Sustainability knowledge management through Benchmarking: the case of CO2 emissions from cement production

Gestão do conhecimento em sustentabilidade através de Benchmarking: o caso das emissões de CO2 da produção de cimento

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ABSTRACT
Sustainability knowledge management consists of the use of relevant information to reduce environmental, economic and social impacts from products and services while benchmarking consists of comparing performance metrics to industry best practices to set up a base line. This study shows how sustainability knowledge management could be achieved through benchmarking CO2 emissions from cement production using data from the Global Cement and Concrete Association companies. A range from 588 to 805 kg CO2/ t of cement is observed from 1990 to 2019. CO2 emissions have decreased from 1990; however, an increase was observed from 2015 which requires immediate attention. The study demonstrates the benefits from benchmarking in order to improve, support validation of data consistency, communication of performance, goals definition and adjustment. A literature review also supports the potential of using benchmarks for sustainability knowledge management.

Keywords: benchmark, environmental performance, eco-efficiency, sustainable construction.

RESUMO
A gestão do conhecimento de sustentabilidade consiste no uso de informações relevantes para reduzir os impactos ambientais, econômicos e sociais de produtos e serviços, enquanto o benchmarking consiste em comparar métricas de desempenho com as melhores práticas da indústria para estabelecer uma linha de base. Este estudo mostra como a gestão do conhecimento de sustentabilidade poderia ser alcançada através do benchmarking das emissões de CO2 da produção de cimento utilizando dados das empresas da Global Cement and Concrete Association. Uma faixa de 588 a 805 kg de CO2/t de cimento é observada de 1990 a 2019. As emissões de CO2 diminuíram a partir de 1990;
entretanto, um aumento foi observado a partir de 2015, o que requer atenção imediata. O estudo demonstra os benefícios do benchmarking a fim de melhorar, apoiar a validação da consistência dos dados, comunicação do desempenho, definição e ajuste de metas. Uma revisão bibliográfica também apóia o potencial do uso de benchmarks para a gestão do conhecimento de sustentabilidade.

**Palavras-chave:** benchmarking, desempenho ambiental, eco Eficiência, construção sustentável.

### 1 INTRODUCTION

Sustainability is described as meeting the needs of the current generations without sacrificing the ability of future generations to meet their own needs (BRUNDTLAND; KHALID, 1987). In order to achieve sustainability, many strategies have been posed (LIMA et al., 2021). One important practice that is sometimes underestimated is sustainability knowledge management. This is even more the case for construction organizations (ROBINSON et al., 2005).

Knowledge management entails sharing and using knowledge among members of an organization, association, economic sector, etc. The objective of knowledge management is to transfer knowledge from the place where it is generated to the place where it could be useful (FUENTES MORALES, 2010). Knowledge management focuses on members of a group knowing what their peers know with the aim of improving the overall performance of all members of the group (BELLY, 2014). This concept is occupied by many organizations looking for improvement in different aspects including sustainability.

In the context of sustainability, knowledge management consists of the administration and use of relevant information in order to reduce environmental, economic and social impacts from our products and services. A benefit of sustainable knowledge management is the possibility of solving issues related to collecting and assessing the knowledge required by a group. This is essential for companies to make construction projects more sustainable (SHELBOURN et al., 2006). Another benefit is the promotion of proven sustainability practices. Furthermore, sustainable knowledge management is required for decision making.

Cement production contributes to approximately 8% of global CO₂ emissions (SCRIVENER; JOHN; GARTNER, 2018). At the same time, it has an
important role for society since it is one of the main building materials worldwide and it is required to attend housing and infrastructure demand due to population growth. The use of cement-based materials is quite popular since this is a durable, easy to use and economic material. For these reasons, cement needs to be produced in a more sustainable way (MONTEIRO; MILLER; HORVATH, 2017).

In order to reduce CO₂ emissions from the production of cement first thing to do is to measure. Quoting Lord Kelvin, “When you can measure what you are speaking about, and express it in numbers, you know something about it…” (THOMPSON, 2011). In this work, sustainable knowledge management is applied through benchmarking - the practice of comparing processes and performance metrics to industry best practices to set up a base line- to continue to reduce CO₂ emissions from cement production.

Benchmarking takes place within a defined group of similar participants to compare their performance in terms of a specific indicator which enables participants from the group to develop strategies for improvement and achieving best practices. By benchmarking, it is possible to identify strong and weak performing units and reasons for their performance. This should be a continuous process to support continuous improvement.

Benchmarking can be internal when comparing teams, departments, branches, plants from the same company or external when comparing the company to other companies in the same economic sector. Another classification of benchmark is according to what is compared. For instance, technological routes, efficiency and strategic benchmarking.

In this context, the aim of this study is to illustrate how sustainability knowledge management could be achieved through benchmarking CO₂ emissions from cement production. The data for this study is published by companies from the Global Cement and Concrete Association (GCCA) (GLOBAL CEMENT AND CONCRETE ASSOCIATION, 2020). These companies have cement plants in many regions of the world. The data on CO₂ emissions have been measured directly in their cement plants (primary data) and is reported following the Global Report Initiative (GRI) (GLOBAL SUSTAINABILITY STANDARDS BOARD, 2016).
2 METHODOLOGY

A qualitative and quantitative approach was used to systematically assess the results of previous research and obtain conclusions regarding the objective of this study.

Initially, an exploratory study was conducted to identify the use of benchmarks in sustainability management in the construction sector. A literature review was conducted using the Google Scholar search engine. The key-words “benchmark”, “construction” and “sustainability” were used, and the results were limited to those from 2000 and having more than 100 citations to include their impact. An analysis and discussion based on the studies that were found were conducted to explore the potential of benchmarking according to these studies.

The concept of knowledge management presented in the introduction is used within the construction sector, specifically the GCCA companies that have published their gross CO₂ emissions withing the Greenhouse Gas (GHG) emissions intensity ratio G4-EN18 indicator for environmental performance based on the Global Reporting Initiative (GRI) G4 Guidelines. The data was collected from published annual reports from Argos, Cemex, Heidelberg, Holcim, Lafarge, LafargeHolcim¹ and Titan which are cement producers.

GCCA companies’ sustainability reports were collected from years 2001 to 2019. Then, data corresponding to the G4-EN18 305-4 indicator from the GRI Sustainability Reporting Standards (GRI Standards) (GLOBAL REPORTING INITIATIVE, 2020) on emissions were collected from each sustainability report. The 305-4 indicator corresponds to greenhouse gases emissions intensity. The reporting organization should calculate this indicator by dividing the absolute GHG emissions by the organization specific metric which in the case of the GCCA companies is the production of cement in tonne. The GRI Sustainability Reporting Standards (GRI Standards) are the first and most widely adopted global standards for sustainability reporting.

The data was tabulated using Microsoft Excel data sheet (see Figure1). This information is needed to compare the performance of the group as well as the performance of each company. It is important to differentiate the year of publication of the report from the year of the data. Usually the reports are published on year

¹ On 7 April 2014, Lafarge and Holcim announced a merger project to create LafargeHolcim.
after the last year of data they present. They also present data from previous years. The data was plotted as a whole -data from all companies that had published their gross CO₂ emissions per t of cement- and by company to identify individual phenomena. Finally, these charts were analysed and discussed.

Figure 1 – Information extracted from GCCA companies’ reports.

<table>
<thead>
<tr>
<th>Company</th>
<th>Year of report</th>
<th>Product</th>
<th>Unit</th>
<th>kgCO₂/t Cement</th>
<th>Year of data</th>
<th>Name of the report</th>
<th>Observations</th>
</tr>
</thead>
</table>

Source: prepared by the author based on Excel sheet used to collect the data.

3 RESULTS AND DISCUSSION

The main results from this study are presented in two sections. The first one, regarding the potential of using benchmark for sustainable construction according to different studies published in scientific journals in the last two decades. The second one consists of a benchmark of cement producers using the kg CO₂ emissions per t of cement indicator. For each section, an analysis has been performed to evaluate how sustainability knowledge management could be achieved through benchmarking.

3.1 POTENTIAL OF BENCHMARKING FOR SUSTAINABLE CONSTRUCTION

Fifty studies where benchmarks are used in the context of sustainable construction were found (Figure 1).

Table 1 – Published studies where benchmarking is used for sustainable knowledge management.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DING, 2004)</td>
<td>The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities</td>
</tr>
<tr>
<td>(ZIMMERMANN; ALTHAUS; HAAS, 2005)</td>
<td>Benchmarks for sustainable construction: A contribution to develop a standard</td>
</tr>
<tr>
<td>(SHEN et al., 2005)</td>
<td>A computer-based scoring method for measuring the environmental performance of construction activities</td>
</tr>
<tr>
<td>(MYERS, 2005)</td>
<td>A review of construction companies’ attitudes to sustainability Indicators and framework for assessing sustainable infrastructure</td>
</tr>
<tr>
<td>(DASGUPTA; TAM, 2005)</td>
<td>Managing knowledge in the context of sustainable construction</td>
</tr>
<tr>
<td>(SHELBOURN et al., 2006)</td>
<td>Sustainable building rating systems summary</td>
</tr>
<tr>
<td>(FOWLER; RAUCH, 2006)</td>
<td>Survey of sustainable building design practices in North America, Europe, and Asia</td>
</tr>
<tr>
<td>(BUNZ; HENZE; TILLER, 2006)</td>
<td>Present and future of building performance assessment tools</td>
</tr>
<tr>
<td>(SINOU; KYVELOU, 2006)</td>
<td>A strategic framework for sustainable construction in developing countries</td>
</tr>
<tr>
<td>(PLESSIS, 2007)</td>
<td></td>
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<tr>
<td>Authors</td>
<td>Title</td>
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<td>-----------------------</td>
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<tr>
<td>AHN; PEARCE, 2007</td>
<td>Green construction: Contractor experiences, expectations, and perceptions</td>
</tr>
<tr>
<td>UGWU; HAUPT, 2007</td>
<td>Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective</td>
</tr>
<tr>
<td>SINGH et al., 2007</td>
<td>Development of composite sustainability performance index for steel industry</td>
</tr>
<tr>
<td>BURNETT, 2007</td>
<td>City buildings—Eco-labels and shades of green!</td>
</tr>
<tr>
<td>DING, 2008</td>
<td>Sustainable construction—The role of environmental assessment tools</td>
</tr>
<tr>
<td>JAILLON; POON, 2008</td>
<td>Sustainable construction aspects of using prefabrication in dense urban environment: a Hong Kong case study</td>
</tr>
<tr>
<td>MATAR; GEORGY; IbraHIM, 2008</td>
<td>Sustainable construction management: introduction of the operational context space (OCS)</td>
</tr>
<tr>
<td>SHARRARD; MATTHEWS; RIES, 2008</td>
<td>Estimating construction project environmental effects using an input-output-based hybrid life-cycle assessment model</td>
</tr>
<tr>
<td>PITT et al., 2009</td>
<td>Towards sustainable construction: promotion and best practices</td>
</tr>
<tr>
<td>CHONG et al., 2009</td>
<td>Understanding and interpreting baseline perceptions of sustainability in construction among civil engineers in the United States</td>
</tr>
<tr>
<td>BAUER; MöSLE; SCHwarz, 2009</td>
<td>Green building: guidebook for sustainable architecture</td>
</tr>
<tr>
<td>ALI; AL NSAIRAT, 2009</td>
<td>Developing a green building assessment tool for developing countries—Case of Jordan</td>
</tr>
<tr>
<td>PRESLEY; MEADE, 2010</td>
<td>Benchmarking for sustainability: an application to the sustainable construction industry</td>
</tr>
<tr>
<td>ZHANG et al., 2010</td>
<td>Dynamic life-cycle modeling of pavement overlay systems: Capturing the impacts of users, construction, and roadway deterioration</td>
</tr>
<tr>
<td>DAMINELI et al., 2010</td>
<td>Measuring the eco-efficiency of cement use</td>
</tr>
<tr>
<td>TAN; SHEN; YAO, 2011</td>
<td>Sustainable construction practice and contractors’ competitiveness: A preliminary study</td>
</tr>
<tr>
<td>MATEUS; BRAGANÇA, 2011</td>
<td>Sustainability assessment and rating of buildings: Developing the methodology SBToolPT-H</td>
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<tr>
<td>SHEN; WU; ZHANG, 2011</td>
<td>Key assessment indicators for the sustainability of infrastructure projects</td>
</tr>
<tr>
<td>KOMNITSAS, 2011</td>
<td>Potential of geopolymer technology towards green buildings and sustainable cities</td>
</tr>
<tr>
<td>LAM et al., 2011</td>
<td>Environmental management system vs green specifications: How do they complement each other in the construction industry?</td>
</tr>
<tr>
<td>DDES; M.SC, 2011</td>
<td>BIM experiences and expectations: the constructors’ perspective</td>
</tr>
<tr>
<td>KÖNING; CRISTOFARO, 2012</td>
<td>Benchmarks for life cycle costs and life cycle assessment of residential buildings</td>
</tr>
<tr>
<td>AHN et al., 2013</td>
<td>Drivers and barriers of sustainable design and construction: The perception of green building experience</td>
</tr>
<tr>
<td>WONG; FAN, 2013</td>
<td>Building information modelling (BIM) for sustainable building design</td>
</tr>
<tr>
<td>YEHEYIS et al., 2013</td>
<td>An overview of construction and demolition waste management in Canada: a lifecycle analysis approach to sustainability</td>
</tr>
<tr>
<td>KUCUKVAR; TATARI, 2013</td>
<td>Towards a triple bottom-line sustainability assessment of the US construction industry</td>
</tr>
<tr>
<td>Li et al., 2013</td>
<td>A model for estimating construction waste generation index for building project in China</td>
</tr>
<tr>
<td>YUDELSON; MEYER, 2013</td>
<td>The world’s greenest buildings: Promise versus performance in sustainable design</td>
</tr>
<tr>
<td>SHI et al., 2013</td>
<td>Identifying the critical factors for green construction—an empirical study in China</td>
</tr>
<tr>
<td>Li et al., 2013</td>
<td>A model for evaluating the social performance of construction waste management</td>
</tr>
<tr>
<td>WILKINSON; REMØY;</td>
<td>Sustainable building adaptation: innovations in decision-making</td>
</tr>
</tbody>
</table>
Most of the studies are scientific papers published in indexed journals. One doctoral thesis (DING, 2004) and three books (BAUER; MÖSLE; SCHWARZ, 2009; WILKINSON; REMØY; LANGSTON, 2014; YUDELSON; MEYER, 2013) were also found. Most of the results could be classified as focused on the construction stage and focused on the use phase. This means that the use of benchmark could be quite beneficial in at least these two phases. In general, the studies demonstrate the use of benchmarking for: building adaptation and renovation (KYLILI; FOKAIDES; LOPEZ JIMENEZ, 2016; WILKINSON; REMØY; LANGSTON, 2014), sustainable building rating systems (ASDRUBALI et al., 2015; BURNETT, 2007; FOWLER; RAUCH, 2006; MATEUS; BRAGANÇA, 2011), the design stage of a structure (eco-design) (AHN et al., 2013; AKINADE et al., 2015; BUNZ; HENZE; TILLER, 2006; DDES; M.SC, 2011; GOU; XIE, 2017; GOVINDAN; MADAN SHANKAR; KANNAN, 2016; WONG; FAN, 2013), life cycle assessment (KÖNIG; CRISTOFARO, 2012; SHARRARD; MATTHEWS; RIES, 2008; YEHEYIS et al., 2013; ZHANG et al., 2010), sustainable production of construction materials (DAMINELI et al., 2010; DE WOLF; POMPONI; MONCASTER, 2017; ELCHALAKANI; ALY; ABU-AISHEH, 2014; KOMNITSAS, 2011; SINGH et al., 2007), sustainable construction (AHN; PEARCE, 2007; CHONG et al., 2009; DING, 2008; JAILLON; POON, 2008; KUCUKVAR; TATARI, 2013; LAM et al., 2011; LI et al., 2013, 2013; MATAR; GEORGY; IBRAHIM, 2008; PITT et al., 2009; PLESSIS, 2007; PRESLEY; MEADE, 2010; SHEN et al., 2005; SHI et al., 2013; TAN; SHEN; YAO, 2011; ZIMMERMANN; ALTHAUS; HAAS, 2005), sustainable
performance of the built environment (ALI; AL NSAIRAT, 2009; BALABAN; PUPPIM DE OLIVEIRA, 2017; BAUER; MÖSLE; SCHWARZ, 2009; DASGUPTA; TAM, 2005; DING, 2004; SHEN; WU; ZHANG, 2011; SINOU; KYVELOU, 2006; UGWU; HAUPT, 2007; YUDELSON; MEYER, 2013) and sustainable supply chains (DADHICH et al., 2015).

For this study, the benchmark will be used for knowledge management of sustainable construction material, i.e. cement. It is worth mentioning that in the case of CO₂ emissions, their potential for environmental impacts is at a global scale and therefore it is possible to use kg of CO₂ emissions as an indicator for both, efficiency and potential environmental impacts. This is different from water related impacts for instance, which depend on the location and season, resulting in different environmental impacts for the same inventory of water flows.

Within CO₂ emissions from cement production, DAMINELI et al. (2010) presents a thorough study using a benchmark of literature data (1585 concrete formulations). From this study, DAMINELI et al. (2010) manages to test two proposed indicators for binder intensity and CO₂ intensity in addition to compare their own laboratory results with a wide range of concrete designs. For this study, DAMINELI et al. (2010) based their comparison on the content of binder and CO₂ emissions per m³ of concrete of a certain compressive strength. This way, the comparison is made among concrete formulations that would achieve the same function.

In the next section, another approach for managing knowledge on CO₂ emissions from cement production is presented by comparing the performance of peer companies along time. This demonstrate yet another useful application of benchmarking for sustainability.

3.2 CO₂ EMISSIONS IN CEMENT PRODUCTION: A BENCHMARK

Figure 2 shows the dispersion of kg of CO₂/t cement data for a group of companies within the GCCA. From

Figure 2 we can observe that there has been a significant reduction since 1990. Possibly because of all the CO₂ reduction agreements to which the cement sector has made a commitment to contribute to. It is observed that from 1990 to 2014, the trend was to decrease. However, from 2015 it can be seen that there is
an increase in the CO₂ emissions from this group of cement producers.

Figure 2 – kg of CO₂ emissions per t of cement from GCCA companies that have published data. Includes data from: Argos, Cemex, Heidelberg, Holcim, Lafarge, LafargeHolcim and Titan.


A range from 588 to 805 kg of CO₂ emissions per t of cement produced is observed considering data from 1990 to 2019. Data dispersion increases from to 2010 to 2019. The lowest values are published by Holcim and Lafarge. However, LafargeHolcim (merged in 2014) also seems to increase their CO₂ emissions from 2015. It would be noteworthy to study in details the sustainable practice that LafargeHolcim cement plants use.

From data gathering, it was observed that some companies have published different values for the same year. This is the case of corrections in calculations done by those companies. From the results plotted in Figure 2 come the question on why are the CO₂ emissions increasing again? This might be because the industry has been using supplementary cementitious materials (SCM) to replace clinker which is the component of cement which has the highest CO₂ emissions due to it calcination at more than 1400 °C; however, these SCM have started to scarce. From this information it can be observed that the industry needs other SCM available in enough quantities to attend cement demand in the future. Also, other sources of CO₂ emissions should be considered as well.
The benchmark that is presented allows companies to compare themselves to their peers. As a company that belong to the GCCA one could identify from this information how good is the performance. In case of a low performance, the company needs to verify if the methodology for measuring and for reporting was correctly applied. Or it could be that the company need to upgrade their sustainability practices. In this case the company could review sustainability practices from companies that present better performance.

In this study, public data from GCCA companies have been used. This is good because low performance company could directly access high performance companies’ data and more important their best practices. However, this type of studies could be conducted under confidentiality agreement as well.

There are three outliers during 2000 which need to be study to identify is those figures are an error or belong to a specific situation for those companies. This demonstrate the importance of benchmarking once again, since if those companies do not compare themselves to the rest of the group, they might not identify this situation and might not correct the data or the issue that led to those values.

Benchmarking for sustainable knowledge management has many advantages as observed in this study. Furthermore, benchmarking could support adjustment to the economic sector goals for instance and better communication to the members of the economic sector as well as for the academic and scientific community that contributes immensely to research and innovation. Last but not least, benchmarking supports communication -in this case of environmental performance- to the society in general who seek sustainable development.

It is worth mentioning, that the CO₂ emissions intensity is linked to the Sustainable Development Goal “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation” specifically to target 9.4 “By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities” through indicator 9.4.1 “CO₂ emission per unit of value added” and to the Sustainable Development Goal 13 “Take urgent action to combat climate change and its impacts” specifically
4 CONCLUSIONS

This study shows the potential of using benchmarks for sustainability knowledge management by benchmarking CO₂ emissions from GCCA cement companies which follow the same measuring and reporting methodology. The study demonstrates the benefits from benchmarking since it allows companies to compare themselves to their peers in order to improve. Benchmarking could also support validation of data consistency, communication of performance, goals definition and adjustment. Furthermore, this study shows a situation that requires immediate action since the CO₂ emissions that have decreased since 1990, have started to increase again. In general, benchmarking could also contribute to the SDG indicators data collection.

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**HEIDELBERG CEMENT.** *Sustainability Report 2016*.


**HEIDELBERG CEMENT.** *Sustainability Report 2019*.


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