosen for implementation within the model presented in this research. The recognition heuristic cannot be applied while gathering sources on library building projects, because of the inherent reliance on recognizing alternatives embedded in the model. Numerous studies indicate that people do not automatically use this class when applicable (Gigerenzer & Gaissmaier, 2011), inferring that other models are preferred when making decisions. It is more clear why the one-reason heuristic class cannot be applied to this research. The objectives do not involve nor include searching for one discerning alternative among the gathered sources on library renovations. Rather, the goal is to collect knowledge on all the alternatives that are considered in such projects. Finally, the social heuristic is not applied, because, while the heuristic model involves calculations based on social interactions, the model presented in this research is founded on calculations based on interactions between a library and its occupants. The latter type of interaction could be applied to the social heuristic model, but as a result there would be less consistency between that interaction and the research question that is presented in the next chapter. The lack of consistency is because the relationship between the interior environment and the occupants would be given less attention as the focus is on the interactions among the occupants making use of that environment. Furthermore, the relationship between the occupants and their environment is not the same as the relationships among the occupants. Therefore, for the sake of answering the research hypothesis, the interactions among occupants who share an environment are less significant than the relationship between those occupants and their environment. It is argued by Gigerenzer & Gaissmaier (2011) that tallying is not widely used because of the low number of cues involved. As sources on library renovation projects are gathered, the number of indoor environmental factors rises, along with the number of their respective architectural features. By this argument as well as the reasons put forward above, tallying is considered the most appropriate heuristic and is applied in this research.

2.5 Applications of Tallying in Qualitative Comparisons

Within different fields of research, the concept of applying the tallying heuristic to quantitatively compare qualitatively different alternatives has been used with the intention of supporting the decision-making process. There are numerous examples of how this application could benefit decision making across a number of professional and research fields. It is necessary to disclose that although research studies have been conducted in using the tallying heuristic in order to make comparisons numerically for qualitatively different items, no such research has been conducted within the context of academic libraries, or libraries in general. At the same time, evidence-based research has been carried out with regard to mental health, because of the prominence of its application in the studies of medicine. However, this approach has not been applied to the relationship of mental health of students with their environment within the university library. Therefore, although there are examples of using the tallying heuristic to draw comparisons in other research case studies, the context presented within this thesis is novel and relatively unexplored.

One application is in the field of technology development. The designs of screens for system interfaces are compared, based on their effectiveness, by tallying the total number of keyboarding errors that occur during online searches (Davis & Shaw, 1989). The researchers describe this methodology as "unobtrusive" for obtaining empirically based data for the sake of making comparisons among different alternatives. By tallying the number of errors that occur while typing words into search engines, the most effective alternative could be found by its association with the lowest count of errors. In this way, the qualitatively different alternatives can be compared in a numeric fashion.

It is argued by (McCammon & Hageli, 2007) that, through the use of a tallying heuristic, accidents involving avalanches can be avoided by counting the number of cues present on a given slope. This heuristic is known as the obvious clues method. In this sense, by accumulating the different qualitative factors from a list compiled by the researchers, one may be able to deem a slope safe or prone to an avalanche and therefore dangerous. Such differing alternatives include whether there was an avalanche in the past 48 hours, whether there is liquid water present on the snow surface due to sudden warming temperatures, and/or collapsing, cracking, and/or hollow sounds in the snow. This research is beneficial and useful for hikers and skiers who would need to know when avalanches could occur.

Another example is the work put forward by (Kim, 2008). In the field of socio-political history, tallying is applied to correspondence among parties with respect to specific and particular subjects under discussion for the ultimate goal of comparing cases selected from differing socio-political contexts. Trends and patterns are uncovered with the use of the demonstrated methodology, with the ultimate goal of identifying the patterns of sustainable national growth, based on implemented state policies. The aim, based on the tallying of correspondence items related to specific subjects, is to compare different state policies by their effectiveness.

In a simpler context, for quantifying the importance of each consideration for arguments where pros and cons are put forward for decision making, tallying is deemed the most appropriate method by which to come to a decision against several other options (Bonnefon et al., 2008). This finding is based on the definition of eight different heuristics for balancing pros against cons.

Kattah et al. (2009) discuss the applications and benefits of heuristics in the field of medicine. Within this discussion is the mention of the tallying heuristic being represented in a three-step bedside exam. The test consists of three parts, a head-impulse test, an observation for the presence of nystagmus, and an ocular alignment test, or test-of-skew. If even one of the three parts in this test confirms a positive indication of a stroke, it is flagged. Because all predictors, as part of the tallying heuristic's nature, are treated equally, this exam yields a large enough sensitivity to make the exam beneficial. 101 patients with acute vestibular syndrome (AVS) were examined using this bedside exam, which was found to be 96% sensitive for indicating strokes. For two-thirds of the patients, the head-impulse test falsely suggested peripheral localization. The test-of-skew test was reported to correctly predict that these same two-thirds had suffered strokes. It is found by the researchers that the test-of-skew can predict which patients with AVS have suffered strokes when the head-impulse test falsely suggests a peripheral lesion. The three-step bedside exam reportedly appears more sensitive for determining strokes than the use of MRIs for patients with AVS. Given its sensitivity, the tallying rule of the exam correctly detected 100% of the patients who had actually suffered a stroke.

Similarly, this simple heuristic is found to be more useful than more complex counterparts in the field of project management with regard to project screening. The following study by Albar & Jetter (2013) involves the use of different heuristics in the selection of sample projects in the early screening stages of the selection process. A sample dataset of 52 projects is used in their research. The tallying heuristic is compared against other counterparts, including take-the-best and elimination-by-aspect heuristics. The tallying heuristic is found to have the highest accuracy (80%)

for predicting winning projects, and is 70% accurate for predicting which projects are bad ideas. The researchers assert that the tallying heuristic is the best choice among the heuristics under comparison.

In the world of human resources, based on previously conducted surveys, a study was carried out to examine how employees are selected based on trust according to hypothetical situations (Hu & Wang, 2014). The surveys previously conducted identified the different alternatives to trustworthiness that could be selected as most significant in the subsequent studies. Besides demonstrating the tally heuristic's application in this field, the observations made by from Hu & Wang (2014) are useful to the research presented in this thesis and its application is explained in the following chapter.

A final example of how tallying can be used to compare qualitatively different items in terms of numerical rank and priority is presented by Tasker (2017). In the story covering the Prime Minister's town hall tour across Canada, a variety of questions were asked by the attendees, who totalled at least 10,000 over the entire tour. The questions are categorized based on the social issue to which they pertain. Of the questions fielded by the Prime Minister, the majority focused on the following issues, in descending order: the country's economy; Indigenous affairs; personal questions about the Prime Minister; Canada's stance on immigration; and the country's role in the global effort to stem the tide of climate change. The questions, based on their categories, were tallied to determine frequency, with the categories with the highest frequency assigned the highest priority. For example, the country's economy was the predominant subject of the questions fielded by Trudeau. Therefore, by that tally, because it is a concern for most of the people in attendence, it is deemed the highest priority.

2.6 Conclusion

Libraries provide numerous benefits, including mental wellness. Preserving space within libraries for the users may help students learn and study more effectively. However, the libraries must be designed to appropriately and properly accommodate users. The importance of the students' well-being must be considered when designing new or renovating existing libraries. Libraries can be designed to meet program needs for storing reference materials, accommodate for seating and studying, and even provide various amenities. But, the motivation behind such designs is for the benefit of the users, in this case: students. They must be provided not only the space and support derived from the building and its services, but the comfort from its indoor environment, in order to be studious and productive. However, the challenge in this regard is that limited information exists that directly corresponds to this condition. Insufficient data is available that directly discusses the importance of the academic library's interior environment for the sake of the well-being of students. To surmount this obstacle, a plethora of data involving library interiors is gathered. Subsequently, to reach conclusive findings on the abilities of the interior environment to promote health, comfort, and learning, this data needs to be organized. Organizing the gathered sources is performed via the tallying heuristic by segregating the sources according to the indoor environmental factors and architectural features that they mention. Furthermore, these segregations are structured by means of a tree diagram, for both establishing relationships among the segregated groups and their breakdowns, as well as visualizing them. In this way, conclusive findings can identify how the academic library's indoor environment could be made comfortable in the sense that students are productive in their learning activities (Chen, 2010). The aim of this study is to assess what features significantly affect students' ability to concentrate and study within library buildings, and to what degree.

3 METHODOLOGY

3.1 Introduction

This chapter explains in detail the methodology proposed in this research. It involves the cyclical process of gathering sources of information, identifying pertinent indoor environmental factors and/or architectural features from those sources, followed by organizing those factors and features based on how often they are mentioned in the gathered sources. As stated in the research assumption in the first chapter, it is believed that the more often a factor and/or feature is/are referenced in the scientific literature, the greater the probable significance of that factor and/or feature. The significance, and the derived effectiveness, of each factor and feature is based on the number of sources from the scientific literature that make reference to them.

It is important to disclose some of the limitations of this methodology. One such limitation is the decision to use values instead of ranges, with regard to the application of the proposed model to a case study. Further in this chapter, which environmental factors and which architectural features are significant, and to what extent, will be described. That is, to what measurable extent do these factors and features support a study space as being conducive for studying? This question is answered through the development of percentages for each of the features for each of the factors identified as most significant and most directly related to the architectural design of libraries. However, these percentages, for each architectural feature, are developed and given as values, rather than range intervals. The reason for this is the approach used consistently throughout the development of the methodology, which is based on the value number of gathered sources that identify pertinent environmental factors, and the value number of sources that identify architectural features related to those factors. From this primary breakdown of factors into features, fractions are created, which are still based on the values related to the number of sources gathered and identify one or more significant elements related to library design. The approach of using values rather than range intervals has been consistently applied across the proposed model.

Another limitation is the lack of measurement, or magnitude, involved. Because of the various backgrounds of the gathered sources, it is necessary to develop and maintain a consistency throughout the proposed model. This consistency facilitates the ability to gather all the various sources of information from the scientific literature that discuss how to design libraries in a manner centered around students to make them more productive in their learning activities. While *some* of the gathered sources may make reference to the particular size of an architectural feature or to what measurable extent an indoor environmental factor is being utilized or enhanced, this is not the case for *all* of the gathered sources. Therefore, for the sake of consistency, magnitude is not considered in this thesis, because it cannot be applied for all of the gathered sources. In the proponent presented in this thesis, from the sources gathered, it is only confirmed whether or not a particular factor or feature is being implemented in order to be able to gather all the available sources of information that discuss the designs of libraries.

These information sources are gathered only if they discuss in some detail the renovations and/or retrofits implemented in libraries. Based on their discussions, factors and/or corresponding features are identified. The tallying heuristic is implemented in order to prioritize which factors and features should be considered first, then second, and so on. The figure below illustrates the steps performed, the first of which is collecting data.

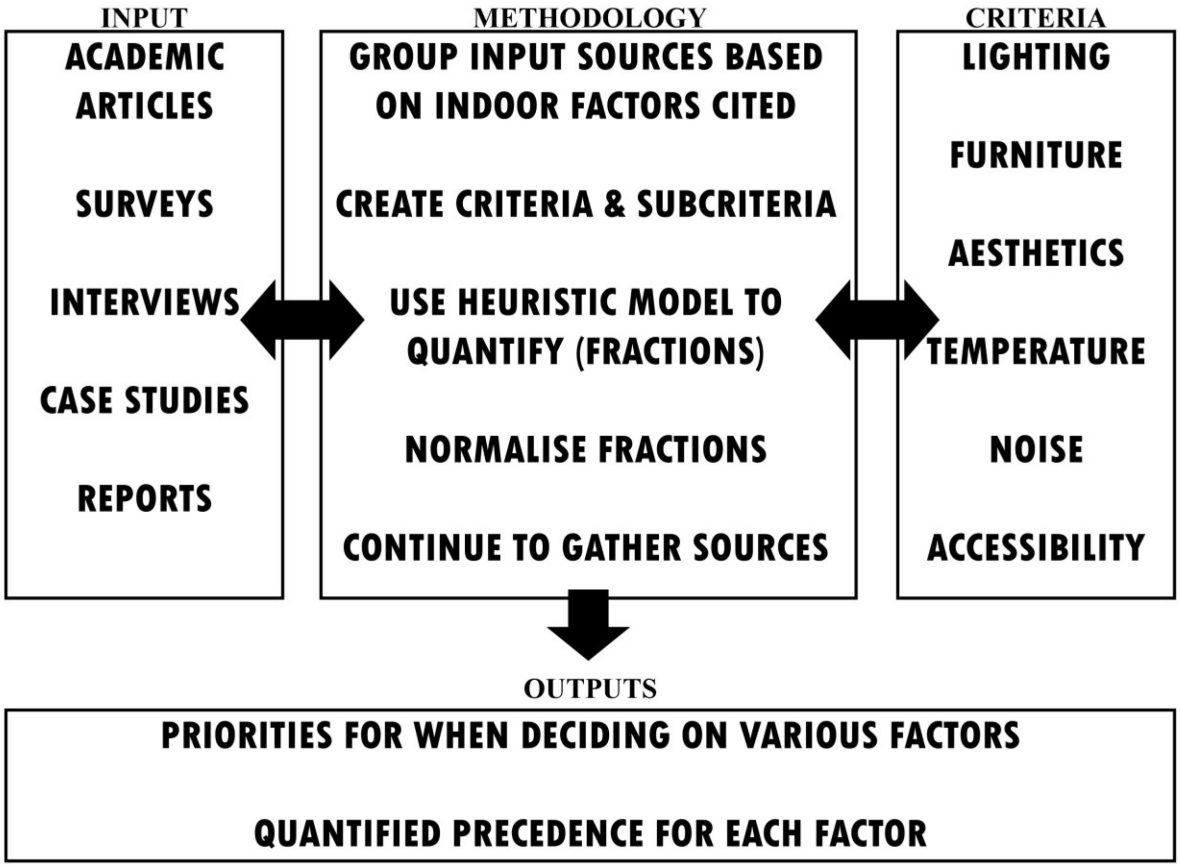

Figure 2: Research methodology

The premise for this model is that architectural features, differing by their respective indoor environmental factors, can be evaluated and compared against one another numerically. Included in this premise is the notion that these architectural features can be measured for their respective contributions toward the effectiveness of the interior environment they comprise: in other words, contributions that make the interior environment conducive to studying. Their comparison is carried out to determine which features have significant influence on the abilities of students to study and perform learning activities.

As part of the methodology, certain terms described in this thesis are represented by abbreviations. The indoor environmental factors are represented by their corresponding first letters; for example, the factor "lighting" is represented by the variable L. The first class of subdivisions from such factors are the "specific details" (*D*) and "no details" (*N*) counterparts. These are represented by the same variable for the "lighting" factor, but now as a subscript to the first degree; so that "lighting" with regard to "specific details" is represented by the variable D_L. Representation of the sub-factors follows the same principle as that of the factors in that variables take the first letter of each sub-factor. In the case of "natural lighting", *N* is used, but with the first degree subscript *D* and *L* now acting as a second degree subscript, so that N_{D_L} is the variable for "natural lighting". The use of these subscripts is to ensure that each factor and sub-factor can be identified by their first letter without the risk of confusion based on the use of letters. The use of these variables is described in more detail further in this chapter, and illustrated in Figure 5.

Quantitative comparison of the different architectural features is carried out via tallying, or counting the number of times one alternative is favoured over another. It is simply computing a score for each alternative by counting the number of positive cues for that alternative (Dawes, 1979). This technique is applied within the presented research because of its frequent appearance in literature on decision heuristics (Bonnefon et al., 2008). Heuristics have been known to be used in decision making by both individuals and organizations, for the specific reason that they can be more accurate than more complex strategies, despite the fact that they process less information

(Gigerenzer & Gaissmaier, 2011). One of their benefits is that, when making a judgment, using heuristics saves effort. Humans are reliant upon heuristics given that gathering and processing information requires considerable time and effort, and this trade-off, although resulting in some loss in accuracy (Shah & Oppenheimer, 2008), provides faster and more frugal cognition. However, the accuracy-effort trade-off is only *considered* a law of cognition; the effort-accuracy trade-offs associated with tallying and similar heuristic models (Evans & Over, 2010) are not always implied, potentially leading to more opportunities for its use in decision making (Marewski et al., 2010). The heuristic function can be applied to compare cases that differ qualitatively and even by context (Kim, 2008), as is the case in the research presented in this thesis.

Tallying is "arguably a privileged format for natural sampling"(Hu & Wang, 2014). Since it provides equally weighted counts for a set of alternatives, it is simplified and can be successfully applied to a wide range of decision situations; furthermore, it provides a means by which to examine the indoor environment without needing to search for, acquire, or process a large amount of information. Complex strategies for gathering and sorting such information are unnecessary, and, within the specific context of students visiting and studying in libraries, allows for the gathering of numerous (and various) sources of information to examine the indoor environment and a number of differing factors.

3.2 Gathering of the Sources

When gathering information sources, a number of broad terms are entered into search databases, including "renovations", "retrofits", and "libraries". This is the first challenge to overcome with regard to understanding how to design a library and implement architectural features that are centered around the users, in this case, university students, because “Collecting information from our own research, or from literature searches, will take time and effort; however, it may be the only way to effectively grow the role of the academic library” (Lindahl, 2014). In order to obtain more knowledge into this practice, other terms are entered with respect to specific indoor environmental factors such as “lighting”, “furniture”, “ergonomics”, “acoustics”, and “color” as well as “colour”. Interestingly, additional sources are obtained merely by changing the spelling of the word “color” to “colour”, understandably so, based on the regions of certain search engines (e.g., USA, Canada, UK). This can also apply to some other terms entered in these search engines based on their regional spelling. Central to entering these terms and their synonyms is the aim to answer the research question, “What physical indoor environmental factors affect students’ abilities to study in libraries?” Sources are gathered, after entering several broad and more specific terms, with the goal of cumulating information in order to answer the research hypothesis.

The first step in this section is to gather articles and other sources of information that specifically examine library renovations and study the resulting effects on students visiting and studying within them. Articles that are found to be pertinent to the terms mentioned in the paragraph above are retained for further steps described in this chapter. This is the first step in order to gain an understanding of the practice of renovating and retrofitting libraries; specifically, to determine the most common parts of the building that undergo repairs and changes, and if the renovations are found to be satisfactory or even acceptable by the occupants. Answering these questions requires accessing numerous information sources, including interviews, newsletters, academic articles, research case studies, and reports. Among these sources, what is examined is whether the physical indoor environment is addressed. That is, whether the indoor environmental factors are addressed. If not, the sources are disregarded. However, if affirmative, the sources are retained for categorizing and organizing in the later steps of this model's methodology.

Creating, conducting, and gathering results from a survey is considered. However, it is deemed to yield fewer results than conducting the research based on evidence. This is specifically due to a number of serious pitfalls in conducting surveys, which include: the design, structure, and complexity of the surveys and/or their techniques (Belson, 1977); non-respondents (Fricker & Schonlau, 2002); interpreting and/or processing the survey results (Chang & Vowles, 2013); and the quality of the data that is gathered, including online surveys in particular (Pecakova, 2016). Specifically, the pitfall of non-respondents puts forward the question of how many participants can be relied upon. Thus, it is decided that the data gathered be based on design standards, previous case studies, and experience.

Conducting interviews is also considered. Conducting a semi-structured interview allows for the identification of the structure of the interview to be a potential pitfall (Harvey-Jordan & Long, 2001), as well as the attention, or lack thereof, to the research process prior to, during, and following the interview. Similar to relying on participants when conducting surveys, there is a certain reliance on an interviewee's use of language when it comes to interviews. A lack of cognizance with regard to this is a serious pitfall in this mode of research. Another pitfall is asking a "why" question. The interviewee could potentially feel threatened by such a question because of the request for a justification. Besides being careful in this manner, the interviewer must also avoid inserting information into a person's mind, that is, giving or implying responses or answers. These are just a few of the potential technical pitfalls that could arise from conducting interviews to gather research (Dana & Dana, 1992); more are identified by Johnson (1976). Furthermore, the necessary paperwork involved in conducting interviews may allow for inconsistencies in the gathered data, because of assumptions that researchers may be forced to make due to unanswered questions (Shepherd & Stuart, 2001). Based on these considerations, the method to gather data in this study is based on the best available evidence, scientific literature, and previously conducted research and case studies.

As such, some gathered sources report findings on those indoor environmental factors and architectural features of the library that have significant effects on occupants, such as lighting and spatial planning (Shill & Tonner, 2004). Another influence is the insufficiencies some libraries confront, such as a lack of available space or a crowded environment (DeClercq & Cranz, 2014). A plethora of information that describes the various influential aspects of the indoor environment of libraries on occupants is presented in subsequent sections of this thesis. It must be noted that some of the studies conducted in this case only acknowledge broad terms, such as lighting, and do not further elaborate on how this feature is addressed in the physical space. Some sources fail to elaborate on how these indoor environmental factors are addressed by not translating them into specific implemented interior architectural features. In order to obtain more information and discover what specific courses of action could be taken with regard to such interior features, further review of literature is necessary. The step for gathering sources of information is repeated, entering alternate terms into databases and search engines. These terms include those listed earlier in this chapter, as well as other synonyms and terms related to library buildings in general. Such terms include “libraries”, “mental health”, “library renovations”, “library retrofits”, “library acoustics”. Other results can be gathered by entering combinations of terms into search engines, for example, “libraries + mental health”, and “libraries + renovations”. The purpose for repeating this step as many times as is deemed necessary is to overcome the shortcomings of insufficient data on specific courses of action to take.

3.3 Establishment of the Factors, Sub-factors, and Architectural Features

Finally, the issue of how to identify the particular features of the library’s physical space is addressed. The question of which features take priority, and how these priorities are assigned will be explored. From the gathered sources (see Appendix A), priorities are given to architectural features on a case-by-case basis. That is, priorities are dependent upon each individual facility and source of information. This causes difficulty in decision making because of the perception that no trend or pattern exists to identify the parts of the library’s physical space that should be acknowledged above others. Although it is acknowledged that the physical space is an important design aspect for the comfort of the users, a method for designing libraries in such a way that they become conducive to learning remains to be determined.

Currently, no metrics exist for assessing the design of spaces conducive to studying. The design is approved according to the owner’s preferences. It is typically only after the library is built that research is carried out to discover which indoor environmental factors, that initially were not considered prior to construction, are in fact significant to the facility’s purpose. Even with this post-occupancy approach to studying library usage, the gathered research is based on qualitative methods, such as interviews or surveys. Such data that is collected by means of qualitative research methods can be difficult to wield because it does not support the measurement of the effects of an indoor environment on its occupants such that the measurement is exact or even sufficiently accurate. This is because of the common features in which numerical formats and systems of measurement are less employed in interviews and surveys than text and terminology. In other words, few sources exist that use quantitative methods in identifying specific factors of a library's physical space or evaluating their significance in a quantitative manner.

Certain sources do report the significance of specific indoor environmental factors, but only in a *relative* manner, in comparison to other factors, but this is disclosed typically with descriptive text rather than in numerical formats. Furthermore, it should be noted that this is applied in a case-by-case context, and not all of the sources necessarily report such findings. As sources are gathered, specific indoor environmental factors are identified and listed. Accordingly, a method to measure their importance is developed.

Since no previous studies are found that outline a method of assessing a factor's importance in the context of this research, an assumption is made: any source that mentions a specific factor counts as a point, indicating the importance of that factor for consideration when designing a conducive study space for students. In other words, if a source cites a factor, such as "lighting", then that factor receives one supporting vote. If another source also cites "lighting", the factor ("lighting") then receives two supporting votes for being most important to consider. This is applied to every factor mentioned as sources are gathered and reviewed and is the basis for the development of the proposed method, which is explained in detail below.

In this step, once all the sources are gathered, or as the number of sources continues to grow, categories, as well as subsequent divisions, are established. These categories are based on the indoor environmental factors that affect users. As more sources are gathered, more categories are identified. From these, subcategories and architectural features are, consequently, also established. These divisions and subdivisions are established using the primary formula

$$a = \frac{b}{c} \tag{1}$$

where a is the formula for the branch divisions; and b is the total number of times a subcategory is mentioned within the greater category, c, which is the total number of times the category is cited. This formula is first applied to create categories based on the primary indoor environmental factors mentioned in the gathered sources (i.e., lighting, temperature, noise, etc.). Accordingly, this formula is used as the steps are repeated for breaking the divisions into subdivisions, such as lighting into artificial and natural subdivisions, as illustrated in Figure 3.

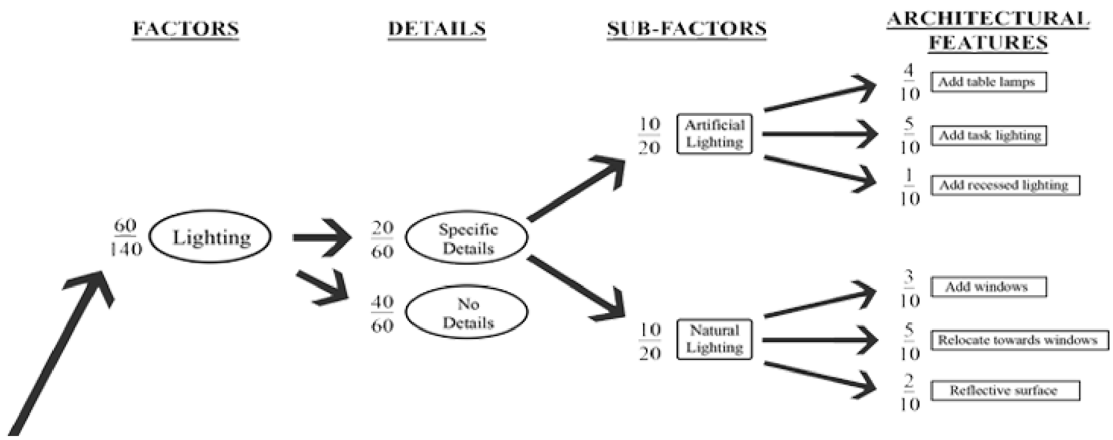

Figure 3: Partial illustration of the tree of the research model

The factors and architectural features are established based on their mention in the sources of gathered information. In Figure 3, the two inner columns of branches are artificially constructed to develop the model. The first column of breakdowns, regarding "specific details" and "no details" identifies whether or not the sources that cite a specific factor actually go on to propose architectural features. If they do, then there is a resulting breakdown of the indoor environmental factors into sub-factors, which function to group the architectural features according to what portion of the indoor environment they address. For example, the only two types of lighting that are utilized in libraries are natural lighting, such as windows and skylights, and artificial lighting, including various electrical fixtures. Likewise with furniture, the two basic types used in libraries are tables and chairs, with variations of these two types mentioned in a number of the gathered sources. Finally, the sub-factors of aesthetics are identified according to which component of the indoor environment they address, such as the floor, walls, and/or ceiling, which intends to maintain consistent groupings of the factors, their sub-factors, and their architectural features for the sake of their relationships with one another, as illustrated in Figure 3.

3.4 Visualization of Relationships

Once the categories, subcategories, and design features are all identified and counted, the next step is to enter them into a relationship with one another. As more sources are gathered, the appendices listing them grow, forming groups and categories. Using the appendices, it is possible to see the relationships among the categories and their subsequent subcategories, and subsequent architectural features. However, using the appendices to do so requires considerable mental effort from the user. This is because the visualization of the information is limited in the table format; images are not utilized to convey information. Images, such as diagrams, charts, and/or pictures can convey knowledge much more effectively than text, tables, and appendices. Also, visualization allows a person to understand and convey knowledge more easily (Burkhard, 2004). This is due to the picture superiority effect, or specifically, the phenomenon in which images are more likely to be remembered than text (McBride & Dosher, 2002). An alternative way of visualizing these relationships is through a tree diagram, as presented in Figures 3 and 4. From left to right, more branches are added as the factors are broken down into sub-factors, and the sub-factors into architectural features. The breakdowns underscore the groupings already established in the appendices. This diagram, based on the appendices, also begins to illustrate the assessment method.

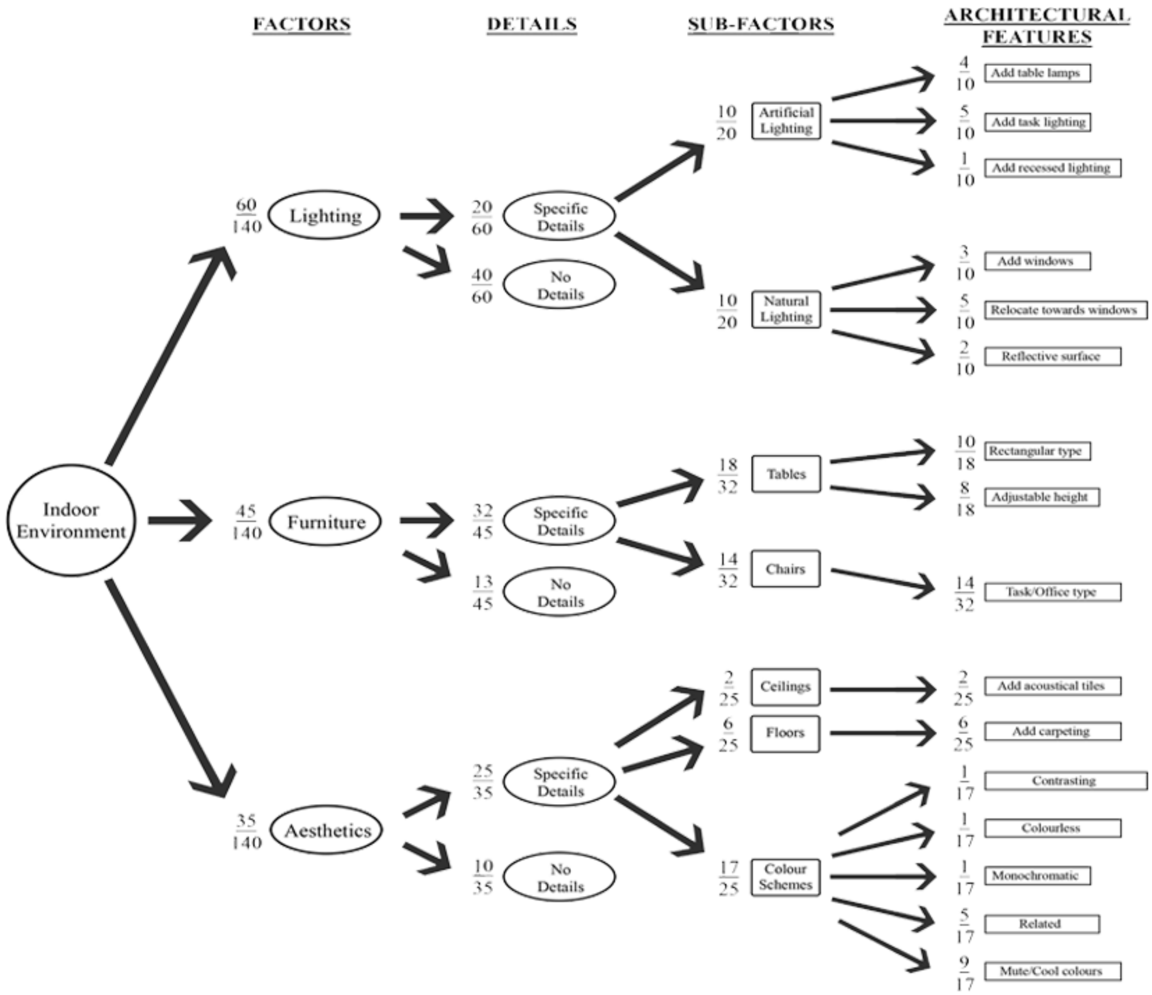

Figure 4: Tree diagram of the research model

As presented in Figure 4, the breakdowns are illustrated as mentioned in the previous paragraph. In the development of this research, an alternative formation of the tree was considered: that the third column of sub-factors would be disregarded and the architectural features would stem directly from their respective "specific details" branches; however, this alternative was not selected because the architectural features must be grouped according to their area of focus on the indoor environment. For instance, it was considered appropriate to segregate the architectural features involving lighting based on which of the two lighting types they belonged to: artificial or natural lighting. However, based on the research findings from Hu & Wang (2014) and Gigerenzer & Gaissmaier (2011), there is a specific purpose for constructing the tree model as it is presented in this thesis (Figure 4). The tallying heuristic counts how often a set of minimal conditions and requirements are met rather than an optimal number of times those conditions need to be met. When the number of requirements is minimal, the heuristic performs better than with an optimal count. It is noted that this tallying heuristic performs best when the number of requirements is small (Hu & Wang, 2014). Based on this finding, it was deemed to not be the most appropriate course to have the architectural features stem directly from their respective indoor environmental factors. Because of the number of features, the number of alternatives to choose from would be too great for the tallying heuristic to be implemented effectively. Thus, it is deemed necessary to keep the number of alternatives stemming from each preceding branch small wherever possible. Therefore, the two subdivisions, regarding "specific details" and sub-factor branches, are created and installed in the tree diagram, as presented in Figure 4.

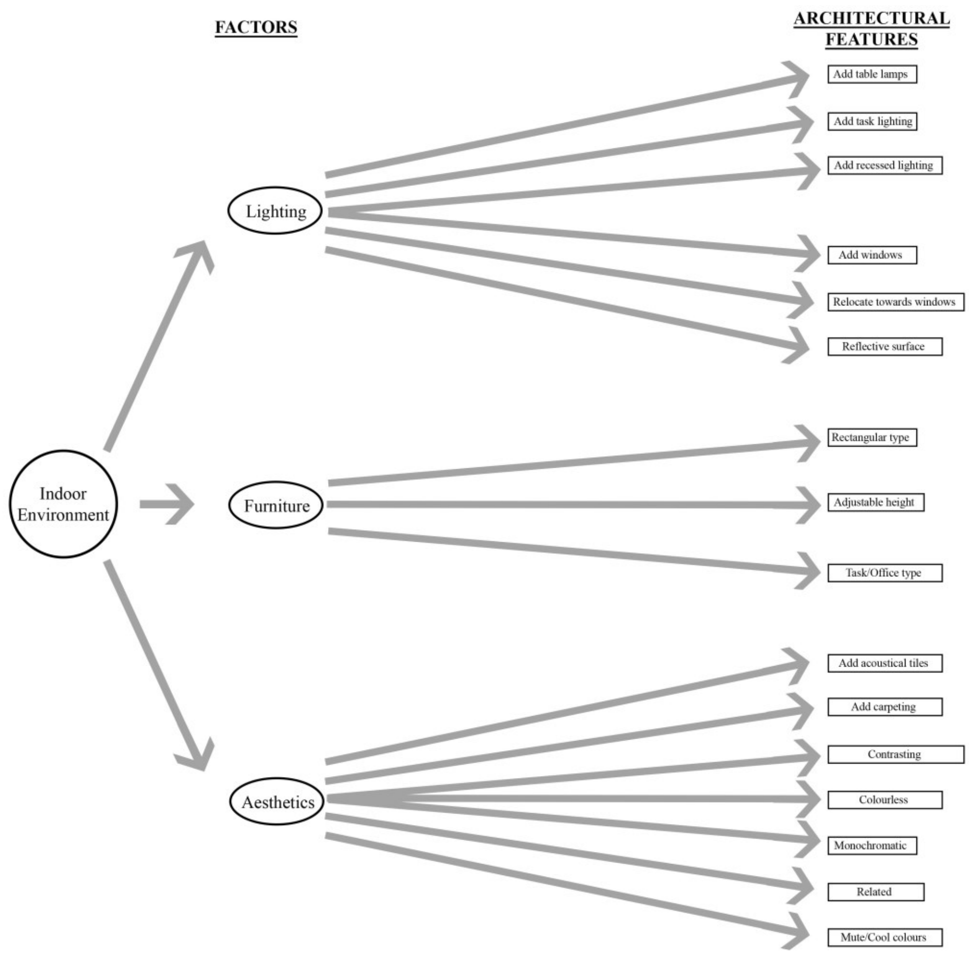

Figure 5: Alternative tree structure

An additional reason for using the tree diagram presented in Figure 4, versus the alternative in Figure 5, is to avoid a greater conflict of selecting architectural features. In specific terms, the intent is to avoid having to select fewer architectural features, one for every indoor environmental factor instead of more than one per factor, to implement for an indoor environment conducive to studying. This elimination of features is explained in more detail in subsequent sections of this chapter. But the reason, with regard to this elimination of features, for considering one tree diagram over another is that one allows for more features to be implemented than the other. This is significant because certain features cannot be installed at the same time as others. If the model presented in Figure 5 were that which is being proposed in this thesis, there would be fewer architectural features identified as significant. For example, only one architectural feature with regard to lighting could be selected, even though both windows and lighting fixtures are commonly used in libraries. The rules for eliminating architectural features in this model, according to the model illustrated in Figure 5, are inconsistent with the real-world practices for renovating libraries. Therefore, Figure 4 is determined to be more appropriate and is the basis of the format of the model presented in this thesis.

In regard to the breakdowns of the different factors, there is a division, or distribution, where a portion of a certain factor's counts are either put into one subcategory, or that of the other counterpart. Tree diagram branches represent a visual relationship between the categories and subcategories. Fractions create a numerical relationship between these categories. It is essential to be able to evaluate and numerically rate the specific design features being proposed and listed. These fractions are identified in Figure 4, and to a lesser extent in Appendices A and B. This is the case for the subcategories and their respective design features, but is not the case for the primary factors. Given that there is not a clear division among the numerators for the factors, their sum is greater than the common denominator. Therefore, to maintain consistency in the model, these fractions need to be normalized; this step is described in the following section.

3.5 Normalization of Categories

Normalization preludes verification of the model, which is outlined in the next step, for a specific reason. The fractions in the first column, the factors column, need to be normalized, unlike the fractions in the latter branches. While the latter branches are all ultimately divided from their main factors' numerators, those particular numerators, for the main factors, need to be normalized. Because of the sharing of sources among the factors, the sum of the numerators for each fraction of each factor would total more than the common denominator. In other words, the sum of the fractions for all three factors would be greater than 1. This can be observed in Figure 7. The fractions for the primary factors are not clearly divided like those of the features, because two or more of those factors are cited in the gathered sources. These fractions, as well as those for the latter branches, must sum exactly 1 to maintain consistency across the entire model for dividing the factors into sub-factors and those sub-factors into architectural features, all according to their tallies. The importance involves the relative frequency of the specific factors and specific architectural features with respect to their counterparts. To normalize the factors, the following formula is applied:

$$f_X = \frac{N_X}{\sum_{Y \in A} N_Y} \quad \textbf{(2)}$$

where f_X is the fraction associated with the attribute X (which in this work is an element of the set $= \{Light, Furniture, Aesthetic\}$), and N_X is the total number of times attribute X is mentioned in the gathered sources.

The factors are embodied in the first column of branches because they are the indoor environmental factors being mentioned in the sources of information. They are only divided into sub-factors, and then environmental features, on the condition that those literary sources include details about renovating and redesigning libraries. As stated earlier in this chapter, these breakdowns occur by introducing the “details” and sub-factor breakdowns from the indoor environmental factors. In addition to the condition of being specific, some sources identify more than one factor as being significant for consideration in design. For example, some of the sources gathered cite lighting as well as aesthetics as significant indoor environmental factors, while other sources identify aesthetics and furniture as significant factors. Some sources even mention all three of the factors presented in Figure 4.

The normalized values can be observed in Table 1 further in this chapter. The number of mentions for each respective factor become the new numerators, and the sum of all three of the numerators is the new denominator. As previously stated, normalization is a prerequisite because of the sharing of factors among the gathered sources. With the normalized values established, the next step is to validate the model.

3.6 Confirmation of the Model

It is necessary to perform this step to ensure that the model functions properly. To verify that the model functions properly, the fractions for each tree branch must be added together corresponding to the columns they are in, and according to which branch they directly stem from, as presented in Figure 7. The sum of the fractions in each column of branches must add up to 1 for the model to function. This rule ensures that the fractions are consistent with one another and with their further breakdowns. The consistency is based on the clear division of counts from the gathered sources for the indoor environmental factors, their sub-factors, and their architectural features. These breakdowns represent the relationships among the factors, their sub-factors, and their architectural features, corresponding to the preferences inferred from the literature on library renovations.

The fractions within each column of branches are added together. This is illustrated in Figure 7. Within the “details”, “sub-factors”, and “architectural features” columns, respectively, the fractions that share common root branches are added together. In order to ensure a clear division of counts from the gathered sources, their sums must add up to 1. This is performed with the following equation:

$$P(Add|a, b, c \ldots) = 1 \quad \textbf{(3)}$$

where P is the conditional frequency formula for each respective breakdown of branches, whose fractions must sum up to 1; and a, b, and c are the fractions for the branches sharing a common root being added together, with additional fractions added as necessary, depending on if there are more than two divisions. The basis for using these formulas is that the breakdowns of the fractions are tied to the rules of conditional probability. In the case of the present research, it is the basis of conditional frequency. This formula is applied for every branch from which two or more branches stem. If the sum of the fractions of the branches sharing a common root branch add up to 1, and this is consistent across every division within the “details”, “sub-factors”, and “architectural features” columns, then the model being presented is validated.

This encompassing formula is applied to every variable within Figures 6 and 7. Figure 6 presents the variables, representing their respective indoor environmental factors, sub-factors, and architectural features. Figure 7 illustrates the application of Equation 3 for the purpose of validating the presented model. The fraction is repeatedly used to ensure that each of the breakdowns, with respect to their common root branches, all add up to and equal 1. The variables are the sums of their breakdowns. Figure 6 is presented to illustrate this function. The first letters from each indoor environmental factor are used to represent them: L for "lighting"; F for "furniture"; and A for "aesthetics". After establishing the variables for the indoor environmental factors, it is necessary to introduce subscripts, as linguistic terms, for representing as well as maintaining consistency among the variables as they are broken down. The following column of breakdowns presented in Figure 6 is converted from variables into subscripts, which subsequently are applied to the variables *D* for "specific details" and *N* for "no details" for each of the indoor environmental factors. For instance, a tally for the portion of gathered sources that mention architectural features under "lighting" would be represented by the variable D_L. In this case L becomes the subscript for the variable D to represent the number of sources that mention architectural features with respect to lighting. The final subdivision involves the sub-factors, and the conversion of variables to subscripts is repeated. Like with the indoor environmental factors, the first letter for each sub-factor represents each one, respectively. For example, A represents artificial lighting and N represents natural lighting under "lighting". Their respective representations are written as A_{D_L} and N_{D_L}. The variable for lighting is now a subscript for the variable for sources that cite corresponding architectural features, which becomes a subscript for the sub-factor variables A and N. This is applied to every sub-factor division for every indoor environmental factor.

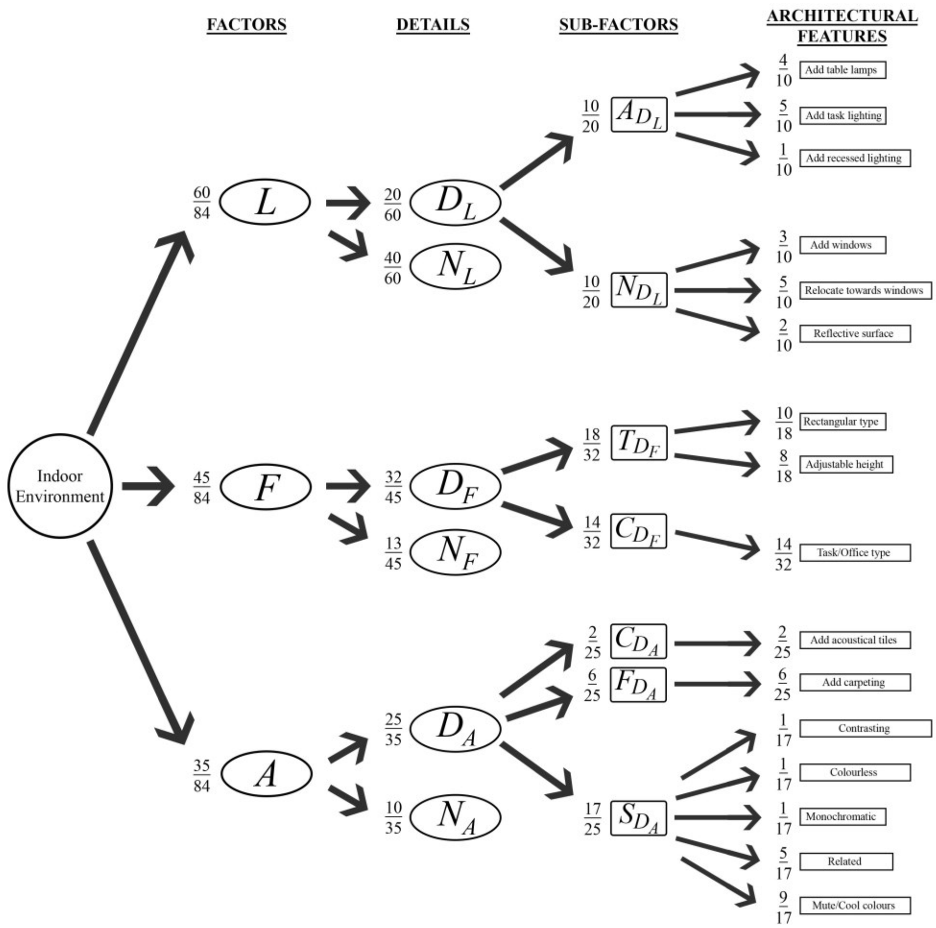

Figure 6: Tree model with variables, first- and second-degree subscripts, representing the factors and their breakdowns

With the variables accounted for, the last step in the validation process is to add them together based on their common root. Using Equation 3, the model presented in Figures 4, 6, and 7 is validated. This validation is illustrated in Figure 7. As an example, the validation for the indoor environment "lighting" is performed by the formatted formula

$$P(Add|D_L, N_L) = 1 \qquad \textbf{(4)}$$

where the fraction for the total number of times "lighting" is mentioned in all the gathered sources is based on the sum of the portion of gathered sources that cite "lighting" as a significant indoor environmental factor and include architectural features, and the count for the gathered sources that cite "lighting" as significant but do not mention any architectural features whatsoever.

Similar to this breakdown within the model, this formula is formatted and applied to later breakdowns. With regard to the "details" division under "lighting", the validation is performed using the same formula, reformatted as

$$P\left(Add|A_{D_L}, N_{D_L}\right) = 1 \quad \textbf{(5)}$$

where the variable for the tally from the gathered sources for "lighting", according to the mention of architectural features, is based on the sum of the two portions that either cite architectural features under the "artificial lighting" sub-factor or the "natural lighting" counterpart.

If the condition is met that the final sum equals 1, then the model, with respect to that particular breakdown, is validated. This formula is formatted and re-entered for every breakdown within the model to ensure that the entire model is validated.

Once each column of branches has been validated, with their sums equal to 1, then each branch path is multiplied separately. Multiplication of the fractions along each respective branch path is performed using the following conditional frequency formula:

$$P(factor\ \cap detail\ \cap sub - factor\ \cap feature) = x \quad \textbf{(6)}$$

where x is the final score for multiplying the fractions for the *factor*, *detail*, *sub-factor*, and *features* included along the branch path. This formula can be reformatted if the branch path, starting from the factor, does not reach to the other end to the architectural feature. In such an event, the formula is reformatted:

$$P(factor \ \cap detail \ \cap sub - factor\ ) = x \quad \textbf{(7)}$$

Similarly, the formula can be reformatted even further when the branch path, entering the “no details” branch, does not reach the “sub-factors” column:

$$P(factor \ \cap detail) = x \quad \textbf{(8)}$$

For the paths that lead to architectural features, these multiplied values become the scores for each feature. With respect to their factors, the architectural features’ values are combined with the final value from the “no details” branch. If the final sum is equal to 1, that respective portion of the tree model is validated. This step is repeated for the other portions of the tree stemming from the branches of the other two factors. For example, as expressed in Table 1, the values under the “normalized” column are summed; if the sum is equal to 1, the model is validated thus far. Stemming from any one of the factors after the “normalized” column, the fractions for the “details” and “no details” branches are added together. If the total sum is equal to 1, the model is still validated. Similarly, this applies to the later sub-factors, their features, and sub-features. For instance, the sub-factors for “lighting” are added together *exclusively*, and not with the fractions for the sub-factors of other factors. This is because they do not all share the same root branch directly.

If the checking and verification of the model is accomplished, then the model is proven to work. If the sum does not equal 1, an error exists and must be corrected. In developing this model, the most significant challenge is placing fractions within appropriate columns, because certain branches extend further than others, as indicated in the tree diagram in Figure 4. For example, from the factor "lighting", there are two branches: (1) "specific details", for which sources specify according to the factor; and (2) "no details", in which sources mention a factor, but do not reference any architectural features being implemented. From the former branch, additional branch paths stem. In contrast, from the latter branch, there are no further branch paths. Multiplying the fractions along each branch path separately, the final values are added.

Once the fractions for each branch have been established, each specific building feature can be scored. This is carried out by multiplying the fractions along the path leading to each individual feature. The final value is the number assigned to its respective architectural feature. The multiplied values for each architectural feature embody the means by which the features, differing by their encompassing factors, can be compared against one another for preference in a *numeric* fashion. Each option and its number is represented in Table 1. Repeating this for each feature, the sum of these values, including the values from paths with fewer branches, should equal 1. This is to ensure that the model is validated.

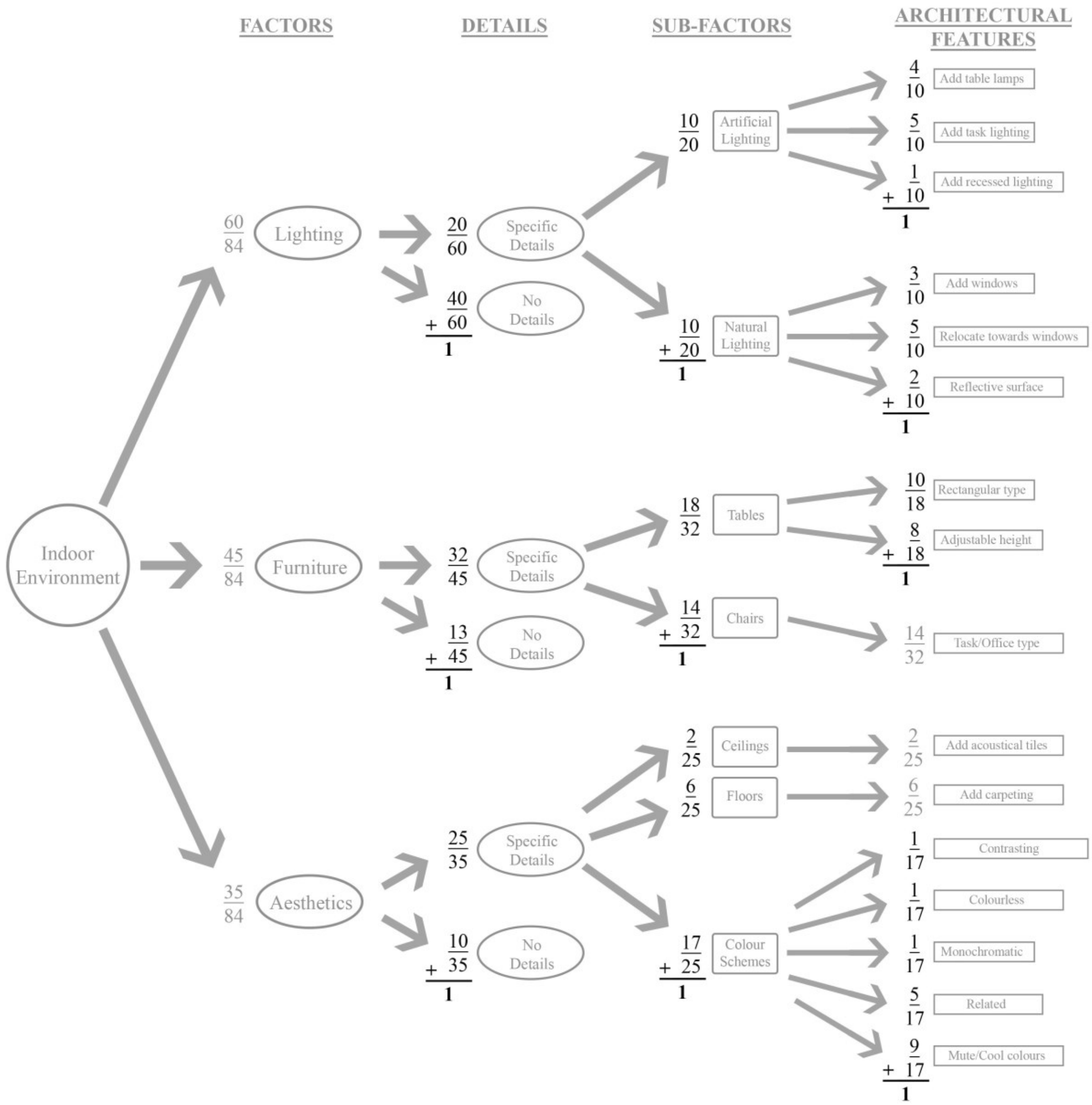

Figure 7: Summing the fractions to validate the model

3.7 Hierarchical Sorting of the Options

Once a score has been given to each of the architectural features, the next step is to organize and rank them according to their final numerical values. All the architectural features are listed and hierarchically ranked as observed in Table 2. They are sorted by these values from highest to lowest; the higher the score, the more often a feature is mentioned, thus the more significant it is considered. In this way, it can be determined which specific features are recommended more often than others. Because their numeric scores are derived from multiplying the fractions along each tree branch, the various architectural features, differing by context and indoor environmental factor, can be compared. This is merely a comparison for the sake of understanding which architectural features are preferred over others. It must be stressed that the scores for the features listed in Table 2 do not measure each feature's contributions toward making a space conducive to studying. That step is performed following the completion of this step.

It is necessary to note that the items listed under the "details" heading are only input into Table 1 for consistency. These items are listed to ensure that the final sum of all the item values is equal to 1, proving that the model is validated; however, they are excluded from the decision analysis. Also, for the comparison of renovating and redecorating alternatives, items labeled "no details" should be disregarded, because, although they are included in the proposed model, they do not support decision making within the model. To a lesser extent, they do not apply to real-world scenarios to which the model presented in this thesis could be applied. Accordingly, although the "no details" branches for each factor have multiplied scores, they are not included among the ranked options in Table 2. Their inclusion in Figure 4 and Table 1 is to maintain consistency with the integrated tallying heuristic and tree model, and does not indicate the trends in preferences for architectural features when renovating library interiors.

With regard to trends, the observed results in Table 2 are of interest, signaling what appears to be the most preferred options for making libraries more conducive to studying. Given that the top two—three of the top five—preferred implementations are related to furniture, it is suggested that furniture has the greatest influence on students' abilities to study, while the interior décor has the least effect. However, this is only a preliminary observation. More knowledge is gathered and presented in the subsequent tables and subsections. In fact, there are certain contrasts between Table 2 and Table 4 that will be discussed in the following chapter.

Table 1: Indoor environmental factors, their architectural features, and their multiplied scores

Category	Count	Total	Normalized	Details	Count	Fraction	Subcategory	Count	Fraction	Design Option	Count	Fraction	Score
Lighting	60	83	0.428571429	Yes	20	0.333333	Artificial	10	0.5	Add table lamps	4	0.4	0.028571429
										Add task lighting	5	0.5	0.035714286
										Add recessed lighting	1	0.1	0.007142857
							Natural	10	0.5	Add windows	3	0.3	0.021428571
										Relocate toward windows	5	0.5	0.035714286
										Reflective surface	2	0.2	0.014285714
				No	40							0.666666667	0.285714286
Furniture	45	83	0.321428571	Yes	32	0.711111	Tables	18	0.5625	Rectangular layout	10	0.555556	0.071428571
										Adjustable height	8	0.444444	0.057142857
							Chairs	14				0.4375	0.100000000
				No	13							0.288888889	0.092857143
Aesthetics	35	83	0.25	Yes	25	0.714286	Ceilings	2				0.08	0.014285714
							Floorings	6				0.24	0.042857143
							Colour Schemes	17	0.68	Colourless	1	0.058824	0.007142857
										Monochromatic	1	0.058824	0.007142857
										Contrasting	1	0.058824	0.007142857
										Related	5	0.294118	0.035714286
										Mute/Cool colours	9	0.529412	0.064285714
				No	10							0.285714286	0.071428571

Table 2: Architectural features ranked by their scores

Score	Architectural Feature	Rank
0.100000000	Add office/task type chairs	1
0.071428571	Rectangular layout for tables	2
0.064285714	Mute/Cool colours for aesthetics	3
0.057142857	Adjustable height for tables	4
0.042857143	Add carpeting for floors	5
0.035714286	Add task lighting	6
0.035714286	Relocate toward windows	7
0.035714286	Related colours for aesthetics	8
0.028571429	Add table lamps	9
0.021428571	Add windows	10
0.014285714	Add reflective surfaces	11
0.014285714	Add acoustical tiles to ceilings	12
0.007142857	Add recessed lighting	13
0.007142857	Colourless scheme for rooms	14
0.007142857	Monochromatic scheme for rooms	15
0.007142857	Contrasting scheme for rooms	16

3.12 Selection of Features from each Category

The next step is to select, from each sub-factor, which architectural features are most often mentioned. This determines which architectural features would be considered most contributory toward making a study space more comfortable. This is with respect to each sub-factor, and with respect to each indoor environmental factor. Corresponding to Figure 4, this is carried out by selecting one feature from each of the sub-factors. For instance, under the factor “lighting”, followed by the sub-factor “artificial lighting”, the architectural feature “add task lighting” would be selected, because, corresponding to Figure 4 and Table 1, this feature is found to have the highest count, thus the highest preference; and similarly, under the sub-factor “natural lighting”, the feature “relocate toward windows” would be chosen. The motivation behind this particular method of selection is that only one choice can be made under each sub-factor. Therefore, the architectural feature with the highest count stemming from its sub-factor would be deemed the most preferred choice for implementation, against that feature’s counterparts. A clear example from the Appendices includes the alternatives for “colour schemes” presented in Figure 4. There are a number of options when determining the colours of the walls, floors, and ceilings; however, only one scheme can be chosen for any one interior room.

This is tied to the explanation regarding Figures 4 and 3 earlier in this chapter. By the rule that only one architectural feature, with respect to their encompassing divisions, can be selected and used, there would be fewer features that could be taken from Table 2 for implementation if the rule for selection was applied with the tree model presented in Figure 5. By removing the “sub-factors” column of branches, fewer architectural features could be selected for implementation. This would make the model inconsistent with real-world practices, in which numerous features sharing the same primary factor are put in place simultaneously. For example, the architectural feature of relocating a study space toward a set of windows is not necessarily in conflict with the feature for installing task lighting over a study space. Therefore, both can be used in conjunction with one another. This is actually the case for one of the study spaces in the University of Alberta's Cameron Library case study presented in the next chapter. But it is essential to argue that it is less effective to use the tree structure illustrated in Figure 5 for the research presented in this thesis than it is to use the tree structure outlined in Figure 4. For this reason, Figure 4 is preferred over Figure 5 in this step. Architectural features, not necessarily in conflict with one another, can be considered significant and therefore listed as features to implement, which is beneficial for the model's application in the case study presented in Chapter 5.

3.13 Measurement of their Contributions

Once all the architectural features have been chosen for each subcategory, the next step is to measure to what degree they promote comfort in a study space conducive to learning. The scores are computed in the same manner as those in Table 1: by multiplying each respective fraction along the branch path from the factor to the sub-factor to the architectural feature. Their percentages can be viewed in Table 3. The resulting values for each subcategory become the contributions from each of their respective architectural features, because those features represent their subcategories, and in those subcategories, respectively, they contribute toward making a space conducive to studying.

Additionally, the ease of use of the model is presented in this thesis. Percentages, rounded to the nearest whole number, tenth, or hundredth decimals, are typically easier to read and measure than integers with up to ten decimal places. This numerical format is most frequently used in the comparisons of sample sizes, quantifying change that is taking place over a period of time, and expressing an increase/decrease from an initial size. By converting numbers into percentage values, those values can be more readily and easily compared. For instance, the best formats for presenting probabilities of health risks are found by Cuite et al. (2008) to be percentages and frequencies (*x* out of 100). These two formats are deemed to best facilitate the performance of comparing probabilities. This percentage format is particularly useful for the model presented in this thesis, and its application to a building is demonstrated in the following chapter. By applying this model to the University of Alberta's Cameron Library, the contributions from each architectural feature identified are not only quantified and compared with one another, but they also represent how they can contribute to making a study space within the library conducive to studying.

With regard to this principle of perception for easier comprehension of presented data, a comparison between Tables 1 and 3 is made to illustrate how it is more effective to relay data by percentages rather than by decimal numbers. Table 1 differs from Table 3 in that the former lists all architectural features identified from all the gathered sources, whereas the latter only lists those features that have the highest count and overcome their counterparts. But, both list architectural features whose values all sum up to 1. Using this baseline, a comparison can be drawn, measuring each feature's contribution. This format for presenting the final features to be implemented is retained and reapplied in the model's case study demonstration in the following chapter.

Table 3: Indoor environmental factors, their architectural features, and their scores (percentage)

Category	Count	Total	Normalized	Details	Count	Fraction	Subcategory	Count	Fraction	Design Option	Score
Lighting	60	83	42.86%	Yes	20	33.33%	Artificial	10	50.00%	Add task lighting	7.14%
							Natural	10	50.00%	Relocate toward windows	7.14%
				No	40	66.67%					28.57%
Furniture	45	83	32.14%	Yes	32	71.11%	Tables	18	56.25%	Rectangular layout	12.86%
							Chairs	14	43.75%	Office/Task type	10.00%
				No	13	28.89%					9.29%
Aesthetics	35	83	25.00%	Yes	25	71.43%	Ceilings	2	8.00%	Add acoustical tiles	1.43%
							Floorings	6	24.00%	Add carpeting	4.29%
							Colour schemes	17	68.00%	Mute/Cool colours	12.14%
				No	10	28.57%					7.14%
											100.00%

4 FINDINGS & ANALYSIS

From the model proposed in this thesis, certain impressions are founded and unfounded. Indoor environmental factors that are initially perceived as more important than others are later found to be less so than their counterparts and vice versa. The same can be said for their corresponding architectural features. The initial impression is based on the first tallied counts for the factors “lighting”, “furniture”, and “aesthetics” (see Appendix A, or Figure 4). Accordingly, it is initially perceived that the architectural features related to “lighting” would carry more significance based on that of their common factor, which is greater than its counterparts “furniture” and “aesthetics”. It is discovered, however, after running the model to find the values for each proposed architectural feature, that a given factor having the highest tally does not necessarily result in its sub-factors and architectural features being given the highest consideration (see Tables 2 and 3). Two explanations for these findings are presented.

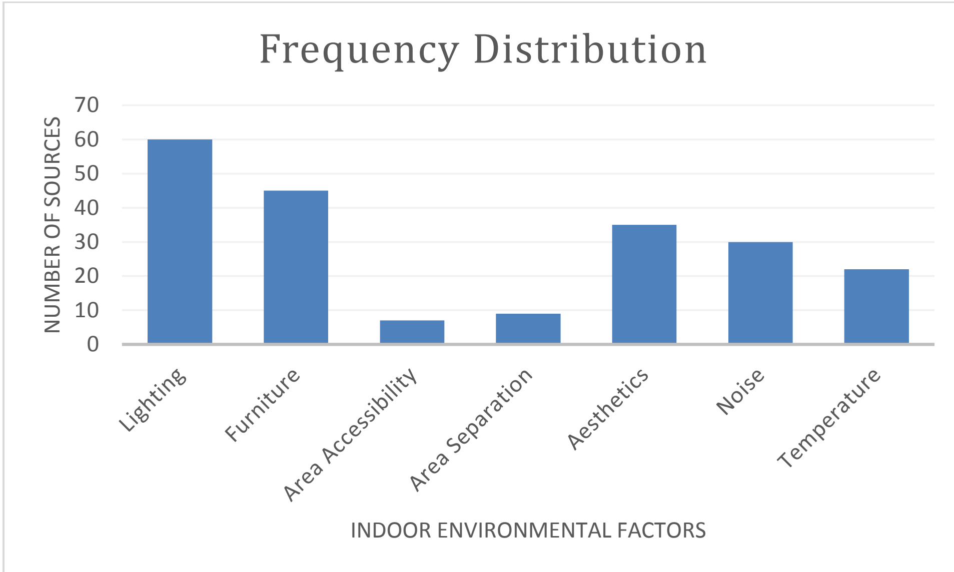

Figure 8: Frequency distribution of the gathered sources

First, as presented in the frequency distribution in Figure 8, the majority of the sources indicate lighting as an important factor in the indoor environment, thereby giving the impression that lighting would take priority. The initial perception is that the architectural features related to lighting would be preferred because their common indoor environmental factor has the majority count. The margin among its count and the counts for both the furniture and aesthetic categories reinforces this belief. Of the 83 sources of information on library indoor environments gathered, 60 mention lighting, while only 45 reference furniture, and 35 aesthetics. Because of this margin, it is believed that the architectural features related to furniture and aesthetics would not be given priority over those related to lighting. It is initially believed that the preference based on the majority count for lighting would be extended to include its corresponding architectural features. The reason for this belief is the impression that the factor's fraction would have a more significant impact on the outcome of its architectural features following the multiplication of the fractions along their branch paths.

Second, the extent of breakdowns, or the number of branches within the tree, is significant. The diagram presented in Figure 4 indicates how many subsequent branches stem from each branch. There are few architectural features related to furniture in comparison to the number of those related to lighting. Although the “lighting” factor carries a higher tally than its “furniture” and “aesthetics” counterparts, “lighting” has more sub-factors and architectural features stemming from it than the other two. Consequently, the increase in divisions amongst the sub-factors and features indicates that there are small tallies for each. There is an inversely proportional relationship among the tallies for a division and the number of subdivisions. As the number of subdivisions increases, the tallies for each decrease. This can be observed by the divisions in “lighting” in contrast to those for “furniture”; one factor experiences a greater distribution of counts among its features than the other two. This is illustrated in the diagram presented in Figure 4. In this case, as a result, each architectural feature under the “furniture” category carries more counts, because that factor has the fewest number of architectural features, and therefore the greatest distribution of counts among them. With regard to the options related to aesthetics, there are a fair number of them to choose among. However, it should be noted that only about half of them carry a high enough tally to be ranked high. Those that are given a low tally are unsurprisingly expected to be given the least priority.

A final note is the breakdown of sources between those that do and those that do not mention architectural features. This can be viewed in Section 3.6, Figure 4, within the second column of branches, each stemming from the indoor environmental factors, “specific details” or “no details”. Similarly, it can also be observed in Appendices C and D, under each category, how many of the articles that cite categories go on to propose suggestions for how to enhance a space with respect to the indoor environmental factor. Although lighting is the most important category, only a third of those sources offer suggestions for how to improve upon this category. On the other hand, although the aesthetics category is given the lowest count in comparison, it has the highest proportional number of sources from that group that offer how a space can be improved. A discrepancy exists between how many sources mention a factor as significant, and how many sources actually cite an architectural feature corresponding to that factor. This is tied to the second explanation discussed above, where divisions play a significant role. In this sense, the respective proportion of each category plays a significant role in determining the priorities of their related architectural features. As indicated in Figure 4, upon examination of the fractions for the factors and their “specific details” and “no details” branches, the proportions for each factor’s number of counts for architectural features can be determined. Proportionally, the indoor environmental factor, “aesthetics”, has the highest number of sources that mention architectural features while “furniture” closely follows. In stark contrast, “lighting” only has half the proportion of its counterparts, because only a third of all the sources that cite this factor actually mention features.

In conclusion, it is observed that inferences cannot be made while the model is being implemented, while sources are being gathered, and their counts are being entered into the model, but rather only the final results can be relied upon to reach conjectures about trends in the interior design of libraries. Mentioning an indoor environmental factor the most does not indicate it is the most important. Granted, the tallying heuristic would give it precedence because of the number of instances it is mentioned, but what is also considered is the number of times an architectural feature related to that particular factor is mentioned. Although an indoor environmental factor can be given importance based on how often it is mentioned, its relationship to an architectural feature, based on how often that feature is also mentioned, can dictate whether or not that feature would have the same level of priority. This is because the importance of a factor, based on a tally, is not automatically passed on to its sub-factors or features. Those subdivisions must have their own tallies to determine their own precedence.

5 CASE STUDY

A case study is introduced to demonstrate how to implement the model into an actual building project. Cameron Library on the University of Alberta's North Campus in Edmonton, Canada is undergoing renovations and will be used as the case study building in this thesis. The intention is to replace the building envelope components, originally built in 1962 and 1969, due to their age and relatively high level of necessary maintenance, resulting in frequent repairs and high cost.

The motivation for selecting this building as a case study is founded upon the opportunity to expand and optimize the building's systems. The University is currently seeking opportunities to provide the same level of indoor thermal comfort for the library's users with a reduced consumption of energy by exploring renewable technology applications. This is the primary goal. The secondary goal is to support learning activities. The driving force behind the present research is to assist in accomplishing these goals, especially the secondary, by assessing how the occupants—predominantly students—interact with the Cameron Library facility.

Quantifying the contributions from each design option, within the context of Cameron Library, is the first step to determining how conducive the library's interior spaces are to learning. Although percentages for each design option under each category are provided in Table 3, these values cannot be applied directly. The "details" column in Figure 4 counts how many articles, when referring to a category, actually cite a specific building feature. For example, in Table 3, of the 83 gathered sources of information, 60 mention lighting. Of those 60 sources, only 20 actually mention a specific building feature when discussing the category. Thus, the remaining 40 do not indicate any building features, yet still contribute toward the total (100%). Additionally, Table 3 must be reformatted so that *only* the architectural features listed add up to 100%; this is completed and can be observed in Table 4. Similar to the discussion in Section 3 of this thesis, the scores for each subcategory are normalized so that the “details” column is no longer necessary to include in Table 4. As a result, only the architectural features corresponding to their categories are listed. And, as also mentioned earlier, validation of this normalization is carried out by adding up all the new values so that they are equal to 1 or 100%. Once the normalization of all the design options is complete, it is easy to observe each option’s contribution toward making a space conducive to studying. It also facilitates examining each option’s relative importance in Table 4.

With the contributions from each architectural feature measured, the first step in this case study is to observe each study space on each floor of Cameron Library to determine which of the design options listed in Table 4 are actually implemented. Specifically, each floor of the library is observed for the purpose of determining (1) if there are any study spaces that implement any of the architectural features listed in Figure 9; and (2) if so, then how many of those features are used. It should be noted that on every floor there is a mixture of study carrels, tables, and computer workstations, but, for the sake of consistency within this research, only the tables are considered.

An examination of the building’s interior spaces is conducted, with the intention to examine whether or not the library implements the architectural features listed in Table 4. In addition to Table 4, Figure 9 presents a checklist for the architectural features that need to be implemented based on the evidence-based research presented in this thesis. This examination takes place in the form of walking through and observing the facility to confirm whether or not the architectural features listed in Figure 9 are actually being implemented. Within the building, amongst the basement and the five floors that are accessible, only the top two floors are closed to the student body. The following indoor environmental factors are examined: lighting, both artificial and natural; furniture, both seating and tables; and aesthetics, which includes colour schemes, the type of flooring on each floor, and the type of ceiling tiles used. The purpose is to compare the features of Cameron Library's indoor spaces with those specific features listed from the model.

After visiting Cameron Library, the following observations are recorded:

- There is a wide variety of combinations of architectural features within the library, including furniture pieces that are both not identified and identified in Table 4 (i.e., study carrels, computer terminals, etc.)
- These study spaces are found on all but the 4^{th} floor and 5^{th} floor, which are not accessible by the student body.
- Each study space varies based on one or more features, primarily based on location, furniture, and lighting. These conditions include proximity to windows and/or light fixtures, and the types of seating and accommodation being used.
- Photographs are taken of the study spaces in the library and are presented in Figures 5 to 11 below. The approach to examining the study spaces is to identify any study tables in particular. Following this, surrounding factors are observed to see if any and/or how many of the architectural features listed in Table 4 are implemented.
- Table 4 below lists the scores resulting from how well each floor performs in providing study spaces for students; these scores are based on whether or not the spaces on each floor meet the design options also listed in the table.

The first indoor environmental factor is furniture. From the model, the two most effective improvements toward a conducive study space are ergonomically designed and anthropometric chairs, and rectangular tables. After touring the library it is confirmed that these features are predominantly implemented. It should be noted that throughout the four publicly accessible floors, there is a mixture of ergonomic chairs and those that are designed as stackable, or "one size fits all". There is also a mixture of tables and study carrels. Another note is the location of the tables. They are primarily located in the basement, main, and second floors, while the third floor accommodates only study carrels. This suggests that the furniture most conducive to learning activities is placed in the basement, and on the ground and second floor, because those floors receive the most pedestrian traffic. The fact that the main entrance to the library connects to a pedway to another academic building is significant, because the entrance is adjoined to a traffic route where students pass by the library on a daily basis, and multiple times per day. The author speculates that tables have not yet been placed on the upper floors, because more attention has gone toward making the library inviting to students, and fewer students access the upper floors to study as the ground floor based on traffic patterns. However, the fact that there are anthropometric chairs on every level indicates that there is the intention to make the library a comfortable place to study, wherever a student may choose to sit. In the interest of students being able to choose where to sit within the library, the tables and ergonomic chairs are fitted with wheels, which may be locked in place as necessary. This furniture is fitted with wheels in order to give the students the ability to take an empty chair and/or table and easily relocate it to another nearby location on the given level. It is believed by the researchers, based on some of the gathered sources discussing library design, that by being able to rearrange furniture, the students making use of that furniture are more comfortable for the time they are occupying that space and therefore more productive in their studies (Spencer et al., 2012). Furthermore, this gives greater freedom to the students to choose to study independently or in a group.

Also, every level of the library includes features involving aesthetics. Specifically, a colour scheme is applied to every floor of the library. Mute and cool colour types are present on the walls on each floor of the case study library. The colours used are soft green and subdued yellow, in reference to the official colours, green and gold, of the university. Additionally, a muted blue is applied throughout the building. It is less significant what the colours are than the particular shades and brightness used, which correlates to studies indicating they make a more effective study space for adults to occupy (Kuller et al., 2006). From this case study, Kuller (2006) puts forward the argument that: (1) a colourful environment is more effective in conducing productivity than a colourless one; and (2) muted colours are best because of the control over both colours and brightness, which in combination together, greatly affect the moods of the occupants. In other words, the brightness and shades of colours are more significant than the choice of colours when decorating a study space. This is because as humans age they increasingly prefer muted and faded colours over bright and vibrant colours (Kuller et al., 2006). Upon examination, the ground and second levels feature no carpeting on the floors. From the sources gathered, it is noted that carpeting is most often applied to spaces which are intended for low volumes. This is consistent with Cameron Library, as the upper floors are generally quiet at all times, while the ground and second floors allow for somewhat louder noise levels due to increased traffic. The flooring utilized on the levels that do not require sound dampening is terrazzo marble tiling, which is more acoustically reflective. While the ground and second floors experience more talkative students and higher volumes of pedestrian traffic, the upper floors are occupied by students who sit and study for extended periods of time. Finally, on every level of the building, acoustical ceiling tiles are installed which also contribute to sound absorption, where the level of sound absorption decreases as the floor-to-ceiling height increases. Although ceiling tiles are not the most significant feature for study spaces, they do serve to conceal the less aesthetically pleasing building components such as structural member and electrical and mechanical infrastructure in addition to sound absorption.

The final category to examine in relation to the case study is lighting. In the artificial sense, there is a mixture of task lighting fixtures and indirect lighting fixtures. The indirect lighting fixtures are predominantly found on the basement, ground, and second levels, while the task lighting fixtures are more concentrated on the third floor and higher. However, it is noted that the clear majority of the seating spaces in the library are located directly under the indirect lighting fixtures, which is a principle that involves task lighting. In this case, the indirect lighting may also constitute as task lighting. Not because of the brightness of the light source or the reflectivity of the ceiling directly over the light, but the light's proximity to the students. From the observations made after visiting Cameron Library, nearly all seating accommodations are placed directly under artificial light fixtures, and/or in close proximity to windows. In reference to the natural counterpart of lighting, every floor offers seating alongside the windows on every side of the library. The basement, ground, and second floors have tables placed beside the windows for natural light, while the upper floors have study carrels placed beside the windows. As mentioned earlier in this chapter, with regard to furniture, a substantial portion of the tables and chairs are easily movable, and thus able to be rearranged, because they are fitted with wheels. This allows for easy relocation, namely from the inner area of a given floor closer to the building's exterior walls, near the windows. Figure 13 depicts a series of tables and chairs that can be rearranged in closer proximity to the windows to gain more natural light. In this regard, a student can decide where to sit and study according to their preference for lighting type in order to promote productivity and studying.

Table 4: Architectural features (multiplied score & percentage)

Category	Subcategory	Design Option	Score	Normalized	Percent
Lighting	Artificial	Add task lighting	0.07143	0.12990	12.99
	Natural	Relocate toward windows	0.07140	0.12990	12.99
Furniture	Tables	Rectangular layout	0.12860	0.23380	23.38
	Chairs	Office/Task type	0.10000	0.18180	18.18
Aesthetics	Ceilings	Add acoustical tiles	0.01430	0.02600	02.60
	Floorings	Add carpeting	0.04290	0.07790	07.79
	Colour Schemes	Mute/Cool colours	0.12140	0.22080	22.08
		Sum	0.55000	1.00000	100%

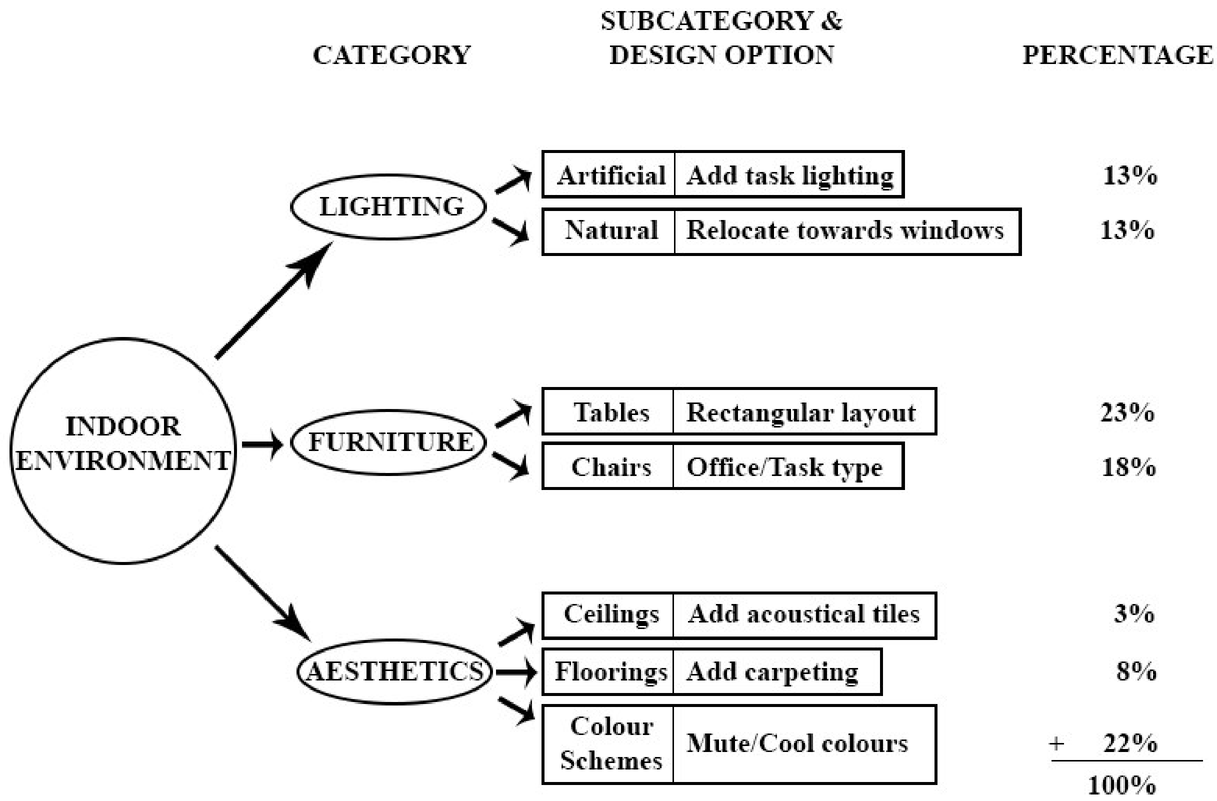

Figure 9: Tree model for Table 4

Table 5: List of architectural features being implemented on each floor

Floors	LIGHTING		FURNITURE		AESTHETICS			Total
	Add task lighting	Relocate toward windows	Rectangular layout	Office/Task type	Add acoustical tiles	Add carpeting	Mute/Cool colours	
5	NA	NA	NA	NA	NA	NA	NA	NA
4	NA	NA	NA	NA	NA	NA	NA	NA
3	Yes	No	Yes	No	Yes	Yes	No	60% or 47%
2	Yes	No	Yes	Yes	Yes	No	Yes	92% or 79%
Main	Yes	Yes	Yes	Yes	Yes	No	Yes	92%
Basement	Yes	Yes	Yes	Yes	Yes	No	Yes	92%

An overview of Table 5 reveals a pattern: from the basement level upward the floors are gradually implementing fewer of the design options listed. It is inferred that the implementations were made after considering where students most often visit Cameron Library; in this case, the basement and ground floors, whereas the second and third floors are less visited, hence lower total scores. It is also inferred that the periodic renovations from 1962 onward considered this. As previously mentioned, the basement, ground, and second floors receive the highest volume of students and pedestrian traffic, while the third floor sees the least amount of visitors. The basement houses the computer lab, which accommodates high demand regularly, and is accessible continuously during exam periods, making it especially appealing to the student body and therefore invites their patronage. The ground and second floors are for students wishing to engage more in social activities and/or collaborative learning activities. It also provides a lounge area with contemporary décor and furniture, adding a distinct appeal. This contemporary furniture is designed and built to be easily movable, so that groups of students can create their own designated spot for socializing, studying, and collaborating from the greater space (Johnson, 2013). Conversely, the upper floors are quieter for students who are studying for extended periods of time. A noticeable observation in the differing scores among the ground and upper floors is presented in Figures 4 to 7. On the ground floor, only ergonomic chairs and long, rectangular tables are present; however, the second floor offers rectangular tables as well as ergonomic chairs, but they are dispersed into smaller groupings. The third floor contains no ergonomic chairs whatsoever, and few tables are near windows, but rather surrounded by book stacks and partition walls. The ergonomic chairs are replaced with the stackable counterpart, the type of chairs that are designed under the “one size fits all” concept.

The contribution from relocating a study space toward a window is noticed in Table 4. But, alternatively, its contribution can be observed from its absence on the second and third floors, as reported in Table 5, which affects the total score considerably. Excluding one area on the third floor, as depicted in Figure 14, every other study space is surrounded by partition walls, columns, and book shelves, as presented in Figures 8 to 12 and 14. These photographs illustrate why the scores represented in Table 5 are considerably lower for the spaces on the third floor than those on the second and lower floors. It is important to note that on the second and third floors, the fact that there are study spaces that are both close to windows for natural lighting and further away from windows is why two scores are given. Depending on the study space, if it has access to natural light, as that depicted in Figure 13, then its score is 92%; if the space is not in close proximity to any windows, such as in Figures 11 and 12, then its score is 79%. The same applies for the study spaces on the third floor, being 60% or 47%, respectively.

Another clear difference is the change in colour schemes. Among Figures 10 to 13, 16, and Figures 14 to 15, the change in colour settings of the spaces can be observed. From the basement level upward, less colour is applied to the interior architectural features. The absence of colours or any colour scheme further hinders how conducive the spaces on the third floor are to studying (Kuller et al., 2006). This pattern is tied to the reasoning behind the flow of pedestrian traffic throughout all the publicly accessible levels of the library. The basement, main, and second levels are the most developed with regard to the colour schemes and the types of ceiling and flooring used. They receive the most pedestrian traffic on a daily basis, and thus are given the most attention and designed so that they are both inviting and accommodating. There is less emphasis on the appearance of the third level because fewer students are inclined to go to the upper levels. It is more convenient to find a space to study on the main level, or downstairs to the adjacent basement level, or upstairs to the adjacent second level. The author of this thesis proposes this reasoning as a possible cause for the third floor featuring a dissimilar colour scheme to the schemes used for the lower levels.

Figure 10: Ground floor

Figure 11: Second floor

Figure 12: Second floor

Figure 13: Second floor

Figure 14: Third floor

Figure 15: Third floor

Figure 16: Basement

6 DISCUSSION & CONCLUSION

6.1 Conclusion

The purpose of this paper is to propose a means by which the different factors of a library's physical space can be compared and ranked. The ultimate goal is to be able to identify which indoor environmental factors would take precedence, and by what means those factors could be enhanced. The enhancements are presented in the form of corresponding architectural features. The identification of features to implement is accomplished by developing a model that treats pertinent gathered sources as counts for respective factors and derives these counts to obtain numerical values for their corresponding features. By use of these scores, the alternative architectural features suggested from various sources can be compared against one another, despite their characteristics from starkly different environmental factors. In this thesis, the method is described in detail to outline the steps and present how the model functions.

From the model's operation, certain statistics are identified. While many information sources cite specific indoor environmental factors as significant for affecting student learning behaviours, less than half of the gathered sources actually indicate means by which to enhance or utilize these factors to conduce studying in libraries. This is significant because of the influence such an occurrence has upon the model's resultant values for each architectural feature that is listed from the gathered sources. From the model presented and illustrated in the methodology chapter of this thesis, an explanation is given for why it is important to note why only a portion of all the gathered sources include architectural features corresponding to the indoor environmental factors they cite. The final numerical value attributed to each feature, prior to sorting the features into a hierarchy in Table 2, is dependent on the fractions of the breakdown of divisions. Starting from normalizing the fractions for each factor out of the total number of gathered sources, those factors are broken down until the architectural features are included. The fractions along each path from the factors to the features are multiplied respectively. In this instance, the fractions for the “details” and “no details” divisions is critical. There is a direct proportional link between the number of gathered sources that include architectural features and the scores for those architectural features listed in Table 1. As the number of sources with features proposed and/or cited increases, so does the numerical score for those features.

An immediate benefit from using the model is that it assists designers in determining which factors to address when redesigning and/or retrofitting interior spaces of libraries. In addition, the model hierarchically ranks the architectural features corresponding to those factors in order to determine which factors should be addressed first, then second, and so on. From the case study, it is likely that the third floor of Cameron Library will undergo renovation and/or redecoration so that the colour scheme used on the lower levels will be cohesive, extending to the third floor. Furthermore, while there is an apparent balance between stackable chairs and their ergonomic counterparts, it is possible that soon only the ergonomic type will be featured in Cameron Library. It is possible that the third floor will undergo renovation and redecoration similar to the main and second floors, in that the stackable chairs will be replaced with task type and ergonomically designed counterparts. Likewise, there is the possibility that the tables on the upper floors will be replaced with counterparts that are fitted with wheels, in order to make the furniture easier to rearrange for the preference and comfort of the students occupying the library’s spaces.

Although energy is a suitable metric by which to evaluate the comfort of indoor environments of libraries, it fails to encompass the benefits toward the occupants for their faculties, such as relaxation, concentration, and productivity. Other benefits, including public health, are equally important to outline the effectiveness of the proposed model in decision making on indoor environmental factors in library renovation projects. This applies not only in the physical sense, but to mental health as well. According to the physical well-being of the users, indoor environments must be able to meet the requirements according to the psychrometric chart, which identifies the requirements for achieving thermal comfort, including temperature and humidity. In the sense of mental health, there is less quantified data available. But designing according to the mental health and well-being of users nonetheless needs to be considered, because that also affects the comfortability of the indoor environment.

Therefore, it is necessary to explore what aspects of the physical indoor environment affect the comfort and mental well-being of its users. This leads to posing the research hypothesis: *interior architectural features for academic libraries in the physical realm have a direct impact on the mental health and mental well-being of students*. The link between the mental health of users and the built environment is based on the gathered scientific literature that discusses and examines specific components of the indoor environment, defining comfort levels for users, improving upon their productivity with regard to learning activities, and being able to study their mental health.

This study aims to develop a means by which different architectural features under differing environmental factors can be compared against one another based on a central tallying heuristic function. This central heuristic function is supported by the tree model, which serves two roles.

The first is to establish and maintain relationships between the indoor environmental factors and their architectural features. The second is to illustrate the model proposed in this thesis to better convey the knowledge gained and present the research. It also aims to answer the research question, “what physical indoor environmental factors affect students’ abilities to study in libraries?” Sources of information are not merely gathered, but also converted into counts for use in the proposed model based on the factors they argue are significant and the features for implementation they suggest. The features are given scores which are based on how often they are mentioned from the gathered sources. These scores allow for the features to be hierarchically ranked. The result is a list of hypothetical combinations of architectural features proposed for implementation in libraries to promote spaces that are conducive to studying.

Most research about the architecture of libraries affecting the behaviour of students is considered too general a topic to be applied. It is necessary to add specifications, including the context of a university campus, the academic variation of the library building, and whether the primary users are undergraduate or graduate students. Localizing the research problem to within these conditions is necessary so that a conclusive answer to the problem can be found. Evidence of the applications of architectural features in the university library setting is particularly rare. The crucial nature of evidence-based decision making compels efforts to capture useful data about how information is accessed.

6.2 Limitations

One of the limitations to the proponent described in this thesis is the lack of measurable degrees or extents. There is a lack of magnitude when carrying out the steps of the methodology. In other words, there are no measurements or standard sizes given for the architectural features to be implemented in the library study spaces, nor are any volumes or standard amounts stated for the amount of each of the indoor environmental factors to be utilized in the library interiors. This limitation is due to the variety of gathered sources, because of the various backgrounds, research fields, and circumstances. This is similar to the discrepancy that not all of the gathered sources that reference an environmental factor *also* reference an architectural feature. With regard to the limitation of no magnitude or measurement given, not all of the gathered sources actually make reference to the sizes of the architectural features being implemented, or for the amount or volume of an environmental factor to enhance. For the purpose of developing and maintaining consistency throughout the proposed model, the principal question is whether or not specific and pertinent factors and features are being implemented at all, without consideration of the extent to which such implementation is taking place.

Another considerable limitation is the use of values instead of range intervals. The reason for using values instead of range intervals is because of the approach used in developing the methodology. This approach is based on the first step in the methodology: determining the values for how many sources make reference to each environmental factor and each architectural feature. It follows that fractions are then produced and multiplied together based on the values and their broken down counterparts. Finally, the scores for the features are ultimately based on the values from the previous steps. However, this does not mean it is impossible to use range intervals. In fact, it is considered that implementing a range interval in place of a value for scoring an architectural feature could ultimately improve the proposed model.

The validation steps in the proposed research prevent operational barriers; however, validation of its ability for assessment in the case study is another matter. The results of the case study and its implementation of architectural features could be validated by a specific means. One option would be to interview randomly selected individuals, including users, library staff, and faculty. However, there is no guarantee that the randomly selected users would represent the greater student population. Similar to surveys, the people being interviewed may be difficult to contact, let alone agree to participate (Johnson, 1976). To a lesser extent, it may become a question of who or how many people to interview, including the architect and owner of the building. These are just a few of the pitfalls of conducting an interview. According to Evinger (1984), there are a number of other pitfalls that could also be encountered. Another option is to conduct a survey in which students would be invited to participate and provide their feedback on the state of Cameron Library. However, designing and administering a survey is no easy task, and surveys are known to have pitfalls, as previously discussed.

Therefore, the proposed task is one of observation. By having a researcher or team of researchers stay and observe the students who visit the library and use its facilities for extended periods, student behaviours can be inferred. Such observations could explain and support the validation of the results from the features both prior to and post implementation. A carefully structured and well-planned observation of students' behaviours in the library can guarantee not only useful data, but also protect against any inherent pitfalls, with examples of this scenario provided by Cowan et al. (2014), when extraordinary circumstances arose that interfered with the regular patterns of students under observation. Avoiding the pitfall of unusual circumstances or events and ensuring that a regular routine or pattern is followed supports the use of observation for data gathering. This leads to a successful observation-based study, as was the case for Bakkalbasi et al. (2014).

An alternative to observing students engaged in the library is distributing a questionnaire. It has been argued in the preceding chapters of this thesis against utilizing a questionnaire to obtain data; however, using the data from questionnaires to validate research findings is a different matter. Distributing a questionnaire to confirm if the findings from the present research, based on the reactions and opinions of the students engaged with the library space, could provide valuable feedback and support or contrast the evidence-based research proposed. This is similar to the study conducted by Davis & Shaw (1989), where the feedback from students who responded to a questionnaire was set against a tallying-based methodology for the effectiveness of the designs of screens for interfaces.

However, the research concern within this thesis is the ability to compare differing architectural features to assist in decision making for the interior design of library renovation projects. Therefore, while the validation of results does play a role in the research, it is not a top priority at this research stage. At the level of development of the research presented within this thesis, the top priority is constructing and presenting a cohesive means of comparison for differing architectural features from differing indoor environmental factors within academic libraries, based on their impact on the mental health of university students.

6.3 Future Research

This model provides a means by which a decision maker can understand which indoor environmental factors are considered more often than others, and to what degree. The usefulness in this manner arises from considering the different perspectives of (re)designing a study space in a library. The results represent an exploration into the preferences given for each of the indoor environmental factors based on their respective architectural features. Only the three most tallied factors are presented in this thesis as a demonstration of how the proponent functions. However, the model could be applied more comprehensively and accommodate all the indoor environmental factors identified in Figure 8. In other words, it could include every environmental factor and subsequent architectural feature in Figure 4 from the gathered sources. This would provide a more detailed study on library interiors and their effects on students and student activities.

New library building projects, as well as additions and extensions to existing libraries, can use this research to evaluate design proposals to determine the benefits with regard to occupancy and use. In the same way that the University of Alberta's Cameron Library was assessed for its implementation of the architectural features listed in the previous section, design plans can be assessed for their implementations as well; the objective remains the same: to confirm if those features are being utilized. If the confirmation is positive, then therein lies another case study that could reinforce the research findings of this model. However, if the confirmation is negative, then therein lies room for improvement to the building by implementing those architectural features identified and listed in this thesis.

A potential improvement to the proposed model is using range intervals in place of values, as previously mentioned in the Limitations section. This is for the portion of the methodology that determines percentages for pertinent architectural features and their contributions toward making a space conducive to studying. This is considered an appropriate innovation of this model, because of the condition applied to the research assumption: the more frequently an indoor environmental factor and/or architecture feature is referenced in the scientific literature, the more *likely* and/or *probable* that referenced factor and/or feature is/are significant in the design of academic libraries. Finally, the proponent could be applied to other types of facilities. The parameters are adjustable in order to address which indoor environmental factors are most influential on an occupant with regard to the type of building and what activity the occupant is performing. It is only a matter of searching for sources of information that speak of that particular building type and the specific indoor environmental factors that are considered and/or found to be significant. Subsequently, a user need only to become familiar with the related terms, both broad and more specific, in order to gather sources that cite particular facts about improving upon the interior space within the building type. In this way, the research presented in this thesis can be applied outside of the library institution and can be geared toward other types of facilities.

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APPENDIX A

#	Source	Indoor Environmental Factors							Specific Details? (Y/N)
		Lighting	Furniture	Area Accessibility	Area Separation	Aesthetics	Noise	Temp.	
1	(Adam et al., 2014)	1	0	0	0	0	0	1	Y
2	(Agosto et al., 2015)	1	1	0	0	0	0	0	Y
3	(Aries et al., 2010)	1	0	0	0	0	0	0	Y
4	(Barton & Jones, Jr., 1997)	1	1	0	0	1	1	0	Y
5	(Bayliss, 2012)	1	0	0	0	0	0	0	N
6	(Bazillion, 2001)	1	0	0	0	0	0	0	N
7	(Boss, 2009)	1	1	0	0	0	1	1	Y
8	(Brown, 1992)	1	1	0	0	1	0	0	N
9	(Bube, 1985)	1	0	0	0	0	1	1	N
10	(Campbell & Shlechter, 1979)	1	0	0	0	0	0	1	N
11	(Cha & Kim, 2015)	0	1	0	0	0	1	0	N
12	(Chandra et al., 2009)	1	1	0	0	0	1	1	N
13	(Cochran & Gisolfi, 1997)	1	0	0	0	1	0	0	Y
14	(Cohen A., 2009)	0	1	0	0	0	0	0	N
15	(Cohen E., 1994)	1	0	0	0	1	0	0	Y
16	(Dang & Chen, 2016)	1	0	0	0	1	1	1	N
17	(DeClercq & Cranz, 2014)	0	1	0	0	0	0	0	Y
18	(Demir, 2013)	1	0	0	0	0	0	0	Y
19	(Engelbrecht, 2003)	0	0	0	0	1	0	0	Y
20	(Ferrer & Villarouco, 2012)	1	1	1	1	1	1	0	Y
21	(Foregger, 1998)	1	0	0	0	0	0	0	Y
22	(Fox & Doshi, 2013)	1	1	0	0	1	0	0	N
23	(Franks & Asher, 2014)	0	1	0	1	0	1	0	N
24	(Fraser & Munro, 2004)	0	0	0	0	1	0	0	N
25	(Gaines & Curry, 2011)	0	0	0	0	1	0	0	Y
26	(Gayton, 2008)	0	1	0	1	0	0	0	N

27	(Guarnerio & Pavesi, 1999)	1	0	1	1	0	1	1	N
28	(Hassanain & Mudhei, 2006)	1	1	0	0	1	1	1	N
29	(Heath & St. Clair, 2011)	0	1	0	0	0	0	0	N
30	(Higgins et al., 2005)	1	1	0	0	1	1	0	N
31	(Hobbs & Klare, 2010)	0	1	0	1	1	0	0	N
32	(Imamoglu & Gurel, 2016)	0	1	0	1	0	0	0	Y
33	(Isacco, 1985)	1	0	0	0	1	0	0	Y
34	(Jaime & Lau, 2012)	1	0	0	0	0	0	0	Y
35	(James & Stewart, 1995)	1	0	0	0	1	1	1	N
36	(Johnson D., 2000)	1	0	0	0	1	1	1	Y
37	(Kilic & Hasirci, 2011)	1	1	0	1	1	0	0	N
38	(Kuller et al., 2006)	1	0	0	0	1	0	0	Y
39	(La Marca, 2010)	1	1	1	0	1	1	1	N
40	(Lackney & Zajfen, 2005)	1	0	1	0	1	1	1	N
41	(LaRue, 1991)	1	0	0	0	0	0	0	Y
42	(Lee, et al., 2012)	1	0	0	0	0	1	1	N
43	(Lee Y. S., 2014)	0	1	0	0	1	1	1	N
44	(Lei, 2010)	1	0	0	0	1	1	1	Y
45	(Lesneski T., 2011)	1	1	1	1	1	1	0	Y
46	(Lesneski & Gallina, 2014)	1	0	0	0	0	0	0	N
47	(Line, 2002)	1	1	0	0	1	1	1	Y
48	(Loder, 2000)	0	1	0	0	0	0	0	Y
49	(Lux et al., 2016)	0	1	0	0	0	0	0	N
50	(Luyben & Cohen, 1981)	0	0	0	0	0	1	0	Y
51	(Mairaj & Naseer, 2013)	1	1	0	0	0	1	1	N
52	(May & Swabey, 2015)	1	1	0	0	0	1	0	Y
53	(Metcalf, 1971)	1	0	0	0	0	0	0	Y
54	(Michaels & Michaels, 1992)	0	1	0	0	0	0	0	Y
55	(Murphy, 1996)	1	0	0	0	0	0	0	Y
56	(Niedzwetzki, 1991)	1	0	0	0	1	0	0	Y
57	(Nielsen et al., 2006)	1	0	0	0	0	0	1	N

58	(Osquei-Zadeh et al., 2012)	0	1	0	0	0	0	0	Y
59	(Reddy J. V., 2015)	0	1	0	0	0	0	0	Y
60	(Reddy et al., 2012)	1	0	0	0	1	1	1	N
61	(Robertson, 1992)	1	1	0	0	1	1	1	Y
62	(Rohlf, 1986)	1	1	0	0	0	0	0	N
63	(Rooney, 1994)	1	1	0	0	1	1	0	Y
64	(Roose, 1986)	1	1	0	0	0	0	0	Y
65	(Samani & Samani, 2012)	1	0	0	0	0	0	0	N
66	(Sandy et al., 2014)	1	1	0	0	0	0	0	N
67	(Scherer, 1999)	1	0	0	0	0	0	0	Y
68	(Schwartz, 2012)	1	0	1	1	0	0	0	Y
69	(Shill & Tonner, 2003)	0	0	0	0	1	0	0	Y
70	(Shill & Tonner, 2004)	1	1	0	0	0	0	0	N
71	(Shoham & Shemer-Shalman, 2003)	0	1	0	0	0	1	0	Y
72	(Simon, 1992)	1	1	1	0	1	0	0	N
73	(Sleegers et al., 2012)	1	0	0	0	0	0	0	N
74	(Summer, 1996)	1	1	0	0	1	0	0	N
75	(Usalis, 1998)	0	1	0	0	1	0	0	Y
76	(Veltri et al., 2006)	1	0	0	0	1	1	1	N
77	(Walton, 2006)	1	1	0	0	1	1	1	N
78	(Webb et al., 2008)	0	1	0	0	0	0	0	Y
79	(White, 1962)	1	1	0	0	0	1	0	N
80	(Wilkins, 2016)	1	0	0	0	1	0	0	Y
81	(Xia, 2005)	0	1	0	0	0	0	0	N
82	(Yildirim et al., 2007)	1	0	0	0	0	0	0	Y
83	(Yilo, 2010)	0	1	0	0	0	0	0	Y
Total Count		60	45	7	9	35	30	22	

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APPENDIX B

Category	Subcategory	Design Option	Source	
Lighting	Artificial Lighting	Add table lamps	(Adam et al., 2014)	4
			(Cochran & Gisolfi, 1997)	
			(Heath & St. Clair, 2011)	
			(Rooney, 1994)	
		Add task lighting	(Barton & Jones, Jr., 1997)	4
			(Murphy, 1996)	
			(Scherer, 1999)	
			(Schwartz, 2012)	
		Add recessed lighting	(Summer, 1996)	1
	Natural Lighting	Add windows	(Agosto et al., 2015)	3
			(Demir, 2013)	
			(Scherer, 1999)	
		Relocate toward windows	(Lesneski T., 2011)	5
			(Loder, 2000)	
			(May & Swabey, 2015)	
			(Rooney, 1994)	
			(Yildirim et al., 2007)	
		Reflective surface	(Jaime & Lau, 2012)	2
			(Scherer, 1999)	
Aesthetics	Ceilings	Add acoustical tiles	(Barton & Jones, Jr., 1997)	2
			(Johnson D., 2000)	
	Floorings	Add carpeting	(Barton & Jones, Jr., 1997)	6
			(Cochran & Gisolfi, 1997)	
			(Cohen E., 1994)	
			(Johnson D., 2000)	
			(Rooney, 1994)	
			(Shill & Tonner, 2003)	
	Colour Schemes	Colourless	(Barton & Jones, Jr., 1997)	1

		Monochromatic	(Barton & Jones, Jr., 1997)	1
		Related	(Barton & Jones, Jr., 1997)	5
			(Lesneski T., 2011)	
			(Shill & Tonner, 2003)	
			(Usalis, 1998)	
			(Wilkins, 2016)	
		Contrasting	(Barton & Jones, Jr., 1997)	1
		Mute/Cool colours	(Barton & Jones, Jr., 1997)	9
			(Cochran & Gisolfi, 1997)	
			(Engelbrecht, 2003)	
			(Isacco, 1985)	
			(Kuller et al., 2006)	
			(Niedzwetzki, 1991)	
			(Robertson, 1992)	
			(Rooney, 1994)	
			(Shill & Tonner, 2003)	
Furniture	Tables	Rectangular type	(Barton & Jones, Jr., 1997)	10
			(Cohen E., 1994)	
			(Ferrer & Villarouco, 2012)	
			(Franks & Asher, 2014)	
			(Imamoglu & Gurel, 2016)	
			(Loder, 2000)	
			(May & Swabey, 2015)	
			(Shoham & Shemer-Shalman, 2003)	
			(Webb et al., 2008)	
			(Xia, 2005)	
		Adjustable height	(Barton & Jones, Jr., 1997)	7
			(Boss, 2009)	
			(Heath & St. Clair, 2011)	
			(Michaels & Michaels, 1992)	
			(Reddy J. V., 2015)	

			(Summer, 1996)	
			(Yilo, 2010)	
	Chairs	Task/Office type	(Barton & Jones, Jr., 1997)	13
			(Boss, 2009)	
			(DeClercq & Cranz, 2014)	
			(Heath & St. Clair, 2011)	
			(May & Swabey, 2015)	
			(Michaels & Michaels, 1992)	
			(Osquei-Zadeh, Ghamari, Abedi, & Shiri, 2012)	
			(Reddy J. V., 2015)	
			(Robertson, 1992)	
			(Rooney, 1994)	
			(Roose, 1986)	
			(Summer, 1996)	
			(Yilo, 2010)	
				74