The overall goals of this dissertation are to investigate the sustainability of the built environment, holistically, by assessing its Triple-Bottom-Line (TBL): environmental, economic, and social impacts, as well as propose cost-effective, socially acceptable, and environmentally benign policies using several decision support models. This research is anticipated to transform life cycle assessment (LCA) of the built environment by using a TBL framework, integrated with Economic Input-Output (EIO) analysis, simulation, and multi-criteria optimization tools. The major objectives of the outlined project are to (1) build a system-based TBL sustainability assessment framework for the sustainable built environment, by (a) advancing a national TBL-LCA model which is not available for the United States of America; (b) extending the integrated sustainability framework through TBL sustainability indicators; and (2) develop a system-based analysis toolbox for sustainable decisions including Monte Carlo simulation and multi-criteria compromised programming.

When assessing the total sustainability impacts by each U.S. construction sector, Residential Permanent Single and Multi-Family Structures" (R-PSMFS) and "Other Non-residential Structures" (NR-OTR) are found to have the highest environmental, economic, and social impacts compared to other construction sectors. The analysis results also show that indirect suppliers of construction sectors have the largest sustainability impacts compared to on-site activities. For example, for all U.S. construction sectors, on-site construction processes are found to be responsible for less than 5% of total water consumption, whereas about 95% of total water use can be attributed to indirect suppliers. In addition, Scope 3 emissions are responsible for the highest carbon emissions compared to Scope 1 and 2.

After analyzing the U.S. construction sectors, a hybrid TBL-LCA model is utilized to analyze the sustainability impacts of the U.S. residential building stock from cradle to grave. Analysis results revealed that construction phase, electricity use, and commuting played important role in much of the sustainability impact categories. Natural gas and electricity consumption accounted for 72% and 78% of the total energy consumed in the U.S. residential buildings. Also, the electricity use was the most dominant component of the environmental impacts with more than 50% of greenhouse gases emitted and energy used through all life stages of the U.S. buildings. Furthermore, electricity generation was responsible for 60% of the total water withdrawal of residential buildings, which was even greater than the direct water consumption in residential buildings. In addition, construction phase had the largest share in income category with 60% of the total income generated through residential building's life cycle. Residential construction sector and its supply chain were responsible for 36% of the foreign purchase, 40% of the business profit, and 50% of the GDP contribution.

In addition, several emerging pavement types are analyzed using a hybrid TBL-LCA framework. WMAs did not perform better in terms of environmental impacts compared to HMA. Asphamin WMA was found to have the highest environmental and socio-economic impacts compared to other pavement types. Material extractions and processing phase had the highest contribution to all environmental impact indicators that shows the importance of cleaner production strategies for pavement materials. Based on stochastic compromised programming results, in a balanced weighting situation, Sasobit WMA had the highest percentage of allocation (61%), while only socio-economic aspects matter, Asphamin WMA had the largest share (57%) among the WMA and HMA mixtures. Consequently, the outcomes of this dissertation will advance the state of the art in built environment sustainability research by investigating novel efficient methodologies capable of offering optimized policy recommendations by taking the TBL impacts of supply chain into account.

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