Machine Learning Algorithms for Big Data Applications With Policy Implementation

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ABSTRACT

This article examines the policy implementation literature using a text mining technique known as a structural topic model (STM) to conduct a comprehensive analysis of 547 articles published by 11 major journals between 2000 and 2019. The subject analyzed was the policy implementation literature, and the search included titles, keywords, and abstracts. The application of the STM not only allowed the authors to provide snapshots of different research topics and variation across covariates but also let them track the evolution and influence of topics over time. Examining the policy implementation literature has contributed to the understanding of public policy areas; the authors also provided recommendations for future studies in policy implementation.

KEYWORDS

Policy Implementation, Structural Topic Model, Text Mining, Topic Diversity

INTRODUCTION

Policy implementation is a critical part of public policy, referred to as the process of carrying out an underlying policy decision, typically made in a statute (Sabatier & Mazmanian, 1980). Researchers have always paid much more attention to policy design and policy evaluation and less on how to implement these policies (Schofield, 2001). The first studies of implementation theory occurred in Oakland, California (Pressman & Wildavsky, 1984). Since then, there has been a rapid rise in the study of policy implementation. Previous work has focused on critical analysis or synthesis of different approaches (Sabatier, 1986). However, policy implementation research remains a niche area of interest.

Given that many studies of policy implementation provide evidence of the importance of implementation, the aim of this study was to further current knowledge of their rigidities. Based on selected published research, this research combines the application of the text mining technique with a structural topic model (STM) to provide a snapshot of policy implementation studies from January 2000 to July 2019 as well as incorporating information about the documents (Roberts et al., 2013). Within the literature analysis, we have tried to highlight the manifestation of the rigidities in policy implementation study development to facilitate future research (Moro et al., 2019). Furthermore, the STM could allow the researcher to discover topics from textual data without predicting them.

Text mining and topic modeling have been successfully used as a valuable tools in research on ethnic marketing (Moro et al., 2019) and cause-related marketing (Guerreiro et al., 2016). The generally accepted use of advanced text mining methodology could provide a comprehensive data-driven analysis of research (Liu et al., 2018). We chose unsupervised algorithms because we had no a priori expectations for categories of scholarly study, especially on topics some researchers might not have considered (Reich et al., 2014). The unsupervised learning model could help researchers

analyze textual data without human intervention. Until now, this methodology has not been applied to the policy implementation literature. In this paper, we demonstrate policy implementation research using topic models instead of focusing on the technical details of the STM.

The main contributions of this study are as follows. First, we uncovered the prevalence and content of topics regarding policy implementation, based on text mining and the STM. Second, we explored the changing trends regarding the proportion of scholarly attention to different topics. Third, we evaluated the levels of scholarly impact by each topic. The rest of this paper is broken into four sections. The next section gives a brief overview of policy implementation, after which we outline text mining and an STM that includes covariates. We then present our results before, finally, drawing our conclusions for policy implementation research.

POLICY IMPLEMENTATION LITERATURE AND SYNTHESIS

Generational Study

In recent years, interest has been growing in summarizing the policy implementation field or parts of it by a variety of methods. Some preliminary work in policy implementation has focused primarily on case studies that address the obstacles between the definition and execution of policy (DeLeon & DeLeon, 2002). The first generation of implementation research did not examine the policy implementation process and focused less on generic implementation theory (Van Meter & Van Horn, 1975). Furthermore, the conclusions of case-based analysis cannot change the analysis of other policies and/or their forecasts of the effects of policy. However, the first-generation literature contributions to scholars' understanding of these specific study streams, even collectively, could help bring the attention of the public to policy failure.

The second generation of implementation studies was much more multivariate and comparative after analysis (Goggin, 1986), as with the top-down perspective and bottom-up perspective. Scholars have drawn our attention to the variety of variables that influence policy implementation and have tried to find the best policy proposal for its successful implementation (DeLeon & DeLeon, 2002). The main limitation of this generation is the definition of policy implementation and the implementation framework. Representative scholars have espoused specific opinions, and therefore there is no common ground for policy implementation. For example, those with a top-down perspective believe that implementation starts with a government's policy decision, which is then implemented, whereas those with a bottom-up perspective focus on the interests of the local area (Sabatier, 1986).

The third generation of implementation studies attempted to synthesize the two perspectives using multiple measures and methods (O'Toole, 1986). The aim of the study of implementation for third-generation research is much more scientific than it might have been for the previous two generations (Goggin, 1990). These researchers were concerned with the variety of policies, time, and governmental units, and then they attempted to predict future implementation behavior. A researcher who conducted a recent review of the literature on policy implementation tried overcoming the problems created by a shortage of cases and an excess of variables in research (Goggin, 1986). Unfortunately, there has been no sustained interest in research from a third-generation perspective (O'Toole Jr, 2000).

Theories of Implementation

It is worth pointing out the three perspectives of policy implementation research: top-down, bottom-up, and synthesis. Sabatier and Mazmanian (1980) and Van Meter and Van Horn (1975) are the representative scholars for the top-down perspective. They have stressed the process of policy implementation and the critical role of the central government. The Sabatier and Mazmanian (1980) framework presents three categories of variables that influence policy implementation. The three stages include 17 variables linked to the tractability of the problem, the ability of the statute to structure implementation and non-statutory variables. We should note that each of the stages can

influence the next one. Even though top-down scholars have sought to find the variables affecting policy implementation, they have ignored the policy implementers and targeted groups' potential effects (Natesan & Marathe, 2015).

Bottom-up scholars, such as Weatherley and Lipsky (1977) and Hjern (1982), have emphasized the local implementers, called "street-level bureaucrats." In the bottom-up perspective, the assumption is that we cannot separate policy decisions from policy implementation. These scholars point out the freedom of action and capacity for action when frontline bureaucrats implementation (Sevä & Jagers, 2013). The main difference between the two perspectives hinges on whether or not policy implementation is a part of policy formulation (DeLeon & DeLeon, 2002). Even though the study of the bottom-up perspective identifies the network of actors involved in policy implementation (Sabatier, 1986), the main limitation of this approach is determining how to balance discretion for street-level bureaucrats. There are two criticisms of the bottom-up perspective: One is normative, related to a democratic system, and the other is that methodology overemphasizes the local autonomy (Matland, 1995).

As for the synthesis representatives, they attempt to combine these two perspectives and other approaches to policy implementation. One group of researchers tried to combine the two views in the same model, and another group of researchers proposed which approach was better for different conditions (Matland, 1995). For example, Elmore (1979) argued that policy makers try to affect the policy implementation process and have a keen interest in changing the process. Sabatier (1986) proposed six sufficient and generally necessary conditions belonging to the initial policy decision and implementation process for effective implementation. Compared with the top-down and bottom-up perspectives, the synthesizers have not only considered the policy makers' effect but also researched the discretion with which local implementers influenced policy implementation. Furthermore, they have proposed new variables influencing policy implementation that few scholars had previously noticed.

Empirical Research

Other studies have contributed to researchers' understanding of policy implementation by presenting new models. Concerned that policy implementation should identify conditions, Matland (1995) proposed an ambiguity-conflict matrix for the policy implementation process. Based on low or high ambiguity and conflict, the four perspectives for implementation follow: administrative, political, experimental, and symbolic. One had to choose the most appropriate implementation under certain conditions. From the different levels of the organization, Yanow (1987) divided policy implementation into four lenses: human relations, political, structural, and systems. Each set of analytic concepts covered specific assumptions and logic. Some scholars have attempted to integrate the macro level of policy makers with the micro level of individual implementers (McLaughlin, 1987).

More than 100 studies were conducted that identified key variables affecting the policy implementation process. In his examination of these studies, O'Toole (1986) argued that half of them showed that policy characteristics and resources were significant. The implementing actor, implementing personnel, clientele, and timing also affected policy implementation. After reviewing and analyzing previous studies, Schofield (2001) divided the implementation variables into three categories: the nature and type of policy, the nature and type of organization, and specific organizational structure.

After examining the implementation studies in terms of organizational levels, Yanow (1987) focused on the policy culture approach to implementation. Different understandings of policy based on different interpretations of policy resulted in varying actions by implementors. Goggin (1990) proposed the communication model, which showed that the federal, state, and local levels influence implementation in states. In his opinion, the implementation process depends on the interactions of the various elements in the model. There is evidence of a growing scholarly interest in institutional analysis, the study of governance, and networks and network management, linking to the main theme as the indirect contribution to policy implementation (O'Toole Jr, 2000). A more recent attempt to

compile research on policy implementation was made by Natesan and Marathe (2015), who pointed to the possibility that implementation of a process, organization, networks, instruments, and stakeholders could be the primary research topics.

Our view is that, while prominent scholars are concerned with synthesizing policy implementation literature, the main focus of this study should be on the prevalence and content of changing topics, even if earlier scholars proposed some policy implementation paradigms and discussed the relevance of the existing literature (Matland, 1995). However, scholars have rarely used automated text analysis methods, especially for consideration of covariate information. STM is an "unsupervised" method that generates latent topics automatically from the written text. It is more effective than using human coders, which we used in the textual analysis (Roberts et al., 2014).

DATA AND METHODS

Selecting Articles

To extract common policy implementation topics, we searched Web of Science core databases from January 2000 to July 2019. We inserted the keywords "policy implementation" and "publication name" as search criteria in the online systems. We selected journals according to their rank, pertaining to public policy and administration searches, in Google 2019 Scholar Metrics. The first search results showed 687 articles. In this study, we excluded the articles that included only the keyword "policy" because some articles related to policy makers or policy innovations. Tables 1 and 2 briefly summarize the resulting set of 547 articles. Table 1 shows the number of articles after articles were removed. Somewhat surprisingly, 10 journals included more than 30 articles. Shifting attention to the journals where the removed articles were published, four journals were eliminated from the original data set less than 10. Table 2 shows the number of articles published each year. It is apparent that the yearly number of articles in the sample was more than 20 after 2003. With 21 articles, 2019 had fewer articles than there were in the previous years, perhaps because the sample covered up to only July of that year.

Table 1. List of selected journals

Journals	Number of articles		
	Initial	Removed	Retained
Public Administration Review	85	22	63
Public Management Review	53	18	35
Journal of Public Administration Research and Theory	68	14	54
Public Administration	89	15	74
Governance	35	3	32
Policy Studies Journal	72	22	50
Environment and Planning C: Government and Policy	95	16	79
Science and Public Policy	24	4	20
Policy Sciences	37	4	33
Administration & Society	47	14	33
Social Policy & Administration	82	8	74
Total	687	140	547

Table 2. Distribution of articles for 2000 to 2019

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
No.	19	20	17	13	24	22	22	27	22	37	
Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	
No.	32	29	40	29	26	41	39	32	35	21	547

Structural Topic Modeling

To identify a dynamic and comprehensive picture of the field of policy implementation, this study used an STM (Roberts et al., 2013). STM is a suite of statistic machine learning methods that analyzes text without assuming topical prevalence or topic content. Topic models are probabilistic, which means they are able to allow each document to exhibit multiple topics with different proportions based on hierarchical Bayesian analysis (Blei & Lafferty, 2007). This sort of topic modeling enables topics to emerge from the study without prior labeling or coding of articles (Liu et al., 2018). In latent Dirichlet allocation (LDA), identification needs to be made by algorithm, in which topics are supposed to be independent: "Each topic is modeled as a distribution over words in the document, where each word has a different probability of belonging to that topic" (Guerreiro et al., 2016).

STM allows some control variables to be added as covariates, such as the author and document properties, which help researchers find the relationships between metadata and topics in the text corpus. Additionally, STM can help researchers identify more significant themes beyond topics (Lucas et al., 2015). The three differences between the STM and LDA model follow: Topics can be correlated, covariate X defines each document, and topic words can vary by covariate U (Roberts et al., 2014). Furthermore, the STM requires a few a priori assumptions about the data under study and incorporates additional information into the estimation process (Roberts et al., 2014). We can use the highest probability words, inferring the semantic meaning of the topic. Some researchers have found that the STM is applicable to different types of articles and different areas (Lucas et al., 2015; Reich et al., 2014; Roberts et al., 2014) and is a suitable method for data-driven research on quantities of interest.

The software application used to analyze the articles was the R statistical tool. There were five analytical steps in the following analysis. First, we did stop word removal and lemmatization for preprocessing textual data. Second, we produced a summary of different topic models, documents, and a word dictionary after running the software package. Human analysis was then used in the third step, in which we assigned descriptive labels to each topic by evaluating the highest probability words or documents. Fourth, we examined how the topic evolved and how important topics differed in time and influence. Finally, we proposed a summary based on the findings from the STM. The results of the 50 times estimations with 50 different starting values with the R package "*stm*", appear in the next section.
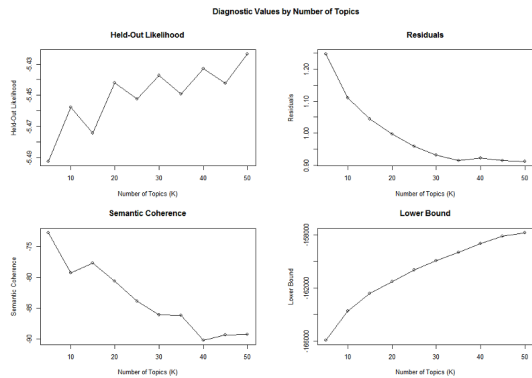
RESULTS

Main Topics

Figure 1 shows the held-out likelihood, residuals, semantic coherence, and lower bound for the 50 most salient topics. In the case of the STM texts, all metrics agreed with the ideal number of latent topics, around 20.

First, we inferred topic labels in Table 3 from the words that were the most representative of the 20 topics. We did this by examining the highest probability words in each topic and the FREX (the words that are frequent and exclusive to each topic). In several topics, we also considered exemplary

Figure 1. Diagnostic values by the number of topics

articles for a topic name, in which articles with the highest proportion of words contributed to the topic. The results in Table 3 indicate that the research in policy implementation addressed conceptual heterogeneity in the literature published between 2000 and 2019, and the topics addressed the policy, multiple, and variables perspectives.

Figure 2 displays the 20 topics together with the three most frequently used terms within each topic. It shows the proportion of the corpus associated with each of the 20 topics and three keywords for each topic. The *X*-axis shows the proportion of topic prevalence. For example, policy goals (Topic 1) and policy process (Topic 16) are most correlated with the indicators for policy implementation, based on the content analysis of the topics. Topic 17, on programs, is the document with the medium estimated proportion of topic-related words and constructs. Other topics, including Topic 15 on communities, Topic 20 on policy systems, and Topic 3 on regulation, are also identifiable. As we can see from Figure 2, these topics have received relatively little attention from policy implementation researchers, who are more focused on external factors than on internal variables related to policy.

The two topics (Topic 1 and Topic 16) most associated with policy implementation, representatively, appear in Figure 3. The most frequently used policy goals (Topic 1) discuss how congruence between resources and policy goals may influence policy implementation. The three correlated words emerging from this topic are "policies," "resources," and "goals." The examples of articles for this topic are on multiple policy goals and interaction of policy implementation (Resh & Pitts, 2013). One of the articles correlated with this topic shows the importance of ambiguity and conflict for successful policy implementation (Howard et al., 2010). As for the resources, the effective implementation of the policy is highly related to the promotion of regional stability and the diffusion of democracy (Samhat, 2000). Furthermore, van Engen et al. (2019) have also wondered whether the policy consistency via frontline workers' perceptions could be a valuable strategy for successful policy implementation.

By contrast, the second most prominent policy process (Topic 16) is a broader policy implementation that discusses the design of policy and the process of policy implementation. The current topic groups highly correlated words such as "design," "learn," and "process." An article related to this topic discussed how international benchmarking relates to inspiration and policy learning for policy design and implementation (Dominique et al., 2013). Articles in this group examined the process of interpretation, identifying the importance of context (Moynihan, 2006), and understanding policy change (Weible & Carter, 2015) for policy implementation studies. The policy design needed systematic updating, which was considered successful at the time (Maor, 2017).

Table 3. The 20 topics found in the policy implementation and the top words

No.	Topic name	Top words (highest probability)
1	Policy goals	polici, implement, studi, relat, resourc, goal, examin FREX: polici, resourc, goal, object, relat, consist, play
2	Participation	work, particip, partnership, govern, new, paper, first FREX: particip, partnership, work, first, establish, shift, paper
3	Regulation	regul, regulatori, approach, protect, author, problem, agenc FREX: regul, regulatori, protect, approach, problem, attempt, first
4	Organization	innov, organ, organiz, system, manag, complex, region FREX: innov, organiz, complex, organ, region, system, manag
5	Network	network, govern, structur, power, articl, polici, illustr FREX: network, structur, power, illustr, govern, complex, relationship
6	Reform	state, reform, welfar, implement, polit, articl, adopt FREX: reform, state, welfar, adopt, test, offici, opportun
7	Strategy	develop, govern, initi, implement, sustain, strategi, paper FREX: initi, sustain, develop, strategi, capac, review, central
8	Collaboration	collabor, govern, stakehold, make, improv, implement, system FREX: collabor, stakehold, improv, make, mechan, will, democrat
9	Institution	institut, inform, rule, formal, account, differ, countri FREX: institut, rule, formal, inform, account, countri, analyz
10	Policy change	health, care, servic, chang, social, time, polici FREX: care, health, chang, time, servic, choic, social
11	Bureaucrat	polici, bureaucrat, polit, influenc, implement, effect, theori FREX: bureaucrat, bureaucraci, influenc, prefer, theori, posit, limit
12	Agency	program, agenc, feder, administr, implement, polit, perform FREX: program, feder, agenc, administr, perform, fund, design
13	Coordination	nation, european, level, govern, intern, coordin, direct FREX: european, nation, coordin, intern, global, direct, level
14	Local	local, govern, plan, develop, project, integr, experi FREX: plan, local, project, integr, experi, challeng, develop
15	Communities	environment, polici, enforc, communiti, implement, decis, outcom FREX: environment, enforc, communiti, protect, decis, outcom, citizen
16	Policy process	polici, process, implement, chang, design, can, learn FREX: design, learn, process, issu, chang, polici, context
17	Program	programm, activ, condit, case, research, perform, employ FREX: program, activ, condit, employ, market, perform, case
18	Social	social, use, organ, articl, group, inform, access FREX: social, access, group, organ, individu, inform, may
19	Private	public, servic, manag, privat, articl, deliveri, administrFREX: public, servic, privat, deliveri, manag, sector, administr
20	Policy system	profession, polici, system, implement, use, measur, perform FREX: profession, measur, target, financi, perform, system, qualiti

Topic Correlations

The explicit estimation of correlations between topics appears in Figure 4. We can learn more about the structure of the topics through the estimated correlation of different topics (Lucas et al., 2015). Some topics were identifiably split from other topics, such as Topic 7 on strategy, Topic 14 on
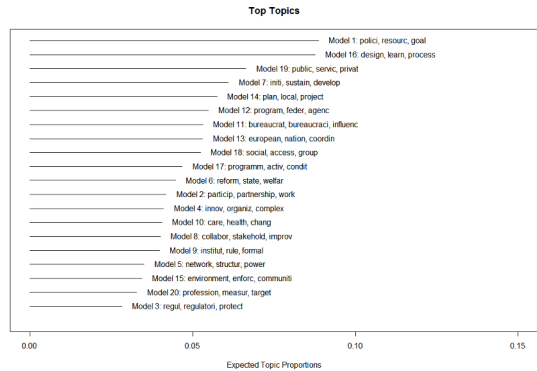
Figure 2.

Figure 3. Vocabulary associated with Topic 1 and Topic 16

Topic 1:
Highest Prob: polici, implement, studi, relat, resourc, goal, examin
FREX: polici, resourc, goal, object, relat, consist, play
Lift: consist, resourc, play, object, goal, knowledg, polici
Score: consist, polici, goal, implement, resourc, object, play
Topic 16:
Highest Prob: polici, process, implement, chang, design, can, learn
FREX: design, learn, process, issu, chang, polici, context
Lift: learn, place, design, reflect, adapt, take, issu
Score: learn, polici, design, process, instrument, chang, issu

**Figure 4. Correlations patterns between topics**
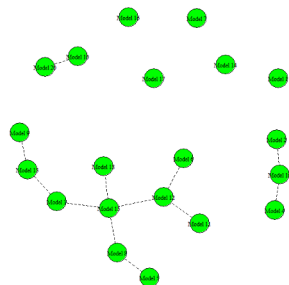
local government, and Topic 17 on programs; these topics were unlikely to be about more than one subject. Besides these, there were three groups of topics from the network of topics. The topics of policy change (Topic 10) and policy system (Topic 20) were most correlated. The group research

is heavily reliant on a policy perspective, but the policy research should be a contingency. In other words, policy implementation should be changed based on different stages and different situations. The second group, participation (Topic 2), private (Topic 19), and organization (Topic 4), were highly correlated; the literature showed that the organization was about the participation and partnership by private individuals and public organizations. Authors who write about policy implementation were also likely to research organizations. The rest of the groups, including institution (Topic 9), coordination (Topic 13), regulation (Topic 3), communities (Topic 15), agency (Topic 12), social (Topic 18), collaboration (Topic 8), network (Topic 5), reform (Topic 6), and bureaucrat (Topic 11), were more complicated; we called them implementation variables.

Topic Evolved

Based on the proportions of Topics 1 and 16 in each article, Figure 5 shows the yearly sum of each topic's weights, interpreted as the degree of researchers' attention to a topic in a particular year. The *X*-axis indicates the year, and the *Y*-axis indicates the expected topic proportion of scholarly attention. The results uncovered that there was a steady downward trend in attention to Topic 1 and an upward trend in attention to Topic 16.

Figure 5. Evolution of Topic 1 and Topic 16
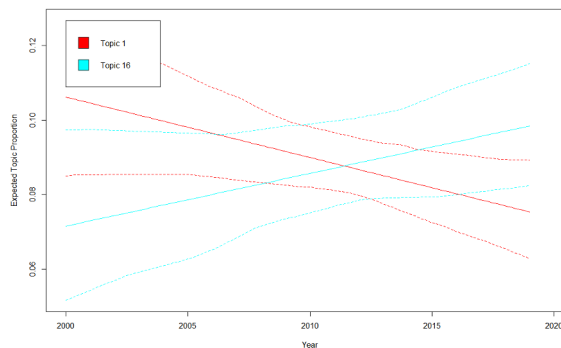
Topic Impact

To calculate the impact of each topic, we used the number of citations each article contained. We counted the citations for all databases during the study period as the paper's total citations. We placed citations on the *X*-axis; the *Y*-axis indicated the expected topic proportion in Figure 6. From this figure, we can see that, overall, Topic 16 had more impact than Topic 1.

Topics Summarized

Figure 7 displays the three perspectives based on the 20 different topics on policy implementation. From the policy perspective, four topics studied policies in terms of goals, changes, processes, and policy systems. As for the multiple perspectives, the research has focused more on organization and participation, which could strengthen policy implementation. The remaining 12 topics consisted of the implementation variables perspective and the literature discussing networks, collaboration, and communities.
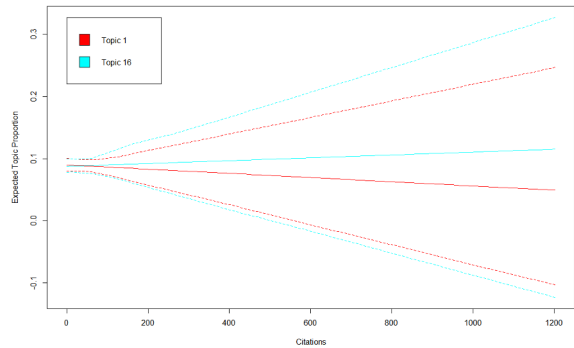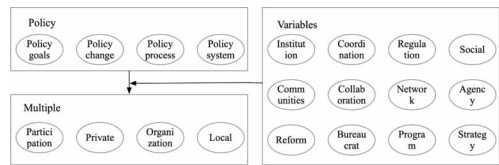
Figure 6. Impact of topics

Figure 7. Topics summarize

CONCLUSION

This paper presented an account of topics for policy implementation research; given that previous studies have attempted to make a comprehensive review of the literature on implementation, the objective here was to reveal topics. We used an STM to find topics and the correlations of different topics in automated text analysis. The work presented here has not only helped to uncover the most relevant policy implementation topics but also the most relevant ones overall. For example, in this study, the STM results suggested that Topic 1 was a topic on its own, unrelated with other topics. Topic 20 was relevant to Topic 10 in the current analysis.

The literature analysis method espoused in this paper also facilitated the process of scholarly attention paid to each of the different topics. Indeed, the study uncovered that Topic 1 and Topic 16 were the most discussed topics in policy implementation. Topic 16 showed a growth trend over the years, meaning that "design," "learn," and "process" remain active. This finding could help scholars garner much more attention for the policy implementation literature. Although Topic 1 shows few published articles in recent years, it is still a popular topic when compared with others.

Using the titles, keywords, and abstracts of published articles, this paper has shown that STM is a useful method for structuring the greater amount of previous literature reviews with unstructured data. The present findings might help to give snapshots of policy implementation research, which would allow scholars to understand the range and quality of this area better. However, we should note that, in the text mining and machine learning algorithm, building topics cannot replace the traditional literature review. That is part of the methodology of synthesizing literature and helps researchers explore correlations between different topics before starting a deeper review analysis of published articles.

Several limitations may have influenced the results obtained. The first might be the number of selected articles. The use of a specific paper would cause some topics, as well as the correlations

present in whole data sets, to be missed. Another possible source of error would be the analysis based on titles, keywords, and abstracts instead of the full text of published articles. The use of whole texts can enhance the strength of the relationship between correlated topics (Guerreiro et al., 2016). Future studies on policy implementation should concentrate on enhancing the quality of articles by analyzing more published articles and using the full texts.

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