SYNERGISING CONTINUOUS IMPROVEMENT WITH CIRCULAR ECONOMY FOR ADVANCING INNOVATION IN THE CONSTRUCTION SECTOR: A TEXT MINING APPROACH

Temitope S Omotayo[1], Bankole Awuzie[2] and Obi Lovelin[3]

[1] *School of Built Environment Engineering and Computing, Leeds Beckett University, City Campus, Leeds, West Yorkshire, LS2 8AG, UK*

[2] *School of Construction Economics and Management, University of Witwatersrand, 10b Yale Rd, Braamfontein, Johannesburg 2000, South Africa*

[3] *Department of Architecture and Built Environment, Northumbria University, Sutherland Building, Northumberland Road, Newcastle-upon-Tyne, NE1 8ST, UK*

Integrating continuous improvement and circular economy principles can promote sustainable construction practices (SCPs) and deliver long-term environmental, social and economic benefits. This study demonstrated how text mining could be applied to explicate the linkage between continuous improvement and circular economy principles in enhancing sustainable construction practices. The research applied unsupervised machine learning using text mining analyses through collocations to identify thematic areas where the integration of continuous improvement and circular economy principles would foster sustainable construction. Eighty-nine (89) peer-reviewed publications were extracted from the Scopus database for text mining analysis. The findings from text mining presented seven cogent themes through which continuous improvement and circular economy can be integrated. The optimal integration of the linkages advocated in this research can facilitate improved SCPs such as design for disassembly, modular construction, adaptive reuse, eco-friendly materials, innovative technologies, industrial symbiosis, life cycle assessment, cradle-to-cradle design, and lean construction practices. This investigation elucidated the utility of machine learning text mining in thematising and advancing sustainable construction research.

Keywords: sustainable construction; improvement; circular economy; text mining

INTRODUCTION

The construction industry contributes significantly to global resource consumption, waste generation, and greenhouse gas emissions (Giesekam *et al.,* 2016). Adopting sustainable practices is essential to reduce the environmental impact of this sector. Continuous improvement is a management philosophy that facilitates incremental change to achieve long-term sustainable growth (Omotayo *et al.,* 2018). Continuous improvement and circular economy are key to promoting sustainable construction

[1] t.s.omotayo@leedsbeckett.ac.uk

Omotayo, T S, Awuzie, B and Lovelin, O (2023) Synergising Continuous Improvement with Circular Economy for Advancing Innovation in the Construction Sector: A Text Mining Approach *In:* Tutesigensi, A and Neilson, C J (Eds) *Proceedings of the 39th Annual ARCOM Conference,* 4-6 September 2023, University of Leeds, Leeds, UK, Association of Researchers in Construction Management, 771-779.

(Bocken *et al.,* 2016). In sustainable construction, continuous improvement involves identifying, prioritising, and implementing strategies to improve environmental, social, and economic performance during construction (Azhar *et al.,* 2011). This approach fosters a culture of innovation and encourages new technologies and processes, such as Building Information Modelling (BIM) and off-site construction. This significantly reduces waste and improves resource efficiency.

This investigation demonstrates how text mining can be applied to elicit and link themes associated with continuous improvement and circular economy towards promoting sustainable construction practices (SCPs).

LITERATURE REVIEW

Osobajo *et al.,* (2020) and Obi *et al.,* (2023) asserted that integrating continuous improvement and circular economy principles is vital for promoting SCPs. Continuous improvement in construction applied the Deming circle of plan-do-check-act to reduce physical and non-physical waste (Omotayo *et al.,* 2022; Tezel *et al.,* 2023). These concepts encourage the adoption of innovative technologies and processes, enhance resource efficiency, and contribute to economic growth, providing a strong foundation for a more sustainable and resilient construction industry. Circular economy involves a paradigm shift from the traditional linear 'take-make-dispose' model to a regenerative system that aims to minimise waste and maximise resource efficiency (Ellen MacArthur Foundation, 2013; Osobajo *et al.,* 2020). Circular economy emphasises the importance of designing for disassembly, reuse, and recycling to keep materials in circulation for as long as possible (Bocken *et al.,* 2016, Ramakrishna *et al.,* 2020).

Circular economy principles can be implemented in the construction sector through various strategies, including modular design, adaptive reuse, and eco-friendly materials (Arup, 2016). The adoption of these concepts in the construction industry not only contributes to environmental sustainability but also provides economic benefits. By reducing waste, conserving resources, and promoting innovation, SCPs can lead to cost savings, new business opportunities, and increased competitiveness (Giesekam *et al.,* 2016). Although the term continuous improvement is not very popular, it is important to emphasise the relevance and recency of continuous improvement in construction cost management, procurement, construction, and building information modelling (to mention a few) through the publication of Omotayo *et al.,* (2022); Tezel *et al.,* (2023) and Rashidian (2023).

Continuous improvement has been applied throughout construction since the 1980s through lean philosophy to reduce construction waste (Omotayo *et al.,* 2022; Tezel *et al.,* 2023). Integrating continuous improvement and circular economy principles in sustainable construction creates a synergistic effect that enhances overall environmental performance. For example, continuous improvement can help identify construction material reuse and recycling opportunities, leading to improved circular economy performance (Bocken *et al.,* 2016). Azhar *et al.,* (2011) further noted that circular economy strategies, such as designing for disassembly and using recycled materials, can be incrementally improved through continuous innovation and learning. Suffice it to state that the combination of continuous improvement and circular economy principles will encourage the development of a more resilient and adaptive industry better equipped to address future sustainability challenges (Arup, 2016). Therefore, establishing measures for integrating continuous improvement and circular economy principles could lead to effective Sustainable construction practices and performance.

This study aims to explicit the function of text mining analysis in mapping and establishing interconnectedness between continuous improvement and circular economy towards improving SCPs and performances within the construction industry.

METHOD

Text mining is extracting useful information and patterns from unstructured text data using computational techniques (Feldman and Sanger, 2007). This includes multiple techniques such as natural language processing (NLP), unsupervised ML, and statistical techniques to analyse and understand text content and structure (Nassirtoussi *et al.,* 2014). Unsupervised ML pertains to a situation where the algorithm learns from unlabeled data without the influence of specific data for outputs. Hence, the outputs are generated automatically by the algorithm. Text mining applications are extensive and span areas such as sentiment analysis, topic modelling, and information extraction (Aggarwal and Zhai, 2012). Text mining enables researchers to extract valuable insights from large amounts of text data that are difficult to analyse manually. As part of this analysis, collocations were used in R Studio's text mining process.

Text mining collocations involve identifying pairs of words frequently occurring together in a corpus more often than expected by chance (Manning and Schütze, 1999). Collocations provide insights into language patterns and help uncover meaningful associations between words, which can be useful in various NLP tasks, such as sentiment analysis or information retrieval (Evert, 2008). Analysing collocations can help reveal hidden semantic structures and improve the understanding of the relationships among words in the context of the text (Baker, 2006) as the exclusion criteria. The text mining data was extracted from Scopus using the keywords “continuous” AND “improvement” AND “circular” AND “economy” AND “the” AND “construction” AND “industry”. Four hundred and sixty-one (461) documents were retrieved from Scopus. Only peer-reviewed articles published between 2012-2022 and in English were considered for use because of quality and validity requirements for the text mining operation (as the exclusion criteria). Additional manual reviews of the document were undertaken to eliminate irrelevant publications. Through this process, eighty-nine (89) peer-reviewed publications were deemed relevant to be included in the text mining collocations analysis.

The formula for calculating collocations in R typically involves using measures such as Pointwise Mutual Information (PMI) or Log-Likelihood Ratio (LLR) to identify pairs of words that frequently co-occur in a corpus (Evert, 2008). PMI is defined as:

$$PMI(w1,w2)=\log_2(P(w1,w2)/(P(w1)*P(w2))) \quad (1)$$

where P(w1, w2) is the probability of observing the two words w1 and w2 together, and P(w1) and P(w2) are the probabilities of observing the individual words (Church and Hanks, 1990). To calculate collocations in R, the "quanteda" package can be used to tokenise text, remove stopwords, and extract n-grams, while the "text2vec" package can be used to compute the PMI or LLR measures (Benoit *et al.,* 2018; Selivanov and Wang, 2016). The text data was analysed using the R script (Figure 1) to identify collocations. The R script is divided into several steps, as highlighted below: related to the terms "improvement”, “continuous”, “circular”, and “economy”.

Step 1: Data pre-processing: Cleaning, tokenisation, and removing stopwords and extra words.
Step 2: Bigram extraction: Extracting bigrams from the tokenised text.

Step 3: Corpus creation and cleaning: Converting the text data into a corpus and removing unnecessary words.
Step 3: Co-occurrence statistics calculation: Calculating co-occurrence statistics for the term "improvement", “Continuous”, “Circular”, and “Economy”.
Step 4: Association strength: Creating a data frame and bigram table with the association strength of the collocating terms.
Step 5: Visualisations: Visual representations of the collocations through a dendrogram and network graph.

Figure 1: R script for collocations of continuous improvement and circular economy

```
#load all files
All_CIfiles <- read_docx("CI.docx")
Contents<- docx_summary(All_CIfiles)
#read text from the content variable
paragraph<- Contents %>% filter(content_type == "paragraph")
Doc_Data<- paragraph$text # Access actual text
paste0(collapse = " ") %>%
  stringr::str_squish() %>%
  stringr::str_remove_all("- ")
Doc_split <- Doc_Data %>%
  as_tibble() %>%
  tidytext::unnest_tokens(words, value)
# create data frame
ci_words <- Doc_split %>%
  dplyr::rename(word1 = words) %>%
  dplyr::mutate(word2 = c(word1[2:length(word1)], NA)) %>%
  na.omit()
ci2grams <- ci_words %>%
  dplyr::mutate(bigram = paste(word1, word2, sep = " ")) %>%
  dplyr::group_by(bigram) %>%
  dplyr::summarise(frequency = n()) %>%
  dplyr::arrange(-frequency)
```

FINDINGS

Framework of Continuous Improvement and Circular Economy

In developing a framework for linking continuous improvement and circular economy principles through text mining collocations, a dendrogram and network diagram, as illustrated in Figures 2 and 3, were produced. The dendrogram categorised the texts from the collocations analyses, and the network diagram exhibited the strength of the collocation in the thicker lines. The dendrogram and network diagram findings can be categorised as a continuous improvement for development; integration into the supply chain; industrial manufacturing processes; organisational culture and leadership; quality and site management; cyclical economic flow; and PDCA decisions.

Table 1 itemises 20 collocations with corresponding frequencies, lengths, lambda values, and Z scores. The lambda score is the measure of association between two variables and the z score is the number of standard deviations a specific variable is away from the mean value (Baker, 2006. The lambda and Z scores reveal the relevance of the collocations. More relevance is suggested by higher lambda and Z scores. For instance, "Continuous Improvement" is a notable keyword in Table 1 because it has the highest Z score (21.97) and the highest lambda score (6.75). Like "Circular economy," with a high lambda (3.95) and Z score (19.00), "Life cycle" also highlights the relevance of these concepts. The Z scores typically decline down Table 1, indicating decreased relevance for these collocations.

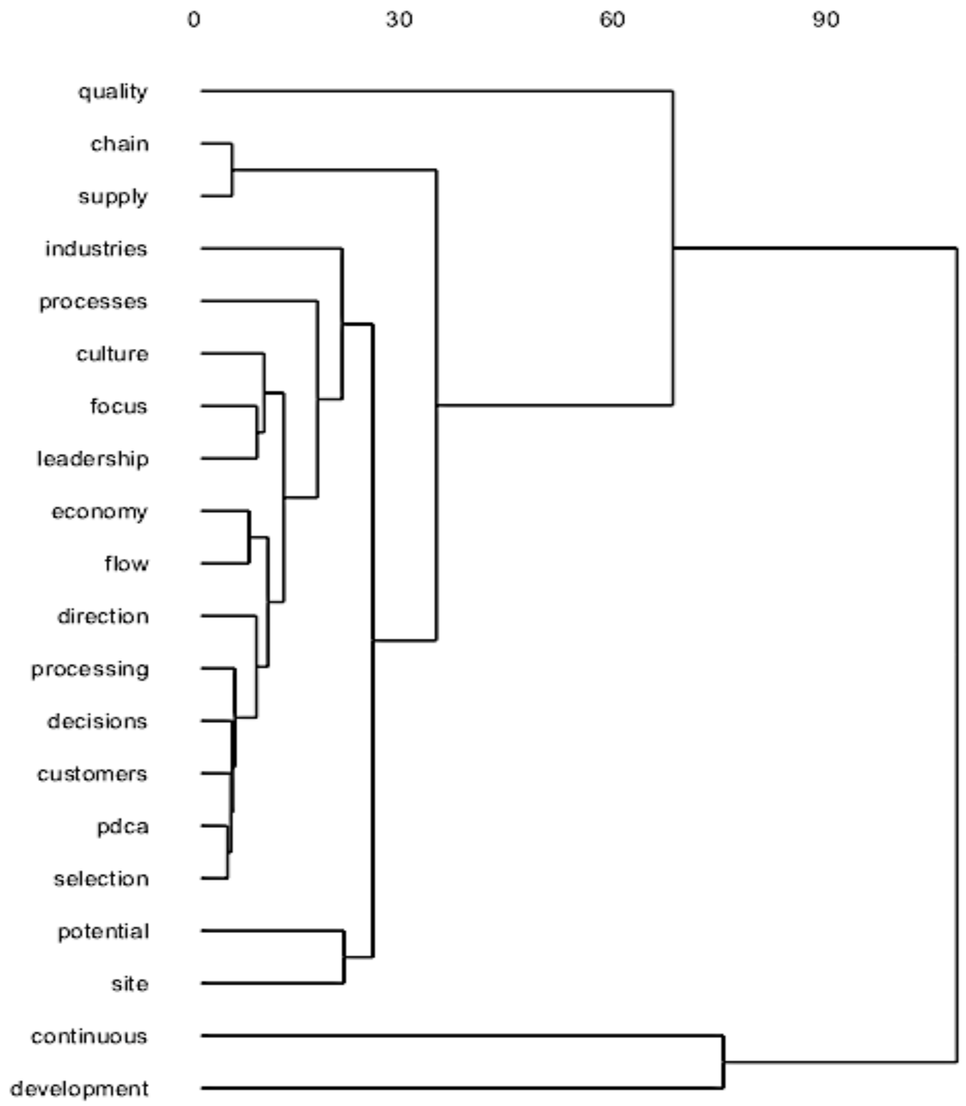

Figure 2: Dendrogram from text mining collocations

Figure 3: Network diagram of continuous improvement and circular economy

To synergise continuous improvement with circular economy principles from Figures 2, 3, and Table 1 text mining collocations produced thematic application areas in the construction sector.

Table 1: Text-mining collocations showing lambda and z values

S/N	Collocation	Count	Length	Lambda	z
1	Continuous Improvement	53	2	6.747401	21.965519
2	Circular economy	47	2	3.949813	19.003393
3	Life cycle	17	2	5.781885	13.695019
4	Construction Resources	11	2	6.408618	13.419721
5	Construction technologies	13	2	8.326186	12.341994
6	Building Information	9	2	6.853042	11.823485
7	Practical Implications	7	2	7.219799	11.523591
8	Modular construction	8	2	7.964179	11.166175
9	Customer Satisfaction	7	2	8.134601	11.095890
10	Safety Performance	9	2	4.463799	11.073083
11	Material Transportation	6	2	7.623686	10.895436
12	Cost Control	6	2	5.733656	10.737258
13	Design Quality	10	2	3.993786	10.736981
14	Green Building	7	2	7.564401	10.706928
15	Construction Projects	14	2	3.867110	10.667298
16	Lean construction	6	2	7.807408	10.458364
17	Soil Recycling	5	2	7.313531	10.373453
18	Life Cycle	5	2	7.456721	10.364844
19	Material Technology	7	2	4.963791	10.339321
20	Workforce Productivity	10	2	7.523062	10.289716

Industrial Symbiosis in Construction

Industrial symbiosis is a concept derived from circular economy that facilitates the exchange of resources, energy and knowledge between different industries to create mutually beneficial relationships (Ramakrishna *et al.,* 2020). An example of industrial symbiosis in the construction industry is using waste from other industries as raw materials for new construction projects (Yuan and Shen, 2011). This practice reduces waste, reduces demand for new materials and contributes to a more sustainable construction sector.

Life Cycle Assessment in Construction

Life Cycle Assessment (LCA) is a method of evaluating the environmental impact of a product or process throughout its life cycle, from raw material extraction to disposal (Rebitzer *et al.,* 2004). By applying her LCA in the construction industry, decision-makers can identify areas for continuous improvement, including material selection, design optimisation, and waste management strategies (Khasreen, *et al.,* 2009). Construction organisations can make more informed decisions and minimise their environmental footprint by implementing their LCA in construction projects.

Cradle-to-Cradle Design in Construction

McDonough and Braungart (2002) and Ricard *et al.,* (2023) detailed that cradle-to-cradle design is a concept that facilitates the development of environmentally friendly, recyclable, and renewable products and processes. The cradle-to-cradle design fosters continuous improvement by encouraging the development of innovative materials, technologies and construction techniques that minimise waste and maximise resource efficiency. Lewandowski (2016) noted that this approach could be applied to the construction industry by using biodegradable materials, integrating renewable energy systems, and designing buildings that can be easily dismantled and reused.

Lean Construction Practices

Lean Construction is an approach focused on minimising waste and maximising the value of the construction process through continuous improvement, collaboration, and efficient processes (Koskela, 1992; Akinade *et al.,* 2018). By implementing lean construction practices, companies can improve resource efficiency, reduce project delays, and improve overall project quality (Salem, Solomon, Genaidy, and Minkarah, 2006). By integrating lean principles into circular economy, we can develop more SCPs and achieve long-term environmental, social and economic goals.

CONCLUSION

This investigation highlighted how text mining as an analytical approach could aid the incorporation of continuous improvement and circular economy principles to promote sustainable construction practices and performances. The research created crucial links between these concepts and their influence on sustainable construction by utilising text mining. Key thematic areas that link continuous improvement and circular economy principles were identified. These include the design for disassembly, modular construction, adaptive reuse, eco-friendly materials, cutting-edge technologies, industrial symbiosis, life cycle assessment, cradle-to-cradle design, and lean construction techniques. Resource efficiency, waste reduction, extended building lifespans, and improved environmental performance. This study also emphasises the significance of machine learning text mining for finding and advancing sustainable construction. Further research applications must be conducted on larger datasets to optimise sustainable construction research for the built environment.

REFERENCES

Aggarwal, C C and Zhai, C (2012) *Mining Text Data*, Cham: Springer Science and Business Media.

Akinade, O O, Oyedele, L O, Ajayi, S O, Bilal, M, Alaka, H A, Owolabi, H A and Arawomo, O O (2018) Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment, *Journal of Cleaner Production*, **180**, 375-385.

Arup (2016) *Circular Economy in the Built Environment*, Available from: https://www.arup.com/perspectives/publications/research/section/circular-economy-in-the-built-environment [Accessed 31 March 2023].

Azhar, S, Carlton, W A, Olsen, D and Ahmad, I (2011) Building information modelling for sustainable design and LEED® rating analysis, *Automation in Construction*, **20**(2), 217-224.

Baker, P (2006) *Using Corpora in Discourse Analysis*, London: Bloomsbury Publishing.

Benoit, K, Watanabe, K, Wang, H, Nulty, P, Obeng, A, Müller, S and Matsuo, A (2018) quanteda: An R package for the quantitative analysis of textual data, *Journal of Open-Source Software*, **3**(30), 774.

Bocken, N M P, de Pauw, I, Bakker, C and van der Grinten, B (2016) Product design and business-model strategies for a circular economy, *Journal of Industrial and Production Engineering*, **33**(5), 308-320.

Church, K W and Hanks, P (1990) Word association norms, mutual information and lexicography, *Computational Linguistics*, **16**(1), 22-29.

Ellen MacArthur Foundation (2013) *Towards the Circular Economy: Economic and Business Rationale for an Accelerated Transition*, Available from: https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf [Accessed 29 March 2023].

Evert, S (2008) Corpora and collocations, *In*: A Lüdeling and M Kytö (Eds.) *Corpus Linguistics: An International Handbook*, Berlin: Mouton de Gruyter, 1212-1248

Feldman, R and Sanger, J (2007) *The Text Mining Handbook: Advanced Approaches to Analysing Unstructured Data*, Cambridge: Cambridge University Press.

Giesekam, J, Barrett, J R, Taylor, P and Owen, A (2016) Construction sector views on low carbon building materials, *Building Research and Information*, **44**(4), 423-444.

Khasreen, M M, Banfill, P F G and Menzies, G F (2009) Life-cycle assessment and the environmental impact of buildings: A review, *Sustainability*, **1**(3), 674-701.

Koskela, L (1992) *Application of the New Production Philosophy to Construction*, Technical Report #72 Center for Integrated Facility Engineering (CIFE), Stanford University Available from: https://pdfs.semanticscholar.org/f45a/2b9437f55e5b5f7b0aae0af6b9d2f1cdd9e6.pdf [Accessed 31 March 2023].

Lewandowski, M (2016) Designing the business models for circular economy - towards the conceptual framework, *Sustainability*, **8**(1), 43.

Manning, C D and Schütze, H (1999) *Foundations of Statistical Natural Language Processing*, Cambridge, MA: MIT Press.

McDonough, W and Braungart, M (2002) *Cradle to Cradle: Remaking the Way We Make Things*, New York: North Point Press.

Nassirtoussi, A K, Aghabozorgi, S, Wah, T Y and Ngo, D C L (2014) Text mining for market prediction: A systematic review, *Expert Systems with Applications*, **41**(16), 7653-7670.

Obi, L, Arif, M, Daniel, E I, Oladinrin, O T and Goulding, J S (2023) Establishing underpinning concepts for integrating circular economy and offsite construction: A bibliometric review, *Built Environment Project and Asset Management*, **13**(1), 123-139.

Omotayo, T S, Boateng, P, Osobajo, O, Oke, A and Obi, L I, (2020) Systems thinking and CMM for continuous improvement in the construction industry, *International Journal of Productivity and Performance Management*, **69**(2), 271-296.

Omotayo, T S, Kulatunga, U and Bjeirmi, B (2018) Critical success factors for Kaizen implementation in the Nigerian construction industry, *International Journal of Productivity and Performance Management*, **67**(9).

Omotayo, T S, Kulatunga, U and Awuzie, B (2022) *Continuous Cost Improvement in Construction: Theory and Practice, 1st Edition*, Abingdon: Routledge.

Osobajo, O A, Oke, A, Omotayo, T and Obi, L I (2020) A systematic review of circular economy research in the construction industry, *Smart and Sustainable Built Environment*, **11**(1), 39-64.

Rashidian, S, Drogemuller, R and Omrani, S (2023) Building information modelling, integrated project delivery and lean construction maturity attributes: A Delphi study, *Buildings*, **13**(2), 281.

Ramakrishna, S, Ngowi, A, Jager, H D and Awuzie, B O (2020) Emerging industrial revolution: Symbiosis of industry 4.0 and circular economy: The role of universities, *Science, Technology and Society*, **25**(3), 505-525.

Rebitzer, G, Ekvall, T, Frischknecht, R, Hunkeler, D, Norris, G, Rydberg, T, Schmidt, W P, Suh, S, Weidema, B P and Pennington, D W (2004) Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis and applications, *Environment International*, **30**(5), 701-720.

Ricard, L M, Hybel, S B and Jofre, S (2023) Design as a catalyst for the circular economy, *In*: H Lehtimäki, L Aarikka-Stenroos, A Jokinen, P Jokinen (Ed.) *The Routledge Handbook of Catalysts for a Sustainable Circular Economy*, Abingdon: Routledge.

Salem, O, Solomon, J, Genaidy, A and Minkarah, I (2006) Lean construction: From theory to implementation, *Journal of Management in Engineering*, **22**(4), 168-175.

Selivanov, D and Wang, Q (2016) *Text2vec: Modern Text Mining Framework for R R Package, Version 0.5.1*, Available from https://CRAN.R-project.org/package=text2vec

Tezel, A, Koskela, L and Tzortzopoulos, P (2023) Implementation of continuous improvement cells: A case study from the civil infrastructure sector in the UK, *Production Planning and Control*, **34**(1), 68-90.