Migrating to a microservice architecture: benefits and challenges

Sh. Salii, J. Ajdari and Xh. Zenuni
Southeast European University, Tetovo, North Macedonia
{ss24742, j.ajdari, xh.zenuni}@seeu.edu.mk

***Abstract*—Considering the need for scalability, flexible configuration, easier development, maintenance, and rapid agile development, many organizations are moving to a microservice architecture. This migration process is undertaken by organizations to change their software architecture and mature the benefits offered by microservice architecture. However, performing a migration towards microservices is not a trivial and structured process, and many challenges have been identified along the way.**

In this research paper, we investigate the migration process and the adoption of microservices in different organizations by conducting a survey with industry practitioners, mainly focusing on the reasons for migration, the advantages that this architecture brings, and the obstacles encountered during the migration.

The expected result of the research is to contribute to the findings reported in the scientific literature, highlighting relevant problems and identifying possible directions for future research.

Keywords—Microservices, Monolith, Microservice Architecture, Monolith to Microservices, Industry Survey

I. INTRODUCTION

Microservice architecture (MSA) is a recent architectural trend gaining tremendous interest in both, industry and academia. It can be defined as an approach to developing software applications as a subset of small, independently deployable services that communicate with each other through HTTP resource APIs [5]. MSA adoption brings several advantages [6]. MSA enables a modular and loosely coupled approach to software development, where it is possible to develop, deploy, and scale each service independently making it easier to implement changes without affecting the entire system [7] [15]. Compared to monolithic architecture, MSA is more fault-tolerant since the failure of one service will not disrupt the whole system [3]. Moreover, microservices allow for different services to be built using different technologies. These advantages and more improve resource allocation and usage, system reliability, availability, and maintenance. Major companies that are using MSAs include Netflix, Uber, and Amazon.

While MSA is suitable for many types of applications, it is not the best fit for all types of software [8] [11]. Considering the economic impact, the trade-offs should be carefully evaluated so that the benefits outweigh the added complexity. The decision to architect a system should always be based on solid information, ensuring that the expected benefits will be met [20]. Adopting MSAs is a very challenging and error-prone process, for either greenfield or brownfield systems [2] [18]. It requires a significant investment in terms of design, development, testing, and maintenance.

In this study we investigate the migration journey of industry practitioners towards MSA, analyzing their migration experience with a main focus on the migration motivations, the challenges encountered and the benefits perceived. The main aim of this study is to highlight industry migration practices toward MSA. To reach this, we designed an online survey questionnaire targeting our network of IT practitioners involved in the migration process. In total, 23 industry practitioners at different professional stages from 23 different IT companies participated in our study. We collected high-quality information on the challenges faced during migration activities and the migration impact.

The main contributions of this paper include the following:

- a survey of industry practitioners that provides insights about motivations, challenges, and barriers during migration and the perceived benefits of migration.
- analysis and interpretation of gathered data.
- discussions on the obtained results.

The audience of this paper targets both researchers and practitioners in the field of software engineering, who are interested in getting an overview of existing challenges during the design and implementation of microservices, as a guide for their organizations' decisions or future scientific contributions.

The rest of the paper is organized as follows. In Section II we summarize relevant related work on the migration toward MSA. In Section III we present the methodology used to conduct the research, including research questions and hypothesis, survey questionnaire structure, and analysis. In Section IV we discuss and interpret the obtained results. In Section V we present threats to validity and in Section VI we summarize the main findings and discuss possible future work.

II. RELATED WORK

The existing body of research on MSA adoption encompasses a wide range of topics, such as motivations [13] [1], challenges [2] [12] [14] [31], and benefits [8] [15] [4] [31]. For instance, Razzaq and Ghayyur [9] use a systematic mapping study to study and examine the transition from monolithic to microservice architectures, while

Balalaie, Heydarnoori, Jamshidi, Tamburri, and Lynn [10] explored a catalog of migration and rearchitecting patterns through a qualitative empirical approach. In addition, the comparison of monolithic and microservice architectures concerning performance and scalability was investigated by Blinowski, Ojdowska, and Przybylek [8].

Various authors have focused on specific aspects of MSA adoption. Capuano and Muccini [13] conducted a Systematic Literature Review of 58 papers to exam- ine the significance of quality attributes in the MSA adoption process. Carrasco, Bladel, and Demeyer [14] presented solutions to common pitfalls in terms of bad smells, while Dinh-Tuan and Beierle [16] analyzed the resource consumption and scalability benefits of stateless microservices-based applications through a prototype implementation using a remake of Flappy Bird. Moreover, the challenges of migrating enterprise legacy source code to microservices architecture (MSA) were explored by Furda, Fidge, Zimmermann, Kelly, and Barros [18]. Their investigation highlighted issues related to multi-tenancy, statefulness, and data consistency.

Several studies employing interviews and survey questionnaires with industry practitioners have been conducted, such as those by Francesco, Malavolta, and Lago [2] and Fritzsch, Bogner, Wagner, and Zimmermann [17], which primarily explored motivations and challenges faced during MSA adoption. In contrast, our study expands the discussion to encompass the impact and benefits of MSA adoption. Auer, Lenarduzzi, Felderer, and Taibi [3] also followed a similar approach, in the form of interviews with professionals, proposing an assessment framework based on a set of metrics to consider before rearchitecting a monolithic system.

Technical lessons learned during the migration process have been documented by Gouigoux and Tamzalit [19] and Faustino, Gonçalves, Portela, and Silva [30] in their respective case studies. Furthermore, Tymchenko, N. Pleskanka, and M. Pleskanka [20] discussed the key steps required for a successful migration, whereas Ponce, Márquez, and Astudillo [4] studied the advantages and challenges of MSA adoption, including infrastructure, team organization, and migration risks. Preti, Araújo Souza, Freiberger, and De Almeida Lacerda [21] developed a migration strategy for the Public Safety Secretariat of Mato Grosso, Brazil, considering risk factors for migration. Raj, Vanga, and Chaudhary [22] focused on event-driven architecture in their study, while also examining Kubernetes [24] and tools for designing cloud-native applications [23]. Ren et al. [25] combined static and dynamic analysis to understand the characteristics of monolithic applications when migrating to MSA. Finally, Romani, O. Tibermacine and C. Tibermacine [26] proposed a data-centric process for identifying microservices in legacy software systems.

Numerous frameworks have been introduced as a result of extensive research in this area. Rubio-Drosdov [27] developed a framework for migrating monolithic systems to MSA and evaluating the performance of the resulting systems. Tankovic, Grbac, Truong, and Dustdar [33] put forth a framework for converting web applications designed for vertical scaling into cloud applications with elastic scaling capabilities, while in a separate study, Tankovic´ and Grbac, together with Žagar, introduced the ElaClo framework [34], a development framework that optimizes topologies of service-based applications based on response-time-based service-level objectives and cloud infrastructure operating costs. Santos and Silva [28] introduced a complexity metric for MSA migration, taking into account factors such as system size, complexity, dependencies, and technical and organizational challenges. Meanwhile, Selmadji et al. [29] proposed a semi-automatic approach for MSA adoption that involves decomposing the monolithic system into a set of microservices.

In summary, the existing research on MSA adoption is vast and encompasses various aspects, including motivations, challenges, benefits, and practical experiences. Our study builds upon this literature by not only examining the motivations and challenges faced by industry practitioners during MSA adoption but also focusing on the impact and benefits after adoption.

III. Study Design

This section outlines the study's design in terms of research questions, questionnaire design, execution, and data analysis.

A. Research Questions and Hypothesis

This study investigates the following research questions (RQs) inside organizations that have adopted MSA or are currently undergoing a migration to MSA:

RQ1: What are the motivations for rearchitecting a monolith system?

RQ2: What challenges are encountered during the migration process?

RQ3: What are the perceived benefits after migration?

To conduct this research, the research questions have been synthesized into 3 main hypotheses to be tested. The following hypotheses are associated with the abovementioned research questions:

H1: Organizations adopt microservices architecture due to scalability issues, complexity, and limited flexibility.

H2: The migration process to microservices architecture poses various challenges such as analyzing the current system, designing the new system, prioritizing functionalities, and overcoming technical and organizational obstacles.

H3: The adoption of microservices architecture offers benefits such as improved scalability, flexibility, fault isolation, and faster development and deployment cycles.

B. Survey Structure and Analysis

In order to ensure the rigor and integrity of the research and survey questionnaire we followed well-established

guidelines for conducting survey studies in Software Engineering by Linåker, Sulaman, De Mello, and Höst [32]. The questionnaire consists of three sections each corresponding to the information we are aiming to collect:

- Demographic Information: general information about the participants, organization, and system.
- Migration Process: motivations, system analysis, system design, and migration execution.
- Migration Impact: impact after MSA adoption.

The survey questionnaire is a web-based questionnaire, created using Google Forms and it is mainly composed of multiple-choice questions, including a few close-ended questions as well. The first section of the questionnaire consists of questions about the participant's role, experience, the organization domain, team size and the age of the system to be rearchitected. The second section of the questionnaire consists of questions about the motivations behind taking the decision to adopt MSA, the existing system assessment and analysis, the design of the new system, and the migration execution. The last section of the questionnaire consists of questions about the migration impact and the perceived benefits.

The populated form generates summarized results and we have used descriptive statistics to better represent the data about the occurrences of each given response.

IV. Survey Results

This section provides a comprehensive discussion and overview of the obtained survey results, covering personal and organizational information, system analysis, new architecture design, migration execution, and the MSA migration impact.

A. Demographic Information.

The participants were asked general questions about their role, organization, and the system they work on. Based on their answers, the participants' roles included the following: 14 out of 23 were developers, 2 out of 23 were solution architects, 4 out of 23 were Chief Executive Officers (CEOs), 2 out of 23 were product owners, and 1 out of 23 was Software Development Engineer in Test (SDET). Out of 23 participants, the majority, 15 of them had between 5 to 10 years of experience, 5 of them had 2 years of experience and 3 of them had more than 10 years of experience. Regarding organization, 20 of the participants worked in outsourcing software houses in North Macedonia, 2 in banks, and 1 in an educational institution. The team sizes varied for less than 10 members for 13 participants, between 10 and 20 for 7 participants, and 20 to 50 for 3 participants. Twelve participants were working on systems younger than 5 years, 6 of them were working on systems aged between 5 and 10 years old, and 5 participants were working on systems older than 20 years. When asked to describe the system migrated to MSA, participants answered as illustrated in Fig. 1. Fourteen of the participants described their system as a

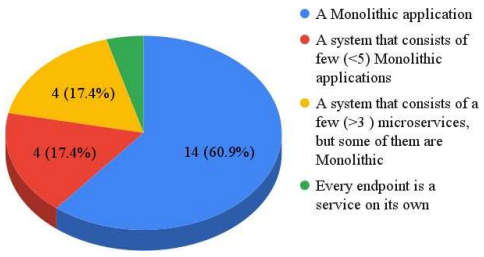

Fig. 1: System description

monolithic application, 4 of them described their system as a system that consists of few (<5) monolithic applications, 4 as a system that consists of a few (>3) microservices, but some of them are monolithic and 1 participant stated that they work on a system where every endpoint is a service on its own.

Participants were also asked about the migration execution phase as well and as illustrated in Fig. 2, we can see that 8 of the participants stated that the migration process was already completed for them, 12 of them were in the execution phase and described their migration stage as with >35% progress, and 3 of them were in the early stage of migration. The participants who were at an early stage of migration were unable to respond to questions about the benefits of MSA adoption, which we will analyze in a later phase.

In order to be able to understand more about the migration execution, we asked participants if there have been delays compared to the initial timeline estimation. As illustrated in Fig. 3, the migration process was not delayed for 14 of the participants, while 9 of them reported that they were delayed. It is important to highlight that none of the participants were highly delayed and that the number of participants who were not delayed is greater than the number of those delayed, meaning that none of the participants experienced enormous challenges.

B. Migration Motivations (RQ1)

Participants were also asked about the driver of the migration and the issues they had with their existing systems. When asked about the issues they had with their current system and what triggered MSA adoption they selected several reasons. However as illustrated in Fig. 4,

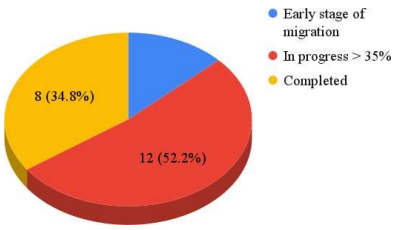

Fig. 2: Migration execution phase

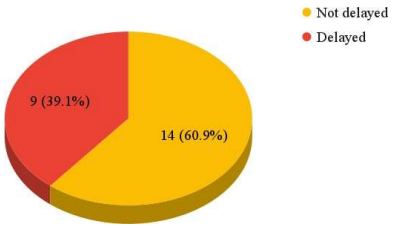

Fig. 3: Migration delay status

Fig. 4: Motivations for migrating to MSA

we can conclude that performance/scaling issues and maintainability were identified as the main drivers for migrating to MSA. The same result was reported in the literature by Fritzsch, Bogner, Wagner, and Zimmermann. [17].

Microservices allow for more flexibility and autonomy in the development and deployment process, where each service can be developed, deployed, and scaled independently, thus allowing more efficient management of the resources. On the other hand, fault tolerance, agility, and cost efficiency were also identified as important factors for deciding to rearchitect the existing systems. While in 4 cases the decision was not taken by the participants, other drivers with 3 occurrences each include the following:

- technological heterogeneity and team autonomy
- testing issues with the existing system
- incompatible system with business requirements
- technology experimentation

Based on these survey results that targeted RQ1, we can conclude that the first hypothesis is supported.

C. *Migration execution activities and challenges (RQ2).*

In order to be able to answer RQ2, the second section of the survey questionnaire consisted of questions about the analysis of the existing system, the design activities, and the migration execution. Analysis of the existing system is important in order to understand it and design the new architecture. Fig. 5 illustrates the sources used to analyze the system, where we can see that documentation and developer knowledge is considered as main resources through which the existing system was analyzed. Both documentation and developer knowledge provide valuable information about the current system, such as its structure, functionality, dependencies, and limitations.

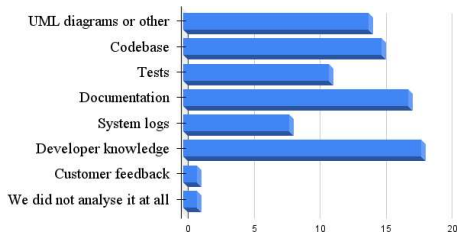

Fig. 5: Sources used to analyse the system

This information can be easily used to identify which parts of the system can be broken down into microservices, how they should be designed, and how they should interact with each other. On the other hand, 15 participants considered diagrams as a good analysis resource, while tests and codebase presented relevancy as well, with 11 and 15 occurrences each. System logs are selected by 8 participants and only one of the participants has used the client's feedback for system analysis. Finally, it is essential to mention that 1 participant did not analyze the system at all before starting the migration process, which should have caused unexpected challenges and delays.

Analyzing an existing system is not a trivial process, therefore it is important to highlight the challenges faced during system analysis. Participants were asked about the challenges they faced during system analysis, and the main obstacle they highlighted was the presence of undocumented functionalities. Fig. 6 illustrates the challenges encountered during system analysis. In addition to documentation, tests are an essential source of information, and the absence of tests and validation is a significant challenge, which occurred 14 times. Lack of database documentation and inconsistency in database documentation is listed as another challenge that occurred 10 times. At the same time, codebase and legacy technologies were also identified as relevant problems, each occurring 7 times.

As mentioned, analyzing the existing system is important in order to be able to design the new system. Survey participants were asked about the activities taken and the challenges faced when designing the new system. Fig. 7 illustrates the activities undertaken by the participants while designing the new system. As we can see, the answers are distributed across multiple options, however, the identification of dependencies is the most selected one with a total of 17 occurrences.

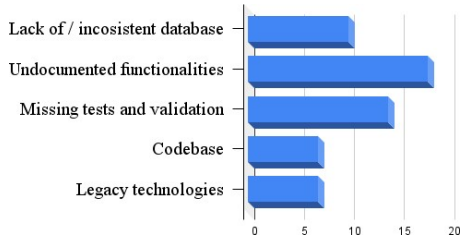

Fig. 6: Challenges encountered during system analysis

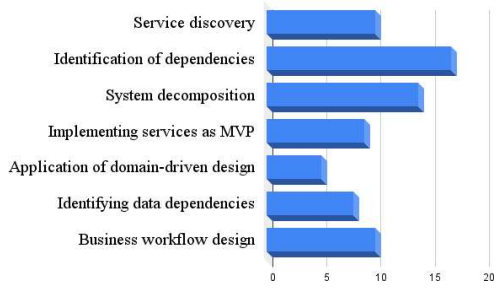

Fig. 7: Activities undertaken for designing the new system

By identifying dependencies early on in the migration process, teams can design and deploy microservices that are loosely coupled and can operate independently, which improves the overall resilience and scalability of the system. Additionally, identifying dependencies also allows teams to better manage and maintain the microservices, as they have a better understanding of how they interact with other parts of the system.

Participants were not only asked about the design of the new system but also about the impact on value delivery. In Fig. 8 we can see that 19 participants confirmed that they have implemented and delivered new functionalities during migration. Migration is not a fast process, therefore it is justifiable that new functionalities and features must be delivered while the migration is in process.

As a follow question, participants were also asked about the challenges encountered during the design phase. The results of the question are illustrated in Fig. 9. As illustrated lack of documentation of the existing system is the leading challenge with the highest number of occurrences during system design. The obtained result is consistent with the most selected challenge during the system analysis phase as well. At the same time, it is important to note that there are multiple answers referring to the identification of services, communication among them, and reducing coupling as well.

The following survey questions were focused on migration execution. Participants were asked about the processes they used for MSA adoption, where based on Fig. 10 we can see that the first-step approach was used by 8 participants, 4 of them used greenfield adoption, and 5 of them strangler pattern. It is important to note that none

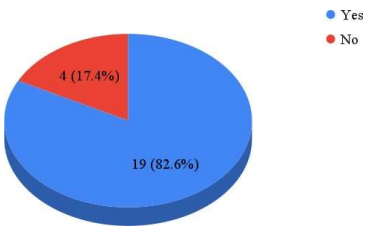

Fig. 8: New functionalities delivered during migration

of the participants used Bing Bang adoption. Migrating all services at once can lead to increased complexity and higher chances of errors. Consequently, participants were also asked about how they handled the existing data during the migration process. The results of the ways how data were handled during migration are illustrated in Fig. 11. Based on the illustrations, we can see that 18 of the participants migrated data to the new system, while 5 of them did not. Migrating data to a new system is important because it helps the organization improve its data management and storage capabilities.

To conclude the questions for this section, the survey participants were asked about the technical and organizational challenges during migration execution. As illustrated in Fig. 12 the main organizational challenge encountered is the lack of expertise/experienced resources with 16 occurrences, which challenge is encountered also during system design. Resistance to change is also a relevant challenge with 9 occurrences. We can clearly state that resistance to change is directly affected by the lack

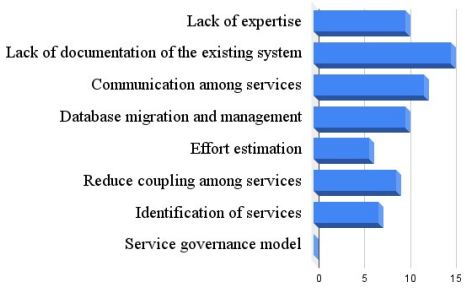

Fig. 9: Challenges encountered while designing the new system

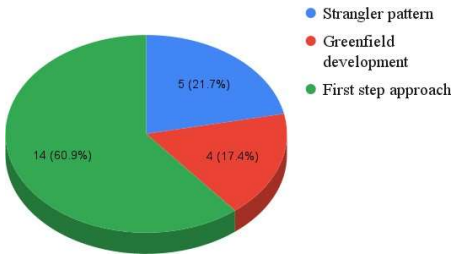

Fig. 10: Microservice adoption process

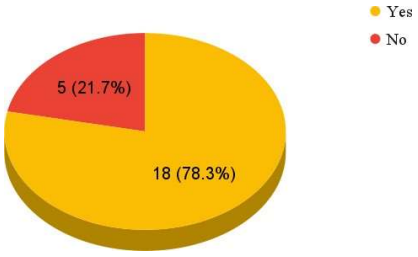

Fig. 11: Data migration

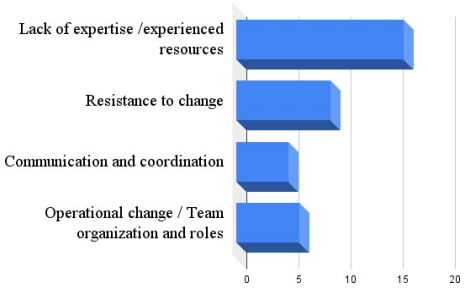

Fig. 12: Operational challenges during MSA adoption

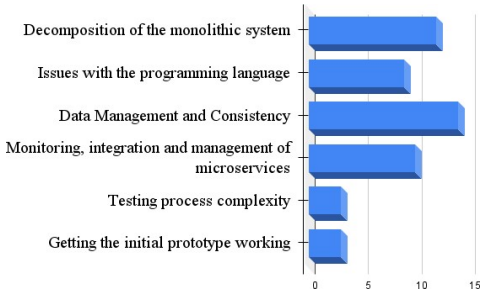

Fig. 13: Technical challenges during MSA adoption

of expertise because employees have difficulty adapting to the new system and processes.

Apart from that, other non-technical challenges that are worth mentioning include the organization of teams, role assignments, and communication/coordination between team members. Similar results are also reported in literature [17] [25] as well. On the other hand, the results of the question for technical challenges are illustrated in Fig. 13, which reveals that the most significant challenges encountered during MSA implementation were the decomposition of the monolithic system and managing data consistency and management. These challenges are consistent with those faced during the system design phase. Other challenges include monitoring, integration, and management of microservices, programming language issues, and the complexity of the testing process, with 10, 9, and 3 occurrences respectively for each challenge.

These results highlight that the migration process to MSA can indeed pose various challenges, therefore it is evident that the second hypothesis H2 is supported.

D. Migration Impact (RQ3).

We asked participants about the impact of adopting MSA and the perceived benefits of rearchitecting their systems. As seen previously, 5 of the participants had already completed the migration and 6 of them had made considerable progress and are able to evaluate the impact. The benefits of migrating to MSA are illustrated in Fig. 14. Based on the illustrations we can conclude that improved scalability is the most recognized improvement after MSA adoption with 17 occurrences, which is immediately followed by an improved performance with 15 occurrences.

Similar results are also reported in literature [31]. At the same time, it is important to mention that improved availability has 13 occurrences, while improved development velocity/team productivity has been selected 8 times. Improved maintainability and cost efficiency appear with 6 occurrences each and at the same time improved deployment velocity has 4 occurrences. Only 2 of the participants selected improved compliance while one of them stated that they are still at an early stage to recognize any benefits.

The survey results provide evidence that supports H3, indicating that the adoption of microservices architecture

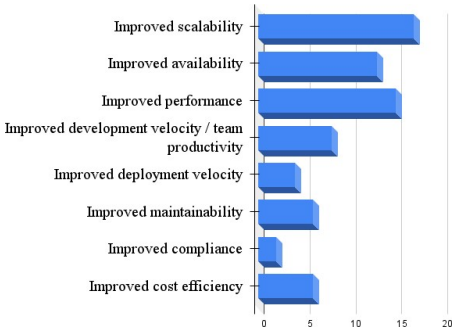

Fig. 14: Benefits of MSA adoption

offers benefits such as improved scalability, flexibility, fault isolation, and faster development and deployment cycles.

E. Correlation analysis of obtained results.

To gain a better understanding of the data collected through the survey, we used the Pearson correlation coefficient and heatmaps as analytical tools. Pearson correlation coefficient was used to measure the strength and direction of the relationships between the various factors related to migration, while heatmaps were used to visualize these correlations.

As seen in Fig. 15, from the heatmap, we are able to observe a positive correlation between the type of system to be migrated and the perceived benefits after migration. This indicates that the type of system has an impact on the perceived benefits of migration. Additionally, we found that the activities undertaken while designing the new system have a weak negative correlation with the challenges faced during migration, suggesting that these activities can influence the challenges faced during the migration process.

Regarding the correlation between migration delivery time and system type, we found a negative correlation, suggesting that the type of system to be migrated can have an impact on the estimated time it takes to complete the migration. On the other hand, the correlation coefficient between migration delivery time and challenges in designing the new system was weakly positive, indicating a positive relationship between the two variables. This

	System type	Sources to analyze current system	Activities while designing the new system	Challenges in designing the new system	Migration motivations	Migration delivery time vs Initial estimation	Technical challenges during migration	Perceived benefits after migration
System type	1.000	0.133	-0.086	-0.061	0.018	-0.178	-0.140	0.169
Sources to analyze current system	0.133	1.000	0.023	-0.046	-0.024	-0.059	-0.044	0.014
Activities while designing the new system	-0.086	0.023	1.000	0.005	-0.097	0.021	0.055	-0.012
Challenges in designing the new system	-0.061	-0.046	0.005	1.000	-0.033	-0.054	0.001	-0.008
Migration motivations	0.018	-0.024	-0.097	-0.033	1.000	-0.306	0.003	0.170
Migration delivery time vs Initial estimation	-0.178	-0.059	0.021	-0.054	-0.306	1.000	-0.129	-0.230
Technical challenges during migration	-0.140	-0.044	0.055	0.001	0.003	-0.129	1.000	-0.013
Perceived benefits after migration	0.169	0.014	-0.012	-0.008	0.170	-0.230	-0.013	1.000

Fig. 15: Correlation plot

suggests that challenges faced during the design of the new system may contribute to a longer delivery time than initially estimated.

The correlation coefficient between the motivations for migration and challenges in designing the new system is negative but weak, indicating that the motivations for migration may have an impact on the challenges faced during the design of the new system.

Finally, we found a weak positive correlation between technical challenges during migration and system type, indicating that the type of system being migrated may impact the technical challenges faced during migration. There is a weak positive correlation between technical challenges during migration and sources used to analyze the current system, suggesting that the sources used to analyze the current system may have an impact on the technical challenges faced during migration.

V. Threats to Validity

While the study contributes valuable insights into the challenges and benefits of MSA adoption, it also acknowledges several limitations that may affect the generalizability of the findings. Firstly, the small sample size of 23 industry practitioners may not fully represent the broader population of IT practitioners interested in MSA adoption. Secondly, the self-reported nature of the data may have introduced biases and may not accurately reflect the participants' actual experiences or behaviors. Thirdly, as the study only included industry practitioners, the experiences and backgrounds of the participants may not have been diverse enough to capture a broad range of perspectives on MSA adoption. While these limitations do not discredit the study's insights, they do highlight the need for further research that addresses these issues in different organizational and industry contexts.

VI. Conclusions and Future Work

Driven by the significance of microservices architecture, this study surveyed 23 industry practitioners to gain insights into their migration experiences, revealing the challenges, benefits, drivers, and issues related to the adoption process.

The study was guided by three hypotheses related to MSA adoption. First, H1 suggested that organizations adopt MSA to address issues related to scalability, complexity, and limited flexibility. Second, H2 suggested that the migration process to MSA poses various challenges, including system analysis and decomposition, new system design, prioritizing functionalities, and overcoming technical and organizational obstacles. Finally, H3 suggested that the adoption of MSA offers benefits such as improved scalability, flexibility, fault isolation, and faster development and deployment cycles. The survey results supported all three hypotheses, demonstrating that organizations are motivated to adopt MSA to overcome challenges related to system scalability, complexity, and limited flexibility and that the migration process to MSA is indeed challenging. Additionally, the results indicated that adopting MSA can offer significant benefits, such as improved scalability, flexibility, fault isolation, and faster development and deployment cycles.

Considering that decomposition of the monolithic system results to be a serious challenge during MSA adoption, as future work we aim to create a roadmap featuring timelines and milestones. This will be achieved through conducting case studies of organizations that have previously undergone MSA adoption and experienced similar challenges. By analyzing best practices and lessons learned, the roadmap will offer a clear and detailed migration plan, ensuring the project's progress remains on track and on schedule.

References

[1] D. Taibi, V. Lenarduzzi and C. Pahl, "Processes, Motivations, and Issues for Migrating to Microservices Architectures: An Empirical Investigation," in IEEE Cloud Computing, vol. 4, no. 5, pp. 22-32, September/October 2017, doi: 10.1109/MCC.2017.4250931.

[2] P. Di Francesco, P. Lago and I. Malavolta, "Migrating Towards Microservice Architectures: An Industrial Survey," 2018 IEEE International Conference on Software Architecture (ICSA), Seattle, WA, USA, 2018, pp. 29-2909, doi: 10.1109/ICSA.2018.00012.

[3] F. Auer, V. Lenarduzzi, M. Felderer, D. Taibi, "From monolithic systems to Microservices: An assessment framework," Information and Software Technology, Volume 137, 2021, 106600, ISSN 0950-5849, doi: 10.1016/j.infsof.2021.106600.

[4] F. Ponce, G. Márquez and H. Astudillo, "Migrating from monolithic architecture to microservices: A Rapid Review," 2019

38th International Conference of the Chilean Computer Science Society (SCCC), Concepcion, Chile, 2019, pp. 1-7, doi: 10.1109/SCCC49216.2019.8966423.

[5] J. Lewis and M. Fowler, “Microservices. A definition of this new architectural term.” https://martinfowler.com/articles/microservices.html.

[6] M. Cardarelli, L. Iovino, P. D. Francesco, A. D. Salle, I. Malavolta, and P. Lago, An extensible data-driven approach for evaluat- ing the quality of microservice architectures. Proceedings of the 34th ACM/SIGAPP Symposium on Applied Computing, 2019, https://doi.org/10.1145/3297280.3297400

[7] P. D. Francesco, I. Malavolta and P. Lago, "Architecting with microservices: A systematic mapping study," Journal of Systems and Software, 2019, 150, 77-97, doi:10.1016/j.jss.2019.01.001

[8] G. Blinowski, A. Ojdowska and A. Przybyłek, "Monolithic vs. Microservice Architecture: A Performance and Scalability Evaluation," in IEEE Access, vol. 10, pp. 20357-20374, 2022, doi: 10.1109/ACCESS.2022.3152803.

[9] A. Razzaq, and S. A.Ghayyur, "A systematic mapping study: The new age of software architecture from monolithic to microservice architecture—awareness and challenges," Computer Applications in Engineering Education, 2022, doi:10.1002/cae.22586

[10] A. Balalaie, A. Heydarnoori, P. Jamshidi, D. A. Tamburri, and T. Lynn, "Microservices Migration Patterns. Software: Practice and Experience," 2018, doi:10.1002/spe.2608

[11] N. Bjørndal, , L. J. P. D. Araújo, A. Bucchiarone, N. Dragoni, and M. Mazzara, "Benchmarks and performance metrics for assessing the migration to microservice-based architectures". Journal of Object Technology. 10.5381/jot.

[12] M. Kalske, N. Mäkitalo, and T. Mikkonen, "Challenges when moving from Monolith to Microservice Architecture," Current Trends in Web Engineering, 2018, 32-47. doi:10.1007/978-3-319-74433-9-3

[13] A. Carrasco, B.V. Bladel, and S. Demeyer, "Migrating towards microservices: Migration and architecture smells," Proceedings of the 2nd International Workshop on Refactoring, 2018, doi:10.1145/3242163.3242164

[14] R. Capuano and H. Muccini, "A Systematic Literature Review on Migration to Microservices: a Quality Attributes perspective," 2022 IEEE 19th International Conference on Software Architecture Companion (ICSA-C), Honolulu, HI, USA, 2022, pp. 120-123, doi: 10.1109/ICSA-C54293.2022.00030.

[15] D. Faustino, N. Gonçalves, M. Portela, and A. R. Silva, "Stepwise Migration of a Monolith to a Microservices Architecture: Performance and Migration Effort Evaluation," 2022, doi:10.48550/ARXIV.2201.07226

[16] H. Dinh-Tuan and F. Beierle, "MS2M: A message-based approach for live stateful microservices migration," 2022 5th Conference on Cloud and Internet of Things (CIoT), Marrakech, Morocco, 2022, pp. 100-107, doi: 10.1109/CIoT53061.2022.9766576.

[17] J. Fritzsch, J. Bogner, S. Wagner and A. Zimmermann, "Microservices Migration in Industry: Intentions, Strategies, and Challenges," 2019 IEEE International Conference on Software Maintenance and Evolution (ICSME), Cleveland, OH, USA, 2019, pp. 481-490, doi: 10.1109/ICSME.2019.00081.

[18] A. Furda, C. Fidge, O. Zimmermann, W. Kelly and A. Barros, "Migrating Enterprise Legacy Source Code to Microservices: On Multitenancy, Statefulness, and Data Consistency," in IEEE Software, vol. 35, no. 3, pp. 63-72, May/June 2018, doi: 10.1109/MS.2017.440134612.

[19] J. -P. Gouigoux and D. Tamzalit, "From Monolith to Microservices: Lessons Learned on an Industrial Migration to a Web Oriented Architecture," 2017 IEEE International Conference on Software Architecture Workshops (ICSAW), Gothenburg, Sweden, 2017, pp. 62-65, doi: 10.1109/ICSAW.2017.35.

[20] M. Kyryk, O. Tymchenko, N. Pleskanka and M. Pleskanka, "Meth- ods and process of service migration from monolithic architecture to microservices," 2022 IEEE 16th International Conference on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TCSET), Lviv-Slavske, Ukraine, 2022, pp. 553-558, doi: 10.1109/TCSET55632.2022.9767055.

[21] J. P. Delgado Preti, A. N. Araújo Souza, E. C. Freiberger and T. De Almeida Lacerda, "Monolithic to Microservices Migration Strategy in Public Safety Secretariat of Mato Grosso," 2021 International Conference on Electrical, Communication, and Computer Engineering (ICECCE), Kuala Lumpur, Malaysia, 2021, pp. 1-5, doi: 10.1109/ICECCE52056.2021.9514268.

[22] P. Raj, S. Vanga; A. Chaudhary, "Microservices Security," in Cloud- native Computing: How to Design, Develop, and Secure Microser- vices and Event-Driven Applications , IEEE, 2023, pp.289-298, doi: 10.1002/9781119814795.ch14.

[23] P. Raj, S. Vanga and A. Chaudhary, "Design, Development, and Deployment of Event-Driven Microservices Practically," in Cloud-native Computing: How to Design, Develop, and Secure Microservices and Event-Driven Applications , IEEE, 2023, pp.129-142, doi: 10.1002/9781119814795.ch7.

[24] P. Raj, S. Vanga and A. Chaudhary, "Kubernetes Architecture, Best Practices, and Patterns," in Cloud-native Computing: How to Design, Develop, and Secure Microservices and Event-Driven Applications , IEEE, 2023, pp.49-70, doi: 10.1002/9781119814795.ch3.

[25] Z. Ren, W. Wang, G. Wu, C. Gao, W. Chen, J. Wei, and T. Huang, "Migrating web applications from monolithic structure to microservices architecture", Proceedings of the Tenth Asia-Pacific Symposium on Internetware, 2018, doi:10.1145/3275219.3275230

[26] Y. Romani, O. Tibermacine and C. Tibermacine, "Towards Migrating Legacy Software Systems to Microservice-based Architectures: a Data-Centric Process for Microservice Identification," 2022 IEEE 19th International Conference on Software Architecture Companion (ICSA-C), Honolulu, HI, USA, 2022, pp. 15-19, doi: 10.1109/ICSA-C54293.2022.00010.

[27] E. Rubio-Drosdov, "A Framework for Microservice Migration and Performance Assesment", Intelligent Environments 2020 Workshop Proceedings of the 16th International Conference on Intelligent Environments, doi:10.3233/AISE200053

[28] N. Santos and A. Rito Silva, "A Complexity Metric for Microservices Architecture Migration," 2020 IEEE International Conference on Software Architecture (ICSA), Salvador, Brazil, 2020, pp. 169-178, doi: 10.1109/ICSA47634.2020.00024.

[29] A. Selmadji, A. -D. Seriai, H. L. Bouziane, R. Oumarou Mahamane, P. Zaragoza and C. Dony, "From Monolithic Architecture Style to Microservice one Based on a Semi-Automatic Approach," 2020 IEEE International Conference on Software Architecture (ICSA), Salvador, Brazil, 2020, pp. 157-168, doi: 10.1109/ICSA47634.2020.00023.

[30] H. H. S. D. Silva, G. Carneiro, and M. P. Monteiro, "An experience report from the migration of Legacy Software Systems to Microservice based architecture," 16th International Conference on Information Technology-New Generations (ITNG 2019), 183-189. doi:10.1007/978-3-030-14070-0-26

[31] P. Yugopuspito, F. Panduwinata and S. Sutrisno, "Microservices architecture: Case on the migration of reservation-based parking system," 2017 IEEE 17th International Conference on Communication Technology (ICCT), Chengdu, China, 2017, pp. 1827-1831, doi: 10.1109/ICCT.2017.8359946.

[32] J. Linåker, S. M. Sulaman, R. M. de Mello and M. Höst, "Guidelines for Conducting Surveys in Software Engineering," Department of Computer Science, Lund University, 2015.

[33] N. Tankovi ć, T. G. Grbac, H. -L. Truong and S. Dustdar, "Trans- forming Vertical Web Applications into Elastic Cloud Applica- tions," 2015 IEEE International Conference on Cloud Engineering, Tempe, AZ, USA, 2015, pp. 135-144, doi: 10.1109/IC2E.2015.15.

[34] N. Tankovi ć, T. G. Grbac, M. Žagar, "ElaClo: A framework for optimizing software application topology in the cloud environment," Expert Systems with Applications, Volume 90, 2017, Pages 62-86, ISSN 0957-4174, doi: 10.1016/j.eswa.2017.07.001.