

25 YEARS OF CONSTRUCTAL THINKING: HOW GLOBAL DISSEMINATION HAS GROWN FROM A SINGLE TREE TO A NETWORK OF TREES

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The Constructal Law has recently passed its 25th anniversary. At the 2023 Constructal Law Conference in Turin, we have looked back, presenting insights on how knowledge of the Constructal Law has spread globally. Here, we expand on our earlier article. Since our initial study, we have seen a daily average of three new publications that mention the term “constructal” in the Scopus database. In parallel, the number of laboratories affiliated with this research has grown from 10,956 to 12,787. Overall, we see a stable annual growth rate exceeding 25 % in our corpus, as well as a global coverage denser than ever. Studying old and new data, we expand on our earlier article not only with new statistics but also with a new insight: the dissemination paths of constructal thinking were initially tree-shaped, but they have presently become a network of overlapping trees. This insight seamlessly aligns with the predictions of the Constructal Law. According to the Constructal Law, trees grow and spread to become forests of trees, which eventually look like networks. This Constructal Law prediction is evidently confirmed in our corpus.

Keywords: Constructal law; Cultural life; Geography; Geographic information retrieval.

1. SUMMARY

The term “constructal” was coined by Adrian Bejan in the mid 1990s (Bejan, 1997). Since then, it has been used in phrases such as “constructal law”, “constructal approach”, “constructal design”, “constructal evolution”, “constructal tree”, etc. All of these phrases are part of a larger body of constructal thinking that has kept growing over nearly three decades (Bejan 2000, 2016, 2020, Bejan & Merx 2007, Bejan & Zane 2012, Bejan & Lorente S 2013, Bejan & Errera 2016). We call this larger body of thought “constructal thinking”.

To quantitatively study constructal thinking, we have collected data through the Scopus database (details in section 2). Overall, the corpus we collected reveals that constructal thinking has exponentially grown since 1996. Specifically, we observe an annual growth rate exceeding 25% with a standard deviation of 0.43. The trend upwards has continued since our 2023 article. Since then, the number of articles has grown from 6,785 (spring 2023) to 7,789 (spring 2024). This averages three new publications every day. During the same period, the number of contributing laboratories affiliated with this research has grown from 10,956 to 12,787.

Next to studying growth, we evaluate how constructal thinking has spread geographically. In particular, we ask how constructal thinking has spread from Duke University to the rest of the world, connecting an increasing number of researchers. Our findings beautifully visualize that dissemination was initially tree-shaped, but the initial dissemination tree has grown into a network of overlapping trees.

Our present study builds on our earlier research, presented at the 2023 CLC conference (Baciú *et al.* 2023), and it also reconfirms the results of earlier research by Razera *et al.* (2018) and Errera (2018). In the following section, we present updates based on our newly expanded corpus.

2. NEW DATA, SPRING 2023 TO SPRING 2024

Our initial dataset was collected through a search for the term “constructal” in the Scopus database. The corpus thus collected includes all documents that contain the term in title, text, references, or keywords. The discussion of our initial results is found in Baciú *et al.* [1].

In Spring 2024, we have collected new data, expanding our corpus with an additional year worth of publications that have been indexed by Scopus since 2023. The analysis of these new data with the methods and code from 2023 reconfirms the earlier findings.

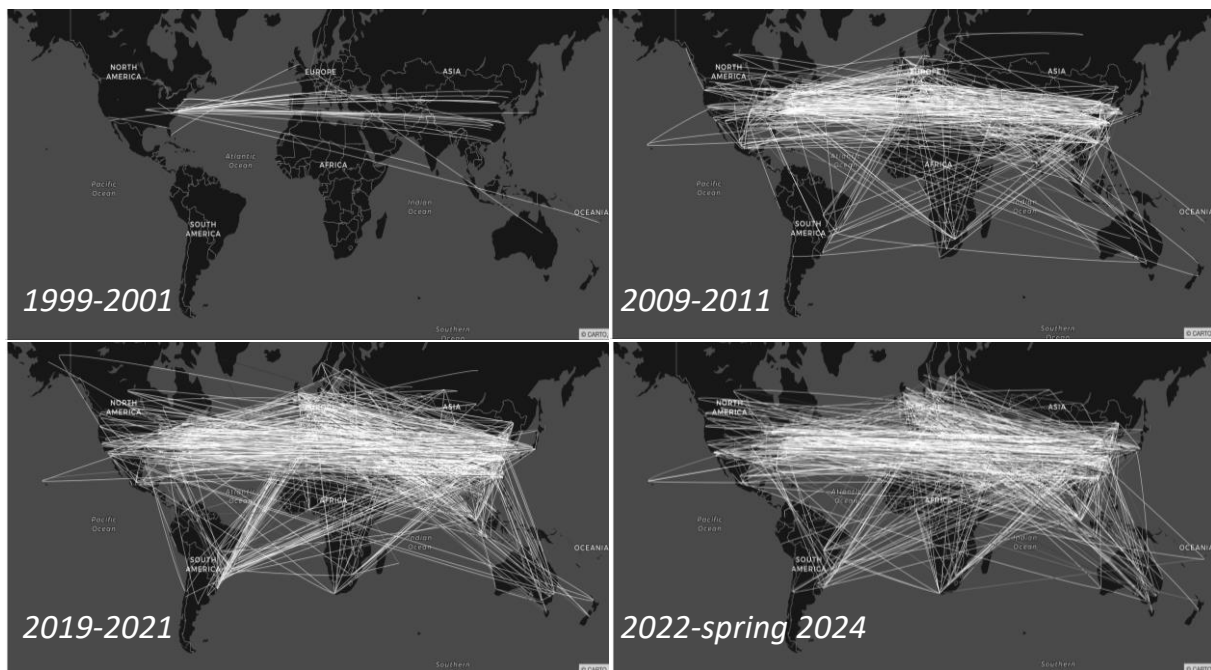


Fig. 1 – Geographical coverage of constructal thinking in four distinct periods of time. Clearly, the geographical distribution of constructal thinking is becoming wider and denser in an s-shaped manner, with the entire globe being the upper bound.

Evaluating the data, we have made an additional observation, visualized in Fig.1. In this visualization, each article is represented as a polygonal chain. The chain goes through the locations of the institutions where the co-authors are located, and it does so in the order in which the co-authors are listed in the publication. Furthermore, the visualization focused on four different time periods: 1999–2001, 2009–2011, 2019–2021, and 2022–Spring 2024. Comparing these four time periods, we punctually represent how constructal thinking has geographically grown, and we observe that it has grown from a tree-shaped configuration into a network. Evidently, the period 1999–2001 shows a system that is a topological tree. It is star-shaped without loops. In contrast, the periods after 2001 show systems that contain loops and are therefore considered to represent networks.

These networks that evolved out of the initial Duke-centered dissemination tree of constructal thinking can be broken back into individual trees. Figure 2 shows a network for the period 2018–2023, and it shows how this network can be broken down into trees. Three sample trees are shown. They are obtained by filtering for articles that have at least a co-author in a given area. Examples are shown for Bucharest, Cape Town, and Toulouse. Note how each of the present trees morphologically resembles the initial Duke-centered tree. As constructal thinking has spread around the world, it has created a forest of dissemination trees that resemble the initial one.



Fig. 2 – The present dissemination network of constructal thinking is a conglomerate of individual trees, which can be revealed by filtering for articles that have at least one author in a given geographical area. Examples are shown for Bucharest, Cape Town, and Toulouse.

Taken together, constructal thinking was initially disseminated from Duke University along divergent paths that followed a tree-shaped flow configuration, seen in Fig. 1, 1999–2001. These paths have kept diverging and converging, eventually becoming a network of overlapping trees, examples of which are shown in Fig. 2. This insight aligns seamlessly with the predictions of the Constructal Law. According to the constructal law, trees grow and become forests of trees, which eventually look like networks [7].

Together, our earlier and present findings demonstrate that constructal thinking is very lively at present, flowing ever faster and further. While it is expected that the growth will follow an s-curve, it is presently still in its initial exponential growth phase, as evidenced by publication counts.

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