Evaluating Custom ArcMap Tools for Migration to ArcGIS Pro

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Capstone in GIS

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Introduction

Esri, a global leader in GIS software, is phasing out its ArcMap desktop GIS software over the next two years which has important implications for organizations who have invested substantial development work into custom tools for ArcMap. In Esri's newer desktop GIS software, ArcGIS Pro, custom functionality is accomplished through various low or no-code options or through more development-heavy add-in tools using the ArcGIS Pro SDK for .NET. There is a lack of research and guidance on the process of evaluating and migrating custom ArcMap tools to ArcGIS Pro, despite existing research on user-centered design of GIS tools, utilizing user stories to build effective products based on user needs, and developing add-in tools for ArcGIS Pro. Such a process should consider not just redeveloping existing custom ArcMap tools as is, but undertaking a full review of existing tools to understand present day user needs and whether the functionality can be accomplished in other ways. Taking the time to evaluate the existing tools first may reduce the number of custom solutions that need to be developed for ArcGIS Pro and save organizations both time and money. This capstone project research employs a case study approach to evaluate the tools within a custom ArcMap toolbar developed by GeoSolutions, a private GIS consulting firm, for migration to ArcGIS Pro and outlines a framework to follow for organizations looking to migrate their custom tools to ArcGIS Pro.

Literature Review

Customization Options in ArcGIS Pro

All customization and extensibility options should be considered when looking to develop custom functionality for ArcGIS Pro. Esri recommends a "configure first, customize only if you have to" principle for ArcGIS Pro. Options for a more customized experience in ArcGIS Pro include ArcGIS Pro Tasks, Python scripts and script tools, which can be easily migrated from ArcMap, attribute rules, as well as Workflow Manager. When a more customized solution is needed, the ArcGIS Pro SDK for .NET offers a modern framework for extending ArcGIS Pro's functionality with add-in tools (Mounzer, 2015).

Add-in tools developed with the ArcGIS Pro SDK for .NET are written in C#, the native coding language for ArcGIS Pro, resulting in faster and more efficient performance compared to tools written in Python, which is a common coding language for developing GIS tools according to previous research (Manchado et al., 2021). However, it is not possible to simply migrate custom ArcMap tools built with ArcObjects to ArcGIS Pro add-in tools, so the functionality would need to be redeveloped for ArcGIS Pro using the ArcGIS Pro SDK for .NET when other customization options do not meet a user's needs (Mounzer, 2015). Therefore, organizations need to evaluate their custom ArcMap tools and determine if the low or no-code customization options in ArcGIS Pro meet their needs for custom solutions or if the custom ArcMap functionality needs to be re-developed using the ArcGIS Pro SDK for .NET.

Custom Tool Development in ArcGIS Pro

Most research involving ArcGIS Pro add-in tools written with the ArcGIS Pro SDK for .NET focuses on the functionality of the tools and their applications to a certain field of study rather than the development process for the tool. Manchado et al. (2021) developed an ArcGIS Pro add-in tool for calculating surface runoff in urban areas and focused most of their study on the functionality of the tool. Ahmari et al. (2022) described a process for developing an ArcGIS Pro add-in tool for analyzing the effects of bridge construction on soil erosion and focused on the functionality of the tool and the method for calculating soil erosion, similar to how Manchado et al. (2021) focused on the math and functionality behind the tools in their add-in for hydrology applications.

Šercl et al. (2022) described four practical examples of applications of GIS to the field of hydrology at the Czech Hydrometeorological Institute. One example involves the use of scripting languages to build custom hydrology tools for ArcGIS desktop products. The first version of the tool was

developed for ArcView GIS 3.x, the second version was developed for ArcGIS Desktop (ArcMap), and the current version of the tool was developed for ArcGIS Pro with the ArcGIS Pro SDK for Microsoft .NET. While the authors outlined the progression of tools built for different ArcGIS products, they did not describe the evaluation of existing tools for migration, user needs analysis, or process of developing tools for ArcGIS Pro, similar to the previous authors.

User-Centered Design in GIS

Research seems to agree that user-centered design is an important part of developing GIS tools and Agile user stories are often used to capture end users' needs. A user story brings end users to the center of the conversation by using informal and non-technical descriptions of a software feature to express how it will bring value to the end user. User stories help software development teams understand what they are building, why they are building it, and the value that it adds for the end user (Rehkopf, n.d.). Kammerhofer and Scholz (2020) used Agile user stories to build a GIS web application with tools based on user workflows and then evaluated whether there were differences in user experience between using a desktop GIS program and a GIS web application with a simpler set of tools.

Similarly, Aguilar et al. (2020) described a process for working with end users to conceptualize a new mapping tool and developed Agile user stories from that process. In their study on the usability of GIS, Brown et al. (2013) noted that well-designed GIS data, as well as tools used to edit and manipulate GIS data, allow users to complete tasks effectively (making the correct decision of which tools to use and in which order to use them), efficiently (timely and with minimal errors), and with satisfaction (for example, the user interface should not be frustrating to use and the user guide should be easy to understand). While these criteria for well-designed GIS tools are generalized, they underscore the importance of involving end users from the beginning as the effectiveness, efficiency, and usability of the product will depend on the details in the user stories.

Research establishes that meaningful feedback must be collected from end users to build effective user stories. Karlovska et al. (2023) employed user-centered design processes to create a redesign of an open-source GIS user interface. While the research focused on open-source GIS software, the user-centered design process and methods are still relevant and useful as a basis for developing methods for the redesign process for migrating custom ArcMap tools to ArcGIS Pro. The authors used multiple response types on their questionnaires including multiple choice and some open-ended responses which were aggregated and grouped based on their similarity.

Zápotocký and Koreň (2022) also analyzed end user requirements to design a new web-based GIS portal for forest research and management. An anonymous questionnaire was given to four end user groups who reviewed a prototype portal and were then asked to rate the importance of different GIS functions according to their needs. The collected data was used to develop a final version of the portal.

To aid in building user stories, focus groups are often used to collect data from a group of people quickly and effectively. Compared to surveys, focus groups allow for the clarification of responses and follow-up questions and for participants to react to and build on the responses of other participants. However, focus groups can also include limitations. Dominant participants may introduce biased responses, especially if more reserved participants are less willing to talk, the moderator may introduce bias through questions or probing, and open-ended responses may be more difficult to summarize and interpret. Despite potential limitations, focus groups can be useful as evaluative tools for confirming hypotheses. For example, product designers often have a general understanding of what their clients want and focus groups can be employed to evaluate the reality of their assumptions (Stewart et al., 2007). Focus groups are therefore an ideal method for evaluating user needs around migrating custom ArcMap tools to ArcGIS Pro.

Data

There is a lack of research on an effective process for evaluating and migrating custom tools from ArcMap to ArcGIS Pro and this capstone project research aims to fill that gap by outlining a framework for evaluating custom ArcMap tools following user-centered design methods. The primary data for this study included the tools presently in GeoSolutions' custom ArcMap toolbar and did not consider new tool needs for ArcGIS Pro, although that is an important topic for future study. GeoSolutions' custom ArcMap toolbar was originally developed around 20 years ago and contains tools for editing, quality control, visualization, and other specialized processes specific to the organization's GIS workflows. Additional data used for evaluating the custom ArcMap tools for migration to ArcGIS Pro include: 1) tools in GeoSolutions' web-based GIS quality control system, 2) editing and geoprocessing tools available from Esri in ArcGIS Pro, and 3) attribute rule functionality available in ArcGIS Pro. The final set of data for the analysis included transcripts from focus group sessions with end users at GeoSolutions.

Methodology

This capstone project research evaluated GeoSolutions' custom tools via a multi-step approach, the first of which was to understand if GeoSolutions' custom ArcMap tools are still relevant to users' workflows. The secondary data was then used to evaluate if the functionality can be accomplished in other ways including through GeoSolutions' web-based quality control system, with existing tools available from Esri in ArcGIS Pro, or via attribute rules in ArcGIS Pro. Questions from this initial evaluation were then reviewed with a focus group made up of GeoSolutions employees to collect end user feedback on migrating the custom ArcMap tools to ArcGIS Pro. The results were aggregated to form a comprehensive overview of user needs and identify whether custom functionality needs to be developed in ArcGIS Pro for each custom ArcMap tool.

A Lenovo laptop meeting Esri's ArcGIS Pro 3.0 system requirements with the Microsoft Windows 11 operating system was used for the analysis. Microsoft Excel was used for documenting existing tools and the results of the research. Mapping platforms and applications used in the analysis include Esri ArcMap 10.8.2, GeoSolutions' custom ArcMap Toolbar for ArcMap 10.8.2, and Esri ArcGIS Pro 3.2. OpenAI's ChatGPT-4 chat box was used for assistance with the researching the four evaluation criteria for each custom ArcMap tool. Microsoft Teams was used to conduct remote focus group sessions and to record the meetings. Transcripts of the recordings were auto generated through Microsoft Stream's transcription feature and cleaned and categorized in Microsoft Word.

Each tool in GeoSolutions' custom ArcMap toolbar was documented in a column in a Microsoft Excel spreadsheet. Seventy-five distinct tools were documented for review. Toolbar functionalities not directly related to editing or manipulating GIS data were not included in the analysis, such as functionality for field mapping and opening the help guide.

Each custom ArcMap tool was evaluated against four criteria. Columns were added to the spreadsheet to track the results of the evaluation criteria and if a clear result could not be determined or more feedback was necessary, the custom ArcMap tool was marked to be reviewed further in the focus group sessions. The four evaluation criteria for the research include:

1. **Relevance to Workflows:** Is the functionality still relevant for current GIS data standards and workflows?
2. **GeoSolutions QC:** Is there equivalent functionality in GeoSolutions' web-based GIS quality control system?
3. **Esri Tool:** Is there an equivalent Esri tool in ArcGIS Pro?
4. **Attribute Rules:** Can the functionality be accomplished via attribute rules in ArcGIS Pro? (If an existing attribute rule was available from Esri, it was also tracked in the Esri Tool column)

Evaluation Criterion 1: Relevance to GeoSolutions' Workflows

First, each custom ArcMap tool was reviewed to determine if the functionality is still relevant to current GIS data standards and workflows used by GeoSolutions. The results of this initial review were documented in the Relevance to Workflows column in the spreadsheet. 38 of the custom ArcMap tools were determined to be relevant to GeoSolutions workflows, 24 were not relevant, and 13 were marked for further review in the focus group, as shown in Table 1.

Table 1. Summarized results from the first evaluation criterion to determine if each custom ArcMap tool is still relevant to GeoSolutions' current GIS data standards and workflows.

Criterion 1: Relevance to GeoSolutions' Workflows	
Result	**Count**
Yes	38
No	24
Need Feedback from Focus Group	13
Total	**75**

Evaluation Criterion 2: Equivalent Functionality in GeoSolutions' Web-Based QC System

Second, each custom ArcMap tool was reviewed against the available quality control tools from GeoSolutions' web-based GIS quality control system and if the functionality exists in the system, the tool name was listed in the GeoSolutions QC column in the spreadsheet. While the custom ArcMap toolbar contains tools to run on-the-fly quality control on selected features in a map, the web-based quality control system allows for comprehensive quality control to be performed on whole datasets on an ongoing basis.

If there was uncertainty about whether the quality control tool from the web-based system accomplishes the same functionality as the custom ArcMap quality control tool, it was marked for further review with the focus group. The overall topic was also marked for further review with the focus group to learn more about user needs for on-the-fly quality control tools in ArcGIS Pro. 14 custom ArcMap tools were found to have equivalent functionality in GeoSolutions' web-based GIS quality control system, 59 tools were found not to have equivalent functionality, and 2 were marked as needing additional feedback from the focus group, as shown in Table 2. The large number of custom ArcMap tools that do not have equivalent functionality in the web-based system are mainly due to a difference in fundamental functionality of some of the tools, as GeoSolutions' web-based system primarily contains quality control tools and is not designed for GIS editing tasks.

Table 2. Summarized results from the second evaluation criterion to determine if the functionality of each custom ArcMap tool can be accomplished via GeoSolutions' web-based quality control system.

Criterion 2: Equivalent Functionality in GeoSolutions' Web-Based Quality Control System	
Result	**Count**
Yes	14
No	59
Need Feedback from Focus Group	2
Total	**75**

Evaluation Criterion 3: Equivalent Esri Functionality in ArcGIS Pro

Third, multiple reference sources were used to determine whether each custom ArcMap tool has a comparable tool available from Esri in ArcGIS Pro. Sources referenced include Esri documentation and

code snippets on GitHub, Esri Community and GIS Stack Exchange forums, and using OpenAI's ChatGPT chatbot (using the GPT-4 model) to assist with identifying available ArcGIS Pro tools. Editing tools, geoprocessing tools, existing attribute rules available in Esri's Address Data Management Solution, and any other tools or general functionality available in ArcGIS Pro were considered.

For example, ArcGIS Pro has edit tracking capability that accomplishes the same functionality as the custom ArcMap toolbar's edit tracking functionality, so this tool was marked as having a comparable Esri tool. If necessary, Esri tools were also tested in ArcGIS Pro to confirm if they meet end user needs. If it was determined the Esri tool only partially accomplishes the same functionality as the custom ArcMap tool, it was marked for further review with the focus group. Results from this step were documented in the Esri Tool column in the spreadsheet. 35 custom ArcMap tools were found to have equivalent functionality in ArcGIS Pro, 37 tools were found not to have equivalent functionality, and 3 were marked as needing additional feedback from the focus group, as shown in Table 3.

Table 3. Summarized results from the third evaluation criterion to determine if each custom ArcMap tool has a comparable tool available from Esri in ArcGIS Pro.

Criterion 3: Equivalent Functionality Available in ArcGIS Pro	
Result	**Count**
Yes	35
No	37
Need Feedback from Focus Group	3
Total	**75**

Evaluation Criterion 4: Attribute Rules in ArcGIS Pro

Finally, each custom ArcMap tool was evaluated to determine if it can be accomplished via attribute rules in ArcGIS Pro. Attribute rules are defined in feature classes using Esri Arcade expressions and run when pre-defined editing conditions are met, such as when features are created, edited, or deleted. Attribute rule types include calculation rules to keep attributes up to date while editing, constraint rules to prevent users from making mistakes in the first place, batch rules to mass populate attributes in features, and validation rules to run quality control checks. Attribute rules provide custom functionality to native ArcGIS Pro editing processes and could be used as an alternative to more programming-intensive options for custom functionality such as add-in tools written with the ArcGIS Pro SDK for .NET.

While more research is needed on whether attribute rules would be a viable alternative to other customization options, initial research and testing was conducted to understand which custom ArcMap tools could potentially be developed as attribute rules in ArcGIS Pro. Esri documentation and GIS forums were again consulted, and multiple prototype attribute rules were developed to test the feasibility of using attribute rules in ArcGIS Pro to replace custom ArcMap functionality. Existing attribute rules available in Esri's Address Data Management Solution were also considered in this step.

The results were documented in the Attribute Rule column in the spreadsheet and research notes on the type of attribute rule, triggers for running the attribute rule, and any other functionality notes learned from the process were documented in an additional notes column for future reference. Initial research found that attribute rules in ArcGIS Pro could be a viable solution for 22 custom ArcMap tools, while 48 custom ArcMap tools could not be accomplished via attribute rules, and 5 custom ArcMap tools were marked for further review with the focus group or for further research and testing, as shown in Table 4. The general topic of using attribute rules to replace standalone tool functionality was also marked for further review with the focus group to get feedback from end users.

Table 4. Summarized results from the fourth evaluation criterion to determine if the functionality of each custom ArcMap tool can be accomplished via attribute rules in ArcGIS Pro.

Criterion 4: Functionality Can Be Accomplished via Attribute Rules in ArcGIS Pro	
Result	**Count**
Yes	22
No	48
Need Feedback from Focus Group or More Research	5
Total	**75**

User Needs Analysis

While useful data was gathered for each custom ArcMap tool in the first phase of the research, user needs and feedback are also important components of developing effective tools. The next phase of the research involved examining the custom ArcMap tools marked for further review across the four evaluation criteria with end users from GeoSolutions to gain a comprehensive understanding of user needs for tools in ArcGIS Pro. Focus group questions were designed based on the individual custom ArcMap tools marked for review and the broader questions of whether on-the-fly quality control tools are necessary to have in ArcGIS Pro and whether custom functionality developed as attribute rules would meet user needs compared to standalone tools such as add-in tools.

Managers from two GIS teams at GeoSolutions each chose two GIS specialists from their team to participate in the focus group. A third GIS team has limited experience with the custom ArcMap tools so the manager of the team, who does have experience with the tools, chose to participate, and the manager from the project management team chose two project managers to participate for a total of seven participants and one moderator. The average years of experience working at GeoSolutions among the participants was 7 years and 8 months. The longest tenure at GeoSolutions among participants was 17 years, the median tenure was 8 years, and the shortest tenure was 3 years. All participants were selected for their familiarity with the custom ArcMap tools and standard workflows for their team.

Three 1-hour long focus group sessions were scheduled with the participants within a time-period of four business days. The focus groups were conducted remotely via Microsoft Teams and were recorded. At the beginning of the first focus group, each participant introduced themselves, the team they were representing, and the number of years they have worked at GeoSolutions. The purpose of the focus group sessions, ground rules, and results of the initial background research were presented to participants. Two opening questions were asked of participants including “What has your experience been like learning ArcGIS Pro and using it for daily work?” and “What is your biggest barrier to using ArcGIS Pro or using it regularly?”. The answers to these questions do not directly answer the main research questions about the custom ArcMap tools but were used to gauge the participants’ experience with ArcGIS Pro and understanding of the reasons for using ArcMap or ArcGIS Pro for their work.

Following the opening questions, the main research questions were presented to the participants by the moderator to gather feedback on evaluating the custom ArcMap tools for migration to ArcGIS Pro. All participants were given an opportunity to respond and were encouraged to provide additional feedback or respond to follow-up questions when needed. For some of the questions, it was determined that additional feedback beyond the focus group and current participants was necessary. Participants identified subject matter experts for the workflows in question and short follow-up interviews were conducted with the subject matter experts to gather additional feedback on end users needs for custom tools in ArcGIS Pro and the interviews were recorded.

After all questions were asked in the final focus group session, participants were asked to respond to two closing questions, including “Is there anything that you feel is important that we missed

in regard to the topics covered in these focus group sessions?" and "Are there any other points you'd like to make?" to ensure end users had the opportunity to provide any additional feedback.

Following the conclusion of the focus group sessions, transcripts of the three recorded meetings were automatically generated via Microsoft Stream and downloaded in Microsoft Word format. The transcripts were individually pared down to the relevant discussions and edited for clarity. All names and potentially identifying information were removed to ensure anonymity for the participants. Headers were added to Word document to differentiate each question and relevant discussion points were added to bullet points under each header. The user feedback from each question was analyzed for themes and further divided into categorized sections. Finally, the user feedback was summarized and documented in the spreadsheet for future reference to provide support to any decisions made about the custom ArcMap tools.

Results

The four evaluation criteria columns were updated to reflect the data gathered from the user feedback for each custom ArcMap tool, as the goal of the focus group sessions was to gain consensus on questions relating to evaluating the custom ArcMap tools for migration to ArcGIS Pro. The summarized results of the four evaluation criteria from before the focus group sessions are shown in Table 5 and the results from after the focus group sessions are shown in Table 6. Three result categories were used to define the custom ArcMap tools prior to the focus group sessions including "Yes", "No", and "Maybe: Need user feedback". Following the focus group sessions, four result categories were used including "Yes", "No", "Nice to have but not critical", and "needs more research".

The number of custom ArcMap tools determined to be relevant to GeoSolutions' workflows increased from 38 to 45 after the focus group sessions were conducted, meaning that users confirmed these tools are still relevant to their workflows. Custom ArcMap tools determined not to be relevant to GeoSolutions' workflows also increased after the focus group sessions from 24 to 26, and 4 custom ArcMap tools were determined to be nice to have but not critical to user workflows.

The number of custom ArcMap tools determined to have equivalent functionality in GeoSolutions' web-based quality control system increased from 14 to 16 after discussing with focus group participants and learning more about the functionality available in the system, while the number of tools without equivalent functionality stayed the same at 59. The 2 custom ArcMap tools marked for further review for this evaluation criterion were resolved via the focus group sessions and no tools were marked as needing further research after the focus group sessions were conducted.

35 custom ArcMap tools were determined to have equivalent tools in ArcGIS Pro prior to the focus group sessions, and this number increased to 38 after discussing with end users from GeoSolutions and determining that certain tools available from Esri in ArcGIS Pro do meet their needs. The number of custom ArcMap tools without equivalent functionality available in ArcGIS Pro stayed the same at 37, and the 3 tools marked as needing further review were resolved through discussions with the focus group participants.

The 22 custom ArcMap tools that can be accomplished via attribute rules in ArcGIS Pro stayed the same after the focus group sessions, as did the 48 tools that cannot be accomplished via attribute rules and the 5 tools that require further research to determine if they can be accomplished via attribute rules. Focus group participants were asked whether attribute rules seem like a user-friendly and viable replacement for standalone tools and it was determined that more research is needed on the viability of attribute rules for this purpose, but knowing which custom ArcMap tools could be accomplished via attribute rules in ArcGIS Pro will be useful for GeoSolutions in the future if they decide to use attribute rules to replicate some of the custom ArcMap tool functionality.

The results show that the focus group sessions were an effective method for resolving questions about the four evaluation criteria for the custom ArcMap tools that were marked for further review, with only minimal number of custom ArcMap tools requiring further research to definitively determine if they meet the evaluation criteria.

Table 5. Summarized results of GeoSolutions' custom ArcMap tools for the four evaluation criteria, prior to conducting the focus group sessions.

Evaluation Criteria Results: Before Conducting Focus Group Sessions				
Result	**Relevant to GeoSolutions' workflows?**	**Equivalent Functionality in GeoSolutions' Web-Based QC System?**	**Equivalent functionality in ArcGIS Pro?**	**Accomplished via attribute rules in ArcGIS Pro?**
Yes	38	14	35	22
No	24	59	37	48
Maybe: Need user feedback	13	2	3	5
Total	**75**	**75**	**75**	**75**

Table 6. Summarized results of GeoSolutions' custom ArcMap tools for the four evaluation criteria, after conducting the focus group sessions.

Evaluation Criteria Results: After Conducting Focus Group Sessions				
Result	**Relevant to GeoSolutions' workflows?**	**Equivalent Functionality in GeoSolutions' Web-Based QC System?**	**Equivalent functionality in ArcGIS Pro?**	**Accomplished via attribute rules in ArcGIS Pro?**
Yes	45	16	38	22
No	26	59	37	48
Nice to have but not critical	4	0	0	0
Needs more research	0	0	0	5
Total	**75**	**75**	**75**	**75**

Finally, the results of the four evaluation criteria and supporting user feedback were used to establish whether custom functionality needs to be developed in ArcGIS Pro for each custom ArcMap tool. Seven result codes were defined, and the results were documented in a new column in the spreadsheet. The summarized results are shown in Table 7.

Six custom ArcMap tools need additional research before a decision can be made about whether GeoSolutions may need to develop custom functionality for them in ArcGIS Pro. More research and testing of functionality within GeoSolutions' web-based quality control system or functionality available from Esri in ArcGIS Pro is necessary to determine if comparable tools meet user needs.

Six of the custom ArcMap tools can be accomplished via GeoSolutions' web-based quality control system, confirming that it is not necessary to have a tool in ArcGIS Pro for these tasks. Another 10 of the custom ArcMap tools can be accomplished via GeoSolutions' web-based quality control system but through talking with end users from GeoSolutions, it was determined that it would be helpful to have on-the-fly quality control tools in ArcGIS Pro for these custom ArcMap tools. Users felt that it would

be useful, but not necessarily critical, to be able to run quality control checks on subsets of data when needed, as opposed to always having to package the GIS data and run comprehensive quality control on the whole dataset via the web-based quality control system. If a decision is made by GeoSolutions that custom tools for on-the-fly quality control should be developed for ArcGIS Pro, the data gathered in this phase of the research can be used for prioritization purposes, as functionality that cannot be accomplished through other methods may take priority to be developed for ArcGIS Pro first over functionality that can be accomplished through other methods.

The results show that 4 of the custom ArcMap tools would be nice to have for occasional unique workflows, but not critical based on standard workflows. Knowing that the tools are not critical to have in ArcGIS Pro, these could also be marked as a lower priority for development of custom tools in ArcGIS Pro.

The findings indicate that users can confidently rely on comparable Esri tools available in ArcGIS Pro to accomplish the same functionality as 12 of the custom ArcMap tools and that developing custom functionality in ArcGIS Pro for these custom ArcMap tools is unnecessary, saving time and software development resources. On the other hand, the evidence suggests that 8 of the custom ArcMap tools do require custom solutions to be developed in ArcGIS Pro, as the functionality for these tools is still relevant to users' workflows and no other existing functionality meets user needs. Finally, the findings confirm that the remaining 29 custom ArcMap tools do not need to be developed or considered in ArcGIS Pro as they are no longer relevant to user workflows.

For the custom ArcMap tools identified as needing custom tools developed for ArcGIS Pro, initial considerations for the format of the custom tool were documented in the spreadsheet, but further research will be necessary to determine the final format for each custom tool developed for ArcGIS Pro. For example, many of the custom ArcMap tools could be accomplished via attribute rules in ArcGIS Pro, but additional research and end user feedback is needed on attribute rules to determine if they are a viable replacement for standalone tools such as add-in tools.

Table 7. Summarized results of whether custom functionality needs to be developed in ArcGIS Pro for GeoSolutions' custom ArcMap tools.

Custom Functionality for ArcGIS Pro Results	
Result	**Count**
More research needed	6
Use GeoSolutions' web-based quality control system	6
Can use GeoSolutions' web-based quality control system, but would be nice to have a tool in ArcGIS Pro	10
Nice to have but not critical	4
Use Esri tool	12
Yes	8
No	29
Total	**75**

Discussion

The results underscore the advantages of evaluating custom ArcMap tools prior to migration to ArcGIS Pro. Some of the custom ArcMap tools developed years ago are no longer relevant to user workflows and some of the functionality can be accomplished via other existing methods, which reduces the number of tools that may need to be developed as custom attribute rules or add-in tools in ArcGIS Pro. Rather than focusing time and money on re-developing all 75 of the custom ArcMap tools as custom tools in ArcGIS Pro, GeoSolutions can focus their efforts on developing only the functionality that

requires a custom solution. For the remaining functionality, GeoSolutions' GIS staff can use tools from the company's web-based quality control system or in ArcGIS Pro. Using already-available solutions also allows GIS staff at GeoSolutions to migrate from ArcMap to ArcGIS much more quickly and efficiently, rather than having to wait for all 75 custom ArcMap tools to be re-developed as custom ArcGIS Pro tools. The results from this capstone project research will allow GeoSolutions to begin forming a plan for migrating their custom ArcMap tools to ArcGIS Pro and developing user stories outlining the complete functional requirements for custom tools in ArcGIS Pro.

Additionally, other organizations looking to migrate their custom ArcMap tools to ArcGIS Pro can benefit from following a similar process. This capstone project research established a framework to outline the organization's custom ArcMap tools, define evaluation criteria, evaluate the custom ArcMap tools against the criteria, gather feedback on end user needs through focus group sessions, and analyze and aggregate the results. This framework provides a solid foundation for identifying which custom ArcMap tools need to be redeveloped as custom solutions in ArcGIS Pro, potentially saving both time and money by pinpointing the truly essential functionality that cannot be accomplished through other methods.

Further research is needed on whether attribute rules are a viable replacement for standalone tools such as add-in tools and on the overall best format to develop each new custom tool in ArcGIS Pro. The usability of attribute rules compared to add-in tools should be studied along with testing additional prototype attribute rules to determine if attribute rules are a viable replacement for custom ArcMap functionality. Additionally, GeoSolutions will need to decide whether there is value in developing on-the-fly quality control tools for ArcGIS Pro, or if end users should rely solely on the quality control tools available in GeoSolutions' web-based quality control system. And finally, while this research focused on evaluating existing custom ArcMap tools, future research should also be conducted with end users at GeoSolutions to understand user needs for new custom functionality in ArcGIS Pro.

Conclusion

With Esri phasing out their ArcMap desktop GIS software over the next two years, this capstone research aimed to fill a gap in existing research around evaluating custom ArcMap tools for migration to ArcGIS Pro when organizations require custom solutions beyond what is natively available from ArcGIS Pro or their own in-house solutions. The research outlined a framework for determining evaluation criteria for custom ArcMap tools, conducting initial research on the evaluation criteria, and gathering end user feedback through focus group sessions to understand which tools truly need to be developed as custom tools in ArcGIS Pro. The results highlight the importance of organizations taking the time to critically evaluate their custom ArcMap tools. Doing so allows organizations to direct software development resources towards developing custom solutions for ArcGIS Pro only for the functionality that is still relevant to users' workflows and cannot be accomplished through other existing methods. While additional research is needed before GeoSolutions can finalize a formal plan for migration of their custom ArcMap tools to ArcGIS Pro, this capstone project research laid the foundation for understanding the current state of user needs for custom tools in ArcGIS Pro. The results can inform user stories outlining the functional requirements for these tools.

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