LIFE CYCLE COST ANALYSIS OF VARIOUS COMMERCIAL FLOOR COVERINGS

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ABSTRACT

A life-cycle cost analysis (LCCA) measures the sum of all relevant costs associated with owning and operating a building system over a specified period of time. In April 2023, Emily Lorenz, PE, F-ACI, authored a life cycle cost analysis report comparing 18 flooring types (shown in Table 1, below) used in a typical office building. The LCCA was conducted according to ASTM E917 *Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems*, and is applicable to flooring used in light to medium commercial office spaces.

Ceramic Tile	Solid Wood
Quarry Tile	Sheet Vinyl
Porcelain Tile	Vinyl Composition Tile (VCT)
Laminate	Flexible Luxury Vinyl Tile (LVF/LVP)
Marble	Rigid Core Flooring (RCB, SPC, WPC, etc.)
Granite	Epoxy Terrazzo
Travertine	Poured Epoxy
Limestone	Carpet Tiles/Carpet Squares
Engineered Wood	Nylon Broadloom Carpet

***Table 1**: Eighteen flooring types of the study*

An LCCA is a powerful tool to aid decision makers in evaluating relevant costs for a given building system; it allows for comparison of the construction and maintenance costs of alternative building systems that meet the same functional requirements.

As consumers look toward more sustainable and durable products, this study provides information that would be of particular interest to investors, architects, purchasers, specifiers, and anyone involved in economic decision-making processes for building design. The results of this analysis showed that for a 75-year study period and 3% discount rate, quarry tile, ceramic tile, and porcelain tile, have the lowest life cycle costs of all 18 flooring types.

The key topics in the report that will be presented include the following:

- Background information on LCCAs, including an overview of key concepts
- Development of the LCCA report including funding and consensus development
- Key report foundations, including assumptions, constraints, and references
- Overview of LCCA results, including sensitivity analyses at various discount rates and study period lengths

BACKGROUND

What is an LCCA?

An LCCA is a robust analysis that provides insight into long-term costs of building systems by allowing them to be compared as net present values using specific economic conditions. For flooring, relevant costs typically include the costs of materials, installation, maintenance, repair, demolition, and replacement.

According to ASTM E917, "the basic premise of the LCC method is that to an investor or decision maker all costs arising from an investment decision are potentially important to that decision, including future as well as present costs." For example, if two materials cost the same to install and maintain but one must be replaced every 10 years, it is evident that the option not in need of replacement will have a lower lifetime cost. However, if the flooring that requires replacement costs significantly less to install, how can one compare the future replacement cost against the money saved by using the cheaper upfront option? LCCA allows material alternatives with different upfront and future costs to be compared by using a calculation, shown in **Equation 1**, that summarizes all relevant costs as "net present values" or "NPVs." NPVs[1] express the value of a sum of money in the present day, in contrast to its future value, if that money had been invested at a compounding interest rate.

[1] For the purposes of this report, the term "NPVs" is considered to have the same meaning as the terms "life cycle costs (LCC)" and "present value life cycle costs (PVLCC)."

Equation 1: Calculation of life cycle costs (expressed as net present values)

$$PVLCC = \sum_{t=0}^{N} \frac{C_t}{(1+i)^t}$$

Where:

PVLCC = present value life cycle cost

C_t = the sum of all relevant costs occurring in year "t"

N = length of study period in years

i = discount rate

To compare costs occurring at different points in the future over a building's lifetime using NPVs, costs must be "discounted" back to the present day by using a specific discount rate. According to ASTM E917, "the discount rate should reflect the investor's time value of money. That is, the discount rate should reflect the rate of interest that makes the investor indifferent between paying or receiving a dollar now or [a larger amount] at some future point in time. The discount rate is used to convert costs occurring at different times to equivalent costs at a common point in time." The discount rate is expressed in terms net of general price inflation, meaning the rate of inflation is subtracted from the rate of interest on an investment. For example, if there is a 6% return per year on an investment, but costs relating to that investment increase 3% per year due to inflation, the discount rate would be 3%.

2005 LCCA Study

Prior to the Lorenz's 2023 LCCA, the most recently available analysis for flooring was a 2005 LCCA.[2] This study was widely referred to in the US. The study showed that various ceramic options had the lowest life cycle costs per year. However, there have been numerous changes to the flooring market since 2005, including pricing changes, availability of new products and technologies, changes to expected lifetimes of materials, and updated maintenance schedules. Further, the 2005 study was based on a 50-year study period, which is inconsistent with the 75-year period utilized by many modern green building standards and PCRs when evaluating the environmental impact of materials.

[2] The 2005 LCCA most recently appeared in Tile Council of North America's *Tile The Natural Choice* in 2021.

SCOPE OF STUDY

Objectives

The objective of Lorenz's LCCA was to determine the life cycle costs of 18 different flooring types, shown in **Table 1**, over a 75-year study period for use in an office building assuming light to medium commercial use. A 3% discount rate was chosen based on the work of Lavappa and Kneifel (2018)[3], which set the real discount rate based on "long-term Treasury Bond rates averaged over 12 months and the general inflation rate." To check the sensitivity of the analysis to this study period and discount rate, additional analyses were run with a study period of 40 years and at various discount rates. Each material type included in the analysis was defined by referencing their respective CSI MasterFormat designations and applicable product specifications (e.g., the referenced specification for ceramic tile was ANSI A137.1 *American National Standard Specification for Ceramic Tile*).

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***Table 1**: Eighteen flooring types of the study*

As shown above, the three ceramic flooring types analyzed in the Lorenz study were ceramic tile, porcelain tile, and quarry tile. Other notable flooring types analyzed in that study that were not included in the 2005 study included plastic-based materials such as flexible LVT/LVP and rigid core flooring, as well as granite, travertine, and limestone flooring.

[3] Lavappa, P. and J. Kneifel. 2018. Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - 2018, Annual Supplement to NIST Handbook 135. NISTIR 85-3273-33, Washington, DC: National Institute of Standards and Technology.

KEY REPORT FOUNDATIONS

Assumptions

Broad financial support was provided by a variety of flooring industry associations to produce the Lorenz LCCA report. As a condition of undertaking the report and to avoid any suggestion of bias favoring the sources of financial support, selection of engineering parameters was made by the author without any outside influence. In evaluating data ambiguities, any reasonable choices that could potentially favor the selection of flooring types other than ceramic tile, porcelain tile, and quarry tile were preferred. These choices are identified and referred to as "conservative assumptions" within the Lorenz LCCA report.

The primary study parameters were a 75-year length of study and 3% discount rate, with life cycle costs expressed as NPVs. Seventy-five years is in line with current green building standards, including ASHRAE 189.1 and the International Green Construction Code (IgCC). Additionally, the most recent UL Product Category Rule for flooring assumes a 75-year building service life when evaluating environmental impacts. A 40-year sensitivity analysis was also included using discount rates of 0%, 5%, and 7%.

It is assumed that each flooring type is initially installed as new construction, with all serviceability and installation requirements met. While the LCCA is based on flooring use in light to medium commercial applications, Lorenz notes that many of the results would be applicable to residential applications with the primary difference being commercial applications experience increased loading due to more frequent rolling of carts and higher pedestrian traffic. All product replacements are assumed to occur at the end of a product's estimated useful life.

Service Life and Maintenance Information

For product-specific estimated service lives (ESL), which were used to determine when product replacement would occur, various industry-average EPDs were consulted. Information was also obtained from the National Association of Home Builders/Bank of America *Study of Life Expectancy of Home Components*, and from Fannie Mae's *Estimated Useful Life* tables. Some flooring types did not have an ESL that aligned with the study period, so residual values were calculated as a percentage of the initial cost and discounted back to NPV from the 75th year of the study period. The ceramic options each had an ESL of 75 years, per the North American industry-average EPD for ceramic tiles. Thus, replacement costs were not included for those materials.

Maintenance frequencies were obtained from various sources, including industry-average EPDs, established flooring association guidelines, and consensus-developed product specifications.

Cost Source Information

Costs of initial installation, maintenance, demolition, and replacement were included in the LCCA study. They were primarily obtained from the RS Means[4] national, commercial construction database. Data from 2020 were used, as those were the most recent available at the time the LCCA was being conducted and which were not affected by global supply chain issues caused by the COVID-19 pandemic. In the absence of RS Means data, "proxy" cost information was obtained from surveys of big-box retailers and industry sources. Common maintenance costs, the costs associated with daily cleaning practices common to each flooring type, were assumed to be the same and built into the final life cycle costs for all flooring types.

Costs related to landfill disposal or recycling fees, manufacturer take back programs, and associated transportation were not considered for the analysis. Requirements vary widely by flooring type, jurisdictional requirements, and availability. In addition, technologies and strategies available 75 years in the future are speculative. Also, costs associated with the loss of retail sales, loss of rental income, or other disruptions due to demolition and reinstallation of flooring at the end of a product's estimated service life were not considered.

LCCA Constraints

This study is not an "apples to apples" comparison of different flooring types as certain floors are more commonly used where the soil load is high and appearance expectations across all flooring types differ. However, all flooring types, regardless of their suitability for different traffic conditions, whether heavy commercial or residential, were evaluated in this study based on light to medium commercial use.

Product maintenance and replacements due to user preferences or design trends were not considered.

RS Means cost data are for generic installation methods. Where cost data were unavailable in RS Means, costs were obtained from various sources in the years 2021 through 2023, but cost fluctuations between those years were not examined.

[4] RS Means is a widely referred to cost database that compiles labor cost information based on rates in the largest 30 US cities, and materials cost information from consultation with material manufacturers, dealers, distributors, and contractors in the US and Canada. RS Means assumes an installing contractor overhead and profit of 10%.

SUMMARY AND RESULTS

Primary Results

The results for a 75-year length of study and 3% discount rate are shown in **Table 3**, sorted from lowest life cycle cost to highest, with life cycle costs expressed as NPVs. The three ceramic options analyzed have the lowest life cycle costs of the 18 options considered.

Material Type	Initial Installation Cost[5] (per sq. ft.)	Life Cycle Cost (per sq. ft.)	Estimated Useful Life	Cost Per Year[6] (per sq. ft.)
Quarry Tile	$9.53	$71.31	75 years	$0.95
Ceramic Tile	$11.03	$72.81	75 years	$0.97
Porcelain Tile	$11.38	$73.16	75 years	$0.98
Solid Wood	$8.92	$75.78	75 years	$1.01
Engineered Wood	$7.92	$78.76	25 years	$1.05
Limestone	$24.30	$101.68	75 years	$1.36
Travertine	$24.30	$101.68	75 years	$1.36
Granite	$26.65	$102.69	75 years	$1.37
Marble	$26.65	$104.03	75 years	$1.39
Nylon Broadloom Carpet	$5.86	$125.41	5 years	$1.67
Flexible LVT/LVP	$4.56	$131.66	15 years	$1.76
Carpet Tiles/Squares	$5.25	$132.57	5 years	$1.77
Rigid Core Flooring	$6.36	$136.13	15 years	$1.82
Epoxy Terrazzo	$13.66	$137.22	75 years	$1.83
Laminate	$8.49	$138.45	20 years	$1.85
Poured Epoxy	$11.49	$155.91	15 years	$2.08
VCT	$3.09	$159.48	15 years	$2.13
Sheet Vinyl	$7.10	$169.46	15 years	$2.26

Table 3: *Life cycle costs for flooring in commercial buildings*

[5] Initial installation costs are the addition of the material and labor costs for each respective material type.
[6] Costs per year are the life cycle costs for each respective material divided by the length of the study period (75 years).

Sensitivity Analysis

To check the sensitivity of the primary results, additional analyses were conducted using the following conditions:

7% discount rate and a 75-year study period

5% discount rate and a 75-year study period

0% discount rate and a 75-year study period

7% discount rate and a 40-year study period

5% discount rate and a 40-year study period

3% discount rate and a 40-year study period

0% discount rate and a 40-year study period

At a 7% discount rate and a 75-year study period, the best performing option was quarry tile at $0.52/sq. ft./year. The worst performing option was sheet vinyl at $1.11/sq. ft./year. The rank orders of these two material types did not change in comparison to the 3% discount rate results. The key difference is the change in cost difference between those two options—at 3% the difference was $1.31/sq. ft./year, at 7% the difference was $0.59/sq. ft./year. This shows that a "higher" discount rate decreases the delta between the best performing option and worst performing option. However, more durable materials with lower future costs still have lower life cycle costs.

At a 0% discount rate and a 75-year study period, the best performing option was quarry tile at $2.21/sq. ft./year. The worst performing option was sheet vinyl at $5.59/sq. ft./year. The rank orders of these two material types did not change in comparison to the 3% discount rate results. The key difference is the change in cost difference between those two options—at 3% the difference was $1.31/sq. ft./year, at 0% the difference was $3.38/sq. ft./year. This shows that a "lower" discount rate increases the delta between the best performing option and worst performing option.

At a 3% discount rate and study length of 40 years, the rank order of all materials stayed the same. The only difference was that the final life cycle costs increased for each option based on their cost per year. The cost of quarry tile was $1.41/sq. ft./year, whereas sheet vinyl cost $3.30/sq. ft./year.

CONCLUSIONS

The sensitivity analyses revealed that regardless of economic conditions, the rank orders always stayed relatively similar in comparison to the primary results (75-year study period, 3% discount rate). Further, ceramic tile, porcelain tile, quarry tile, solid wood, and engineered wood always had the lowest costs per year per square foot. The poured epoxy, VCT, and sheet vinyl options always had the highest costs per year per square foot.

ACKNOWLEDGEMENTS

Tile Council of North America thanks Ms. Emily Lorenz, who conducted the life cycle cost analysis and prepared the report that this paper is based on. For further in-depth analysis on this study, please refer to her report titled *Life-cycle costs for flooring in commercial buildings*, which can be obtained for free at https://whytile.com/guide/resource-library/.

REFERENCES

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[3] Fannie Mae. 2019. *Estimated Useful Life Tables*.

[4] https://multifamily.fanniemae.com/media/6701/display.

[5] Lavappa, P. and J. Kneifel. 2018. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - 2018, Annual Supplement to NIST Handbook 135*. NISTIR 85-3273-33, Washington, DC: National Institute of Standards and Technology.

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[9] UL Environment. 2018. *Product Category Rules (PCR) Guidance for Building-Related Products and Services Part B: Flooring EPD Requirements*. UL 10010-7, Northbrook, IL: UL Environment.