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From classical interpretive structural modeling to total interpretive structural modeling and beyond: A half-century of business research

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ABSTRACT

Despite the widespread use of interpretive structural modeling (ISM) in business research, little is known about its overall scientific productivity and impact on business research. This study presents a comprehensive review of the published ISM research and its latest editions in business using text mining. A two-tier review (narrative and systematic) is used to examine the methods and provide a comprehensive bibliometric analysis and an application roadmap. We demonstrate the number of ISM publications has been increasing in the past fifteen years, even though ISM was developed half a century ago. The study provides evidence for the increasing impact of ISM research in business. Content analysis shows an increase in the application of an updated edition of ISM, total interpretive structural modeling (TISM). In addition, the overall scientific productivity of ISM and TISM is assessed, and an ISM/TISM method selection roadmap is proposed. We further develop ISM^{+}, a new integrated framework combining ISM and its latest editions to improve its performance and potential applications in business research.

1. Introduction

Business research is the systematic process of collecting and analyzing data for informed business decision-making. Making decisions is never easy, and dismissing them as unimportant can result in costly failures (Ali et al., 2016). Decisions about which alternatives should be pursued require a clear understanding of the decision goals and criteria and an accurate assessment of each alternative's success in achieving the goals. These problems are known as multi-criteria decision-making (MCDM) and typically involve multiple and often conflicting criteria. Interpretive structural modeling (ISM), decision-making trial and evaluation laboratory (DEMATEL), weighted product model (WPM), and weighted sum model (WSM) are some examples of popular MCDM methods. MCDM methods are now widely used to solve many complex decision-making problems. DEMATEL and ISM are two popular MCDM methods used to study the relationship between the decision criteria in business decision-making. While DEMATEL is an analytical method for investigating the cause-and-effect relationship between decision criteria, ISM decomposes a complex problem into smaller components and builds a hierarchical structure to express the relations among the problem components. The ISM method also checks the model's validity to eliminate or reduce inconsistencies in decision-making (Jafari-Sadeghi et al., 2021). Although DEMATEL uses a larger range of scales to complete the cause-and-effect interactions, ISM is more user-friendly because its binary scale and algorithm are designed to avoid inconsistencies (Chauhan et al., 2018; Jafari-Sadeghi et al., 2021).

Warfield introduced ISM in 1973 and developed it in the following years to study and represent complex issues as logical and understandable graphs (Warfield, 1973a, 1973b, 1982). ISM is described as a process that converts vague, poorly articulated mental models of systems into observable and well-defined models (Attri et al., 2013). The basic idea is to break a complicated system into several components, develop a multi-level structural model, and offer knowledge of challenging situations to establish a problem-solving strategy (Zekhnini et al., 2022). ISM could be traced back to structural modeling (SM), which represents a problem geometrically rather than algebraically and describes formation instead of quantification (Lendaris, 1980). It is a methodology that shows the structure of a complicated subject, system, or body of

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knowledge and focuses on choosing the components of a model, and clearly describes their connection (McLean and Shepherd, 1976). This implies that the model illustrating the links of the different variables in SM takes a qualitative shape in graphs and interconnections rather than a quantitative one. Warfield extended SM to ISM by adding practical understanding and the expertise of professionals as another dimension to SM (Poduval and Pramod, 2015). The interrelationships between the different aspects of the problem are based on pairwise relationships between the elements, with interpretation based on the opinion of a group of experts. The structural model generated by the interrelationships of the components, utilizing words and digraphs, may be understood in terms of practical knowledge that will guide in developing measures to alleviate the issue (Poduval and Pramod, 2015; Zekhnini et al., 2022). The ISM approach has evolved into one of the most widely used interactive learning techniques (Kumar and Goel, 2022). It is one of the most effective methods for determining interrelationships across multiple components (Zekhnini et al., 2022).

ISM has been used in academia, industry, and research to identify an issue's multi-disciplinary obstacles, problems, and drivers. The applicability of this technique has been reported in diverse research domains (Poduval and Pramod, 2015; Kumar and Goel, 2022). However, according to the data retrieved from the Scopus database, there is a relatively new emerging trend of publications relevant to particular business research. Despite that, little attempt has been made to validate the overall applicability of ISM in business research and applications. Furthermore, very few reviews of the ISM method have been conducted in the literature. This literature survey is intended to fill a gap in the ISM publications by following historical/literature guides and trends to contribute to the model's development.

This research presents an inclusive (breadth) and thorough (depth) analysis of the existing research in ISM with a well-structured presentation of useful and valuable data and findings. These results are expected to help decision-makers realize the strengths and weaknesses of the method and use it effectively for business problem-solving and decision-making. Section 2 uses a bibliometric review of the literature to statistically and analytically describe the developments in ISM. We demonstrate ISM's contribution to business research, followed by ISM applications. Section 3 examines the historical trends and developments in the ISM literature. In addition, this section provides a mixed systematic and narrative review that explains and compares the ISM method and its updated version(s). Sections 4 and 5 propose a roadmap for practitioners choosing and applying the ISM and its alternative updated version(s). Section 6 presents a new integrated ISM framework. Section 7 concludes with our conclusions and future research directions.

2. Systematic review

Literature review and analysis may yield varying results depending on the database used (Mongeon and Paul-Hus, 2016). Scopus and Web of Science (WoS) are the two leading databases for literature review (Aghaei Chadegani et al., 2013; Mongeon and Paul-Hus, 2016), while Google Scholar's data quality makes its archive questionable (Mongeon and Paul-Hus 2016). We used the number of documents returned by our keyword search to decide which database to use. The Scopus database was the preferred choice because it produced more data for analysis. Scopus is a comprehensive abstract and citation database that provides broad coverage of peer-reviewed journals, books, conference papers, and patents in natural sciences, social sciences, arts, and humanities (Aghaei Chadegani et al., 2013). This study conducts a Scopus database search for the terms "interpretive structural modeling" or "interpretive structural modelling" using the title, abstract, and keywords of the archived document (published or in press) in 08/07/2022, yielding 2167 documents.

Other than 69 documents with undefined countries, the rest of the notes covered 79 countries contributing to ISM implementations in their publications, demonstrating global interest in this technique. The collected data included 77.0 % articles and 18.6 % conference papers. The earliest records were for 1974 when there were eight publications. Among these eight documents, the highest citation was for a work that describes the application of ISM to the Ohio Environmental Protection Agency's goals and objectives hierarchy (Hart and Malone, 1974), with 25, 15, and 4 citations in Google Scholar, Scopus, and WoS, respectively. As shown in Fig. 1, the publishing trend has remained increasing.

India contributed the most to the list of contributing countries, accounting for more than half of the publications (52 %), with the Indian Institute of Technology Delhi with 182 articles, Amity University (52 articles), Amrita Vishwa Vidyapeetham (51 articles), and J.C. Bose University of Science and Technology (50 articles). Following India (with 1127 documents), China and Iran contributed to the list with 248 and 154 articles, respectively. The field with the most documents was business research (Business, Management, and Accounting), with 1068 documents with close to half of the records (49.28 %). Engineering ranks second with 834 articles, followed by computer and decision sciences with 460 articles.

In the business research, the search showed 950 journal papers, 77 conference proceedings, 26 review papers, and eight book chapters. The rest of the documents were conference reviews, letters, and a note; these seven records have been deleted from the collected data. India, Iran, and United Kingdom have contributed the most documents in business research, with 715, 76, and 66 papers, respectively. Not all the papers were available in English - three articles were non-English. Still, the researchers found no pattern in non-English publications, so these documents were removed from the records to avoid language barriers in future examinations. Fig. 2 exhibits an overview of the literature selection process used in this study.

The filtration did not affect the country rankings. What's more, for the remained documents, only Amrita Vishwa Vidyapeetham and Amity University offered their places to another Indian institute, the Indian Institute of Technology Roorkee and the National Institute of Industrial Engineering, among the four institutions with the highest ISM publication. Indian Institute of Technology Delhi remained the highest with slightly more than 13.5 % contribution to the number of documents. Comparing the business research publishing trend in Fig. 3 to the overall publication trend in Fig. 1 reveals a resemblance in publication trends. The visualization of the publishing frequency divides it into two eras, before and after 2007. The literature from the second defined era (after 2007) appears to be the most informative since it shows how the ISM method expanded in adoption and implementation over time.

The rest of the study includes both bibliometric analysis and data visualization. Content and citation analysis is used to investigate the available material. The VoSviewer software and the Scopus analysis platform function developed by Scopus were used to analyze, ScienceScape online tool (https://medialab.github.io/sciencescape/) and build visual charts via the Scopus archived data. ScienceScape was developed as an online science visualization program to allow users to create desired charts by uploading data from a scientific database such as Scopus (Ji and Gan, 2020). Besides, VOSviewer was developed by researchers at the University of Leiden in the Netherlands to help users with text mining with a focus, constructive functionality, and concurrent visualization. It employs visualization extensively for different bibliometric data, networks, and research (Kumar and Goel, 2022). Version 1.6.18 of the software, released in January 2022, was used in this study. VOSviewer was chosen because it can read CSV files exported from the Scopus database and analyze the results based on pre-defined criteria. ScienceScape was used as a supplemental online data visualization tool. This combination of analytical tools has been utilized successfully in previous studies, including Hiena (2020) and Sorooshian et al. (2022). In addition, Bibliometrix (a supplemental R program) was used to help with the analysis and data interpretation.

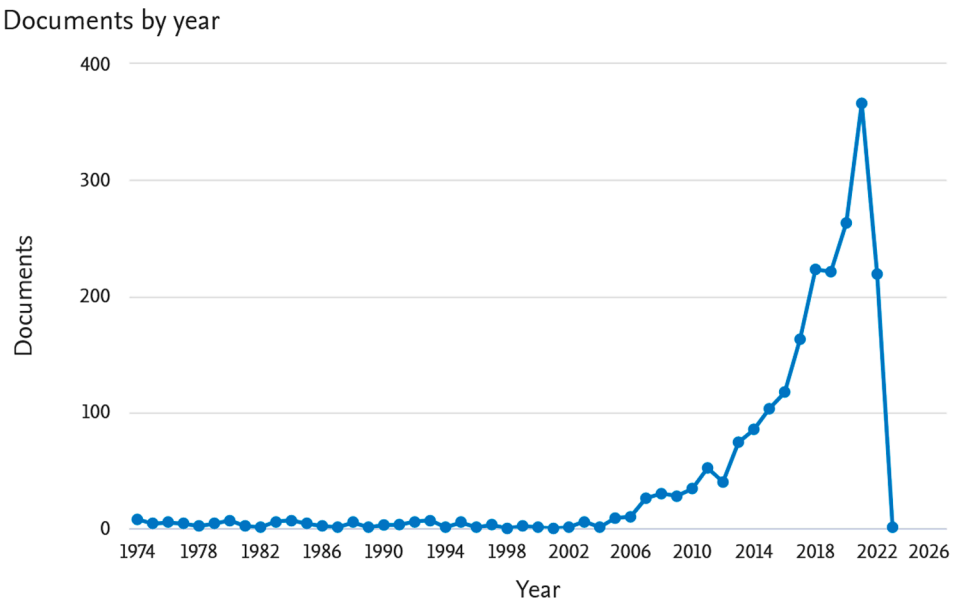


Fig. 1. Overall publication trend.

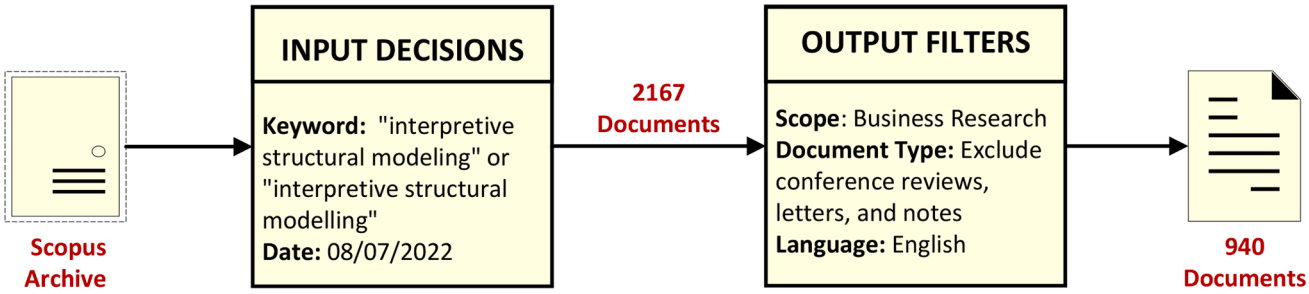


Fig. 2. ISM literature selection.

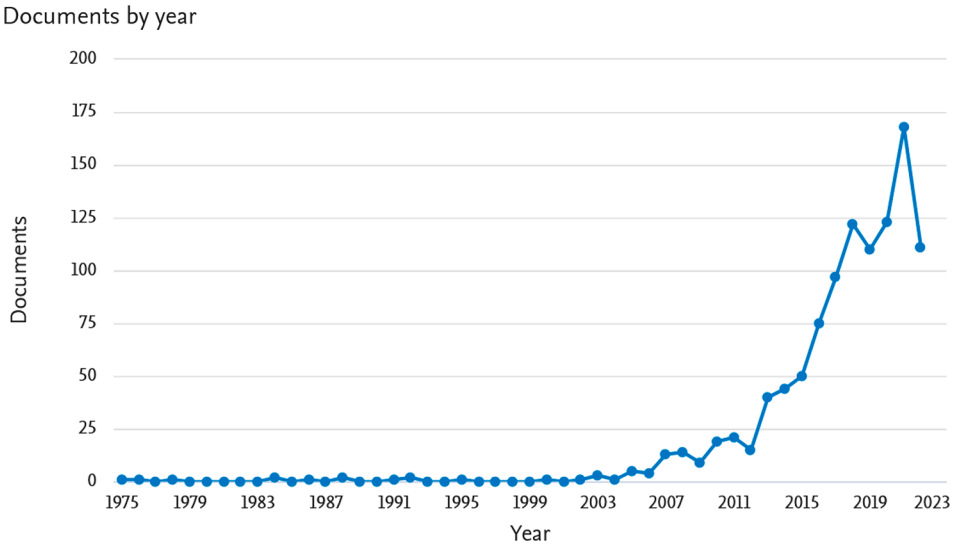


Fig. 3. Publication trend in business research.

2.1. ISM application interests

Among document types published after 2007, 925 articles and 76 conference papers have been observed, accounting for 96.7 percent of the total records. The average number of citations per document is 22.62, which is quite high; 326 %higher citations per document, when for instance, compared to the average of 6.92 citations per document with the use of time-series techniques (Ale Ebrahim et al., 2020); and 146 % higher citations per document, compared to the average of 15.42 of citation in the business research field (SJR, 2022). 23,935 citations

have been recorded by 12,116 documents, and the top citing scopes were business research (26.7 %), engineering (16.7 %), and decision sciences (10.7 %). This provides evidence for ISM usability in business and engineering research. Fig. 4 depicts a citation overview from 2007 until the day of data collection in 2022.

India stands with the most contributions, accounting for 68 %, and certainly is in the lead with ISM applications after 2007. Three authors from India, Shankar, R., Sushil, and Suresh, M., are the top contributors to publications, each with more than 20 documented documents. Yet, Iran, the United Kingdom, and China are following behind India, with a significant gap in publishing numbers. With an h-index of 76, publications from India appeared to be the most referencing means to the Scopus archived sources using ISM. In that order, the authors cite business, management, accounting, decision sciences, computer science, Economics, Econometrics, and Finance documents. Table 1 provides the top nine publishing and citing platforms for ISM documents.

Still, ISM popularity is observable as statistics demonstrate that the ISM is referenced in publications by a wide range of countries. Australia, Italy, Bangladesh, Saudi Arabia, Netherland, Turkey, and Brazil are among the countries that recently joined the ISM publishing collaboration network, as illustrated in Fig. 5. Nevertheless, some countries, including Argentina, Algeria, Greece, Mexico, Peru, Romania, Sweden and Singapore, are still not listed among the contributors to the list of publications.

However, Fig. 6 shows a density representation of the data that illustrates that certain authors with high publication records, regardless of their details, are not members of any co-authorship network.

Attri et al. (2013) and Jena et al. (2017) show that the ISM technique encourages problem analysis by allowing participants to assess system components and present arguments for specific circumstances. ISM is designed to evaluate potential pairwise relationships between system components, either directly from participant responses or indirectly through transitive inference. It generates a structured model or graphical representation of the underlying issues. Users can easily answer relational queries, and the transitive inferences can minimize the number of relational queries. Focusing respondents' attention on one question at a time improves transdisciplinary and interpersonal communication within a problem. ISM organizes and documents the outcomes of group decision-making on complicated subjects. It is a learning tool helping users comprehend the value and purpose of a given element and its connections. ISM helps users isolate opportunities for action or analysis, such as specific policy action areas that advance or leverage desired outcomes. Fig. 7 shows the keywords' co-occurrence network density for investigating leading and emerging subjects in the ISM research domain.

Table 1
Publishing vs citing platforms.

Publishing platforms	Frequency	Rank	Citing platforms	Frequency
Journal of modelling in management	59	1	Journal of cleaner production	546
Journal of cleaner production	54	2	sustainability Switzerland	526
Benchmarking	53	3	Benchmarking	275
Global journal of flexible systems management	27	4	International journal of production research	209
International journal of logistics systems and management	25	5	production planning and control	160
International journal of productivity and performance management	22	6	International journal of logistics systems and management	136
International journal of production research	20	7	International journal of productivity and performance management	132
Journal of advances in management research	20	8	International journal of production economics	131
International journal of services and operations management	19	9	Global journal of flexible systems management	26

Researchers used unsupervised machine learning to visualize the subjects to provide a map of their relationship. Fig. 8 presents a conceptual structured map of the literature using multiple correspondence analysis (MCA). This method compresses large amounts of data with multiple parameters into a two-dimensional plane that uses proximity to illustrate theme homology (Meghana et al., 2021). The MCA yields two clusters of the method's efficacy, particularly in risk management.

We explore this further by analyzing the title and abstract keywords based on their co-occurrence data. A co-occurrence matrix-based similarity matrix is computed first using the Vosviewer software. Next, the

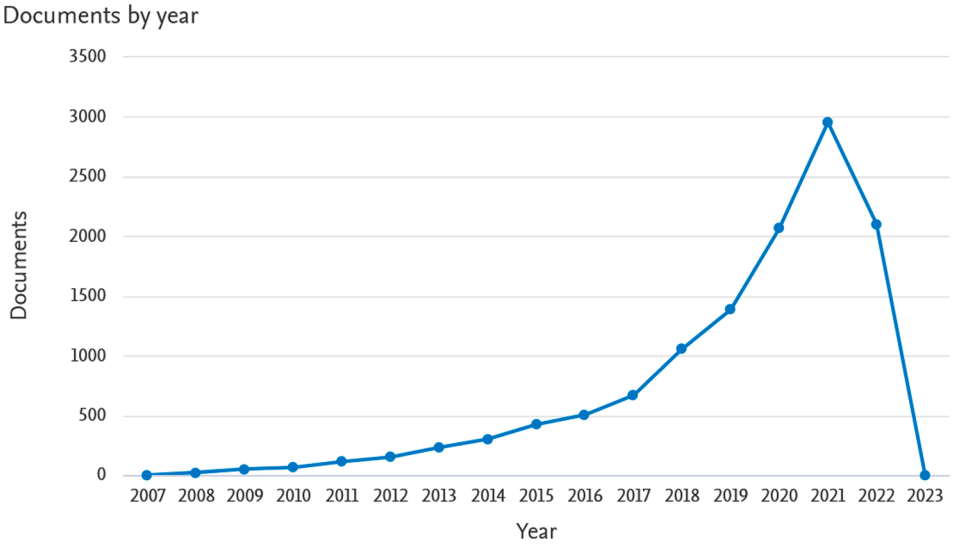


Fig. 4. Citation overview.

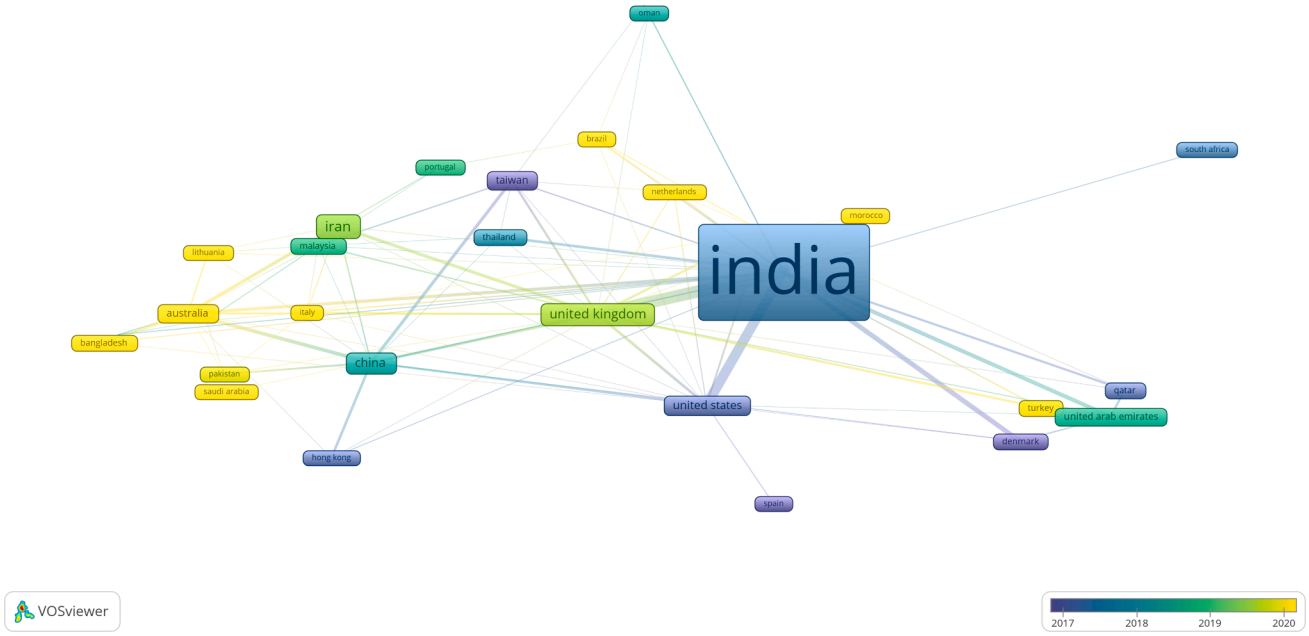


Fig. 5. Collaboration network.

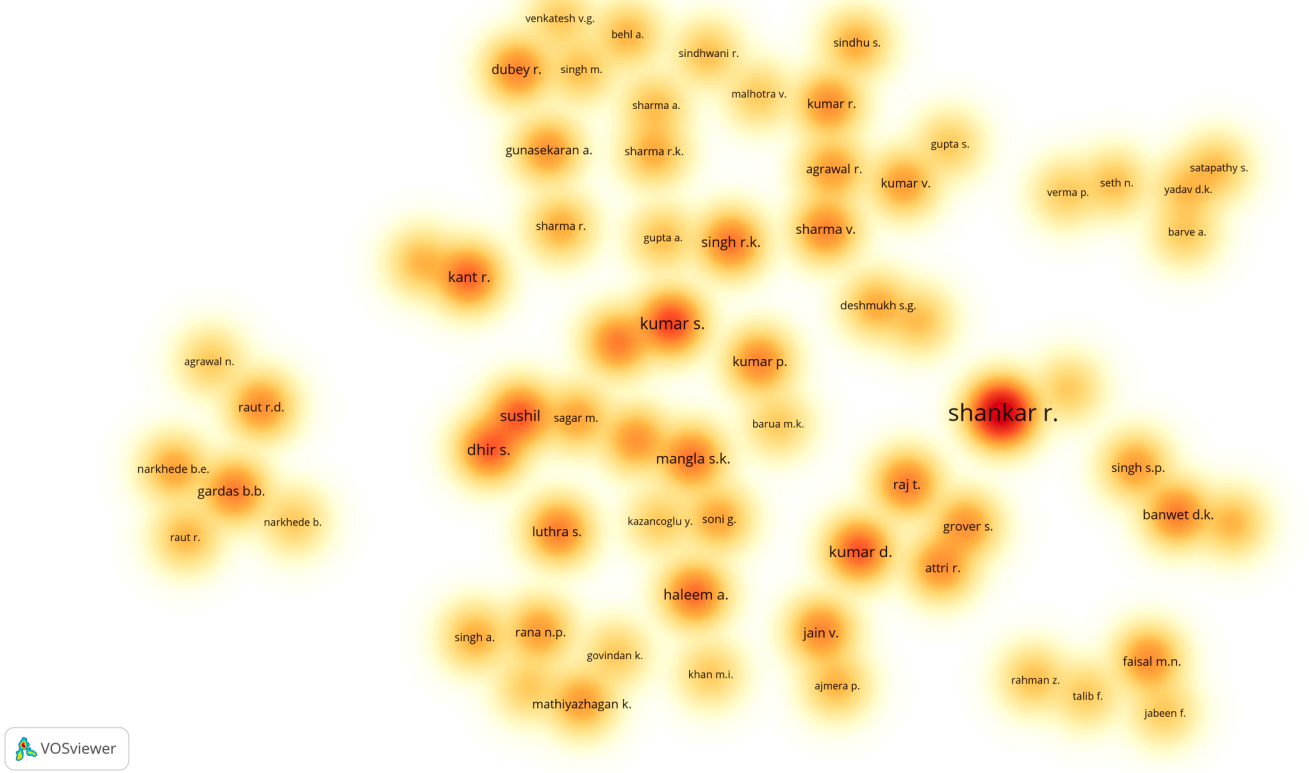


Fig. 6. Co-authorship network.

similarity matrix is mapped using visualization of similarities (VOS) mapping. The VOS mapping technique is widely used due to its well-validated performance (Van Eck and Waltman, 2010). Here, the document's minimum number of phrase occurrences was adjusted from 10 (software's default) to 30 to get single cluster. As a result, Fig. 9 shows the software's outputs for density and overlay visualizations. Fig. 9 (part A) depicts the ISM implementations and key applications such as risks, barriers, enablers, and success factors. A wide range of issues can be addressed by ISM. Management, quality, circular economy, sustainability, supply chain, smaller enterprises, performance, and projects are among the area that used ISM. Complexity concept and supplementary and supportive methods of the analytic hierarchy process (AHP), MICMAC, and DEMATEL were also replicated in documents.

As the analysis shows, uncertainty is an added concern to decision

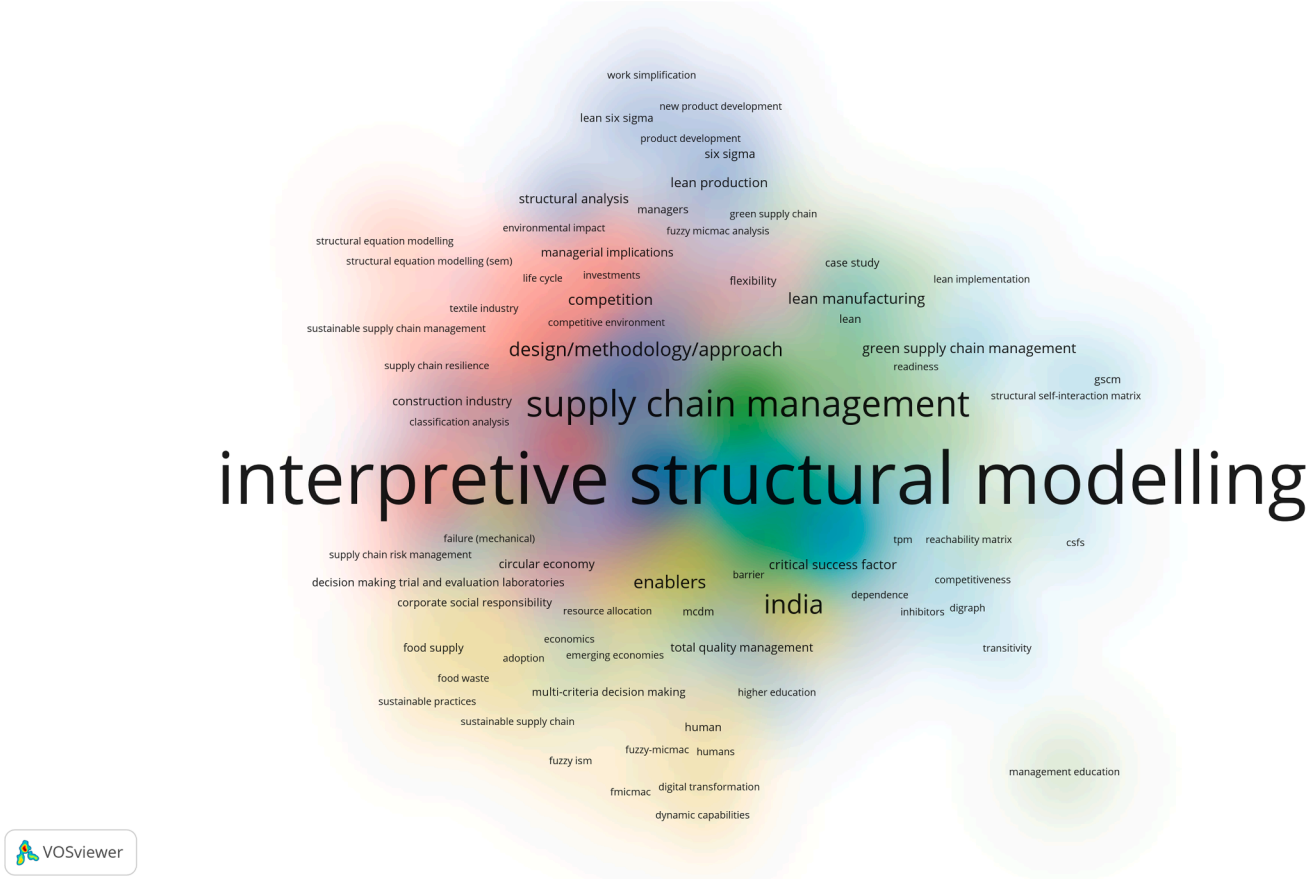


Fig. 7. Keywords co-occurrence network cluster.

complexity. For decades, many articles and researchers have studied various uncertainties in decision-making. Probabilistic and Bayesian frameworks, as well as non-probabilistic frameworks, such as gray theory and fuzzy logic, have been developed and used to represent uncertainty and limited information (Baraldi et al., 2015). More specifically, while ISM examines the presence of an interaction between components, the potential of interaction is also considered uncertainty. As a result, uncertainty-dealing frameworks have surpassed ISM.

Our literature review reveals that ISM is used with the cross-impact matrix multiplication applied to classification (MICMAC) analysis in complex situations such as modeling critical success factors, key risks, and system drivers. The MICMAC (Duperrin and Godet, 1973) is a procedure for classifying alternatives on their capacity to influence other alternatives (Farooq et al., 2020). MICMAC entails creating a graph that categorizes elements based on driving power and reliance (Koca and Eğilmez, 2021). It is utilized by researchers to identify the components and verify the ISM factors (Koca and Eğilmez, 2021). When used together, ISM and MICMAC can visually exhibit the context hierarchy and relationships (He and Chen, 2021).

Furthermore, Fig. 9 (Part B) shows emphasis has been placed on innovation, sustainability, circular economy, and the usage of the revised ISM approach known as total interpretive structural modeling (TISM).

3. ISM shift

Despite the uncertainty and MICMAC additions, there are some downsides to the ISM approach. For one, the ISM method gets increasingly complicated as the variables in a problem or issue increase. Since it is binary, aspects that have minimal impact on a problem or issue may be left out (Attri et al., 2013). The ISM uses nodes to represent the components and connections to show the link, but it does not explain why or what caused the relationship (Jena et al., 2017; Ramiya and Suresh, 2021; Kazancoglu et al., 2022). The interpretation of structural modeling, TISM, has evolved to overcome the weaknesses of the ISM. TISM is comparable to the ISM but makes it more consistent and transparent by removing the risk of user interpretation differences (Wilczynski, 2017; Logesh and Vinodh, 2021). Fig. 10 presents the keywords evolution graph where varying color schemes depict the volume of used keywords from dark to light (Sorooshian et al., 2022). This figure shows that TISM is rapidly gaining popularity among researchers.

The procedure depicted in Fig. 11 was used to study the application of TISM in business research. 68.3 % of the documents using TISM originated in business research. Fig. 12 shows the increasing application of TISM in business research based on the Scopus archive.

India still has the most TISM users in business research, followed by UK and US. Yet, researchers in 30 countries shown in Fig. 13 have a publication with TISM, and the potential growth is yet to be realized. The heat map depicts the intensity of country publications. Most of the papers were articles, and no TISM systematic review (or bibliometrics study) was observed among them. Hence, this paper's review and bibliometrics study effort also contribute to the TISM field. Nonetheless, from the archived data, 95.9 % of the published documents are articles; still, the average citation is very high, 23.7 per document (the documents' citation trends are shown in Fig. 14).

Although in ISM using, Shankar, R., Haleem, A., and Suresh, M. were the top three users, here in TISM, only Suresh, M. (from India) appeared to be the leading author based on the number of recorded publications. Fig. 15 shows the use by country networks where users of different countries seem unconnected and provide a warning for the lack of international collaborations using the technique. However, for the existing works, Fig. 16 presents the TISM by keyword overlay network, which is

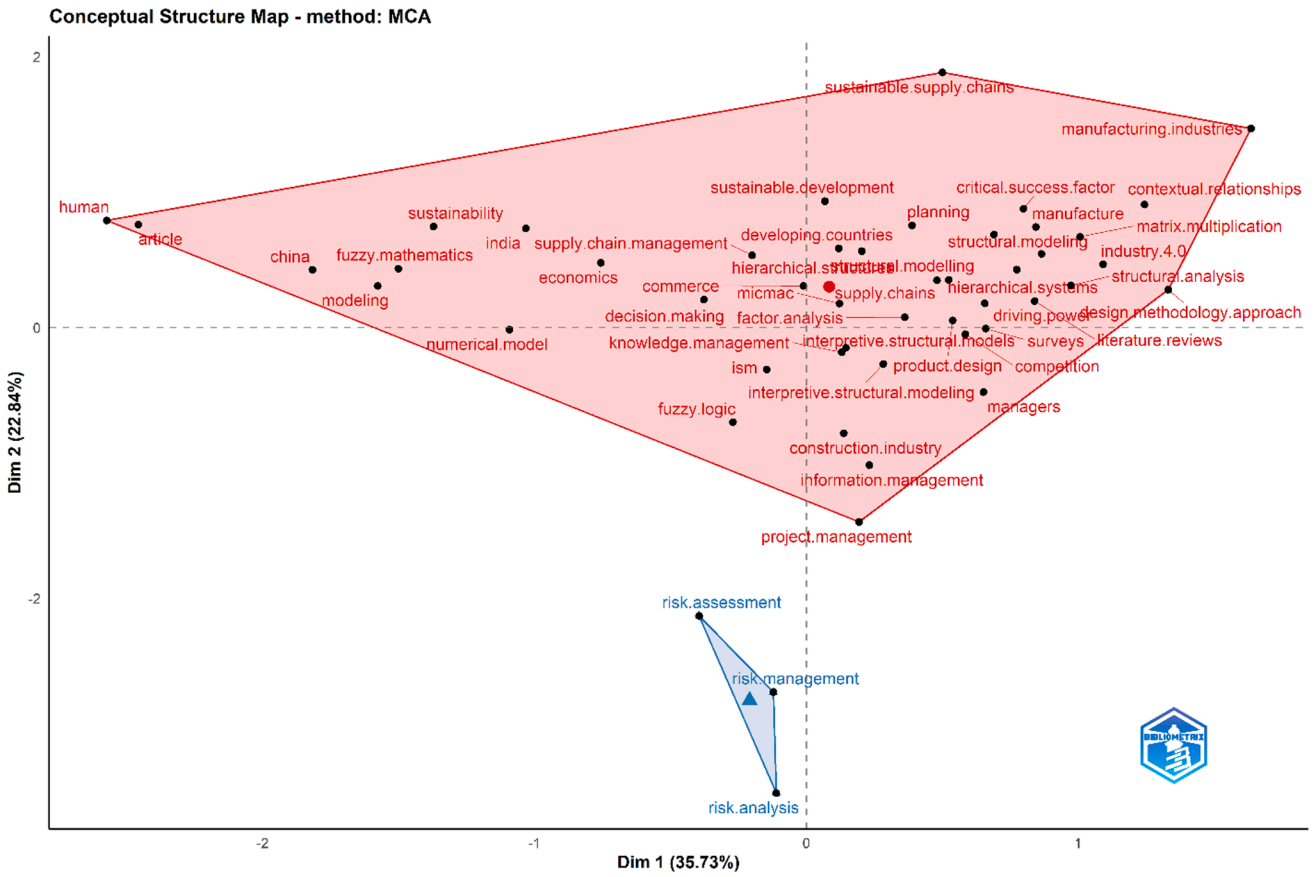


Fig. 8. Conceptual structured map.

mainly linked to keywords such as technology, readiness factors, stakeholders, complexity, resilience, lean management, and most recently, to keywords such as organizational learning, COVID (Coronavirus disease) and artificial intelligence.

Some of the top keywords used in publications using ISM or TISM analysis have changed over time. The Sankey diagram in Fig. 17 depicts and contrasts the most popular topics used with the ISM or TISM methods based on the top-used keywords.

Sushil (2017) introduced an updated version of the TISM methodology with polarity (TISM-P). TISM-P has 27 Scopus citations. Suresh, the leading author of ISM and TISM, is also the most productive author of TISM-P; the Indian Institute of Technology Delhi also stays on top of the list of affiliation publishing with the new technique. Sushil and other researchers are now working on modifications of ISM and TISM, evident by recent research and publications (e.g., Hasan et al., 2019; Agrawal, 2020; Sharma et al., 2021; Amini and Alimohammadlou, 2021; Rajan et al., 2021; Singh and Dhir, 2022; Yadav and Sagar, 2021; Palit et al., 2022), and the trend indicates that this will continue.

4. ISM and TISM frameworks

This section explains the ISM and TISM frameworks and presents a selection roadmap for practitioners.

4.1. ISM framework

This section describes a series of continuous and connected ISM steps within three phases: preparation, operation, and post-operation. Each step is essential, connected to the one before, and cannot be skipped (Poduval and Pramod, 2015). This structure is organized according to the ISM procedure primarily described by Poduval and Pramod (2015) and Kumar and Goel (2021), and other secondary resources in the literature are used for editing, expanding, and validating the procedure (e.g. Singhal et al., 2018; Hughes et al., 2020; Abbasnejad et al., 2021; Mishra et al., 2021; Suresh et al., 2021; Vatankhah and Ilkhanizadeh, 2021).

In the preparation phase, five steps are included:

Step 1: Identify the issue/problem.

This step is designed to explain if the problem is complicated enough to warrant the use of ISM. This phase explains if the individual feel overwhelmed by the sheer number of linkages and interrelationships between the variables requiring a methodology to examine and present them in an easy-to-read and easy-to-understand format.

Step 2: Identify the component/variable.

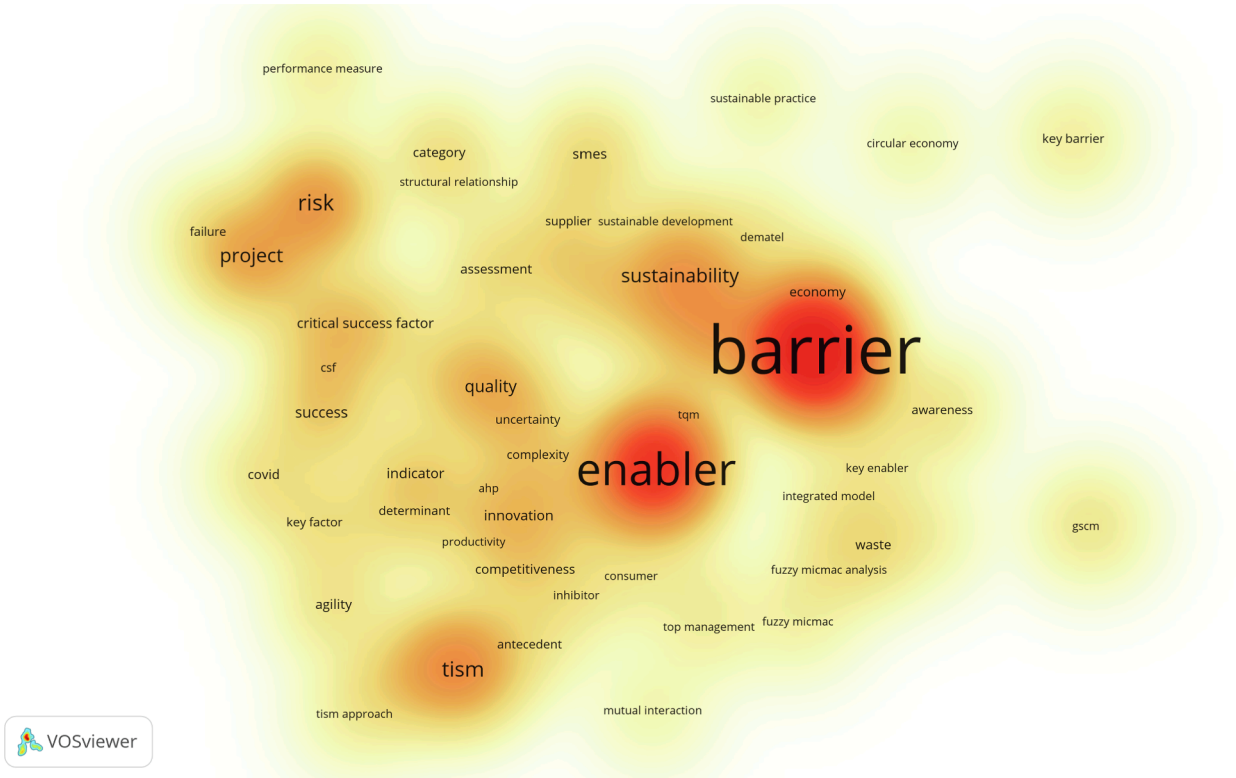
Once a decision is made on the suitability of the problem for ISM, the next step is to identify all of the components/variables in the problem. This is done by motivating evidence, literature and/or expert support through a survey or group idea generation techniques (i.e., Brainstorming, nominal group technology, and the Delphi method, among others (Sorooshian and Parsia, 2019).

Step 3: Decide on the structure/contextual relationship.

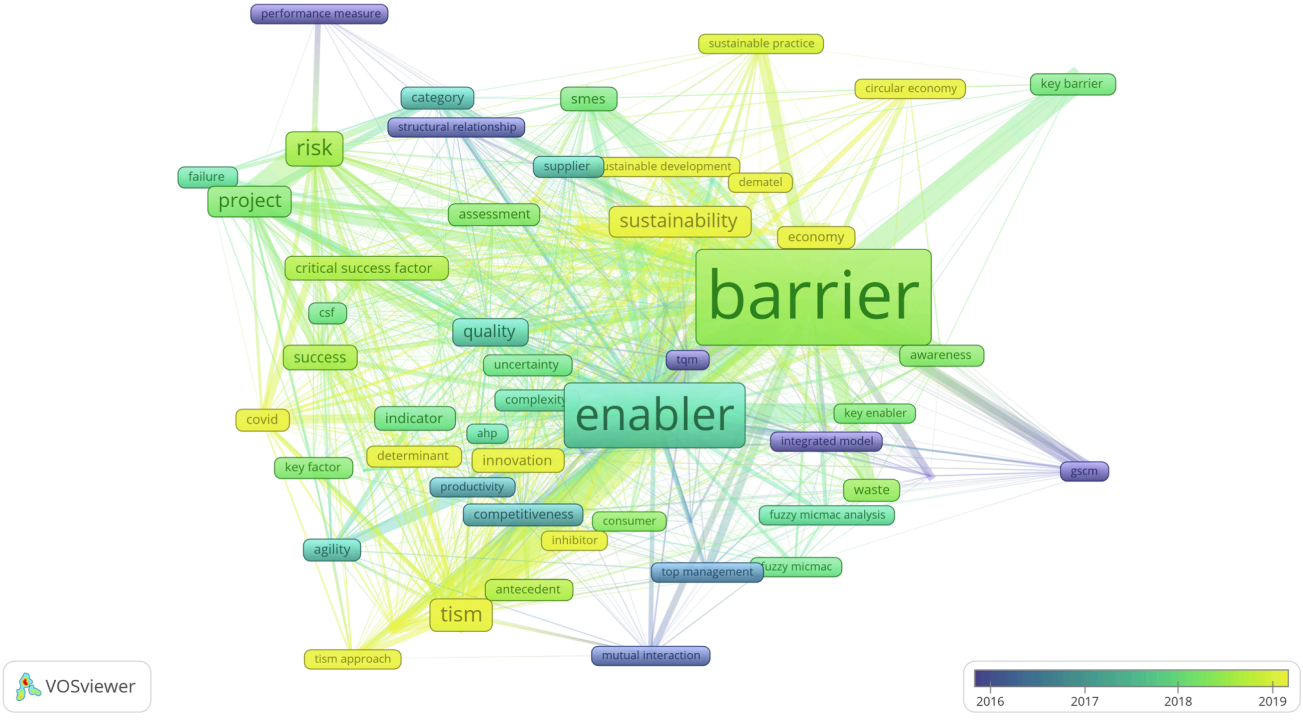
After evaluating the issue/problem and its components/variables, the next step is to decide on the contextual connections in the ISM, which will determine how the variables will be connected. Although different structures based on Warfield's taxonomy are defined, the two most prevalent structures are intent structure and priority structure. Intent structure exists when a variable aids in the achievement of another variable, and priority structure exists when a variable has more significant importance or preference over another variable (Janes, 1988; Poduval and Pramod, 2015).

Step 4: Create the data collection checklist.

Some researchers stress a phase that provides clear instructions for the investigator(s) on how they approach the data collection phase (Kumar and Goel, 2022). Past studies have mostly trusted their expert(s)



(a) density visualization



(b) Overlay visualization

Fig. 9. ISM Keywords Network.

opinion as input data to note the structure/contextual relationship, and pre-defined symbols are often used to record the direction of the relationship between components/variables. The pre-defined symbols need to be directional and capable of recording if contextual linkages (if any) are either one way or both ways.

Step 5: Determine pairwise connections between variables.

Warfield described ISM as a technique for creating hierarchical structures for a collection of items based on minimal knowledge about

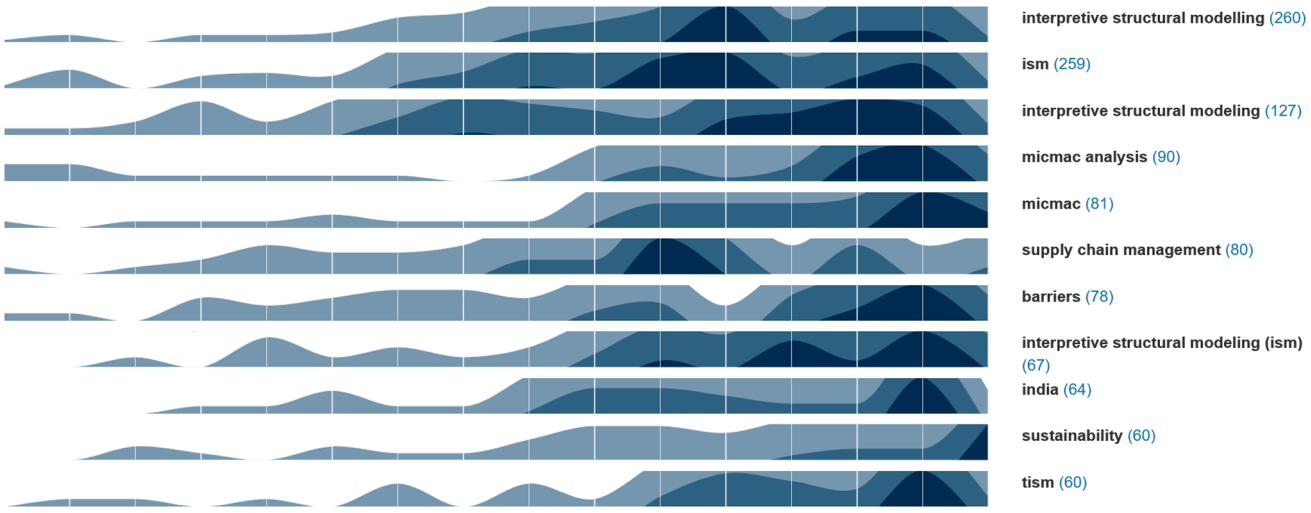


Fig. 10. Keywords Evolution.

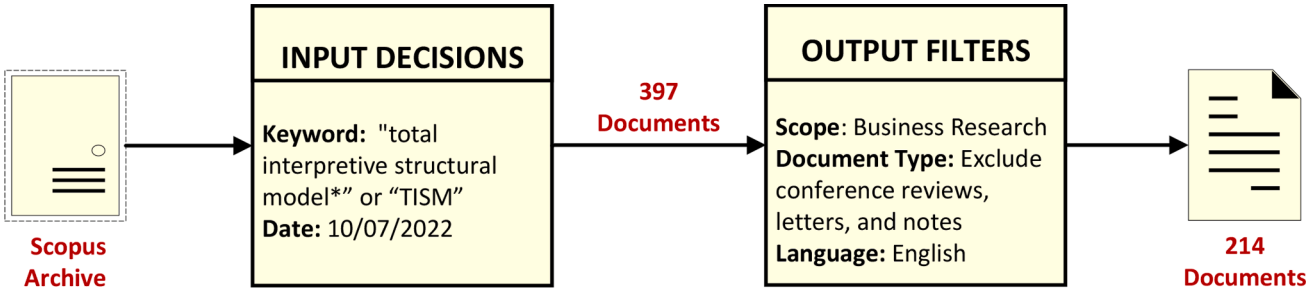


Fig. 11. TISM literature selection.

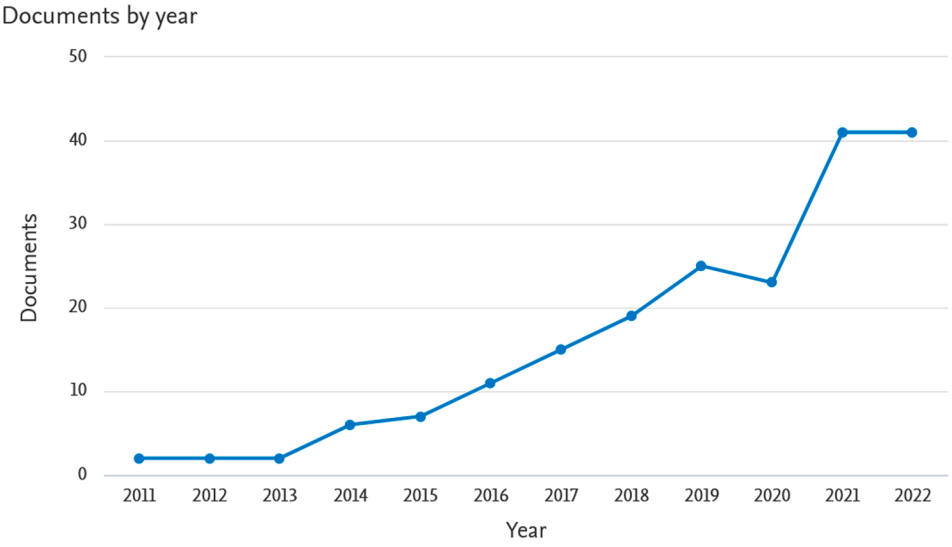


Fig. 12. TISM publication trend in Scopus.

pairwise connections (Poduval and Pramod, 2015). After defining the contextual relationship or structure, the fourth phase of model development is to determine whether the contextual relationship exists between pairs of components or variables. Each variable is cross-checked with all other variables to determine whether the relationship exists in any particular pair.

Furthermore, a few steps in the ISM operations phase are listed below.

Step 6: Create a structural self-interaction matrix (SSIM).

The pairwise linkages recorded in Step 4 are formed into a matrix. Reviewing the literature shows that some studies have shifted Step 6 as part of operational steps. However, there have been several instances when the data collection phase from experts was designated as Step 5 to gather data by survey or interview. Step 6 was performed for data entry.

Step 7: Create the initial reachability matrix.

The SSIM is then turned into a reachability matrix that displays the

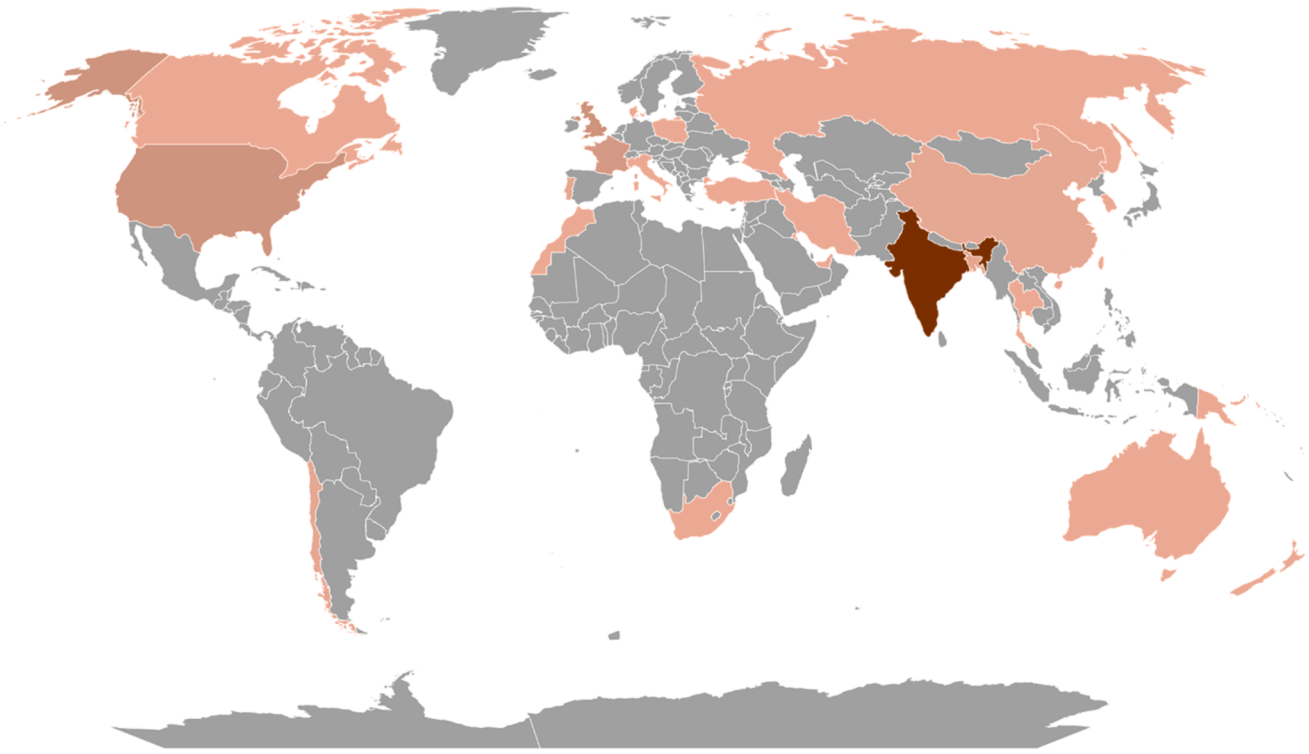


Fig. 13. TISM publishing countries.

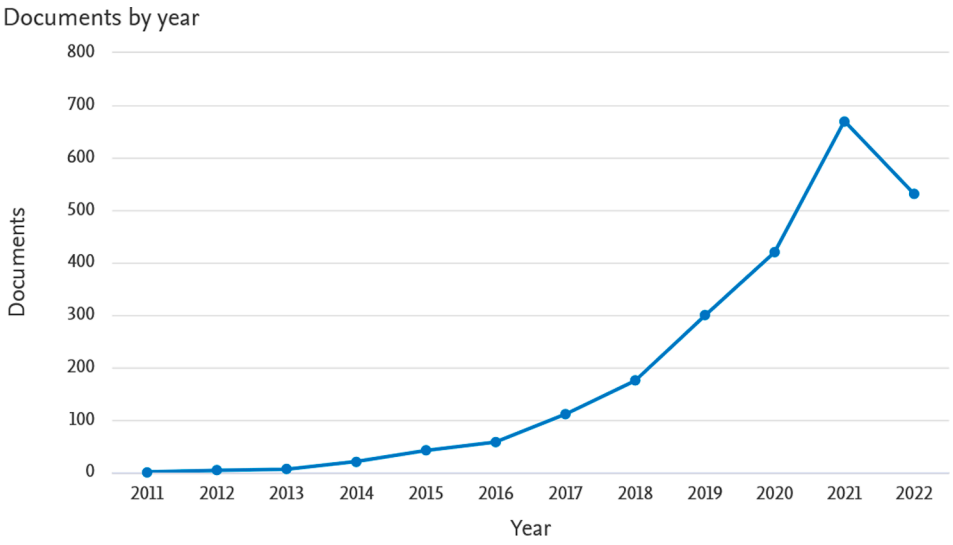


Fig. 14. TISM citation trend in Scopus.

pairwise connection in the binary notation of 1 and 0. This matrix is called the reachability matrix because it indicates whether any variable can be reached from the other variables.

Step 8: Consider transitivity and create the final reachability matrix.

Transitivity is defined in this paradigm as if variable X leads to variable Y and Y leads to variable Z; then variable X leads to variable Z. The following procedure is required to include transitivity in the original reachability matrix:

Determine if a variable has a connection with the other variables.

Determine if there is a link between the second and third variables.

Determine which of the third variables has a connection.

Apply transitivity to those variables so the cell will be shown by a pre-defined designation in the final reachability matrix.

Repeat the preceding steps for all variables in the original reachability matrix to create the final Reachability Matrix.

Step 9: Define reachability and antecedent sets.

The reachability matrix is useful for developing hierarchical reorganization, and as a preparation phase before running the next operations, reachability and antecedent sets need to be defined. An antecedent set is defined for each variable as a collection of variables that may reach that variable. The intersection set contains the variables shared by both the reachability and antecedent sets.

Step 10: Create level partitions.

The original reachability matrix's reachability, antecedent, and intersection sets are established only for informational and instructional purposes. Studies are interested in the final reachability matrix for

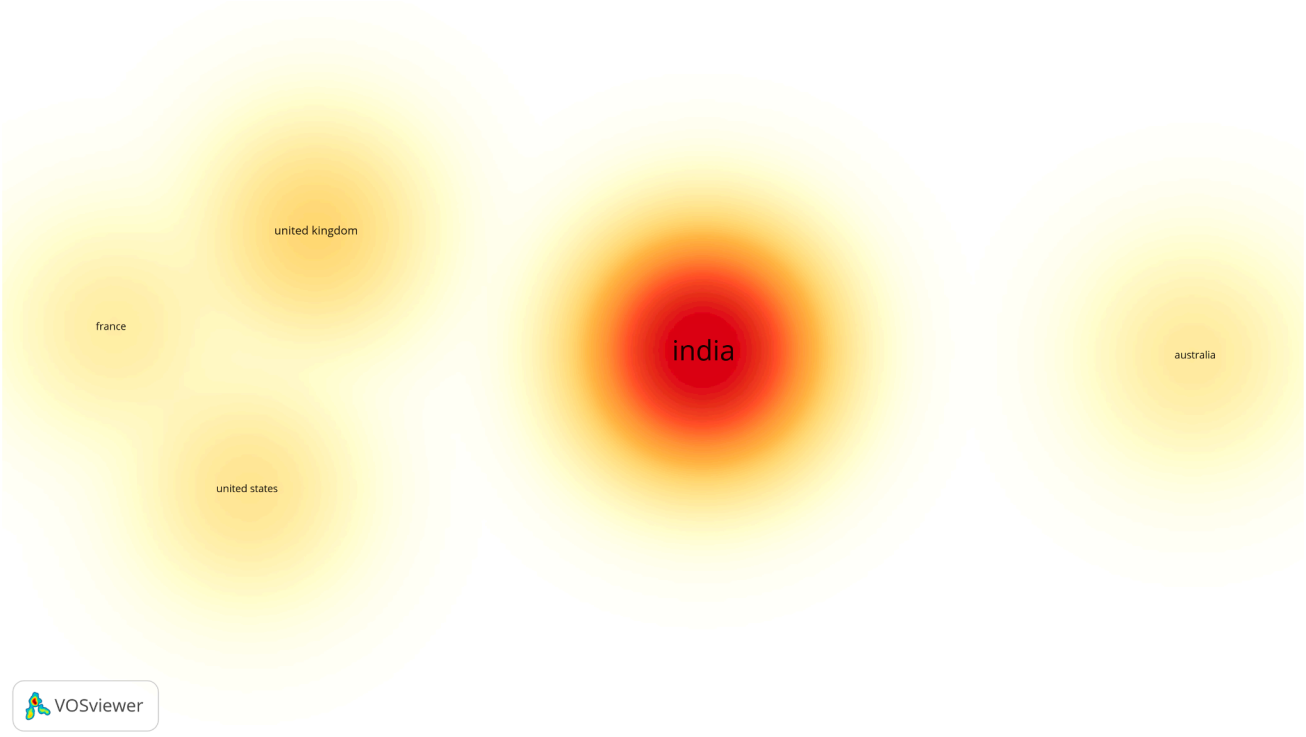


Fig. 15. Density visualization.

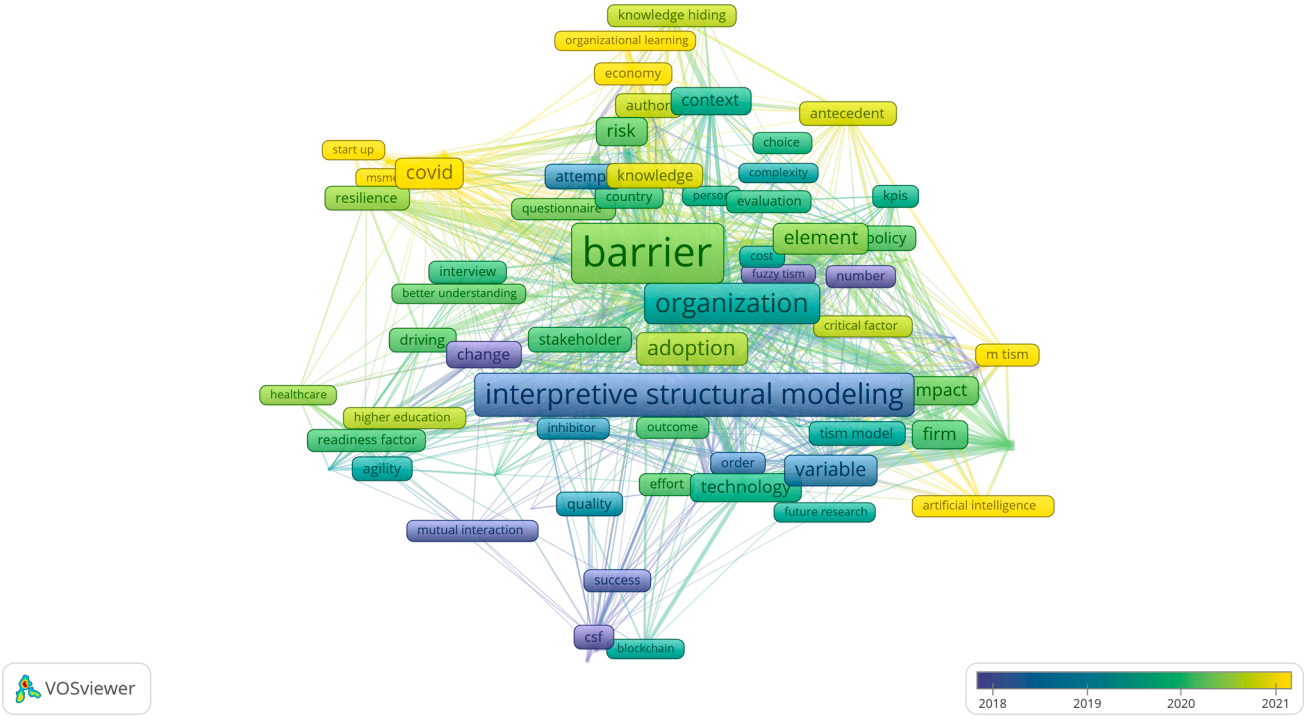


Fig. 16. TISM Keyword networks.

creating the digraph. Level partitions, or various levels depending on a sequence of iterations, have to be constructed for this. The variables for which the reachability and intersection sets are the same (meaning that both sets include the same variables) in each iteration are contained in the levels beginning with the top level. The first level is determined by examining the final reachability matrix variables with the same reachability and intersection sets. The factors with the same reachability and intersection sets occupy the top level in the ISM hierarchy. The top-level factors will not lead the other factors over their level in the hierarchy. The second level is created by deleting variables from the first level and the reachability, antecedent, and intersection sets of variables that do not inhabit the first level. Similarly, the third level is generated by deleting variables from the second level, and so on, in an iterative process until the final level is achieved, which has variables in all three sets that

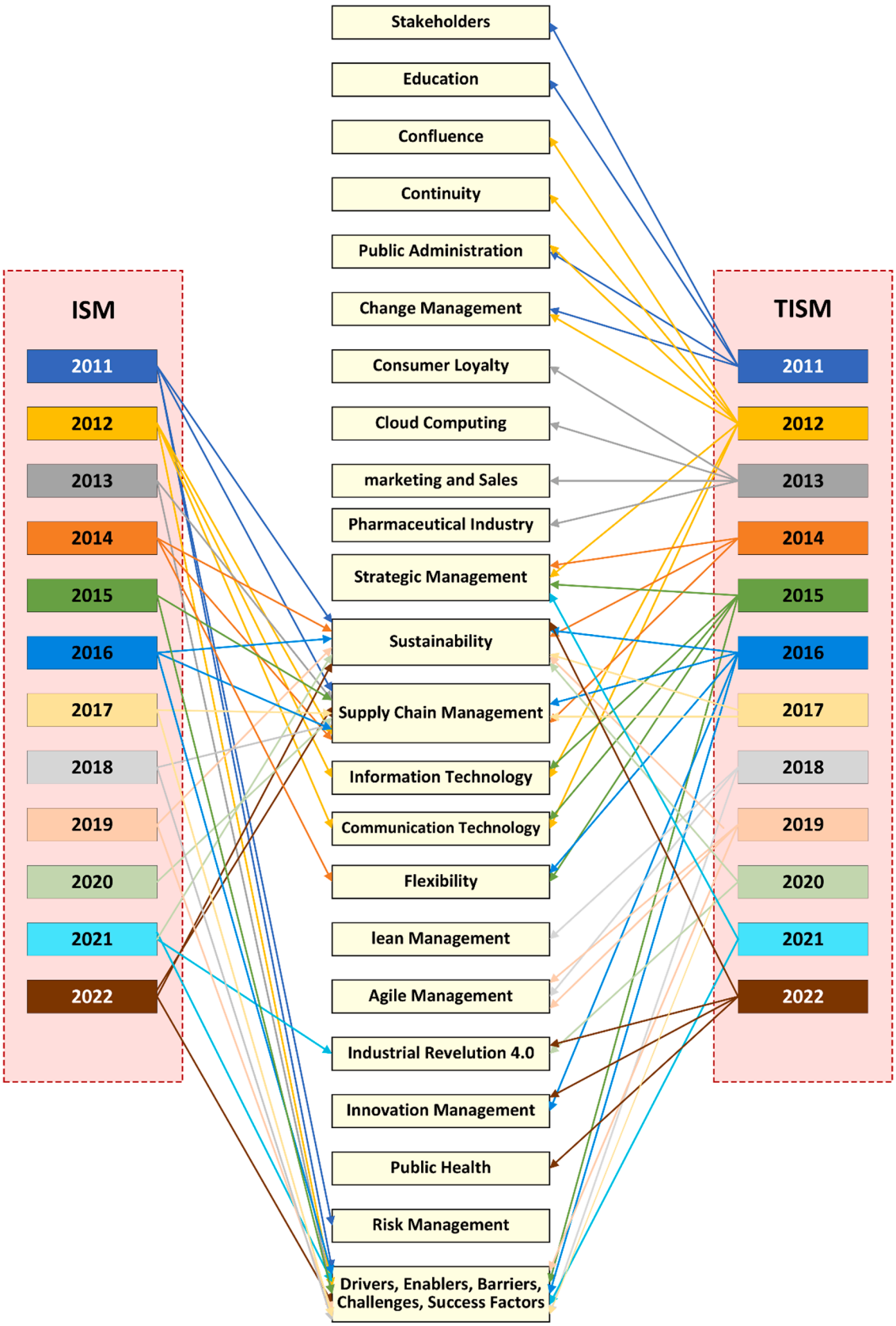


Fig. 17. Comparison of ISM and TISM applications over time.

are the same as the variables corresponding to the three sets.

Step 11: Interpretive structural model.

This step *is divided into three sub-steps, i1-i3:*

Step 11.i1: Develop the conical matrix.

The conical matrix is created by combining variables at the same level across rows and columns of the final reachability matrix. The variables are placed on the X- and Y-axes in the order of their levels, beginning with the first level. The conical matrix is identical to the reachability matrix, except that the variables in the conical matrix are written on the X- and Y-axes according to their levels. The variables' associations are derived from the reachability matrix.

o ***Step 11.i2: Construct a digraph***

The first digraph is constructed using the conical matrix. A digraph is a collection of nodes (representing the variables in the conical matrix) connected according to the matrix's relationship. All linkages are depicted as arrows showing the direction from one node to the other. The initial digraph is created by considering the transitivity linkages in the conical matrix. The top level of the digraph consists of variables in the first level of the level partitions, followed by the second level of the second-level variables, and so on.

Step 11.i3: Create an interpretive structural model.

The last step in the ISM process is converting the final digraph to an interpretive structural model by substituting the node numbers with the variable descriptions in text boxes.

Moreover, additional steps are included in the post-operation phase as follows:

Step 12: Verify possible inconsistencies and transitivity.

If any probable contradiction or transitivity remains, return to Step 5. A new view is predicted if the ISM digraphs demonstrate transitivity and irregularity in the connection between variables. This necessitates a new round of interaction with prominent specialists in the field, as well as the redevelopment of the ISM digraph.

Step 13: Develop the variable power classification.

The ISM assists us in deriving correlations between the many variables in the situation under consideration. It is also interesting to know how much one variable impacts and is impacted by the other factors in the situation under consideration. This is accomplished using MICMAC analysis. For that:

Calculate each variable's driving and reliant power by adding the 0 s and 1 s in the columns and rows corresponding to each variable in the conical matrix.

Higher driving power indicates the amount the variable influences the other variables. In comparison, higher dependency power suggests the extent to which the variable is impacted by/depends on the other factors.

4.2. TISM framework

Although the ISM strategy can tackle several management difficulties through hierarchical representation, it also has a few drawbacks (Sushil, 2012; Choudhury et al., 2021). Sushil (2012) examined the ISM idea and changed the current model to add a logical interpretation of documented interrelationships between variables with TISM. ISM solely understands nodes, but the TISM framework interprets nodes and connections. Furthermore, all transitive relationships are deleted in ISM, but TISM can give a stronger explanatory framework with essential transitive links (Choudhury et al., 2021).

Based on the explanation of TISM by Sushil (2012), and a few other secondary resources in the literature, expanding and validating the procedure (e.g., Yadav, 2014; Jena et al., 2017; Menon and Suresh, 2019; Choudhury et al., 2021; Logesh and Vinodh, 2021), in comparison to ISM procedure, the TISM procedure is depicted in Fig. 18 and described as follows:

4.2.1. TISM procedure

Step 1–10: reachability matrix.

The first ten steps of ISM apply to TISM. Reachability and transitivity are fundamental ISM principles that contribute to developing various TISM levels. In short, in TISM also, relationships are defined by how one element affects or improves another. When comparing pairwise, each item is compared independently. Here, this reachability matrix is also transitivity tested.

- ***Step 11: Total interpretive structural model***

This step *is divided into seven sub-steps, t1-t7:*

o ***Step 11.t1: Interpreting relationships***

This step is beyond traditional ISM. The contextual connection assesses the relationship's structure but not its function. In TISM, the connections between the elements must be clarified. In the case of intent structures, we should ask how A will help B. The connection is interpreted differently for each objective combination by answering the interpretative question, making deep-seated knowledge explicit.

o ***Step 11.t2: Comparing pairs Interpretation***

SSIM is developed by comparing ISM's elements. However, only the relationship's direction is interpreted. TISM recommended using an interpretive matrix to interpret each paired comparison regarding how that directional connection functions in the system under examination by answering the initial interpretive inquiry. The *i*th element is compared to each item from $(i+1)th$ to nth. If there are n items, every n $(n-1)/2$ will be paired. The knowledge base will have $n(n\text{-}1)$ rows since each pair of items (i,j) may have two-directional linkages *i-j* or *j-i*. Each *i-j* connection item may be 'Yes' or 'No,' and if 'Yes,' it must be further interpreted. Interpretative logic of paired connections is revealed as 'Interpretive Logic—Knowledge Base.'.

Step 11.t3: Check transitivity and reachability.

The paired comparisons in the interpretative logic—knowledge base are translated into a reachability matrix by entering 1 in the *i-j* cell if the corresponding item is 'Yes' or 0 if it is 'No' This matrix is updated until full transitivity is established. In the interpretation column, type 'Transitive' for 'No.' If the transitive relationship can be described meaningfully, the reasoning is included; otherwise, it is left alone.

Step 11.t4: Level Partition on Reachability Matrix.

Level partitioning determines element placement. Reachability and antecedent sets are determined. Top-level elements can not reach higher-level elements. The reachability set for a top-level element includes the element itself and other elements on the same level it can reach, such as components of a strongly connected subset. A top-level element's antecedent set includes the element itself, lower-level elements that reach it, and any highly connected top-level subset. If the element is at the top level, the reachability set intersects with the antecedent set. Top-level elements that meet the requirement should be deleted, and the process should be repeated until all levels are determined.

o ***Step 11.t5: Digraph Design***

Graphically organizing elements into levels and making directed links based on the reachability matrix. Step-by-step deletion of transitive linkages from the initial digraph is based on their knowledge base meaning. Only critical transitive relationships may be kept.

Step 11.t6:: Create an interaction matrix.

The resulting digraph is converted into a binary interaction matrix. Single-entry cells are interpreted using an Interpretive Matrix.

Step 11.t7:: Create Total Interpretive Structural Model.

The TISM is derived from the interpretive direct interaction matrix

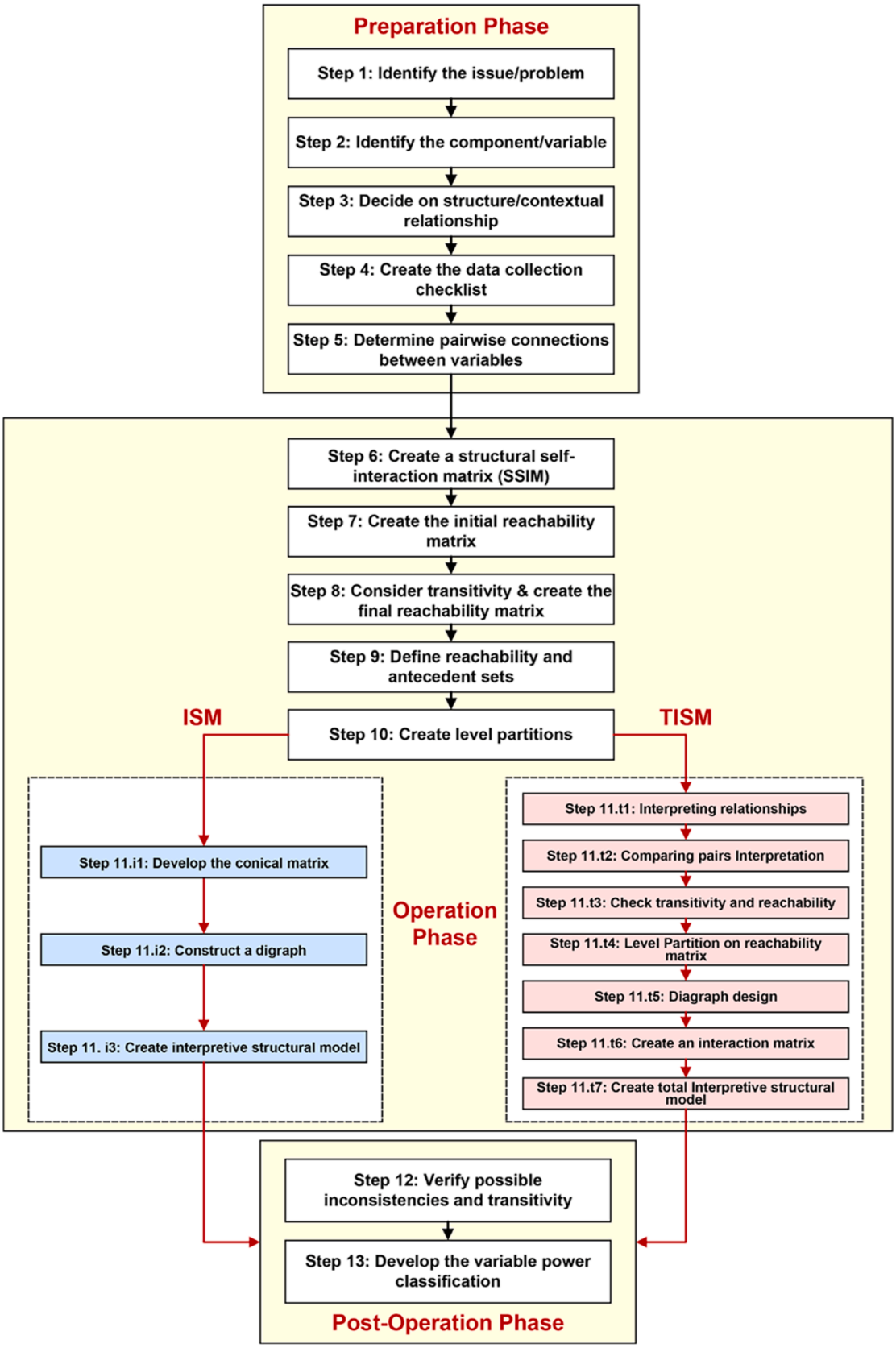


Fig. 18. ISM vs TISM Framework.

and digraph's connective and interpretative information. The nodes in the digraph are replaced by the interpretation of components contained in boxes. The interpretation is depicted in the cells of the interpretative direct interaction matrix on the side of the relevant linkages in the structural model. As a result, the structural model is completely interpreted in terms of node interpretation.

Steps 12 and 13: Post-Operations.

The two post operations steps are fitting the ISM two post operations.

This TISM methodology's lack of statistical validity is debatable, as its rising use in data analysis establishes it as an analytical tool capable of developing an initial model (Menon and Suresh, 2019). Moreover, it is claimed that a significant proportion of published ISM or even TISM applications contained technical problems (Sushil, 2018a and b), and more shortcomings in the application of both ISM and TISM have also been claimed (Sushil, 2017; Sushil, 2018a and b; Hasan et al., 2019; Rajan et al., 2021). So, as explained in previous sections, more new versions of the ISM methodology have started to be introduced and tested by scholars.

ISM and TISM are both MCDMs that use interactive approaches (Kaur et al., 2019). They both aid in theory development and conceptualization (Sushil, 2018a and b). consequently, there is some confusion regarding the distinction between ISM and TISM, as well as other modifications of ISM (or TISM) methods. The following section provides a practical guide for selecting ISM and TISM.

5. ISM/TISM selection checklist

Sushil (2012, 2018), Kaur et al. (2019), and Jain and Raj (2021) explain that the TISM interprets the nodes representing 'what' and the linkages interpreting 'how' and 'why.' They further explain that while ISM studies the contextual links between distinct variables, TISM investigates the causes behind the associations. The TISM can help to combine many pairwise comparisons into a hierarchical model utilizing ISM (Sushil, 2018; Jain and Raj, 2021). ISM merely gives the interrelationship of the components associated with the issue of a complicated problem; however, TISM is the approach that provides the details for the interconnectivity of the enablers or elements.

The ISM and TISM have been used in diverse fields for a long time, yet some confusion exists regarding their application. A relevant guideline is provided to ensure the accuracy of ISM/TISM (Sushil, 2018); another guide also has been published for more general MCDM (Saaty and Ergu, 2015). Table 2 outlines the two guidelines.

Table 2
Method selection checklist.

Method selection	Choose ISM or TISM (ISM should be chosen for a simple view of the components next to each other. However, TISM should be chosen to understand how the enablers or components work together). Is the selected method justified? Does the expected outcome have a validation plan? Did you consider the Simplicity of execution? Are you aware of the selected method's logical procedure? Are you aware of the alternative method's logical procedure?
Elements (ISM and TISM)	Is the topic's literature lists all relevant elements? Does the list include a performance-related item? Are the study's elements verified empirically or with big data analytics?
Relationship and its interpretation (TISM)	Are the contextual relationships accurate representations of the model's intent? Is the interpretation of the contextual relationship representative of the model's intent?
Interpretive logic (TISM)	Is the knowledge base for interpretive logic unbiased?
Reachability matrix (ISM and TISM)	Have all 0 and 1′s in the reachability matrix been verified?
Transitivity (TISM)	Have you checked that at least one column contains all '1′ entries except '0′ for elements at the same level that are not interconnected, depicting the ultimate dependent element?Have you checked if at least one row has all '1′ entries except '0′ for elements at the same level that are not interconnected with it, depicting the driver element (s) ?
Level partitioning (TISM only)	If there are two or more strongly connected elements at a level, did these come together in intersection sets of the respective elements?
Digraph (TISM)	Have you looked through the digraph for distinct transitive links? Have you checked that all of the digraph's direct and distinct transitive links are entered as '1′ in their respective cells of the direct iteration matrix? Have you checked to see if the knowledge base's interpretation of '1′ entries in the direct interaction matrix is correct?
Distinct transitive (TISM)	Have you verified that the transitive links already present in the knowledge base and the original reachability matrix have distinct interpretations and should be kept?Have you checked the transitive link(s) established during the transitivity check for any distinct interpretation, and should it be retained in the case of clear causal logic?
The final model (ISM)	Have you confirmed that the two elements on the same level could not have a one-way link?
The final model (TISM)	Have you confirmed that the two elements on the same level could not have a one-way link? Have you ensured that the higher-level element does not affect the lower-level element?

6. New ISM^{+} method

As shown in Section 3, the number of new ISM editions is increasing, suggesting that this trend will continue. While the original ISM can be used in a wide range of contexts, its editions could complicate selecting the best fit method. Thus, we characterize ISM* as a symbol for referring to each of the new ISM editions, whether they have been introduced already or are still in the development phase. This section proposes combining ISM and ISM*s to capitalize on their synergistic benefits, drawing on lessons learned from the formation of the weighted aggregated sum product assessment (WASPAS).

The WASPAS method was proposed as a powerful decision-making method in 2012 by combining two popular methods of WPM and WSM. WASPAS' procedure is more accurate than traditional WSM and WPM techniques (Zavadskas et al., 2014; Badalpur and Nurbakhsh, 2021; Senapati and Chen, 2022; Sorooshian et al., 2022). WASPAS is now widely viewed as a dominant decision-making tool because of the integration of WSM and WPM (Zavadskas et al., 2014; Chakraborty et al., 2015; Mardani et al., 2017; Tunas Bangsa Pematangsiantar, 2017; Alam et al., 2018; Maliene et al., 2018; Chourabi et al., 2019; Senapati and Chen, 2022).

This section proposes integrating the original ISM with ISM* in a new framework called ISM^{+}. The ISM^{+} is designed to capitalize on the advantages of the ISM and any of its editions using a combination parameter (λ), similar to the WASPAS method (Zavadskas et al., 2012). In ISM^{+}, for each variable's driving and reliant powers, $ISM^{+}_{(k)} = \lambda \times ISM^{*}_{(k)} + (1-\lambda) \times ISM_{(k)}$, where k refers to the variables that were identified in Step 2 of ISM and used for the creation of the SSIM. The ISM^{+} users should define λ to address their decision accuracy ($0 \leq \lambda \leq 1$). When $\lambda = 0$, the ISM^{+} method is transformed into ISM, and when $\lambda = 1$, the ISM* method is preferred. The key benefit of using the ISM^{+} model is that it offers a more precise interpretation of the driving and dependence powers among components and variables when dealing with complicated MCDM problems. This is especially useful in cases where it is unclear which of the two competing models (ISM or ISM*) provides the best fit. The ISM^{+} can clearly explain the extent to which one factor affects or is affected by the other variables. Besides, ISM^{+} is useful since MICMAC depends on ISM or its editions output (Pablo et al.,

2014). Finlay and Wilson (1987) show the existing research in ISM and ISM* applications provide conceptual validation for ISM$^+$.

7. Conclusion and future research directions

This study employed a comprehensive bibliometric review of ISM research to examine its scientific productivity, scrutinize its validity, analyze its variations, and highlight its multi-disciplinary applications. The s of this study are somewhat different from Kumar and Goel's (2021) review. First, Kumar and Goel (2021) only include publications from 2000 to 2020, whereas this study consists of all work completed before 2022 with no time limit. Furthermore, they relied on tests such as exploring organizations based on total citations, country-citation view, source citation overlay, and top-cited contributions. In contrast, this research emphasized the evolution of ISM over a half-century. Despite using similar tests, the results from the two studies do not fully support each other's conclusions because of different viewpoints. This study complements Kumar and Goel's (2021) review by providing additional insight into the revised ISM (TISM) bibliometrics. We suggest researchers carefully examine both papers because they are among the few available bibliometrics studies in ISM research.

The search of the Scopus database using the search formulation TITLE ("interpretive structural modeling" OR "interpretive structural modelling") AND (LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (SUBJAREA, "BUSI") confirmed some similarity of Attri's (2017) literature review to ours. Attri's (2017) review relied on archived literature (about 400 documents), and its classifier was confined to ten disciplines. The literature was labeled according to publishing years; authors' affiliations, publication journals; integration with other methods; and ISM version. The limitations of Attri (2017) include a small number of publishers, the search was restricted to articles published before 2017, and the study did not use any systematic bibliometrics analysis.

To conclude, this study focused on applying ISM and its editions in business research. The results confirm the suitability of the methods by evaluating existing bibliometric information and analyzing the multi-disciplinary applications of the ISM and TISM. We demonstrated the citations, and the impact of ISM and TISM in multi-disciplinary research is increasing steadily. In addition, this systematic review found an evolutionary trend in the ISM family of methods. This work identified four periods in ISM history: (1) before 2007, when the technique was introduced; (2) between 2007 and 2011, when ISM became popular; (3) after 2011, when TISM was introduced to complement ISM; and (4) more recently, when alternative editions of ISM were introduced.

This study shows a growing interest in ISM and TISM research. We developed a roadmap for selecting between ISM and TISM. We recommend using the integrated ISM framework, called ISM$^+$, to assist practitioners in reaping the benefits of both classic ISM and its recent editions. ISM is a tool for finding functional frameworks within a system (Sindhwani et al., 2018) and ISM$^+$ has the same capability. Similar to ISM, TISM, and other ISM editions, ISM$^+$ can be updated to handle inherent uncertainties in real-life applications.

More research is needed to evaluate ISM and its editions systematically. We encourage researchers to assess ISM$^+$ to understand its advantages and disadvantages in various problems and applications. Empirical and analytical studies are needed to investigate further the validity of the methods proposed in this study. More research is required to evaluate the performance of ISM with various MCDM methods. Choosing a suitable MCDM model with ISM could be overwhelming and confusing for practicing managers. We encourage researchers to identify practical roadmaps for selecting the most suitable MCDM models with ISM in real-life applications.

CRediT authorship contribution statement

Shahryar Sorooshian: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Madjid Tavana:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis. **Samuel Ribeiro-Navarrete:** Writing – original draft, Visualization, Validation, Methodology, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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