The Ultimate Configuration Management Tool?
Lessons from a Mixed Methods Study of Ansible's Challenges

Carolina Carreira*
carolina.carreira@tecnico.ulisboa.pt
Carnegie Mellon University, INESC-ID, and IST, University
of Lisbon
Lisbon, Portugal

Nuno Saavedra*
nuno.saavedra@tecnico.ulisboa.pt
INESC-ID and IST, University of Lisbon
Lisbon, Portugal

Alexandra Mendes
alexandra@archimendes.com
INESC TEC, Faculty of Engineering, University of Porto
Porto, Portugal

João F. Ferreira
joao@joaoff.com
INESC-ID and Faculty of Engineering, University of Porto
Porto, Portugal

Abstract

Infrastructure as Code (IaC) tools have transformed the way IT infrastructure is automated and managed, but their growing adoption has also exposed numerous challenges for practitioners. In this paper, we investigate these challenges through the lens of Ansible, a popular IaC tool. Using a mixed methods approach, we investigate challenges faced by practitioners. We analyze 59,157 posts from Stack Overflow, Reddit, and the Ansible Forum to identify common pain points, complemented by 20 semi-structured interviews with practitioners of varying expertise levels.

Based on our findings, we highlight key directions for improving Ansible, with implications for other IaC technologies, including stronger failure locality to support debugging, clearer separation of language and templating boundaries, targeted documentation, and improved execution backends to address performance issues. By grounding these insights in the real-world struggles of Ansible users, this study provides actionable guidance for tool designers and for the broader IaC community, and contributes to a deeper understanding of the trade-offs inherent in IaC tools.

Keywords

Infrastructure as Code, Ansible, Practitioners Issues, User Study, Topic Modeling

1 Introduction

Infrastructure as Code (IaC) has emerged as a critical paradigm in modern software engineering, enabling organizations to automate the configuration, provisioning, and management of IT infrastructure. By treating infrastructure configurations as code, IaC enables practitioners to use software engineering practices such as automated testing and version control, and facilitates reproducibility, scalability, and maintainability of infrastructure resources.

IaC has become widespread across industries, with several tools gaining significant adoption. Examples of widely used IaC tools include Ansible [52], Chef [44], and Puppet [41] for configuration management, and Terraform [24] and CloudFormation [3] for infrastructure provisioning. These tools allow organizations to automate complex infrastructure tasks, reducing manual effort and the risk of human error. For example, NASA and Siemens use Ansible to

automate infrastructure deployment and configuration management [37, 57]. The widespread adoption of these tools highlights their importance in modern software operations.

Despite the significant advantages of IaC, practitioners face several challenges. Since IaC involves writing code, errors can be introduced, leading to misconfigurations that affect system security [40, 47, 49, 60, 63, 65] and system reliability [20, 21, 27, 30, 71, 76]. For example, due to bugs in their IaC scripts, GitHub experienced an outage of its DNS infrastructure [19] and Amazon Web Services lost around 150 million dollars after issues with its S3 billing system [26]. To address this, there has been an effort by the research community to categorize, identify and repair defects [14, 15, 25, 34, 39, 40, 46, 47, 49–51, 60, 63–68, 78]. In addition, IaC tools themselves present challenges, such as unintuitive debugging mechanisms, inconsistent behaviors, and complex learning curves. Prior research has explored challenges faced by IaC practitioners, identifying common issues and limitations of existing tools [13, 22, 48, 75]. However, existing studies often take a broad perspective, examining challenges across multiple DevOps or IaC tools, which can dilute insights specific to any one tool. Studies focused on a single IaC tool have not, so far, included Ansible.

In this paper, we aim to deepen the understanding of the challenges faced by Ansible users. Ansible is currently the most widely used configuration management tool [72] and, although Ansible is known to have issues, such as difficulties with variable scoping [38] and debugging [23], the specifics of these challenges and their impact on practitioners remain underexplored. Using a mixed methods approach, we analyze a large corpus of online discussions and conduct semi-structured interviews to systematically examine the obstacles faced by Ansible users. Our study is the first to provide a detailed account of these issues and to offer actionable recommendations for improvement. Our contributions are:

- A large-scale empirical analysis of 59,157 online discussions from Stack Overflow, Reddit, and the Ansible Forum to identify common challenges and issues in Ansible.
- Insights from 20 semi-structured interviews with Ansible practitioners of varying expertise levels, providing qualitative perspectives on usability and technical challenges.
- Recommendations for improving Ansible, with implications for other IaC technologies, focusing on stronger failure locality to

---

*Both authors contributed equally to this research.

```
1    ---
2    - name: Set up and configure web server
3      hosts: all
4      gather_facts: yes
5      tasks:
6        - name: Display system facts
7          debug:
8            msg: "The system OS is {{ ansible_facts['os_family'] }}."
9          when: ansible_facts['os_family'] == 'Debian'
10       - name: Ensure Nginx is installed
11         apt:
12           name: nginx
13       - name: Deploy an index.html template
14         template:
15           src: templates/index.html.j2
16           dest: /var/www/html/index.html
17       (...)
```

Figure 1: Excerpt from a web server Ansible playbook.

support debugging, better defined language boundaries, targeted documentation, and improved execution backends.

Our study aims to inform Ansible's developers, educators, and the broader IaC community, fostering improvements that enhance the effectiveness and usability of IaC tools. A replication package with all the supplementary materials, data, and code used in this study is available [4].

2 Ansible

Ansible is the most widely used configuration management tool [72]. Configurations are written as YAML playbooks composed of plays and tasks, optionally organized into reusable roles. Tasks call modules with arguments to enforce the desired state on target hosts. For example, the *ansible.builtin.shell* module runs shell commands on the host. Ansible executes tasks sequentially in the order in which they appear in a playbook. It uses variables to manage system differences, allowing the same variable name to hold different values for each host. These variables can be used in playbooks to adjust task behavior based on the target host. Ansible leverages Jinja2 templating to enable dynamic expressions and access to variables [10], both within the playbooks and in configuration files used via the *template* module. Unlike pull-based technologies such as Chef or Puppet, Ansible follows an agentless, push-based model, typically applying changes from a control node to target hosts over SSH.

Fig. 1 shows excerpts of an Ansible playbook for the configuration of a web server, consisting of a single play with three tasks. The playbook targets all hosts in the inventory, uses Ansible variables and Jinja2 expressions for conditional execution, and applies a template to generate a customized web page.

3 Mixed Methods Study

In this section, we outline our research questions and describe the methodology used to answer them. Our study follows a mixed methods approach (see Fig. 2). First, we collected posts from Q&A platforms and used topic modeling to understand the challenges faced by Ansible practitioners. We then conducted semi-structured interviews to gain deeper insights into the participants' experiences.

3.1 Research Questions

We aim to answer the following research questions.

RQ1: [Issues] What are the common issues practitioners face when using Ansible? In this question, we investigate the common challenges that practitioners face while working with Ansible. By analyzing the emergent topics from practitioners' posts in Q&A platforms and practitioners feedback from interviews, we aim to categorize these challenges and identify patterns that can help us to understand pain points across various praticioner groups.

RQ2: [Adoption] What are the aspects that influence the adoption of Ansible? This question focuses on the factors that drive Ansible's adoption, identified via interviews with practitioners.

RQ3: [Improvements] What changes would improve Ansible? This question aims to identify actionable suggestions for improving Ansible. The goal is to provide insights for Ansible's development community, and broader IaC community, on how to refine the tool to better meet practitioners' expectations and needs.

RQ1 is addressed using both topics extracted from online Q&A data and practitioner interviews, enabling triangulation between large-scale community discussions and in-depth qualitative insights. RQ2 and RQ3 are answered exclusively through interviews, as public technical artifacts primarily reflect post-adoption troubleshooting and rarely capture adoption rationales or broader improvement considerations. The key directions discussed in Section 7 are grounded in the combined results of all three research questions, integrating evidence from both data sources.

3.2 Topic Modeling

Building on previous studies [13, 75], we apply topic modeling techniques to identify the challenges practitioners face when using a specific tool, in our case, Ansible. We use TopicGPT, a prompt-based framework that uses LLMs to uncover latent topics in a text collection [42]. TopicGPT provides interpretable topics that align better with human categorizations than other topic modeling approaches [42]. After data is collected, TopicGPT consists of three steps: *Topic Generation*, *Topic Refinement*, and *Topic Assignment*. We also perform manual validation of the *Topic Assignment* step. We configured TopicGPT to use GPT-4o mini via the OpenAI API.

Data Collection We start by collecting posts about challenges, obstacles, and issues faced by Ansible practitioners from three Q&A platforms: StackOverflow [70], Reddit [58], and the Ansible Forum [53] (① in Fig. 2). To collect posts from StackOverflow, we used the Stack Exchange API [69] and retrieved all posts with the tag *Ansible*, which corresponds to 23,000 posts. For Reddit, we used the PullPush API [45] to collect all 7,187 posts on the subreddit *r/ansible* that contained the keyword *Ansible* in addition to keywords possibly related to issues, such as *error* and *help*. For the Ansible Forum, we used web scraping techniques to collect 28,970 posts in the *Get Help* and *Archives* categories. We included the category *Archives* in our analysis, as it contains all posts from the *Ansible Google Group*, the predecessor of the Ansible Forum, which were migrated to the Ansible Forum [54]. We filter out posts related to announcements by the Ansible team. In total, we collected 59,157 posts from the three Q&A platforms, forming our final dataset. Data collection took place between January 24 and February 1, 2025.

Topic Generation We use TopicGPT to generate a set of topics given our whole dataset as input (② in Fig. 2). A topic consists of a name and a description. For each post, TopicGPT prompts GPT-4o Mini to assign one or more of the already generated topics and generate any
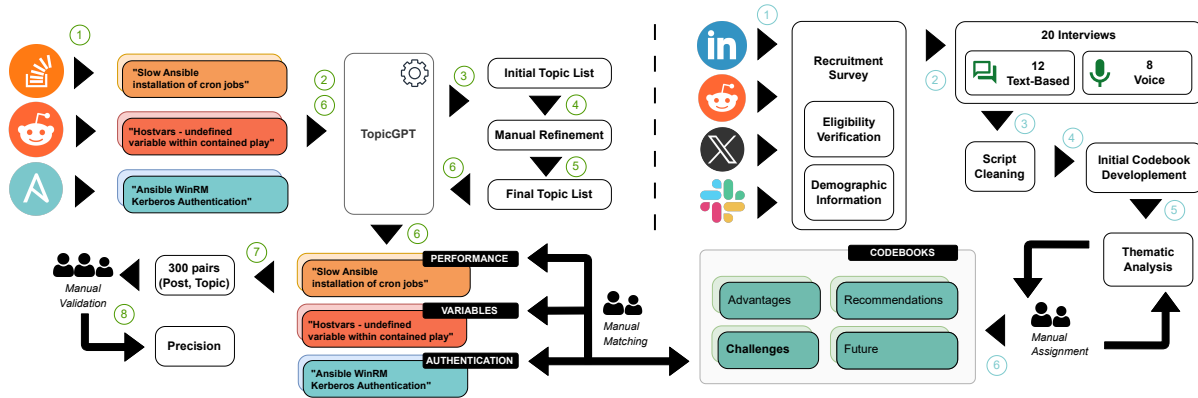
Figure 2: Overview of the research methodology combining automated topic extraction and thematic analysis.

new relevant topics that are missing, assigning them accordingly. To ensure relevance, we constrained the TopicGPT prompt to generate topics centered on the challenges faced by Ansible practitioners. In the end, TopicGPT generated 3,573 topics (③ in Fig. 2).

Topic Refinement TopicGPT produces numerous topics that, while generally relevant, are often overly granular, duplicated, or out of scope [42]. To mitigate these limitations, we include an automated topic refinement step. However, in our preliminary experiments, automated refinement did not reliably merge semantically equivalent topics. For this reason, we adopted an approach similar to TopicGPT, but instead of using LLMs, we relied on manual effort to ensure a reliable final topic list (④ in Fig. 2). First, instead of merging the topics first and then removing the infrequent ones, we reversed the order, reducing the number of topic pairs that needed to be analyzed during the merging process. The topic frequencies follow a power-law distribution. To ensure coverage, we retained the most frequent topics until they accounted for 80% of all attributions. Topics that were not included in the final set were discarded. After this step, our topic list was reduced from 3,573 to 153 topics.

Next, we applied an iterative manual refinement process similar to the merging step in TopicGPT. Each iteration evaluated topic pairs above a predefined cosine similarity threshold. Then, for each pair, one author determined whether the topics should be merged and, if so, whether they should be combined into one of the existing topics or assigned to a newly created topic. The criterion for merging topics was the presence of significant semantic overlap between them. A second author reviewed the merged topics, documenting any disagreements or ambiguous cases requiring further discussion. Subsequently, both authors met to resolve discrepancies and reach a consensus. The process was repeated six times until no further merges were identified, resulting in a candidate topic list. After the merging process, we reduced our topic list from 153 to 105 topics.

Finally, following the approaches used in previous studies [11, 29], we manually inspected the topics to identify those relevant to our study. A topic was considered relevant if it is related to the challenges, frustrations, issues, or drawbacks associated with using Ansible. We considered only topics that were specific enough to provide meaningful information about a post. In addition, we refined topic names and descriptions. A topic name was considered

improved if it more effectively represented its description, while a description was considered improved if it maintained its core ideas while increasing generality, eliminating unnecessary details, or using a clearer and more concise language. Finally, we merged any additional pairs of topics that met our merging criteria but were not initially detected during the merging process.

An author reviewed each topic, determining whether it should be removed, renamed, or modified. Subsequently, a second author independently reviewed the proposed changes, documenting any disagreements or ambiguous cases requiring further discussion. Subsequently, both authors met to resolve discrepancies and reach a consensus. This resulted in a final list of 87 topics (⑤ in Fig. 2, see Supplemental Materials for the full topic list).

Topic Assignment We used TopicGPT to assign the final topics to posts and applying its self-correction mechanism [42] (⑥ in Fig. 2).

Validation We evaluated topic assignment using confirmation labeling [77]. To calculate the precision of topic assignment, this method involves sampling *(post, topic)* pairs of assignments under evaluation. Rather than presenting raters with the entire taxonomy and asking them to manually assign topics to posts, confirmation labeling simplifies the process by requiring raters to provide binary judgments on whether a given topic is relevant to a particular post. This approach effectively reduces the cognitive overload of a large and complex taxonomy [77]. Two authors independently performed confirmation labeling on a sample of 300 *(post, topic)* pairs (⑦ in Fig. 2). A third author resolved disagreements between the initial raters, with final decisions made by majority vote, yielding a precision of 82.67% (⑧ in Fig. 2).

Analysis To integrate topic modeling and interview findings, we merged the final topic list with the thematic codes identified in the interviews (Section 3.3). Specifically, we integrated the topics with a set of *Challenges* codes by aligning each topic with the most closely related theme. This process was iterative and followed a double-blind procedure: first, two coders independently grouped the topics into themes. Then, both coders met to discuss disagreements and reach a consensus. In analyzing the merged data, we examined the relative frequency of each topic across the resulting themes and investigated how these frequencies evolved. **To better**

reflect current and emerging concerns, we limited our analysis to Q&A data from the five years preceding the end of data collection on February 1, 2025, resulting in a total of 24,132 posts. In addition to recent posts, we leveraged the data older than five years to identify evolution trends.

3.3 Interviews

In addition to the large-scale analysis of Q&A posts, we conducted semi-structured interviews to gain deeper insight into practitioners' experiences with Ansible.

Participants Participants were categorized by Ansible expertise using years of experience, following prior work [32, 62], and to mitigate self-assessment bias, such as the Dunning–Kruger effect [35]. We define three levels: **Beginner** (< 2 years, n=5), **Intermediate** (2 ≥ and ≤ 5 years, n=7), and **Experienced** (> 5 years, n=8).

Recruitment We recruited 20 participants through a pre-screening survey distributed via email and various social media platforms, including LinkedIn, X (formerly Twitter), Discord, and Slack (①️ in Fig. 2). To meet our eligibility criteria, participants had to have prior experience using Ansible. Following this stage, participants selected their preferred interview modality: a text-based or video-based session conducted via Zoom. The availability of both formats was intended to address known challenges in recruiting software developers for research studies [12], a challenge we also encountered in our study. A total of 118 of 127 survey participants were eligible, and among them, 20 were available for an interview (an interview rate of 15.7%). Most of the participants (12 out of 20) opted for a text interview. Several participants mentioned that they would only be able to participate in the interview if it were conducted via text. As an incentive, the interviewed participants could enter a raffle for a $100 gift card. Demographic details are provided in the Supplemental Materials. In summary, participants reported 1 to over 9 years of Ansible experience; most were active users (15), identified as male (17), were aged 18–34 (11), held at least a bachelor's degree (17), and had CS education and employment (17).

Ethical Considerations Before participating in the survey or the interview, all individuals reviewed the consent form and provided informed consent. This study was reviewed and approved by the ethics board at the first authors' institution.

Interviews We conducted semi-structured interviews to obtain a nuanced understanding of the participants' experiences with Ansible (②️ in Fig. 2). Semi-structured interviews are the most widely used interviewing method [18] and allow adaptability to explore emerging themes and seek clarifications [33]. We piloted the protocol with four participants. Both text and voice-based interviews required around 30 minutes of attention time. The latter were recorded and automatically transcribed with participant consent using Zoom's built-in transcription functionality. Research team members manually reviewed and corrected the resulting transcripts. Each interview followed a structured protocol that encompassed four key thematic areas: perceived **advantages**, **challenges**, **recommendations**, and **future** of Ansible. The interview started with general background questions. We then moved the discussion towards the *advantages* of Ansible and adoption *challenges*. Then, we focused the discussion on Ansible's limitations. The interview concluded with exploring

recommendations to improve Ansible and *future* perspectives. We actively sought clarification whenever responses were ambiguous or required elaboration, both in textual and voice-based interviews.

Analysis We developed four emergent codebooks using thematic analysis [16, 33], following a bottom-up approach that allowed themes and codes to emerge inductively from our data. We started by reading the transcripts to highlight recurring ideas, creating initial codes, and iteratively refining them into coherent themes (③️ and ④️ in Fig. 2). Our codebooks are related to the four key thematic areas as follows: (1) **Advantages**: Identifying the key motivations behind adoption; (2) **Challenges**: Documenting difficulties and limitations; (3) **Recommendations**: Capturing participants' wishes; (4) **Future**: Addressing potential future developments.

For each of these four areas, we developed a codebook. We followed a methodology similar to the one present in prior work [28, 31, 74], and that is recommended by Human-Centered research guidelines [33]. One of the authors developed an initial codebook that captured key aspects of the responses. The initial codebook was shared with a second coder (also an author), who reviewed and suggested modifications based on a subset of interview data. We repeated this process multiple times until consensus was reached and the codebook was deemed stable. Once we established the final version of the codebook, we double-coded all of the interviews, where one coder systematically applied the codes to all interview responses, and the second coder independently reviewed the applied codes. This review involved cross-checking all coded transcripts to identify inconsistencies or overlooked themes. The second coder made detailed notes on any disagreements. When there was a change to the codebook, for example, a new code, the coding process was restarted. Finally, both coders met to discuss discrepancies and reach a consensus (⑤️ and ⑥️ in Fig. 2). When attributing quotes, we report the participant ID and the experience of the participant: (B)eginner, (I)ntermediate or (E)xperienced. For example, B1 refers to a beginner participant. See Supplemental Materials for the full codebooks.

4 RQ1: Common Issues in Ansible Usage

This section presents the seven primary challenge categories encountered by Ansible practitioners, ordered by prevalence. Figure 3 shows the distribution of posts by topic and theme.

Control/Data Flow and Execution is the most prevalent challenge category for Ansible practitioners. This category accounts for 10,721 posts, representing 44.4% of recent discussions.

Topic Analysis *Loops* represent the most significant challenge for Ansible practitioners (13.9%). As one practitioner stated in the posts, "I don't understand why loops are so hard to do in this language." *Loops* are followed by *SSH Connection Issues* to hosts (12.7%), *Variable Management* (12.3%), *Conditional Execution* (10.6%), and *Undefined Variables* (10.4%).

Interviews Participants described various *control flow issues*. For instance, B1 mentioned frustration with *sequential execution* slowing runs and a *lack of synchronization primitives* (n=2). In more advanced setups, complexities grew around *managing dependencies*
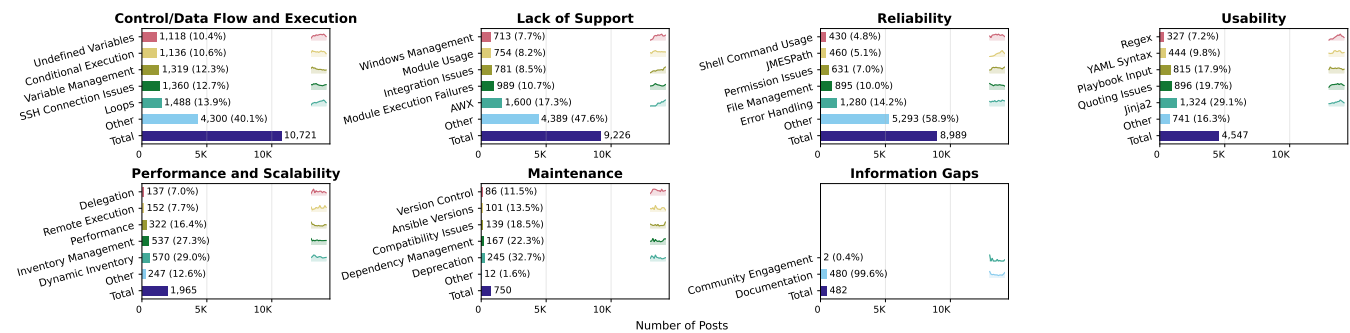
Figure 3: Topic distribution (Feb 2020–Feb 2025). Sparklines show yearly percentage trends across the full Ansible post history.

(n=3). Beyond these granular concerns, a handful of participants reflected on *code structure/organization* difficulties (n=5). In contrast, others cited Ansible's inherently *stateless* (n=5) nature as making it simpler to run but also lacking built-in features for preserving or comparing states. The *push model/agentless* (n=5) was both praised for minimal overhead and criticized for complicating continuous enforcement.

Lack of Support is the second most significant theme, accounting for 38.2% of the recent posts with a total of 9,226 posts.

Topic Analysis AWX-related issues, where AWX is the open-source upstream project for Ansible Tower, dominated discussions (17.3%), followed by module execution failures (10.7%), integration issues (8.5%), module usage problems (8.2%), and Windows-related challenges (7.7%).

Interviews Interviewees reported missing features that require custom modules (n=3) and limited OS support (n=4). Other participants criticized the *lack of support for certain modules* (n=7). As E4 put it "There's a lack of support for some modules (...). You often have to write your own or hope someone did it."

Reliability emerged as the third most discussed theme, accounting for approximately 37.2% of all recent posts.

Topic Analysis Although *Error Handling* is the most represented topic (14.2%), TopicGPT's interpretation of it is generic. As a result, despite its description being related to the handling of errors in Ansible playbooks, the topic was frequently used in cases where arbitrary errors occurred. Following *Error Handling*, the most discussed issues are related to file management (10.0%), permissions (7.0%), JMESPath (5.1%) and the use of shell commands (4.8%).

Interviews Reliability issues primarily emerged around debugging. Multiple participants reported that Ansible is *hard to debug* (n=10). I7 tries to avoid Ansible to debug complex cases: "if there's some more complex stages in my playbooks what I try to do is to transfer those to a shell script that I can pass outside of Ansible and I can test those separately." B2 described moments when "it would get stuck for 15 minutes in a supposedly 1 min script before I forced it to close without any visible changes on the terminal." Some lamented the lack of built-in *infrastructure debugging tools* (n=5), while others pointed to *bad error messages* (n=5) when modules returned cryptic outputs. As B4 put it, "I actually believe that there's not a proper way to debugging this type of scripts and tools."

Usability represents ~18.8% of recent posts (3,846 posts).

Topic Analysis Issues related to *Jinja2* are the most prevalent, accounting for 29.1% of usability-related posts. Issues related to quoting (19.7%), playbook inputs (17.9%), YAML syntax (9.8%), and regex (7.2%) are also prominently discussed. When talking about their issues with YAML, a practitioner mentioned: "I find YAML or Ansible's interpretation of YAML very frustrating and confusing."

Interviews Ansible's *usability* emerged as a significant concern for many participants. Participants described Ansible as *challenging for beginners* (n=12), particularly for those *without a coding background* (n=2). Others felt they had to make a *mental shift* (n=4), especially if they were used to more imperative scripting. As E8 said, "If you've never seen Terraform, CloudFormation (...) it'll look weird and alienating". Some participants found it *hard to pick the right approach* (n=4). Participants also complained about *complex syntax* (n=4). Ansible's reliance on YAML and Jinja introduced the problems of *YAML and Jinja complexity* (n=5 and 6). As E5 said, "I once spent 8 hours of work figuring out the escaping on a line of SQL (...) The hell that is escaping in YAML will never die."

Performance and Scalability represents approximately 8.1% of recent posts, with 1,965 posts discussing these issues.

Topic Analysis Dynamic inventories (29.0%) and inventory management (27.3%) dominate discussions, followed by performance (16.3%), remote execution (7.7%), and delegation (7.0%).

Interviews Participants managing large infrastructures frequently reported *scalability limitations* (n=7). B1 stated: "When you run a playbook for like 100 hosts, it gets really confusing trying to make sense of the messages". Participants specifically described problems related to *code awareness* (n=4) in large projects. A related source of concern was *slow execution* (n=8). While some liked the simplicity of SSH-based workflows, a few individuals cited *agentless* (n=4) as detrimental in high-volume scenarios. E4 was particularly direct: "It does not scale when you start to manage 100th of servers, it becomes slow because there is no agent."

Maintenance challenges appear in 750 posts, which corresponds to about 3.1% of the total of recent posts.

Topic Analysis Challenges related to deprecated features and settings in Ansible (32.7%), dependency management (22.3%), compatibility issues (18.5%) (e.g., with legacy OSs), different Ansible

versions (13.5%) or version controlling Ansible projects (11.5%) are the most relevant topics in the *Maintenance* theme.

Interviews Participants noted that *removing configurations is difficult* (n=3) as modifying the playbook alone does not guarantee that older changes get undone. E2 explained that "Doing things like removing config from hosts tends not to work so well in Ansible,". *Configuration drift* (n=5) was also mentioned. As I3 described "Deletes are hard: one cannot merely delete parts of the Ansible playbook and expect those changes to be undone in hosts. Instead, we must change or even add tasks undoing the configuration we want gone." Other participants mentioned that Ansible can be *hard to maintain* (n=5) and were concerned about *deprecations* (n=5).

Information Gaps is the least prevalent theme, accounting for only 482 posts, or about 2% of all recent posts. Of these 482 posts, 480 address the challenges practitioners face with documentation.

Interviews Another concern revolved around *information gaps*, particularly incomplete documentation. E2 talked about *misleading information*: "Another issue is incorrect or misleading answers on forums and newsgroups. Beginners may struggle to distinguish good advice from bad." Participants that talked about *documentation gaps* (n=9) described the difficulty of locating relevant or clear information among Ansible's extensive (but sometimes inconsistent) references. Although multiple participants praised Ansible's core documentation (described in Section 5), they also identified a steep learning curve for interpreting advanced instructions.

4.1 Topic Evolution

Figure 3 shows the yearly percentage evolution of each topic over the entire Ansible post history until 2024. Most topics exhibit a stable prevalence over time. However, issues related to AWX, integration and compatibility issues, and documentation increase in prominence, whereas topics such as variable management and module development show a gradual decrease.

> **RQ1:** We identified seven core challenge categories: *Control/-Data Flow and Execution*, *Reliability*, *Lack of Support*, *Usability*, *Performance and Scalability*, *Maintenance* and *Information Gaps*. Our Q&A analysis highlighted frequent technical issues (e.g., loops, SSH connectivity), while interviews revealed deeper concerns such as stale configurations, misleading community advice, and complex setup.

5 RQ2: Factors Influencing Ansible Adoption

This section analyzes how interview participants first encountered Ansible and the reasons they selected it over other IaC solutions.

Accessibility & Usability. A significant theme in our *Advantages* codebook is the role of Ansible's accessibility in driving adoption. Several participants described it as *Easy to use* (n=13), *Easy to onboard to new people* (n=7), and with a *Low Barrier to Entry for Setup* (n=6) highlighting how they only needed to master a limited set of concepts—such as basic playbook structures and inventory configuration—before managing a wide range of environments. B1 remarked, "To get things done, I only really needed to understand a small set of concepts regarding how Ansible works (...)". Participants also cited Ansible's *Readable syntax* (n=6), E6 highlighted that "[we] were looking into Ansible because it has a nice YAML syntax".

Tool Qualities & Ecosystem. Beyond accessibility, Ansible was praised for its *tool qualities*, with participants discussing its *Scalability* (n=5). Another advantage of Ansible is its *Flexibility*, since it can be a *One-Tool Solution* (n=2) capable of managing heterogeneous environments (e.g., Windows, Linux, or network devices). As E3 puts it, the "One tool that does it all". Several participants emphasized that Ansible's *Compatibility* (n=6) with various operational requirements and existing workflows set it apart from other tools, and its *Agentless* (n=9) model that depends solely on SSH. *Idempotence* (n=2) was also considered important for participants, ensuring the same playbook can be applied repeatedly to converge infrastructure into a consistent state. As I3 described: "Some commands are dangerous to invoke twice." From an *Ecosystem* standpoint, respondents highlighted features such as *Easy to extend* (n=4), and the fact that *It's implemented in Python* (n=2).

Participants frequently framed their rationale in comparative terms, highlighting Ansible's advantages over alternatives like Puppet, Chef, and Salt. A common comparative advantage cited was the elimination of agent management overhead.

E5 provided an illustrative anecdote highlighting Ansible's comparative operational model advantages: "(...) a place I was working was using Puppet, and the admin was woken up at 3 am from a page, fixed the issue, went to bed, and then Puppet restored the broken configuration, so he woke up again, fixed the Puppet, and then went to bed. Then, was woken up again because Puppet updated itself from git."

Community. A third central theme centers on Ansible's Community. The tool's *Popularity* (n=4) and *Community* (n=4) are significant advantages. E1 noted: "Ansible's advantages (...) are it being a well-supported IaC tool. Since there is a large community around it, it is easier to find solutions to specific problems online." I1 summarized it as: "Ansible was just the hot topic at the time." Participants also mentioned that Ansible's strong market presence often led their organizations to mandate its use (n=8) ("it was standard by the time I joined the team", I3). Moreover, if it was not mandatory, it was often *Recommended* (n=3) by colleagues or professors.

> **RQ2:** Ansible's adoption is influenced by its ease of use, low barrier to entry, and agentless design. Participants highlighted that minimal setup requirements and an approachable syntax enabled them to quickly manage diverse infrastructures. They also praised Ansible's extensibility, strong community presence, and popularity.

6 RQ3: Improving Ansible

This section describes the *Recommendations* described in Section 3.3. While participants generally acknowledged Ansible's strengths, they also offered concrete recommendations to improve.

Documentation and Learning Resources. A recurring concern expressed by participants (n=10) was the need to *improve documentation*. E4 described the current official documentation as scattered, noting that it "is poor considering the other configuration tools (take a look at Puppet's). The websites are not appealing and not properly organized". Strong concepts are scattered over different pages." I3 identified specific documentation challenges regarding module organization: "Documentation needs a big revamp: it's not clear what modules are built-in or part of Ansible Galaxy." E8 found the documentation examples helpful but noted that "sometimes they don't [provide] all the examples" The participants also called for *better onboarding* resources (n=6) and *more education* (n=9). As E3 put it " When you educate beginners, they can identify incorrect information and avoid it."

Debugging and Troubleshooting. Several participants highlighted limitations in Ansible's current debugging capabilities. *Better debugging tools* (n=5) and *improved error messages* (n=6) were frequently mentioned. E2 stressed that "error messages when plugins fail could be improved," as they can sometimes be "misleading". I2 reinforced this point, saying that "more specific error messages would be very helpful. Understanding exactly where an issue presents is the most important part of the debugging process". Another concept frequently raised was the lack of *rollback-on-failure* support (n=5).

Performance and Scalability. Participants also critiqued performance and mentioned the need to *improve speed* (n=7) and improve *parallelization* (n=4). As E2 put "Slow runs is an eternal pain point." E1 advocated for integrating solutions akin to Mitogen [36], to help optimize remote execution over SSH to reduce overhead and B1 proposed a tag-based approach: "Having the ability to set group tags for tasks, and have groups of tasks be able to run in parallel would be a decent enough solution (tasks with tag A can run in parallel with tasks with tag B)."

Advanced Programming Capabilities. A group of participants called for the expansion of Ansible's programming model. While some participants advocated for *more high-level language concepts* (n=3) (e.g., real loops, complex conditionals, and synchronization primitives), others (n=5) stressed *state management*. E7, for instance, argued for "functionality in Ansible to handle state management effectively" and provided an extensive analysis of Ansible's state management limitations, saying, "even though Ansible claims to be completely stateless, which is supposed to be its strength, I'm not so convinced. Without state management, it's challenging to handle certain problems."

> **RQ3:** Interviewees emphasized the need for better documentation, improved debugging, and enhanced error reporting. Many highlighted performance optimizations, including faster execution and parallelization, while others advocated for rollback support and stronger third-party integrations.

7 Discussion

This section discusses the implications of our findings for Ansible as well as for other IaC technologies.

7.1 Failure Locality Guarantees

Our quantitative and qualitative analyses indicate that many Ansible challenges stem from difficulties in localizing failures during playbook execution. High-frequency topics such as *Error Handling*, *Undefined Variables*, and *YAML, Jinja and Quoting-related syntax issues* frequently involve failures that surface far from their root causes. Interview participants consistently described situations where Ansible "gets stuck", produces misleading errors, or provides insufficient context to determine where execution went wrong. Several interviewees explicitly noted limitations in the current error messages and expressed a need for clearer, more informative feedback. Notably, these observations were made by interviewees with substantial Ansible experience (on average, approximately 4 years), suggesting that these difficulties persist beyond initial onboarding.

We conceptualize this recurring pattern as *failure locality*: the degree to which an IaC tool enables practitioners to clearly identify the origin and propagation of failures during execution. In Ansible, low failure locality manifests when errors arise late, lack actionable context, or are disconnected from their causes.

This lack of failure locality is reflected in the interviews, where half of the participants reported that Ansible is hard to debug and frequently cited the absence of meaningful progress or termination feedback during execution. As discussed in Section 4, a participant reported a playbook that stalled for 15 minutes despite being expected to run in one minute, with no visible terminal feedback. In such cases, users cannot determine whether the execution is progressing or identify the task responsible for the stall. As a result, failure localization often requires manual interruption, additional logging, or trial-and-error instrumentation.

This lack of execution feedback is also reflected in community discussions. We identified 160 recent posts (≈0.7%) whose titles contain terms such as *stuck*, *hang*, or *freeze*, suggesting that non-terminating or stalled executions are a recurring concern. We restricted the search to post titles to avoid overcounting incidental mentions and to focus on posts where non-termination was the central issue. These reports align with documented Ansible issues that describe stalled executions with limited diagnostic output [5, 6]. Many of these posts were attributed topics related to SSH connection issues (50 posts), AWX (23), and WinRM (10), which is Ansible's primary remote management protocol for Windows hosts, suggesting that stalled executions often arise at integration boundaries, such as remote connections and AWX-mediated execution orchestration, where Ansible provides limited visibility into progress and blocking conditions.

> **Insight for Ansible:** Ansible could provide phase-aware execution progress and stall diagnostics at integration boundaries such as remote connections. Surfacing the current execution phase (e.g., connection establishment or module execution), along with task and host context, and warning when a phase stalls would help practitioners localize blocking behavior without manual interruption.

The low failure locality in Ansible is not limited to a single class of failures. Our analysis shows that failures related to YAML syntax

and quoting exhibit particularly poor locality characteristics, making them among the most prominent usability challenges faced by practitioners. An inspection of the Q&A posts revealed a recurring error message that appears in 706 posts: *"The error appears to have been in file X: line Z, column Y, but may be elsewhere in the file depending on the exact syntax problem."*

Such messages acknowledge the uncertainty about the fault's location, forcing users to search beyond the reported location. This behavior undermines failure locality, as the system is unable to confine the failure to the construct that caused it. Instead of narrowing the search space, the diagnostic output expands it, increasing the cognitive effort required to diagnose even minor errors.

The interview data further illustrate the practical impact of this loss of locality. As mentioned in Section 4, a *participant with 9 years of Ansible experience* spent several hours debugging a YAML quoting issue. This example highlights how small, localized mistakes can propagate into failures that are difficult to attribute, diagnose, and correct due to ambiguous or misleading error reporting.

> **Insight for YAML-based IaC technologies:** Improving debugging effectiveness requires compensating for YAML's weak syntactic failure locality. YAML-based IaC tools could provide early, schema-guided validation, precise diagnostics for quoting and escaping errors that identify the exact responsible construct instead of approximate file locations, and clear distinctions between parsing, templating, and execution failures, thereby reducing the diagnostic search space.

7.2 Blurred Language Boundaries

Our Q&A analysis indicates that issues related to *Loops, Jinja2, Conditional Execution*, and *Undefined Variables* are among the most frequently reported by practitioners Moreover, these topics exhibit strong co-occurrence in Ansible-related discussions. Table 1 reports the pairwise co-occurrences and coverage among these four topics. Additionally, across all topics, roughly one-fifth of posts associated with any topic also involve at least one of the others. These results suggest that practitioners reason about these concepts together. They experience them as a tightly coupled cluster of challenges that emerge at the intersection of Ansible's execution model and the Jinja2 templating system. This is consistent with our interview data, in which participants repeatedly highlighted difficulties with Jinja2, mainly experienced practitioners with an average of seven years of Ansible experience, and suggested the addition of higher-level language constructs as a potential improvement.

Playbooks operate at the intersection of multiple languages and abstraction layers: YAML as a data serialization format, Ansible-specific schema extensions (e.g. when), and Jinja2 as an embedded templating language. Their composition creates blurred semantic boundaries that are difficult for practitioners to internalize.

This interaction helps to explain an apparent tension in our findings. In RQ2, participants frequently described Ansible's readable syntax as a key factor influencing adoption. However, our results indicate that this readability may not scale uniformly with the complexity of playbooks. As playbooks become increasingly entangled across language boundaries, practitioners must simultaneously determine in which language they are currently writing in, which

Table 1: Pairwise co-occurrences between topics *Jinja2, Loops, Conditional Execution*, and *Undefined Variables*.

Topic Pair (T1)	Topic 2 (T2)	Count	Coverage (%) T1	T2
Jinja2	Loops	134	10.1	9.0
Cond. Exec.	Loops	129	11.4	8.7
Jinja2	Undef. Vars.	95	7.2	8.5
Cond. Exec.	Undef. Vars.	79	7.0	7.1
Loops	Undef. Vars.	76	5.1	6.8
Cond. Exec.	Jinja2	67	5.9	5.1

evaluation model applies, and where expressions are interpreted. Maintaining an accurate mental model of these shifting boundaries imposes considerable cognitive overhead.

Nested Loops A clear manifestation of this boundary breakdown appears in the handling of nested loops, which account for 7.3% of all loop-related discussions. Notably, Ansible's official documentation explicitly discourages nested loops [56]: "The simplest way to 'nest' loops is to avoid nesting loops, just format the data to achieve the same result". Instead, Ansible recommends that users restructure data and rely on Jinja2 filters, to simulate nested iteration. This design choice introduces a tension between Ansible's declarative model and the imperative nature of iteration. While loops are exposed as imperative constructs, their expressiveness is deliberately constrained, pushing users toward a functional programming style implemented via Jinja2 filters. As a result, users are expected to translate imperative intent into functional transformations, increasing cognitive load and reducing readability.

Ansible-specific filters This tension is further amplified by Ansible's reliance on Ansible-specific Jinja2 extensions and filters. For example, the documentation prescribes the use of the *dict2items* filter, an Ansible-specific addition, to iterate over dictionaries [55]. We obtained the list of Ansible-specific filters from the official documentation [8] and subsequently searched the Q&A posts for corresponding invocation patterns for each filter. We identified the usage of Ansible-specific filters in user-provided examples in 3,014 posts, corresponding to 12.5% of all recent posts.

We then assessed whether these filters were central to the issues discussed in the posts. To this end, we selected posts that not only matched the aforementioned pattern but also referenced the same filter, or a semantically related term, in the post title. For example, for the *regex_findall* filter, we additionally searched for the terms *regex, regular, expression*, and *findall*. Of the 3,014 posts containing filter usages, 706 satisfied this criterion, indicating that at least 3% of all recent posts are related to the use of Ansible-specific filters.

Although technically effective, such constructs deepen the entanglement between Ansible and Jinja2, forcing users to learn not only the Jinja2 semantics but also the customized Ansible dialect. Rather than cleanly separating concerns, this approach layers declarative configuration, imperative execution, and functional transformation into a single syntactic space, making it harder for users to predict behavior and diagnose errors.

Templating boundaries Inconsistencies in templating boundaries further obscure the mental model practitioners must maintain. Conditional execution (*when*) implicitly evaluates Jinja2 expressions without requiring the explicit Jinja2 delimiters used in Ansible, while loops require Jinja2 expressions to be explicitly enclosed within these delimiters. In fact, on April 14, 2025, a commit [9] was pushed to Ansible that introduces a new deprecation warning that *"Conditionals should not be surrounded by templating delimiters such as {{ }} or {% %}. This feature will be removed from ansible-core version 2.23"*. A similar warning had already been introduced in Ansible 2.3, as one collected post mentions [43]. The recurrence of this guidance across versions suggests a long-standing source of confusion. Consistent with this, we observe that this warning message appears 37 times in recent posts. Such inconsistencies make it unclear when users are writing Jinja2, how expressions are parsed and evaluated, and consequently weaken boundary visibility.

Taken together, these findings suggest that many of Ansible's usability challenges may not be due to individual features, but to boundary friction between languages and paradigms that overlap.

> **Insight for Ansible:** Our findings suggest the need to revisit the design and exposure of control-flow abstractions, with a focus on making language boundaries explicit and reducing cross-paradigm leakage. Ansible could benefit from first-class expressive control-flow constructs that align with the mental models of practitioners, including native support for nested iteration and richer conditionals, thus reducing the dependency on Jinja2 as a workaround language and lowering the cognitive overhead introduced by functional-style filters.
>
> In parallel, Ansible could strive for consistent templating semantics by standardizing expression evaluation rules across constructs or explicitly signaling evaluation contexts. Treating Jinja2 as a clearly delineated component, with explicit role, scope, and limitations in both syntax and documentation, would improve learnability and reduce boundary confusion.

> **Insight for designers of new IaC technologies:** Our results highlight the risks of polyglot configuration models that blend declarative, imperative, and templating paradigms without clear separation. Our findings show that boundary ambiguity can become a primary source of user difficulty. Future IaC tools could therefore treat boundary design as a first-class concern, explicitly modeling where data declaration ends, where control flow begins, and how (or whether) templating is allowed to intervene.

7.3 Documentation Gaps

Documentation is the primary means by which users learn and troubleshoot IaC tools, however, our findings show that Ansible's documentation exhibits both explicit gaps (directly reported as missing or inadequate) and implicit gaps, inferred from recurring questions that existing documentation fails to resolve.

Topic modeling indicates that documentation issues constitute a subset of the *Information Gaps* theme (480 posts, 2% of recent posts). Participants across experience levels (n=10) repeatedly called to

improve documentation. E4 described the current official documentation as scattered, noting that "strong concepts are scattered over different pages." E8 found the documentation examples helpful but noted that "sometimes they don't [provide] all the examples"

Because topic modeling captures only explicit discussion of documentation, we conducted a post-hoc analysis to identify documentation issues embedded in technical posts. This analysis shows that 5.4% of all posts (1,301) report documentation problems (2.5× higher than topic modeling suggests). This result comes from a two-stage process: a keyword search followed by manual validation. The search identified 1,858 posts (7.7%) mentioning "documentation" or "docs", which were then refined through review to isolate genuine documentation issues. Using a conservative proportion of 0.5 with finite-population correction, we sampled 353 posts to achieve a 95% CI with a ±5% error margin. One author coded the posts, with a second author independently reviewing the classifications as either true positives (e.g., missing, unclear, or mismatched information) or false positives. Of the sample, 247 posts (70.0% ± 5%, 95% CI) were true positives and 106 (30.0% ± 5%, 95% CI) false positives, thus, about 5.05% of recent posts genuinely report documentation issues. We also saw that the percentage of posts reporting documentation problems has increased over time from approximately 4.2% in 2016-2020 to 7.6% in 2024 and 10.9% in early 2025. Because this post-hoc analysis relies on manual interpretation of discussion content, the resulting proportion should be interpreted as an approximate estimate rather than an exact prevalence. Documentation concerns also arise while discussing other technical topics, including Module Usage (∼80 posts), Integration Issues (∼74), Python Issues (∼97), and Error Handling (∼53). Users in posts report missing documentation ("Couldn't find Ansible documentation on GPG" [73]), mismatches between documentation and behaviour ("If I read the documentation to the letter it should fail" [7]), and finding existing documentation insufficient ("the documentation is still very vague about how this actually works and behaves" [59]).

> **Insight for IaC tools:** The finding that 5.4% of recent posts report documentation issues within technical discussions suggests that documentation gaps surface during implementation rather than through explicit documentation queries. Although high-quality documentation lowers barriers to entry [2, 61], many tools fail to keep pace with rapid feature growth and expanding user bases [1]. Tool developers can apply our topic modeling approach to mine community Q&A data and prioritize documentation improvements by technical domain, focusing on topics that most frequently co-occur with documentation mentions. While demonstrated on Ansible, this method generalizes to other IaC and software tools.

7.4 Execution Backends and Scalability

Performance and scalability concerns are reflected in both our quantitative and qualitative results. Performance and Scalability account for 8.1% of recent posts, and within this category, posts explicitly classified under *Performance* represent 16.3%. An analysis of topic co-occurrence within *Performance* posts shows that *AWX* (10.6%), *Loops* (10.2%), *SSH Connection Issues* (9.0%), *Error Handling* (5.6%), and *Asynchronous Execution* (5.0%) are the most frequent

co-occurring topics, where percentages denote the proportion of *Performance* posts in which each topic appears. The prominence of *SSH Connection Issues* and *Asynchronous Execution* indicates that performance problems are frequently associated with remote execution overhead and limitations in parallel execution models.

Interview participants emphasized *slow execution* and the need to *improve speed* and *parallelization*, particularly when managing large infrastructures. Several participants identified the *agentless* execution model as a contributing factor to scalability limitations, with one E2 describing slow runs as "an eternal pain point".

This concern must be viewed in light of the factors driving Ansible's adoption. Participants highlighted the agentless, SSH-based execution model as a key advantage. Rather than suggesting that agentless execution should be abandoned, our findings point to the need for execution backends that preserve this model while mitigating its performance costs. In this context, an experienced participant advocated for integrating solutions similar to Mitogen [36] to reduce SSH overhead and improve execution efficiency.

Mitogen is an alternative execution framework for Ansible that optimizes remote task execution by minimizing repeated SSH connection setup and Python interpreter initialization. Instead of spawning a new remote process for each task invocation, Mitogen establishes persistent execution contexts and reuses them across tasks, significantly reducing communication and startup overhead, while preserving Ansible's agentless execution model.

> **Insight for Ansible:** Mitogen illustrates that Ansible's performance limitations are not inherent to declarative IaC workflows, but are shaped by the characteristics of its execution backend. An implication for Ansible is therefore to treat optimized execution frameworks, such as Mitogen-like approaches, as first-class supported components with clear integration into the platform. Such support would allow users to systematically address *slow execution* and *parallelization* challenges in large-scale deployments, rather than relying on external or ad hoc optimizations.

7.5 Future Work

We identify opportunities for Ansible's evolution and broader trade-offs in IaC tool design. First, our concept of failure locality warrants engineering validation through the implementation and evaluation of phase-aware diagnostics and error reporting in controlled experiments. The blurred language boundaries we identified also suggest a need for design guidelines, including formal design patterns for composing declarative, imperative, and templating paradigms in IaC languages, potentially via prototype DSL development. Mining large-scale Ansible repositories to quantify the prevalence of identified anti-patterns (nested loops, Jinja2 complexity, variable scoping issues) would provide complementary behavioral evidence and enable correlation with code quality metrics. We also argue that our mixed methodology of combining large-scale topic modeling of community discussions with targeted practitioner interviews to identify challenges is easily replicable in other contexts. Applying this methodology to tools such as Terraform or Kubernetes could enable a cross-tool comparison of challenge patterns and inform tool selection and improvement priorities across the IaC ecosystem.

8 Threats to Validity

Threats to Internal Validity. The use of LLMs via TopicGPT introduces a risk of hallucination and unreliable outputs, potentially affecting result precision. We mitigated this through a two-stage manual validation during topic generation and topic assignment. Semi-structured interviews also risk interviewer bias; this was mitigated by using a consistent protocol and piloting the interviews.

Threats to External Validity. Our findings may be limited by practitioners discussing Ansible on Q&A platforms not included in our dataset; we mitigated this by collecting data from three distinct platforms. While some findings may generalize to other IaC tools, particularly configuration management tools, further research is needed to confirm their applicability. Interview participants were primarily recruited online, introducing potential self-selection bias and limiting representativeness across expertise levels. As with qualitative research generally, interview results provide contextual insights but are not statistically representative of the broader Ansible community. Our analysis relies on public Q&A platforms whose usage patterns are changing as generative AI adoption increases [17]. We mitigated this by restricting analysis to posts from the five years prior to data collection; the resulting corpus of 24,132 posts still exhibits diverse topics, indicating continued platform relevance. Nevertheless, as generative AI increasingly addresses common issues, future forum discussions may shift toward more complex problems, potentially affecting long-term generalizability.

9 Related Work

To identify challenges that practitioners face in IaC, Rahman et al. analyzed 2,758 Puppet-related questions from Stack Overflow [48], identifying 16 major categories, many of which (e.g., *Syntax Error*, *Filesystem*) also appear in our study. While their focus is Puppet, we study Ansible, a more widely used configuration management tool as of 2024, and consider more recent posts and interviews. Furthermore, Rahman et al. analyzed questions posted between January 2010 and December 2016, while our interviews and posts reflect the scenario as of 2024.

Guerriero et al. conducted 44 semi-structured interviews with practitioners to examine IaC practices, tools, and challenges [22], highlighting issues such as testing and debugging. Our study provides a more granular analysis and identifies Ansible-specific issues such as lack of failure locality and blurred language boundaries.

Begoug et al. collected 52,692 questions and 64,078 responses from Stack Overflow to investigate challenges developers encounter with IaC [13]. The dataset includes questions related to Ansible, Pulumi, Terraform, CloudFormation, and other IaC technologies. The authors grouped questions into topics using the Latent Dirichlet Allocation (LDA) method optimized with a Genetic Algorithm (GA) for parameter fine-tuning. Our analysis of practitioners' questions follows a similar approach. However, we collected data from two additional sources: Reddit and the Ansible forum. Additionally, instead of using LDA, we use TopicGPT, which not only provides interpretable topics but also produces topics that align better with human categorizations [42]. We both found common topics such as *File Management* and *Templating*, but we found additional challenges faced by practitioners such as Jinja and AWX issues. Another key distinction between our study and those described above is

that while they focus either on interviews or on questions posted by practitioners, our study employs a mixed-method approach that integrates data from both sources.

To our knowledge, the only other mixed-methods study on IaC challenges is that by Tanzil et al. [75]. However, their study addresses DevOps challenges in general, with IaC as just one category. They used LDA to perform topic modeling on approximately 174,000 Stack Overflow posts, identifying 23 distinct topics. These were grouped into four categories, with IaC being one of them, encompassing seven specific subtopics. Finally, the authors validated and extended their findings with a survey of 21 professional DevOps practitioners. Although there is some overlap in the findings between our study and that of Tanzil et al. (e.g., both identify challenges related to *File Management* and *Syntax*), we focus exclusively on challenges related to Ansible and IaC, which provides a more focused scope with different insights such as difficulties with YAML and the risks of designing a polygot technology. We also employ a different topic modeling approach and focus on interviews over surveys.

10 Conclusion

We combined a large-scale quantitative analysis of 59,157 online Ansible discussions with 20 practitioner interviews to identify key challenges, contextualize their real-world impact, and propose solutions. We found issues related to control flow, performance bottlenecks, limited debugging capabilities, and inconsistent documentation, highlighting the tensions among usability, flexibility, and scalability in Ansible's ecosystem. We offer concrete recommendations and show how Ansible can better serve users and large-scale deployments. These contributions, alongside broader reflections on community-driven knowledge, provide a replicable roadmap for assessing and improving IaC solutions.

Acknowledgments

References

[1] Emad Aghajani, Csaba Nagy, Mario Linares-Vásquez, Laura Moreno, Gabriele Bavota, Michele Lanza, and David C Shepherd. 2020. Software documentation: the practitioners' perspective. In *Proceedings of the acm/ieee 42nd international conference on software engineering*. 590–601.

[2] Emad Aghajani, Csaba Nagy, Olga Lucero Vega-Márquez, Mario Linares-Vásquez, Laura Moreno, Gabriele Bavota, and Michele Lanza. 2019. Software documentation issues unveiled. In *2019 IEEE/ACM 41st International Conference on Software Engineering (ICSE)*. IEEE, 1199–1210.

[3] Amazon Web Services, Inc. 2011. AWS CloudFormation: Infrastructure as Code & AWS Resource Provisioning. https://aws.amazon.com/cloudformation. Accessed: 2025-03-10.

[4] Anonymous Author(s). 2025. Replication Package. https://doi.org/10.5281/zenodo.15031088 Accessed 20-02-2025.

[5] Ansible Community. 2016. Issue #18305. https://github.com/ansible/ansible/issues/18305. GitHub issue.

[6] Ansible Community. 2017. Issue #30411. https://github.com/ansible/ansible/issues/30411. GitHub issue.

[7] Ansible Community. 2024. Doubt regarding loops and conditionals. https://forum.ansible.com/t/doubt-regarding-loops-and-conditionals/32257 Accessed 21-01-2026.

[8] Ansible, Inc. 2026. Ansible.Builtin Collection Documentation. https://docs.ansible.com/projects/ansible/13/collections/ansible/builtin/ Accessed 21-01-2026.

[9] Ansible Project. 2026. Ansible Commit: Deprecation Warning for Templating Delimiters in Conditionals. https://github.com/ansible/ansible/blob/35750ed3218e7bce68b21f473cecb0a3b9d60321/lib/ansible/_internal/_templating/_engine.py#L477 Accessed 21-01-2026.

[10] Ansible project contributors. 2025. Ansible Community Documentation. https://docs.ansible.com/ansible/latest Accessed 03-03-2025.

[11] Claus Boye Asmussen and Charles Møller. 2019. Smart literature review: a practical topic modelling approach to exploratory literature review. *Journal of Big Data* 6, 1 (2019), 1–18.

[12] Sebastian Baltes and Stephan Diehl. 2016. Worse than spam: Issues in sampling software developers. In *Proceedings of the 10th ACM/IEEE international symposium on empirical software engineering and measurement*. 1–6.

[13] Mahi Begoug, Narjes Bessghaier, Ali Ouni, Eman Abdullah AlOmar, and Mohamed Wiem Mkaouer. 2023. What do infrastructure-as-code practitioners discuss: An empirical study on stack overflow. In *2023 ACM/IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM)*. IEEE, 1–12.

[14] Mahi Begoug, Moataz Chouchen, Ali Ouni, Eman Abdullah Alomar, and Mohamed Wiem Mkaouer. 2024. Fine-grained just-in-time defect prediction at the block level in Infrastructure-as-Code (IaC). In *Proceedings of the 21st International Conference on Mining Software Repositories*. 100–112.

[15] Narjes Bessghaier, Mahi Begoug, Chemseddine Mebarki, Ali Ouni, Mohammed Sayagh, and Mohamed Wiem Mkaouer. 2024. On the prevalence, co-occurrence, and impact of infrastructure-as-code smells. In *2024 IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER)*. IEEE, 23–34.

[16] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[17] Gordon Burtch, Dokyun Lee, and Zhichen Chen. 2024. The consequences of generative AI for online knowledge communities. *Scientific Reports* 14, 1 (2024), 10413.

[18] Barbara DiCicco-Bloom and Benjamin F Crabtree. 2006. The qualitative research interview. *Medical education* 40, 4 (2006), 314–321.

[19] James Fryman. 2014. DNS outage post mortem. https://github.blog/2014-01-18-dns-outage-post-mortem/ Accessed: 3 May 2022.

[20] GitLab. 2014. Gitlab.com Downtime 2014-07-07 Postmortem. https://docs.google.com/document/d/1ScqXAdb6BjhsDzCo3qdPYbt1uULzgZqPO8zHeHHarS0 [Accessed 04-09-2024].

[21] gooeyblob. 2016. Why Reddit was down on Aug 11. https://web.archive.org/web/20221029203405/https://www.reddit.com/r/announcements/comments/4y0m56/why_reddit_was_down_on_aug_11/ [Accessed 04-09-2024].

[22] Michele Guerriero, Martin Garriga, Damian A Tamburri, and Fabio Palomba. 2019. Adoption, support, and challenges of infrastructure-as-code: Insights from industry. In *2019 IEEE International conference on software maintenance and evolution (ICSME)*. IEEE, 580–589.

[23] Hacker News User gizdan. 2021. Ansible Techniques I Wish I'd Known Earlier. https://web.archive.org/web/20220611223833/https://news.ycombinator.com/item?id=28332684#expand Accessed: 2025-03-14.

[24] HashiCorp. 2024. Terraform by HashiCorp. https://www.terraform.io/ Accessed 13-09-2024.

[25] Md Mahadi Hassan, John Salvador, Shubhra Kanti Karmaker Santu, and Akond Rahman. 2024. State Reconciliation Defects in Infrastructure as Code. *Proceedings of the ACM on Software Engineering* 1, FSE (2024), 1865–1888.

[26] Rebecca Hersher. 2017. Amazon and the $150 Million typo. https://www.npr.org/sections/thetwo-way/2017/03/03/518322734/amazon-and-the-150-million-typo?t=1651588365675 Accessed: 3 May 2022.

[27] Honeycomb. 2021. Incident Resolution: Do You Remember, the Twenty Fires of September? https://www.honeycomb.io/blog/incident-resolution-september-retrospective [Accessed 04-09-2024].

[28] Victoria Jackson, André Van Der Hoek, and Rafael Prikladnicki. 2024. Co-Creation in Fully Remote Software Teams. In *2024 IEEE/ACM 46th International Conference on Software Engineering (ICSE)*. 604–615. doi:10.1145/3597503.3623297

[29] Carina Jacobi, Wouter Van Atteveldt, and Kasper Welbers. 2018. Quantitative analysis of large amounts of journalistic texts using topic modelling. In *Rethinking research methods in an age of digital journalism*. Routledge, 89–106.

[30] Jan David Nose. 2023. DNS Outage on 2023-01-25. https://blog.rust-lang.org/inside-rust/2023/02/08/dns-outage-portmortem.html [Accessed 04-09-2024].

[31] Lena Karlsson, Åsa G Dahlstedt, Björn Regnell, Johan Natt och Dag, and Anne Persson. 2007. Requirements engineering challenges in market-driven software development–An interview study with practitioners. *Information and Software technology* 49, 6 (2007), 588–604.

[32] Thomas D LaToza and Brad A Myers. 2010. Developers ask reachability questions. In *Proceedings of the 32Nd ACM/IEEE International Conference on Software Engineering-Volume 1*. 185–194.

[33] Jonathan Lazar, Jinjuan Heidi Feng, and Harry Hochheiser. 2017. *Research methods in human-computer interaction*. Morgan Kaufmann.

[34] Julien Lepiller, Ruzica Piskac, Martin Schäf, and Mark Santolucito. 2021. Analyzing infrastructure as code to prevent intra-update sniping vulnerabilities. In *Tools and Algorithms for the Construction and Analysis of Systems: 27th International Conference, TACAS 2021, Held as Part of the European Joint Conferences on Theory and Practice of Software, ETAPS 2021, Luxembourg City, Luxembourg, March 27–April 1, 2021, Proceedings, Part II 27*. Springer, 105–123.

[35] Khalid Mahmood. 2016. Do people overestimate their information literacy skills? A systematic review of empirical evidence on the Dunning-Kruger effect. *Communications in Information Literacy* 10, 2 (2016), 3.

[36] Mitogen Contributors. 2025. Mitogen for Ansible. https://mitogen.networkgenomics.com/ansible_detailed.html Accessed 15-03-2025.

[37] NASA Goddard Space Flight Center. 2023. SIGNAL: Summer 2023. *SIGNAL* Summer 2023 (2023). https://tempo.gsfc.nasa.gov/static-files/SIGNAL%20Summer%202023.pdf Accessed: 2025-03-10.

[38] Ruben Opdebeeck. 2024. *Static Analysis for Quality Assurance of Ansible Infrastructure-as-Code Artefacts*. Ph. D. Dissertation. Vrije Universiteit Brussel.

[39] Ruben Opdebeeck, Ahmed Zerouali, and Coen De Roover. 2022. Smelly variables in ansible infrastructure code: Detection, prevalence, and lifetime. In *Proceedings of the 19th International Conference on Mining Software Repositories*. 61–72.

[40] Ruben Opdebeeck, Ahmed Zerouali, and Coen De Roover. 2023. Control and data flow in security smell detection for infrastructure as code: Is it worth the effort?. In *2023 IEEE/ACM 20th International Conference on Mining Software Repositories (MSR)*. IEEE, 534–545.

[41] Perforce. 2024. Puppet Infrastructure & IT Automation at Scale. https://www.puppet.com/ Accessed 13-09-2024.

[42] Chau Pham, Alexander Hoyle, Simeng Sun, Philip Resnik, and Mohit Iyyer. 2024. TopicGPT: A Prompt-based Topic Modeling Framework. In *Proceedings of the 2024 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies (Volume 1: Long Papers)*. 2956–2984.

[43] PhilEv and Ansible Community. 2017. New Warning in Ansible 2.3. https://forum.ansible.com/t/new-warning-in-ansible-2-3/24330 Published April 26–27 2017; Accessed 21-01-2026.

[44] Progress. 2024. Chef Software DevOps Automation Solutions. https://www.chef.io/ Accessed 13-09-2024.

[45] PullPush team. 2025. PullPush Reddit API. https://pullpush.io/ Accessed 20-02-2025.

[46] Akond Rahman, Effat Farhana, Chris Parnin, and Laurie Williams. 2020. Gang of eight: A defect taxonomy for infrastructure as code scripts. In *2020 IEEE/ACM 42nd International Conference on Software Engineering (ICSE)*. IEEE, 752–764.

[47] Akond Rahman, Chris Parnin, and Laurie Williams. 2019. The seven sins: Security smells in infrastructure as code scripts. In *2019 IEEE/ACM 41st International Conference on Software Engineering (ICSE)*. IEEE, 164–175.

[48] Akond Rahman, Asif Partho, Patrick Morrison, and Laurie Williams. 2018. What questions do programmers ask about configuration as code?. In *Proceedings of the 4th International Workshop on Rapid Continuous Software Engineering*. 16–22.

[49] Akond Rahman, Md Rayhanur Rahman, Chris Parnin, and Laurie Williams. 2021. Security smells in ansible and chef scripts: A replication study. *ACM Transactions on Software Engineering and Methodology (TOSEM)* 30, 1 (2021), 1–31.

[50] Akond Rahman, Shazibul Islam Shamim, Dibyendu Brinto Bose, and Rahul Pandita. 2023. Security misconfigurations in open source kubernetes manifests: An empirical study. *ACM Transactions on Software Engineering and Methodology* 32, 4 (2023), 1–36.

[51] Akond Rahman and Laurie Williams. 2018. Characterizing defective configuration scripts used for continuous deployment. In *2018 IEEE 11th International conference on software testing, verification and validation (ICST)*. IEEE, 34–45.

[52] Red Hat. 2024. Ansible. https://www.ansible.com/ Accessed 13-09-2024.

[53] Red Hat. 2025. Ansible Forum. https://forum.ansible.com/ Accessed 20-02-2025.

[54] Red Hat. 2025. Ansible Forum. https://forum.ansible.com/t/important-ansible-google-group-moving-to-ansible-forum/38853 Accessed 21-02-2025.

[55] Red Hat. 2026. Ansible - Iterating over a Dictionary. https://docs.ansible.com/projects/ansible/13/playbook_guide/playbooks_loops.html#iterating-over-a-dictionary Accessed 21-01-2026.

[56] Red Hat. 2026. Ansible - Loops and Nested Loops. https://docs.ansible.com/projects/ansible/13/playbook_guide/playbooks_loops.html#nested-loops Accessed 21-01-2026.

[57] Red Hat, Inc. 2023. *Siemens standardizes on Red Hat Ansible Automation Platform for DevOps*. Case Study. Red Hat, Inc. https://www.redhat.com/en/resources/siemens-case-study Accessed: 2025-03-10.

[58] Reddit. 2025. Reddit. https://www.reddit.com Accessed 20-02-2025.

[59] Reddit Ansible Community. 2023. What's the logic behind builtin failed/successful? https://www.reddit.com/r/ansible/comments/10rma2g/whats_the_logic_behind_builtin_failedsuccessful/ Accessed 21-01-2026.

[60] Sofia Reis, Rui Abreu, Marcelo d'Amorim, and Daniel Fortunato. 2022. Leveraging practitioners' feedback to improve a security linter. In *Proceedings of the 37th IEEE/ACM International Conference on Automated Software Engineering*. 1–12.

[61] Martin P Robillard. 2009. What makes APIs hard to learn? Answers from developers. *IEEE software* 26, 6 (2009), 27–34.

[62] Tobias Roehm, Rebecca Tiarks, Rainer Koschke, and Walid Maalej. 2012. How do professional developers comprehend software?. In *2012 34th International Conference on Software Engineering (ICSE)*. IEEE, 255–265.

[63] Nuno Saavedra and João F Ferreira. 2022. GLITCH: Automated Polyglot Security Smell Detection in Infrastructure as Code. In *Proceedings of the 37th IEEE/ACM International Conference on Automated Software Engineering*.

[64] Nuno Saavedra, João F Ferreira, and Alexandra Mendes. 2025. InfraFix: Technology-Agnostic Repair of Infrastructure as Code. *arXiv preprint arXiv:2503.17220* (2025).

[65] Nuno Saavedra, João Gonçalves, Miguel Henriques, João F Ferreira, and Alexandra Mendes. 2023. Polyglot Code Smell Detection for Infrastructure as Code with GLITCH. In *Proceedings of the 38th IEEE/ACM International Conference on Automated Software Engineering*.

[66] Julian Schwarz, Andreas Steffens, and Horst Lichter. 2018. Code smells in infrastructure as code. In *2018 11Th international conference on the quality of information and communications technology (QUATIC)*. IEEE, 220–228.

[67] Tushar Sharma, Marios Fragkoulis, and Diomidis Spinellis. 2016. Does your configuration code smell?. In *Proceedings of the 13th international conference on mining software repositories*. 189–200.

[68] Thodoris Sotiropoulos, Dimitris Mitropoulos, and Diomidis Spinellis. 2020. Practical fault detection in puppet programs. In *Proceedings of the ACM/IEEE 42nd International Conference on Software Engineering*. 26–37.

[69] Stack Exchange. 2025. Stack Exchange API. https://api.stackexchange.com Accessed 20-02-2025.

[70] Stack Exchange. 2025. Stack Overflow. https://stackoverflow.com Accessed 20-02-2025.

[71] Stack Exchange Network. 2014. Outage Post-Mortem: August 25th, 2014. https://web.archive.org/web/20201020103424/https://stackstatus.net/post/96025967369/outage-post-mortem-august-25th-2014 [Accessed 04-09-2024].

[72] Stack Overflow. 2024. Stack Overflow Developer Survey 2024. https://survey.stackoverflow.co/2024/ [Accessed 03-09-2024].

[73] Stack Overflow Community. 2019. How to retrieve and use a tar.gz.asc from GitHub in an Ansible playbook with Ansible Vault? https://stackoverflow.com/questions/57834711/how-to-retrieve-and-use-a-tar-gz-asc-from-github-in-an-ansible-playbook-with-a Accessed 21-01-2026.

[74] Trevor Stalnaker, Nathan Wintersgill, Oscar Chaparro, Massimiliano Di Penta, Daniel M German, and Denys Poshyvanyk. 2024. BOMs Away! Inside the Minds of Stakeholders: A Comprehensive Study of Bills of Materials for Software Systems. In *2024 IEEE/ACM 46th International Conference on Software Engineering (ICSE)*. 517–529. doi:10.1145/3597503.3623347

[75] Minaoar Hossain Tanzil, Masud Sarker, Gias Uddin, and Anindya Iqbal. 2023. A mixed method study of DevOps challenges. *Information and Software Technology* 161 (2023), 107244.

[76] Wikimedia. 2017. Incidents/2017-01-18 Labs. https://wikitech.wikimedia.org/wiki/Incidents/2017-01-18_Labs [Accessed 04-09-2024].

[77] Shuang-Hong Yang, Alek Kolcz, Andy Schlaikjer, and Pankaj Gupta. 2014. Large-scale high-precision topic modeling on twitter. In *Proceedings of the 20th ACM SIGKDD international conference on Knowledge discovery and data mining*. 1907–1916.

[78] Ahmed Zerouali, Ruben Opdebeeck, and Coen De Roover. 2023. Helm charts for Kubernetes applications: Evolution, outdatedness and security risks. In *2023 IEEE/ACM 20th International Conference on Mining Software Repositories (MSR)*. IEEE, 523–533.