# MLOps Adoption in the Manufacturing Industry

## A Case Study With Zeiss SMT

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# Motivation



- Production deployment of machine learning (ML) remains rare[1]
- ML Operations (MLOps) promises a solution
  - Extending DevOps principles to ML-based systems
- Adopting MLOps involves a plethora of options and trade-offs[2][3]
  - Practitioners lack guidance and feel overwhelmed

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[1] Meulen R van der, McCall T (2018) Gartner Says Nearly Half of CIOs Are Planning to Deploy Artificial Intelligence. https://www.gartner.com/en/newsroom/press-releases/2018-02-13-gartner-says-nearly-half-of-cios-are-planning-to-deploy-artificial-intelligence. Accessed 4 Mar 2025

[2] Lewis GA, Ozkaya I, Xu X (2021) Software Architecture Challenges for ML Systems. In: 2021 IEEE International Conference on Software Maintenance and Evolution (ICSME). IEEE, Luxembourg, pp 634–638

[3] Nazir R, Bucaioni A, Pelliccione P (2024) Architecting ML-enabled systems: Challenges, best practices, and design decisions. Journal of Systems and Software 207:111860. https://doi.org/10.1016/j.jss.2023.111860

# Research Questions



**RQ1** Which challenges do practitioners face when implementing MLOps in practice, especially when integrating ML-based components into existing software systems?

**RQ2** How do practitioners deal with these challenges?

**RQ3** How does integrating ML-based components impact the software architecture of the existing software system?

# Approach



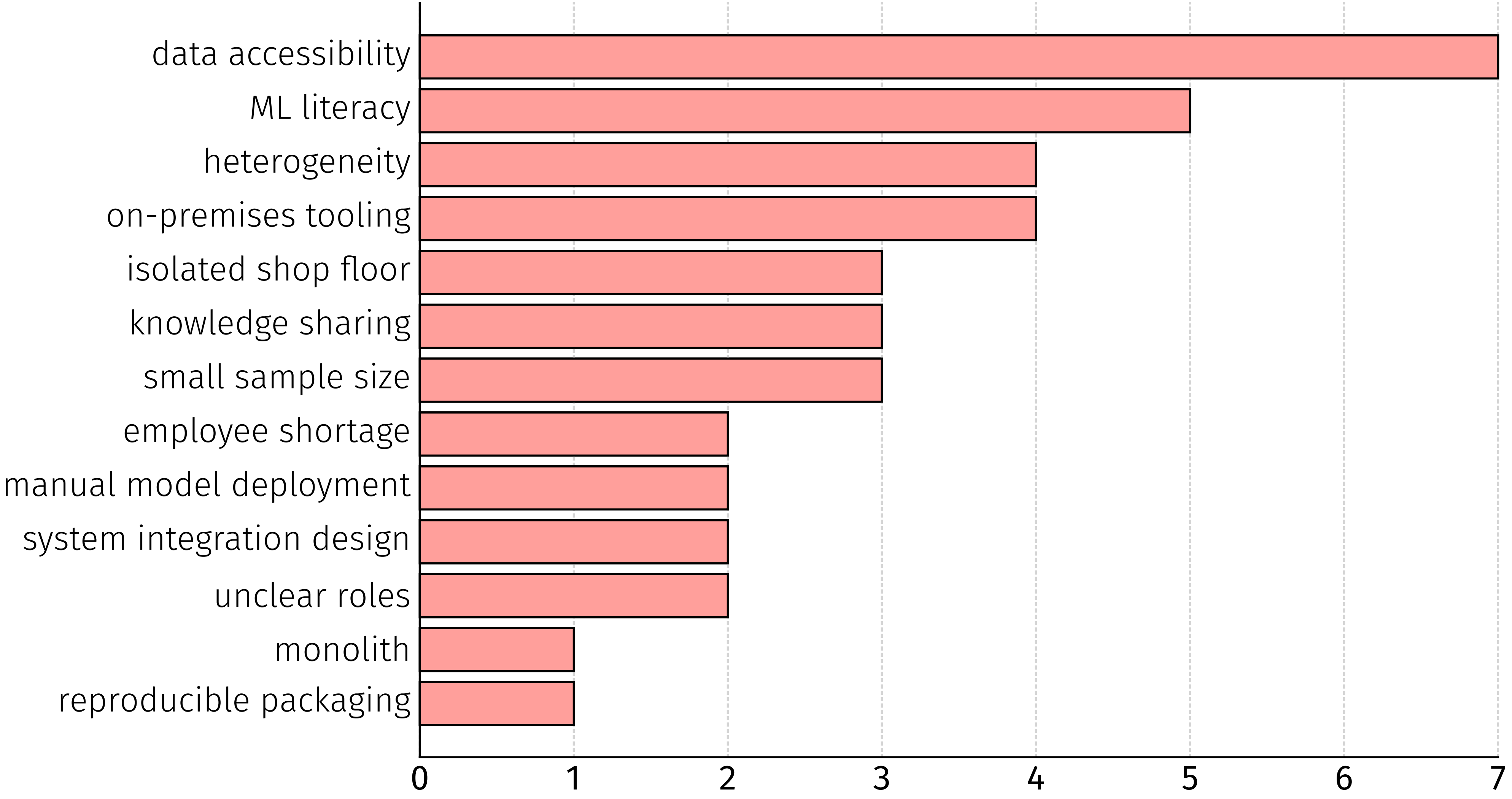
Preparation → Interview → Transcription → Approval → Analysis

# Participants



| | | Experience (years) | | | | | |
|---|---|---|---|---|---|---|---|
| **ID** | **Role** | **Role** | **SE** | **Ops** | **DevOps** | **ML** | **MLOps** |
| **P01** | data scientist | 1.0 | 0.0 | 0.0 | 0 | 3.5 | 0.0 |
| **P02** | software developer | 4.0 | 25.0 | 0.0 | 4 | 8.0 | 1.0 |
| **P03** | software developer | 1.0 | 2.0 | 0.0 | 2 | 2.0 | 1.0 |
| **P04** | system developer | 2.5 | 5.0 | 0.0 | 0 | 5.5 | 0.5 |
| **P05** | data scientist | 3.0 | 4.0 | 0.0 | 0 | 3.0 | 0.0 |
| **P06** | data scientist | 0.5 | 10.0 | 0.0 | 0 | 5.0 | 0.0 |
| **P07** | process engineer | 5.0 | 0.0 | 0.0 | 0 | 5.0 | 0.0 |
| **P08** | ML engineer | 2.0 | 12.0 | 1.5 | 0 | 6.0 | 0.0 |
| **P09** | data scientist | 6.0 | 10.0 | 0.0 | 2 | 13.0 | 0.0 |
| **P10** | data scientist | 3.0 | 10.0 | 0.0 | 2 | 3.0 | 0.0 |
| **P11** | data scientist | 2.5 | 7.5 | 1.5 | 1 | 7.5 | 1.0 |
| **P12** | physicist | 2.0 | 9.0 | 2.0 | 2 | 7.0 | 0.0 |

# Challenges


data accessibility
ML literacy
heterogeneity
on-premises tooling
isolated shop floor
knowledge sharing
small sample size
employee shortage
manual model deployment
system integration design
unclear roles
monolith
reproducible packaging
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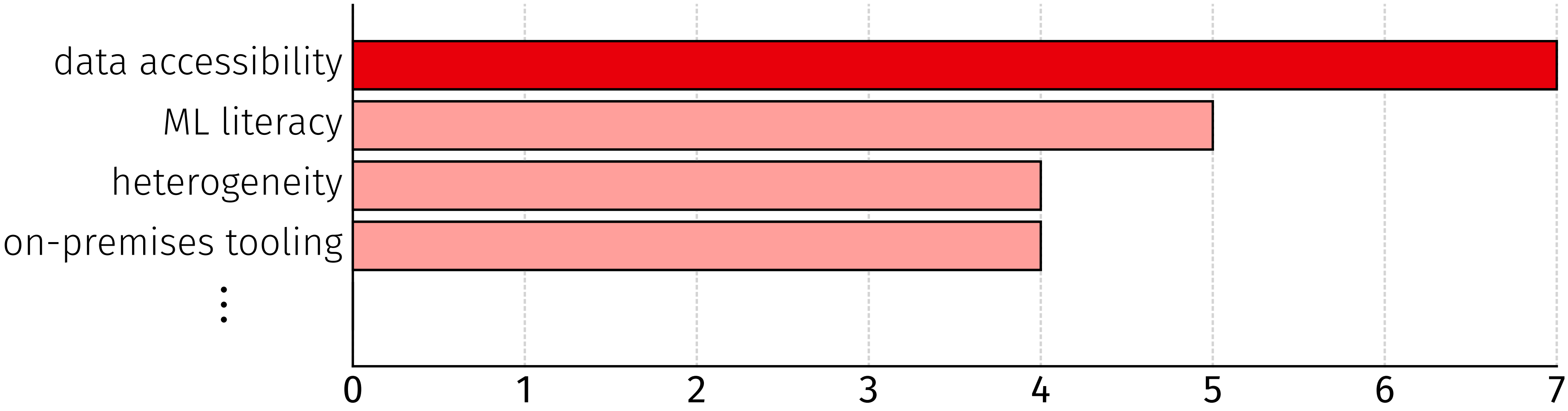
# Challenges




**Key Insight** Participants expressed difficulties identifying and accessing appropriate data sets for their ML projects.

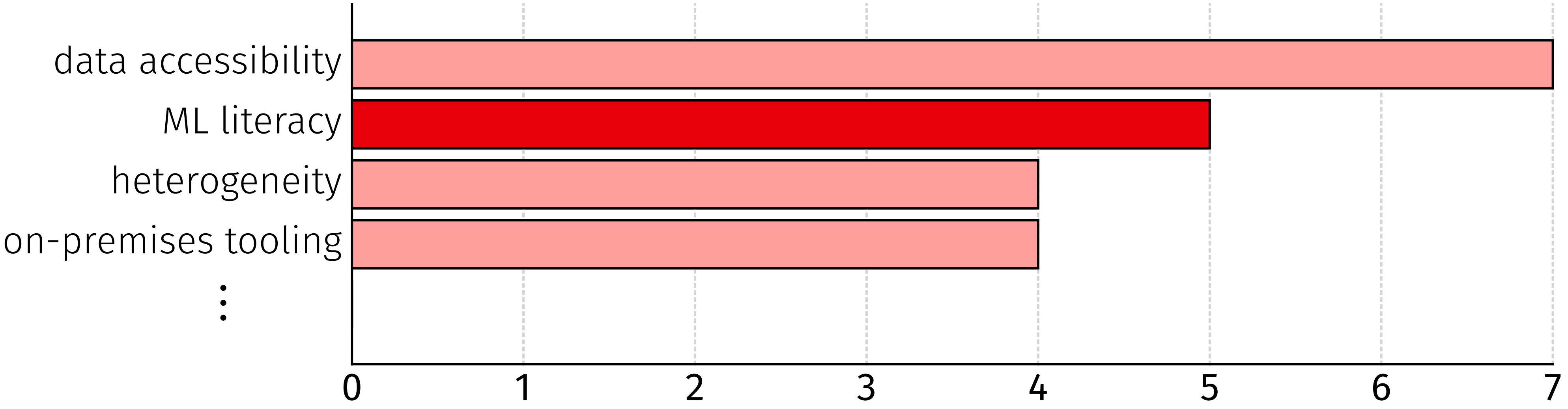
**Sub Aspects**

**data discovery** identifying an appropriate data set

**data ownership** identifying data owner & obtaining access

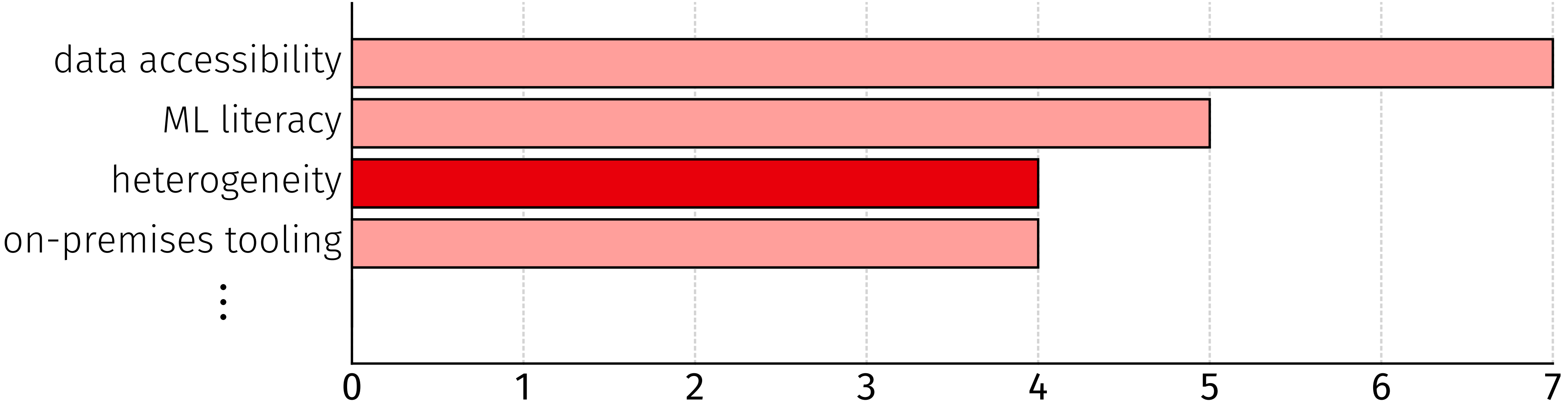
**data security** handling data securely (e.g., access to cloud resources)

# Challenges



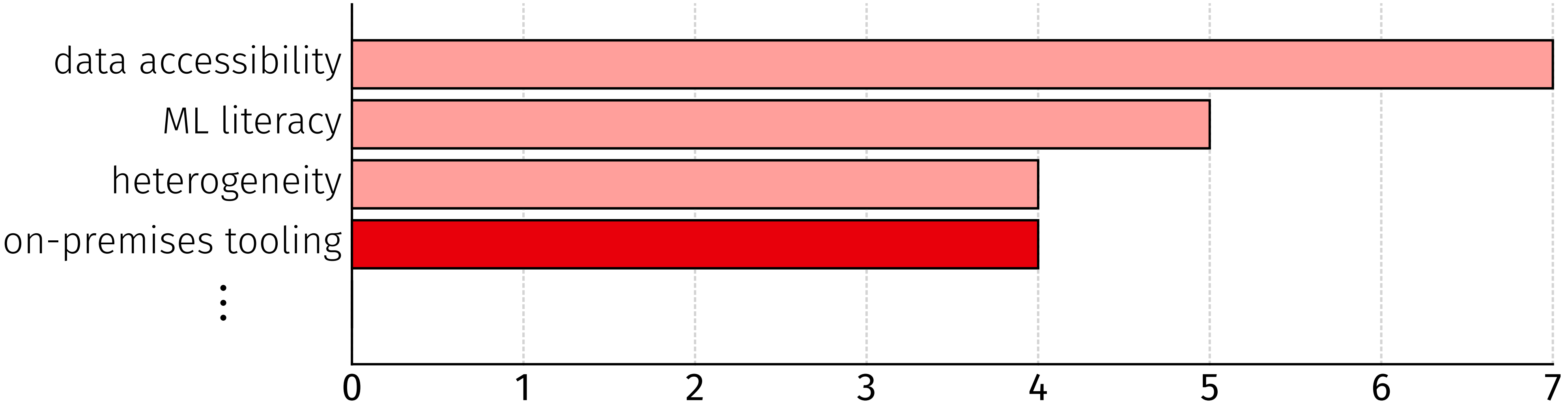

**Key Insight** Project stakeholders do not understand properties of ML (projects)

# Challenges



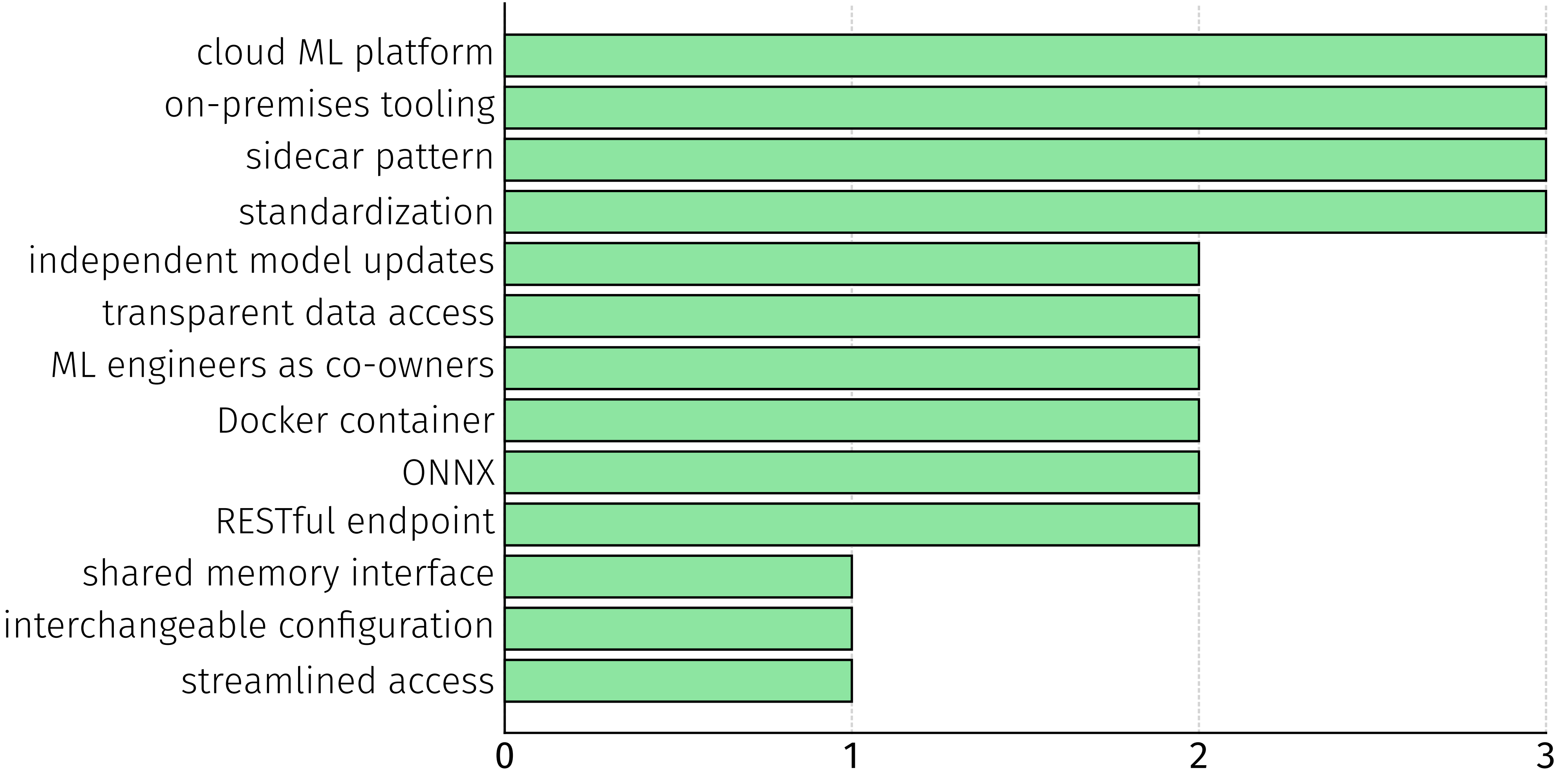

**Key Insight** Projects employ a multitude of different tools

# Challenges




**Key Insight** Available on-premise tooling is not competitive with cloud offerings regarding user experience

# Solutions


cloud ML platform
on-premises tooling
sidecar pattern
standardization
independent model updates
transparent data access
ML engineers as co-owners
Docker container
ONNX
RESTful endpoint
shared memory interface
interchangeable configuration
streamlined access
0
1
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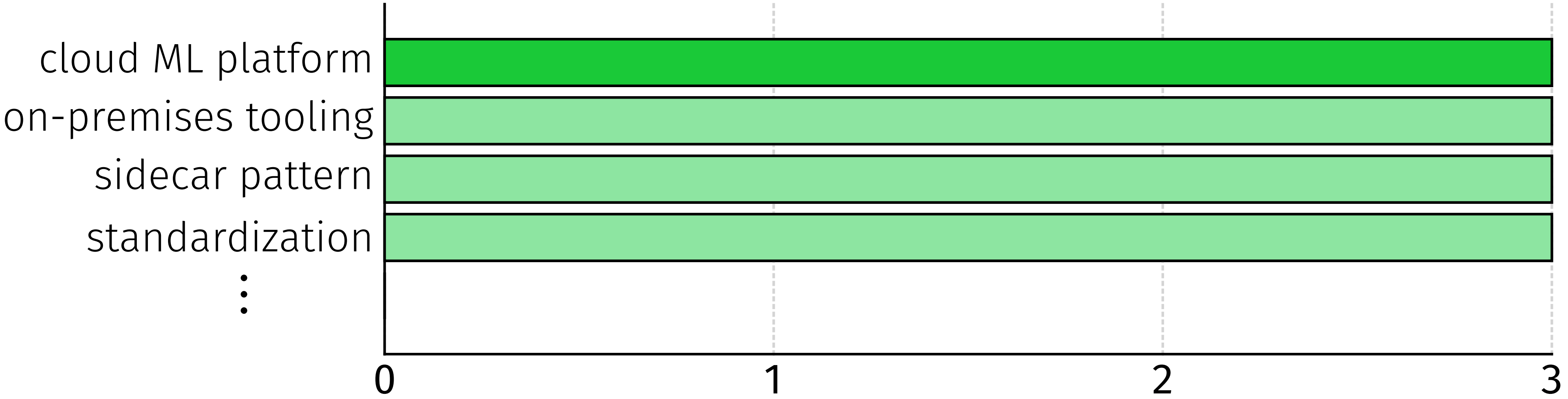
3

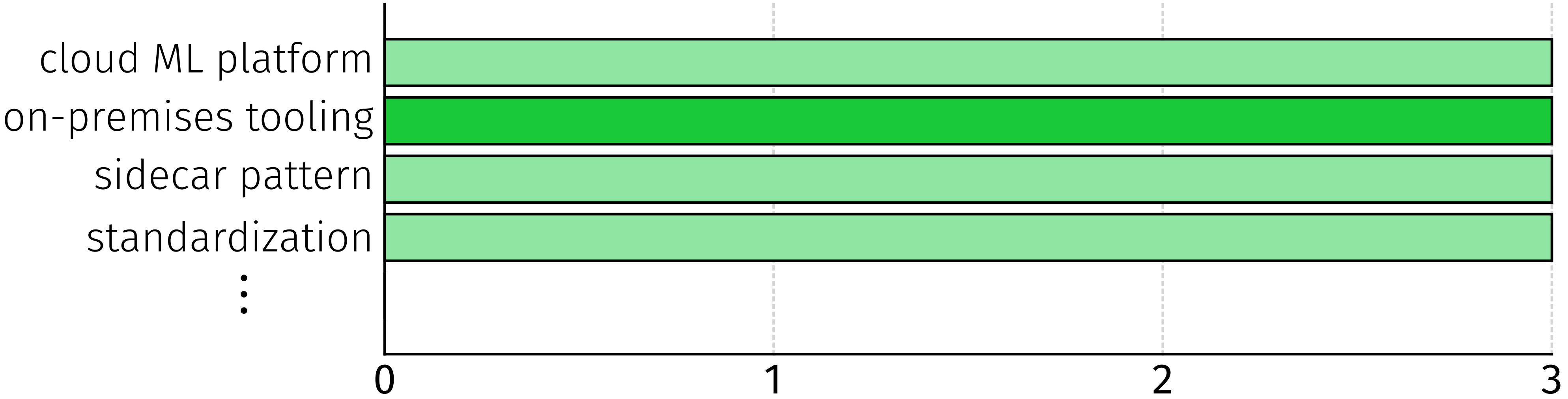
# Solutions




**Key Insight** Participants prefer cloud ML infrastructure for its usability and automation capabilities.

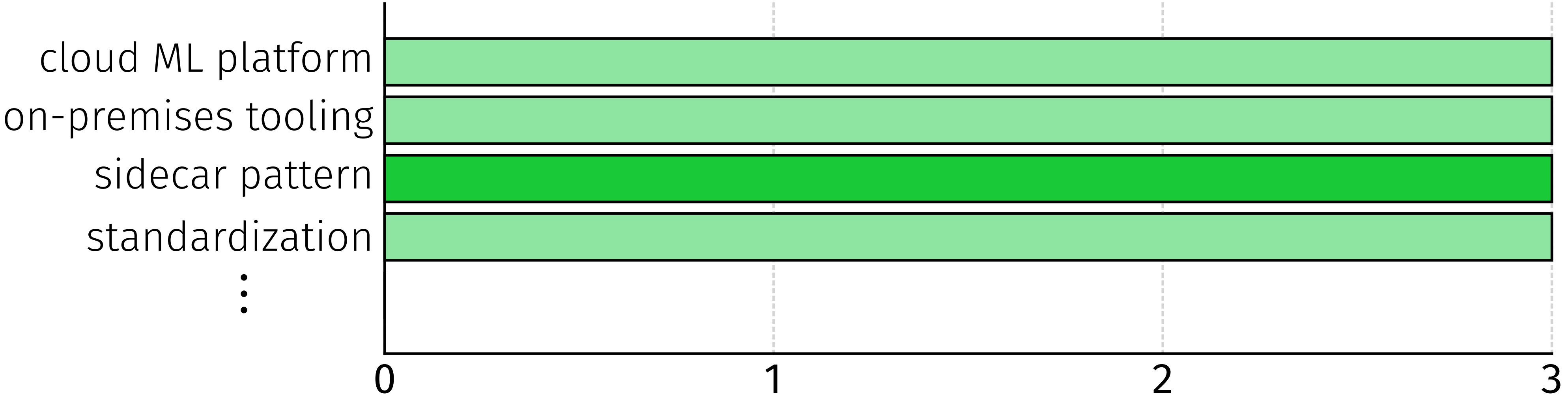
# Solutions






**Key Insight** After cloud ML infrastructure, participants prefer centralized on-premise ML infrastructure.

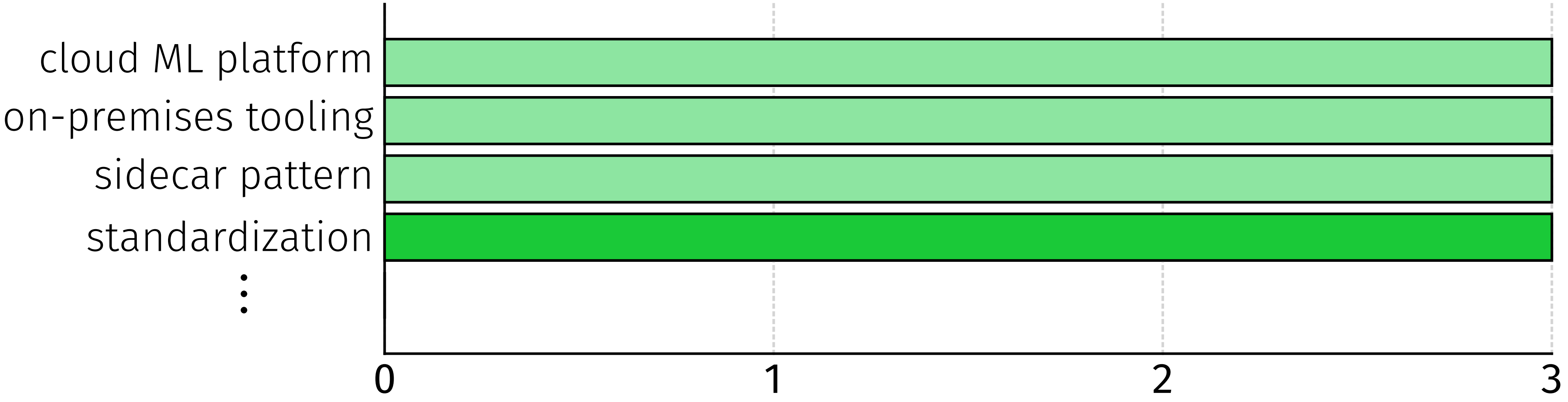
# Solutions




**Key Insight** As a last resort, participants fall back on the sidecar pattern for ML model deployment.

Model is deployed next to the system using its results.

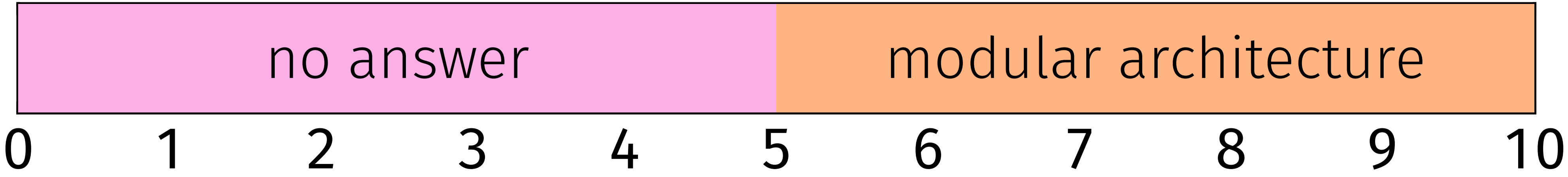
# Solutions




**Key Insight** Participants wish for a best practice guidelines on ML system architecture & technology selection

# Software Architecture Impact

**How did integrating an ML model into the system change the software architecture?**




**Key Insight** Generally, existing systems are so well-architected that ML-based functionality can be integrated without major changes to the software architecture.

**However** ML models may require specialized hardware (e.g., GPUs)

# Discussion



- Challenges mainly stem from the trade-off between **Security** and **Usability**
  - Focus on security is a key challenge
  - In some cases, data may be classified too conservatively

# Threats to Validity



- Subjective bias
- Incomplete results
- Limited scope of case study

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## Conclusion

- Interview-based case study on MLOps adoption at Zeiss SMT
- Collected challenges & solutions from 10 interviews
- Key challenge is trade-off between **Security** and **Usability**

## Future Work

- Improved on-premise ML infrastructure
- MLOps guidelines
- Comparison with other manufacturing companies

# Appendix

# Bibliography



Lewis GA, Ozkaya I, Xu X (2021) Software Architecture Challenges for ML Systems. In: 2021 IEEE International Conference on Software Maintenance and Evolution (ICSME). IEEE, Luxembourg, pp 634–638

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