

ADVANCED COMPUTATIONAL SIGNAL- AND DATA-DRIVEN ANALYTICS FOR MODELING LEADERSHIP AND ORGANISATIONAL BEHAVIOR

Dr. Indrajit Goswami^{1*}, Dr. Somasekhar Donthu², Dr. Ajayraj Vyas³, Dr. Amit Singh⁴, Sreejana Saha⁵, Kalya Lakshmi Sainath⁶, Trinkul Kalita⁷

^{1*}Professor, School of Commerce and Management Studies, Dayananda Sagar University, Bengaluru-560114
ORCID-0000-0003-2770-6022 idrgoswami@gmail.com

²Assistant Professor, School of Business, GITAM University, Bangalore, Karnataka somuecom@gmail.com

³Assistant Professor, Department of Management, SEMCOM College, The CVM University, Vallabh Vidyanagar- Gujarat Specialization- HRM, ORCID ID: 0000-0001-6113-9004, Email id - ajayraj.vyas@cvmu.edu.in

⁴Associate Professor, Madhav University, Sirohi, Rajasthan, India , Email Id: amitsinghyadav1987@gmail.com

⁵Assistant Professor, Department of Management, Shri Ramasamy Memorial University Sikkim, Gangtok-737102, Sikkim, ORCID ID: 0000-0003-3756-0274, Email ID: sreejanasaha@gmail.com

⁶ Doctoral Student IBS Hyderabad, IFHE University, Hyderabad, India, Email ID: k.l.sainath143@gmail.com
ORCID ID: 0000-0001-5130-7895

⁷Assistant Professor, Assam down town University ORCID ID: 0009-0006-4996-9738 trinkulk91@gmail.com

Abstract:

The recent advances in signal- and data-driven analytics have enabled systematic modeling of the complex human-centred systems on the basis of data on interaction. The paper proposed a computational model of the analysis of the leadership and organisational behaviour relying on the organisational interactions representation as a time-dependent signal and networks. The approach applied to test the validity of the framework was the case-study approach which applied the real interaction records of organisations. The temporal network analysis and centrality-based indicators of the dynamics of influence in the leadership role were used to study the behavioural evolution. Change-point detection methods were detecting statistically significant behavioural transitions that related to organisational restructuring phases. It was identified that stability of leadership patterns and network structures was stable within robustness and sensitivity analysis of different time aggregation and the modelling settings. The results indicated that the impact of leadership was dynamic and relied on interaction signaling as compared to the official role posture. The work used the concepts of signal-processing to organisations and behaviour, with the combination of signal representation and temporal network modelling, and the validity of the results. The findings suggest the topicality of the recent signal and data analytics to gain insights into the complex organisational systems and contribute to the methodological problems in the context of the International Journal of Advances in Signal and Image Sciences.

Keywords: Signal-Based Analytics, Temporal Networks, Leadership Modeling, Organisational Behaviour; Case Study

1. Introduction

Signal- and data-driven analytics have transformed the approach of modelling, interpreting and optimising complex systems in fields of scientific and engineering applications. The emerging paradigm of information processing is more concerned with the interactive relationship between information processing systems and human beings regarding the behavioural pattern which emerges as a result of the dynamic interaction as compared to the strict regulations of behavioural pattern [1]. Leadership and behaviours dynamics are complex adaptive systems that occur in organisational settings and are triggered by communication signals, interaction structures, and also temporal coordination. These dynamics generate lots of interaction information that may be captured by a computational signal representation that enables systematic study of influence, coordination and behavioural development. The methodology transforms the organisational behaviour into a signal-processing task, generalises the signal and image sciences to the social-organisational setting.

The past researches indicate that the performance and leadership influence of organisations and leaders are directly related to the structural placement of an actor within the interaction networks. It has been empirically proved that centrality of the leader networks is a leading predictor of team performance mediated by collaborative structures and moderated by the situational context, such as the size of the team [2]. The same methodological advance has similarly extended the scope of behavioural analytics by integration of heterogeneous data sources including social media, surveys and digital traces to detect latent behavioural signals [3]. At the same time, computational text and embedding-based methods have shown that social signals are a type of structural prejudice/behavioural patterns that exist in large scale communication systems [4]. The network-based knowledge-flow modelling has also been able to demonstrate how influence diffuses through the structured interaction and communication pathways which validates the importance of relational signal analysis [5].

Much more recent findings in the network science have provided deeper understanding on the connection between connectivity, cohesion and community building in both online and offline systems with focus on structural robustness and comparative network analysis [6]. However, it has been shown that data quality and signal integrity contributes significantly to accuracy of the inferences particularly in intervention-based studies of the network [7].

Higher-order connections have since been researched further to indicate that behavioural processes cannot be deterministically described as interactions between two individuals, which has emphasised the significance of using more elaborate representations of signals [8]. The influence of digital behavioural cue on stratification, judgment and transactional behaviour has been explored by other secondary research, which justifies the applicability of signal-based modelling in various settings [9,10]. Collectively, this body of literature provides a solid basis on which to apply advanced signal and data analytics to behavioural and leadership phenomena.

Despite the drastic improvement in network analytics and behavioural modelling, the existing literature regarding leadership and organisational behaviour is mostly parted into two sides using the disciplines as the main division. The majority of the studies focus on the fixed snapshots of the interaction networks or make role based assumptions of the leadership which cannot permit them to infer dynamic transitions of behaviour. Moreover, signal- and data-driven approaches have been widely applied in online and financial and knowledge networks, but the systematic application on organisational leadership as a time-varying signal-processing problem has not been expounded. There are still no integrative frameworks that would unite temporal network representation, change detection and robustness analysis in order to explain the leadership influence as an emergent and data-driven process of actual organisational systems.

There are a few critical gaps in the reviewed literature. To start with, the dynamic aspects of the modelling of the leadership dynamics have been underemphasized as dynamic interaction cues in lieu of the structural positioning. Second, there are not numerous studies that put together the identification of temporal change and robustness validation in learning actual behavioural change and methodological artefactual changes. Third, the existing organisational studies have a tendency to neglect the recent signal-based methods such as time division, higher order forms of relation and sensitivity analysis. Finally, there are scant studies that have been carried out through case studies to warrant more sophisticated computational analytics for the operational realities of an organisation though with methodological rigor consistent with signal and image sciences. The objectives of the study were as follows, based on the gaps that were identified:

1. To develop a signal- and data-driven analytical framework for modelling leadership and organisational behaviour as temporal interaction networks.
2. To validate the robustness and effectiveness of the proposed framework through a real-world organisational case study using advanced network and change-detection techniques.

2. Methodology

2.1 Research Design

To explore the leadership and organisational behaviour with signal- and data-driven analytics, the research design of a case-study employed to the computational research was applied. The empirical environment of the formulation and testing of the analytical models in terms of the actual organisational interaction data has been presented in the case study. It was in this structure that it was possible to investigate the influences of the leadership, structure of behaviour and change in organisations as dynamic processes and not predetermined traits. Observable interaction cues were operationalised to have organisational behaviour that can be analysed computationally but retain a rich context. The technique helped in the longitudinal investigation of the change of behaviour in an organisation system that exists as a natural occurrence.

2.2 Case Study Context and Selection

The case study was placed in an organisation in a leadership transition and structural change, which allowed exploring the reconfiguration of behaviour using the data of interaction. The choice of studies was informed by the previous empirical case studies that showed the effects of formal restructuring on communication networks [11], the effects of leadership churn on the organisational learning process with time [12], and how the limited organisational cases could be examined with the social network diagnostics to inform the improvement efforts [13]. Further argument was based on the research which viewed organisational communication as signals of behaviour that could be analysed [14] and those which revealed leadership and community architecture based on network analysis within a specific project ecosystem [15]. Taken together, the studies facilitated the choice of a longitudinal, data-intensive organisational case that was appropriate in signal-based leadership modelling.

2.3 Data Sources and Signal Construction

Data were collected using the records of the interactions between organisations (time-stamped digital communications, organised relational information regarding collaboration and information exchange). All data were anonymised, de-duplicated and time-aligned and analysed. The interaction events were totalled at specific intervals of time to form behavioural indicators of organisational activity. These were translated into weighted directed network models of the directionality and frequency of interaction. Temporal segmentation by ensuring short-term variability enabled the longer duration behavioural and the leadership variability to be studied in the period of the case study.

2.4 Analytical Framework and Modelling

Organisational behaviour was done as temporal network, whereby nodes showed organisational actors and also the intensity of interaction per time window. Extracting network-based indicators of leadership influence,

behavioural structure and change over time were put into analytical focus. Influence positioning was approximated using centrality measures, whereas connectivity and cohesion measures described organisation integration and formation of subgroups. Temporal analysis was used in examining the changes in these indicators over periods of observation. This framework allowed leadership to be conceptualised as an outcome of interaction patterns and not a title given to a person.

2.5 Evaluation and Validation

This was tested according to network level measures and time consistency tests between successive observation windows. Comparison analysed the behavioural and leadership patterns in the pre identified organisational changes and the post identified organisational changes. Sensitivity analysis was conducted to determine the sensitivity of the methods to variations in the temporal aggregation parameters and network construction parameters. The validation was based on the analytical consistency between different model configurations compared to individual pointers. The means of ethical protection was the anonymisation of organisational participants and secure computing of interactivity data. This validation plan was employed to ensure that the leadership and behavioural patterns that were observed were reflective of actual signal driven structures in the organisational system.

3. Results

3.1 Descriptive Characteristics of Organisational Signals

The built interaction signals showed constant temporal continuity through the time span under observation and a distinct difference in intensity of interaction at different time windows. The overall connectivity between network density and average degrees were moderate, which means that the interaction is sustained in the organisation rather than a disjointed communication structure. Temporal segmentation indicated times of high frequency of interaction between various people that were identified as specific organisational transition periods as indicated in Table 1. Signal distributions were skewed to the right indicating that there was a small group of actors that contributed a disproportionate number of interactions. These descriptive features ensured the appropriateness of the constructed signals into further network-based and time-related analysis modelling.

Table 1: Descriptive Statistics of Organisational Interaction Signals

Signal Characteristic	Analytical Measure	Observed Pattern
Temporal continuity	Signal persistence across time windows	Stable interaction activity observed across all observation periods
Interaction intensity	Mean interaction frequency per window	Noticeable variation with identifiable peaks during transition phases
Network connectivity	Network density and average degree	Moderate connectivity indicating sustained organisational interaction
Distributional properties	Degree and interaction frequency distribution	Right-skewed distribution with concentration among a limited set of actors
Signal suitability	Structural and temporal consistency	Signals appropriate for network-based and temporal analytical modeling

3.2 Temporal Network Structure and Behavioural Dynamics

The analysis of temporal network revealed that structural change can be measured across observation windows. The changes of the network density, clustering coefficient and the path lengths were used to illustrate the changes of the patterns of behavioural coordination over time. Figure 1 allows seeing that there were cohesion of the network decreases in the moments of transition, and it was re-stabilised gradually later in the windows. The temporary subgroup formations were identified through the modularity analysis which implied the short-lived rearrangement of the patterns of interaction. Temporal dynamics of structural measures showed that organisational behaviour was not taken in a single form over time but it varied in relation to the processes of internal change and supported the usefulness of time signal representations in the analysis.

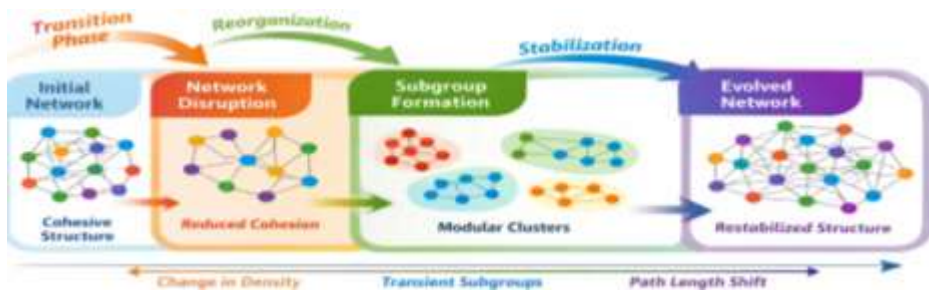


Figure 1: Temporal Evolution of Organisational Network Structure and Behavioural Dynamics

3.3 Leadership Influence and Centrality Patterns

The indicators of centrality gave various trends of leadership influence during the case study. There were also actors who were always in high-centrality roles and those who had fluctuating power depending on the shift within the organisation. Betweenness and eigenvector centrality measures became different with the distribution of the brokerage and influence during the times of restructuring (Table 2). The decentralisation of influence of the leadership was as fast as the transition events were occurring and it was re-distributed slowly during the follow-up windows. These results indicated that leadership influence exercise was dynamic depending on the signal of interaction and not depending on the position of formal positions.

Table 2: Centrality-Based Leadership Influence Patterns Across Observation Windows

Centrality Indicator	Analytical Purpose	Observed Leadership Pattern
Degree centrality	Interaction activity and visibility	Consistently high values for a limited set of actors across time windows
Betweenness centrality	Brokerage and control of information flow	Temporal shifts indicating redistribution of brokerage during transition phases
Eigenvector centrality	Influence within the broader network structure	Fluctuating influence scores associated with organisational restructuring
Centralisation index	Concentration of leadership influence	Reduced centralisation immediately after transitions, followed by gradual re-stabilisation
Temporal rank stability	Persistence of leadership positions	Partial stability with intermittent role reconfiguration across observation periods

3.4 Behavioural Change Detection and Transition Analysis

Change-point analysis revealed statistically significant changes in the patterns of interaction consistent with transition stages recorded in organisations. The observed changes points were identified with, sudden changes in the network density and centralisation measures, which validated the reconfigurations of behaviour in the organisational system. Trend analysis indicated that the post-transition times were marked by more dispersion in interactions and post-transition less reliant on fewer central actors (Figure 2). These results showed that signal-based change detection methods were effective in real organisational settings to detect behavioural transitions.

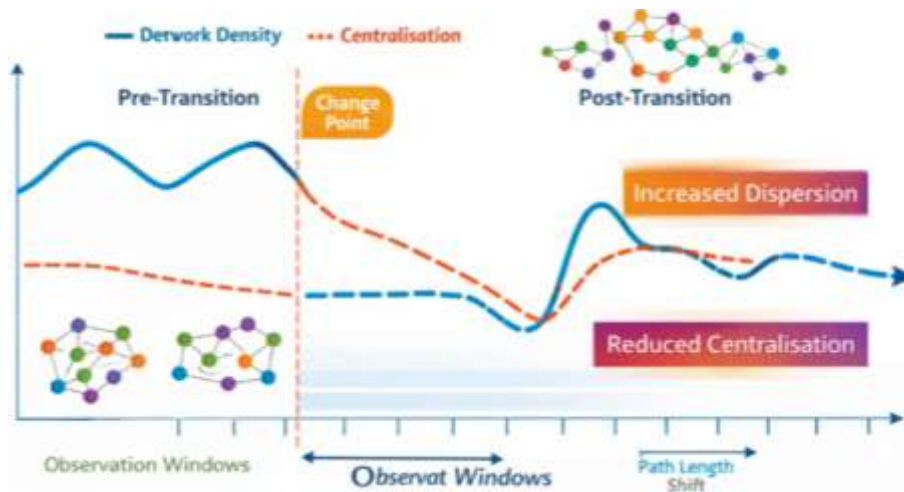


Figure 2: Signal-Based Behavioural Change Detection and Transition Dynamics in Organisational Networks

3.5 Robustness and Sensitivity Results

Sensitivity analysis showed that core leadership and behavioural patterns were not affected by alternative sizes of time window and edge-weighting scheme. Although absolute metric values were affected by the parameter of aggregation, the relative rank of influential actors and general trends in the time were retained. There was also a high level of consistency in network topology and change points spotted between modelling configurations which implies that the analytical framework is robust (Table 3). These findings validated the fact that the perceived patterns were caused by organisational signals as opposed to parameter selection artefacts or specification artefacts of the model.

Table 3: Sensitivity Analysis of Signal-Based Leadership and Behavioural Models

Analysis Dimension	Parameter Variation	Observed Stability	Analytical Implication
Temporal aggregation	Window size adjustment	Leadership rankings preserved	Robust influence estimation across time scales
Edge weighting scheme	Frequency vs. weighted interactions	Network topology consistent	Structural patterns not parameter-dependent

Centrality computation	Alternative centrality metrics	Relative actor influence stable	Leadership detection resilient to metric choice
Change-point detection	Model configuration variation	Consistent transition identification	Behavioural shifts reflect genuine signal dynamics

4. Discussion

The findings of this study suggested that the leadership and organisational behaviour can be successfully described as signal-based processes in contrast to structural and inert ones. The temporal network analysis demonstrated that there were visible shifts in the form of interaction during the organisational period that were characterised by the lack of cohesion, diffusion and temporary subgroup organisation. The centrality indicators too revealed that the effects of the leadership were dynamic and changed following an organisational change event. It has been established that behavioural transitions were not learnt indirectly but directly via the use of interaction signals and this has statistically proven the statistical significance of points of change observed. These findings were backed up by similar robustness analysis, which showed that leadership rankings, modeling configurations, transition detecting and network topology were fixed. The collection of the findings confirms the model of the analysis as a reasonable signal-based model of the complex organisational systems as per the goals of the advanced signal and data sciences.

The functioning of the patterns of signal-driven behaviour is in line with the existing data, which social and organisational structures do undergo the measurable change that is studied in the form of data of the interaction. The online community studies have also established that mod/ structural induction brings forth evident shift in relation patterns and influence that confirm the presence of signal-based behavioural detection [16]. Digital habit quantitative studies have discovered that consistency of patterns of behaviour is also linked with changing, dynamically over time, as of the persistence and fluctuation statistics of patterns of leadership have been confirmed [17]. The social media interaction analysis also assists in the understanding that when there is a change in context, the interaction networks restructure to ad hoc clusters and the fact is also compatible with the liquidations of the modules which are reconfigured in this paper [18]. Similar studies have been carried out on the connectivity associated with community structure on the heterogeneous social networks and the structural measure of these meanings appears to be high on all datasets as it was in the context of sensitivity analysis [19]. The data-driven methods of quantifying social influence in a situation, which also presupposes the decision-making process, are the modeling sense of the concept of leadership as an emergent consequence of the interaction signals and not a role [20]. Although the domain of bibliometric network research is different in environmental and agricultural systems, they focus on similar methodological ideas of signal-based structural inference, and that is why it is appropriate to use the framework proposed to more complex systems [21].

Although the study is analytically valid, it has a number of weaknesses. First, there is weak generalisability based on the organisational settings that are defined as varying norms of communication or hierarchical settings as the research is based on a local organisational case study. Second, the indicators of interaction were obtained based on the primary sources of digital and relationship recordings that might not be sufficient to capture informal or unrecorded interactions. Third, although the decisions founded on time aggregation were proven to be robust, they can smooth short behavioural occurrences. Fourth, the positioning of leadership was structural, as opposed to expression of behaviour that can be applied to streamline subtle leadership behaviours. Lastly, the framework lacked signal property on the semantic or content level and therefore constrained the understanding of the qualitative nature of interactions.

The study of signal and image sciences has an immense implication of the results. The paper elaborates signal-based analytics of the socio-organisational systems by showing that organisational behaviour and leadership processes can be described as interaction signals that are realised over time. The framework shows to assemble the network representations, change-point detection, and robustness analysis into one signal-processing pipeline applicable to systems of humans of complex format. The methodology could be implemented in developing transferable analysis tools that have the capability to realize the structural change in most of its operations such as the communication systems, socio-technical networks and flexible organisational infrastructures. The outcomes also enlarge the possibilities of how the multimodal signs such as the traces of text or visual contact might be presented in future in the study of the science field of signals and images.

5. Conclusion

This study has revealed that signal- and data-driven analytics on interaction networks can be a useful model of leadership and organisational behaviour. The proposed framework described structural evolution, shifts in behaviour, and the dynamics of influence by an organisation leader as signals of organisational activity, which explains the temporal-based representation of organisation activity with a real-life case scenario. The temporal network analysis showed that organisational behaviour was measurably varied over observation windows, especially when there was a structural or leadership shift. There were indicators of centrality that demonstrated that leadership influence was an active creation through interaction patterns instead of being held rigid to official positions. The change-point detection also ensured that reconfigurations in behaviour could be obtained directly by using interaction signals and the robustness analysis proved that the stability of the results of analytical

calculations was independent of the alternative modelling settings. The results have a contribution to the signal and image sciences literature as it can expand signal-processing concepts into the organisational and behavioural fields. The fact that leadership and behaviour are treated as emergent characteristics of interaction cues allowed the rigorous quantitative analysis and retained contextual relevance. It was also shown in the study that the use of case-study-based validation may be used to support advanced computational modeling without affecting analytical robustness. This framework could be expanded in future studies to include multimodal signals, including textual or visual communication information, to expand behavioural representations. Longitudinal multi-organisational research might also determine the extent of generalisability to different institutional settings and structural forms. Moreover, real-time analytics and adaptive modelling techniques integration could aid in the predictive evaluation of the dynamics of leadership and organisational resilience. This would enhance the contribution of signal-and data-driven methods to the comprehension of complex human-centred systems.

6. References

- [1]. Ifenthaler D. Information processing re-visited: reciprocal perspectives on artificial intelligence and human-centered systems. *AI Enhanced Learning*. 2025;1(1):229–243.
- [2]. Yuan Y, Van Knippenberg D. Leader network centrality and team performance: team size as moderator and collaboration as mediator. *J Bus Psychol*. 2022;37(2):283–296.
- [3]. Liu S, Sloan L, Al Baghal T, Williams M, Jessop C, Serôdio P. Linking survey with Twitter data: examining associations among smartphone usage, privacy concern and Twitter linkage consent. *Int J Soc Res Methodol*. 2025;28(1):71–85.
- [4]. Ohamadike N, Durrheim K, Primus M. The news in black and white: word embeddings quantify racism in South African news. *EPJ Data Sci*. 2025;14(1):83.
- [5]. Song Y, Kim S, Yoon B. Development of a fundamental patent exploration methodology based on technology knowledge flow. *EPJ Data Sci*. 2025;14(1):81.
- [6]. Menyhért M, Bokányi E, Corten R, Heemskerk EM, Kazmina Y, Takes FW. Connectivity and community structure of online and register-based social networks. *EPJ Data Sci*. 2025;14(1):8.
- [7]. Yeung WN, Di Clemente R, Lambiotte R. Garbage in garbage out? impacts of data quality on criminal network intervention. *EPJ Data Sci*. 2025;14(1):37.
- [8]. Ceria A, Takes FW. The relevance of higher-order ties. *EPJ Data Sci*. 2025;14(1):62.
- [9]. Yue Y. Decoding digital influence: the role of social media behavior in scientific stratification through logistic attribution method. *arXiv preprint*. 2024;arXiv:2407.15854.
- [10]. Zhang Y, Li Y, Zhang J, Tessone CJ. Bitcoin transaction behavior modes exploration based on balance data. *EPJ Data Sci*. 2025;14(1):46.
- [11]. Maurer M, Bach N, Oertel S. Changes in formal structure towards self-managing organization and their effects on the intra-organizational communication network. *J Organ Des*. 2023;12(3):83–98.
- [12]. Caduff A, Daly AJ, Finnigan KS, Leal CC. The churning of organizational learning: a case study of district and school leaders using social network analysis. *J Sch Leadersh*. 2023;33(4):355–381.
- [13]. Courtney MB, Foster KA. Social network analysis as a driver of continuous improvement: a case study. *J Sch Adm Res Dev*. 2023;8(2):109–116.
- [14]. Shah H, Jaidka K, Ungar L, Fagan J, Grosser T. Building a multimodal classifier of email behavior: towards a social network understanding of organizational communication. *Information*. 2023;14(12):661.
- [15]. Morea F, Soraci A, De Stefano D. Mapping leadership and communities in EU-funded research through network analysis. *Open Res Eur*. 2025;4:268.
- [16]. Lerman K, Chu MD, Bickham C, Luceri L, Ferrara E. Safe spaces or toxic places? content moderation and social dynamics of online eating disorder communities. *EPJ Data Sci*. 2025;14(1):55.
- [17]. Sharpe M, Bowen M, Lambiotte R. Quantifying digital habits. *EPJ Data Sci*. 2025;14(1):72.
- [18]. Fraxanet E, Kaltenbrunner A, Germano F, Gómez V. Analyzing news engagement on Facebook: tracking ideological segregation and news quality in the Facebook URL dataset. *EPJ Data Sci*. 2025;14(1):73.
- [19]. Menyhért M, Bokányi E, Corten R, Heemskerk EM, Kazmina Y, Takes FW. Connectivity and community structure of online and register-based social networks. *EPJ Data Sci*. 2025;14(1):8.
- [20]. Zheng R. *Data-driven modelling and inference for quantifying the effect of social influence in decision-making* [doctoral dissertation]. Manchester (UK): The University of Manchester; 2025.
- [21]. Espitia JJ, Amado G, Rodriguez J, Gomez L, Gil R, Flores-Velasquez J, et al. CO₂ enrichment in protected agriculture: a bibliometric review on greenhouses, controlled environment systems, and vertical farms—part 1. *Horticulturae*. 2025;11(5):476.