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Challenges and Perspectives in Urban Flood Management Automation

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Abstract— *Automation or digital transformation have become essential in various disciplines and organizations, including urban flood management. Urban floods are recurring natural disasters that can be mitigated through engineering solutions, but their management involves stakeholders from model developers to decision makers. Therefore, automating urban hydrological models presents challenges related to data integration, interdisciplinary requirements, and the usability of tools for non-technical decision makers. This research focuses on the understand the perspectives of computing professionals in urban flood management automation. A survey-based analysis was conducted using a questionnaire to understand the current practices and knowledge areas relevant to multi-model automation. The questionnaire was developed following a systematic methodology and validated through expert panels. The data collected from 44 computing professionals were analysed using trapezoidal membership function of fuzzy logic to determine their perspectives on various aspects of automation. The study identified eight independent variables such as, stakeholders' and developers' responsibilities, business rules, multi-model automation, calibration and verification of models, usability, security, multiple models in a single tool scenario, and automation frameworks. The findings provide insights into the gaps of unviability of HydroGIS tool development framework and satisfactory practices in urban flood management automation. The results urge to develop a suitable framework to HydroGIS tool automation and suitable guidelines and procedures to computing professionals in urban flood management projects.*

Keywords— **Automation, Digital transformation, Software Frameworks, HydroGIS tools**

I. INTRODUCTION

Automation or Digital Transformation refers to the use of machines and computers to replace human tasks and processes. Initial automation processes happen in good old days were limited to the individual department or single discipline but today it has enhanced across organization or disciplinary boundaries (Pezzini, 2023; Vogel-Heuser and Biffl, 2016). There are different concepts were evolved in the across discipline digital transformation such as Enterprise Automation, Multidisciplinary Design Automation, Industry 4.0, and MLOps (Gupta, 2021; Heikkinen, 2018; Pezzini, 2023). The common requirements of all these approaches can be summarised to (1) Bring business value in terms of reduced costs, increased efficiency, effectiveness, and business agility (2) Achieve IT-related benefits such as clear goals, synergies, optimization, and the ability to tackle complex scenarios in development (3) Better planning, management, monitoring, and governance of integration and automation initiatives in project management. However, as a fundamental requirement, in individual automation attempts it urges the computing processionals to be better understand the individual inter-process scenario which are yet to be promoted among the researchers.

The present work paid its attention to Automation of Urban floods decision making process. As a background, the urban flood is a frequently occurring natural disaster, which can be managed through engineering options. However the hydrological models used in urban flood management are sensitive not only due to small watershed and effective area, but also involving stakeholders ranging from model developers to decision makers and the general public (Hellmers et al., 2014; Yu, Yin and Liu, 2016; Konrad, 2003; Xia et al., 2011; Carver, 2016; Fatichi et al., 2016; Gray et al., 2017; Weiler and Beven, 2015; Eger, Chandler and Driscoll, 2017; Gupta, 2012). Then automating of the urban hydrological model are faced different challenges such as data flowing across different disciplines and integration of requirement of different experts and stakeholders.

The special case in urban flood management is Urban decision makers, who lack expertise in hydrology, are responsible for making daily flood management decisions due to ongoing land enhancements in urban areas are increasing surface runoff. To mitigate the impact on flood generation, these decision makers must run a hydro model using spatial and non-spatial data, a complex task that necessitates automation to support their non-technical background (Assaf et al., 2008). These kinds of automated tools are called as HydroGIS tools.

According to the fundamental concept, in any automation process, it considers three categories: inputs, process, and outputs. In the context of urban flood management automations, non-technical decision makers handle the input and output, while the hydrology professionals focus on developing the process or modelling the water behaviour accruing to the individual requirement. Then it is important for the input and output of the hydrology model to align with the aspirations of hydro modellers and be understandable to non-technical decision makers in usability perspective.

Therefore, to ensure effective automation of the foresaid functions given HydroGIS tool, it is crucial to understand the computing professionals' perspective on input-process-output requirements same as the hydrologists and non-technical decision makers. The previous of this research, it has studied the hydrologists' expectations over the said input-process-output (Pradeep and Wijesekera, 2019).

Therefore, this research aims to explore computing professionals' practises regarding the key knowledge areas in urban flood management automation.
However, such projects are belonged to outside organization, then there is a project sponsor. In the present work the project sponsor is called as modeller, who is aware of multidisciplinary model and be the contact person of the development project..

II. METHODS

A survey-based analysis was carried out to find the practises of the computing professional. For the purpose it developed a 30-question questionnaire following the systematic questionnaire development method proposed by Radhakrishna, (2007).

According to the Radhakrishna, (2007) systematic development methodology, it has already identified the objective as describe above. Then the purpose of this survey was to find the gaps in practises by analysing the computing professionals' present understating on the situation. So as the basic research question, it identified; "what are the gaps and satisfied computing practises exiting in an automation of urban flood management model, a multi-model process?".

Then to conceptualise the questionnaire, it carried out a comprehensive literature review to identify the main interested areas of the computing processional when multi-model tool automation. Further the automation perspectives of urban flood management tool development were identified through a critical study on the development process of a related HydroGIS tool named GIS2MUSCLE (Pradeep and Wijesekera, 2012; Pradeep, 2012; Pradeep and Wijesekera, 2020). The it conceptualised those identified interests as the independent variables of the research.
Further 3-8 dependent variables were identified for each independent variable and developed questions. All those questions except one were developed as statements to capture the agreement in 5-scale Likert scale but allow to provide any other answer if the participants wish. Only one question was asked to describe the individually practising software framework as it is one of the main interests of the automation process which may lost the valuable information on the current practises if asked in Likert scale. The answers are planned to group into independent variables identified based on the agreement in thematic manner.

When format questionnaire, it focused only to the computing professionals who involved in software development life cycle. Further to evaluate the perspectives dependencies to the different job roles it captured the job title of the computing professionals.

It established the validity of the questionnaire through 2 panels of experts (2 members and 4 members) in two stages. In such process, expert panels validate the questionnaire's validity and understandability. Finally, the questionnaire was field tested by involving 10 members to evaluate the reliability.
The final version of the questionnaire was distributed among 2332 computing professional through emails and WhatsApp groups.

III. DATA ANALYSIS

G. Data Collection

There are 44 successful participants were replied on 2332 invitations, which is 0.02%. Out of them are 52% employed in the software engineering management (Mgt) category such as Quality engineers, Business Analysts and Project Managers. Rest of 48% employed as Software Engineers and Senior Architects which considered as Software Technical (Tech) category. (Figure 1).

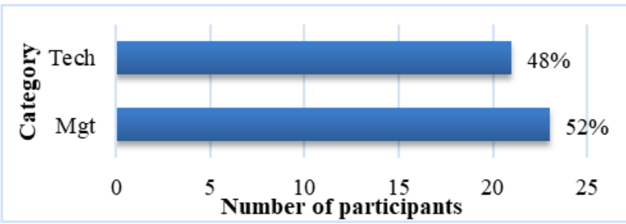

Figure1. Professional Categories of the participants

H. Identified Indeendent Variables

The present research has identified 8 independent variables (IV) on the computing professional perspectives on multi-model automation. There are 29 statements and 1 question were developed based on the dependant variables (DV) of each independent variables (Figure 2).

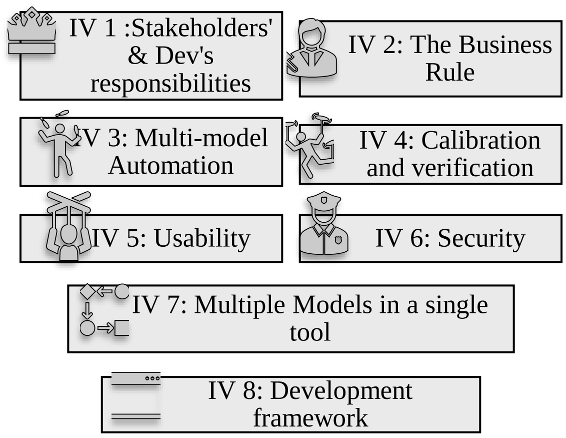

Figure 2. Conceptual framework of the Questionnaire
Note: IV: Independent Variables

I. Likert Scale Vlaues

The 1-5 Likert scale was employed to capture the Agreement on the statements provided in the questionnaire. Then scale to values and changing of affinity on the acceptance are shown in Figure 3.

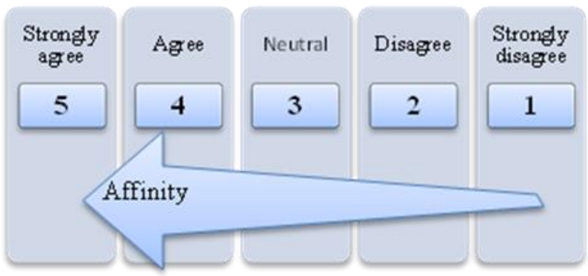

Figure 3. Assigned values to different Likert Scale options

The data analysis was performed using trapezoidal membership functions, representing the five Likert scale categories (Table 1).

Table 1. Trapezoidal Membership Functions for Likert Scale

Dependent Variable	Trapezoidal membership function
Strongly Disagree	[0, 0, 0.5, 1]
Disagree	[0.5, 1, 2, 2.5]
Neutral	[1.5, 2, 3, 3.5]
Agree	[2.5, 3, 4, 4.5]
Strongly Agree	[4, 4.5, 5, 5]

J. The Dependent Variables

1) Stakeholders' and Developer's Responsibilities: This attribute examines computing professional perspective on the roles and responsibilities of stakeholders and the software professional in the multi-model automation. Under this variable, there are 8 dependent variables were identified(Table 2:). The average agreement on each statement are shown in Figure 4 according to the two computing job categories.

Table 2. Dependent Variables of Stakeholders' and Developer's Responsibilities

Dependent Variable	Statement in the questionnaire
DV 1.1: End User and Modeler Identification: Knowledge on who are end users and modelers.	“Stakeholders” are (1) End Users of the software and (2) Modelers who provide business rules & logic / computation algorithms to develop the software
DV 1.2: Requirement Acquisition Process:	End users (decision-makers) can express the recipient stakeholders’ requirements to the developer (to you) whilst requirement acquisition
DV 1.3: Collaboration with Modelers:	Modelers assist developers (to you) whist develop the software, by providing calibrated business logic/advanced computational model
DV 1.4: Clear Definition of Inputs:	Modelers should clearly define inputs which need to run the business logic/ computational model
DV 1.5: Data Utilization:.	Developer (you) should know how to correctly prepare such inputs utilizing the data which are given by users or other models/modelers
DV 1.6: Output Definition:	Modelers should clearly define the outputs from their models
DV 1.7: Output Conversion:	Developer (you) should know how to convert such outputs in to the required formats by the destination (users or another model/modeler)
DV 1.8: Automated Communication Facilitation:	When communicate between users & different models/modelers, as well in-between different models, the developer (you) should facilitates such communication by automated mechanism

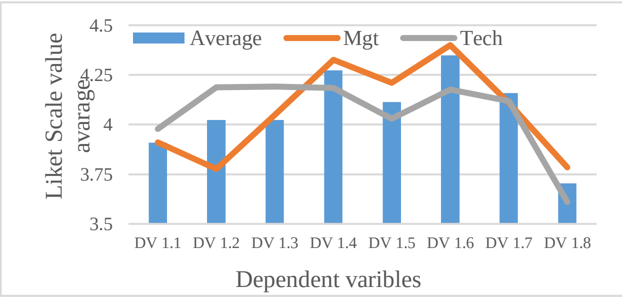

Figure 4. Summary results of perspectives on Stakeholders Responsibilities

2) The Business Rules: This independent variable, evaluates the view of computer professionals on business rules (Guidelines/rules & regulations /norms). Under this variable, there are 3 dependent variables were created

(Table 3). The average agreement on each statements are shown in according to the two computing job categories.

Table 3. Dependent variables of the Business Rules

Dependent Variable	Statement in the questionnaire
DV 2.1: Automation Accommodation.	Automation should accommodate business rules
DV 2.2: Decision Maker Knows	Decision makers should educate the developers (you) about business rules
DV 2.3: Flexibility for Changing Business Rules:	As business rules are changing, automated tool should allow to accommodate such changes when necessary

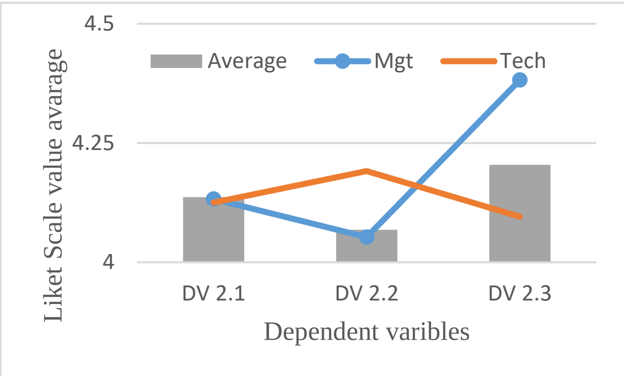

Figure 5. Summary results of perspectives on The Business Rules

3) Multi-model Automation: This focuses on the automation of advanced processes and the development of user-friendly tools in software development. It examines the importance and implications of automating various specific models and the responsibilities of developers in user interface development, communication automation, and testing methodologies. This variable explores the possibilities and challenges associated with incorporating multiple models and automation techniques to enhance the efficiency and usability of software systems. Under this variable, there are 4 dependent variables were identified (Table 4). The average agreement on each statement are shown in Figure 6 according to the two computing job categories.

Table 4. Dependent variables of the Multi-model Automation

Dependent Variable	Statement in the questionnaire
DV 3.1: Automation of Advanced Processes	All the advanced processes(all specific models) should be automated
DV 3.2: Testing of Advanced Processes	Advanced processes should be tested consulting the particular process modelers
DV 3.3.: UI and Automation of Communication	The user interface development and automation of communication between models and users are responsibility of developers (you)
DV 3.4: Development of User-Friendly Tool	To develop user friendly tool, the developer (you) should utilize adequacy, formative, summative and acceptance testing methods

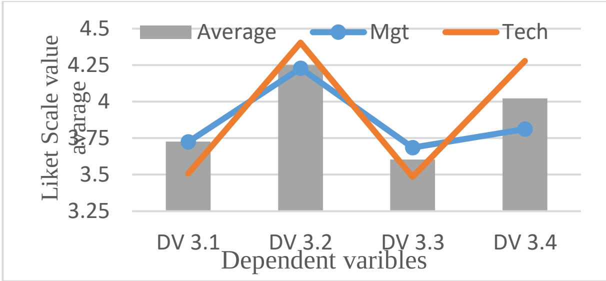

Figure 6: Summary results of perspectives on Multi-model Automation

4) Calibration and Verification of Different Models:

This independent variable," focuses on the importance of ensuring accurate and reliable models in software development. This variable examines the responsibilities of modelers in calibrating the models, the automation of calibrated models by developers, and the provision of verification facilities by automated tools. Under this variable, there are 3 dependent variables were identified (Table 5). The average agreement on each statement are shown in Figure according to the two computing job categories

Table 5: Dependent variables of the Calibration and Verification of Different Models

Dependent Variable	Statement in the questionnaire
DV 4.1: Model Calibration	The calibrations of the models are a responsibility of particular modelers
DV 4.2: Automation of Calibrated Models	Developers (you) automate calibrated models which provided by the particular modelers
DV 4.3: Verification Facility	Automated tool should provide verification facility to modelers (such as; Comparison of model result with actual, Accuracy level percentages/ indicators/ indexes)

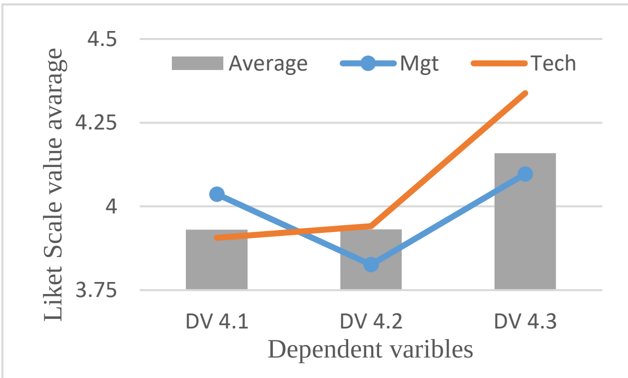

Figure 7 Summary results of perspectives on Calibration and Verification of Different Models

5) Usability : This independent variable focuses on the importance of designing software tools that are user-friendly and intuitive. It explores the achievement of usability by adhering to general guidelines and the need for specific usability considerations tailored to unique scenarios. Then this divided to 2 dependent variables (Table). The average agreement on each statements are shown in **Error! Reference source not found.** according t o the two computing job categories

6) Security : This focuses on the importance of ensuring data protection and access control mechanisms within software tools. It developed 3 dependent variables (Table). The average agreement on each statements are shown in Figure according to the two computing job categories.

Table 6: Dependent variables of the Usability

Dependent Variable	Statement in the questionnaire
DV 5.1 General Usability	Tool should achieve usability align with the general guidelines such as; Compatibility, User guidance and support, Informative feedback, Appropriate functionality, Portability, Explicitness, Easy to install and etc
DV 5.2: Specific Scenario Usability	As well special usability consideration on specific scenarios should be achieve (Eg. For GIS tool, map size, GUI size, on-screen modifications, zooming, pan and etc)

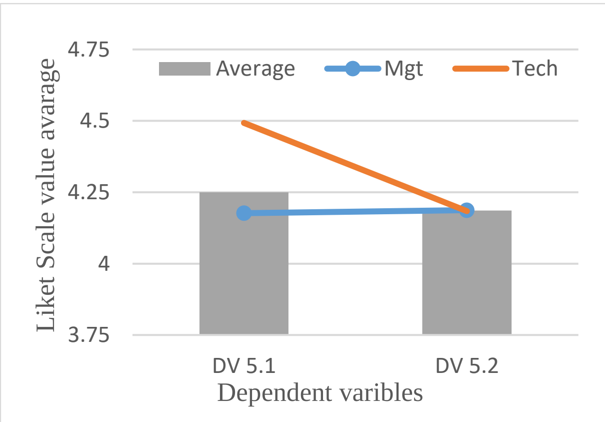

Figure 8. Summary results of perspectives on Usability

Table 7: Dependent variables of the Security

Dependent Variable	Statement in the questionnaire
DV 6.1: Data Protection Mechanism	Due to nature of the spatial data (requirement of sharing and updating by different users/ organization), the tool should provide a data protection mechanism if it use spatial data
DV 6.2: Access Control Mechanism	Processes of the tool should be protected using access control mechanism
DV 6.3: Role-Based Access Authentication	Role-based access authentication is required when different end users are involved

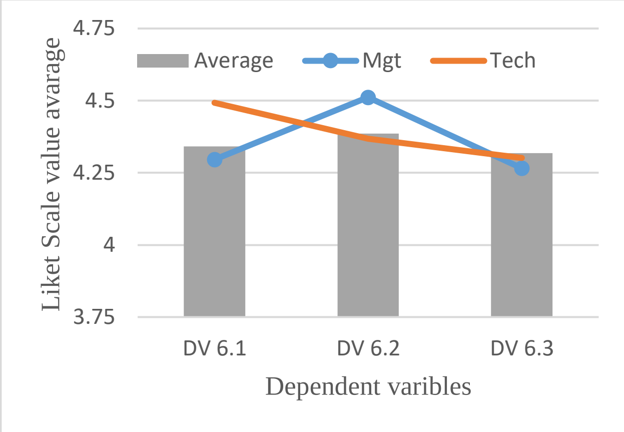

Figure 9: Summary results of perspectives on Security

7) Multiple Models in a single tool Scenario : This independent variable explores the utilization of multiple models within a single software tool. It focuses on the importance of the developer's understanding of the running sequences of processes and data acquisition from users or other models. It has developed 2 dependent variables (Table 8). The average agreement on each statements are shown in Figure 10 according to the two computing job categories.

Table 8. Dependent variables of the Multiple Models in a single tool Scenario

Dependent Variable	Statement in the questionnaire
DV 7.1: Understanding of Running Sequences	Developer (you) must have clear understand about the running sequences of processes and computations in different models
DV 7.2: Automation of Data Acquisition and Conversion	Developer (you) should automate the process of acquiring data from users or models then convert data according to the receiving-end (user or model) requirements

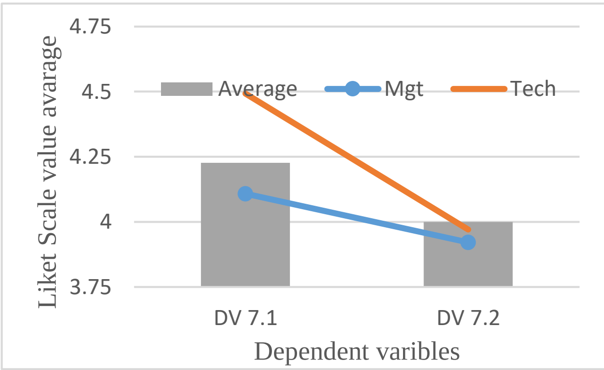

Figure 10. Summary results of perspectives on Multiple Models in a single tool Scenario

8) Hydro-GIS tool development framework This pertains to the creation of a framework for developing a Hydro-GIS tool, which is the considering scenario for this work. It encompasses aspects such as the applicability of previous principles, identification of suitable frameworks, integration methods for hydrology

and GIS, and factors contributing to the satisfaction of automating a Hydro-GIS or any integrated process (Table 9). Table 10 shows the acceptance of the professional categories to comply the previously inquired perspectives to the HydroGIS tool also.

Table 9. Dependent variables of the Hydro-GIS tool development framework

Dependent Variable	Statement/ Questions in the questionnaire
DV 8.1: Applicability of Multi-Model Automation	**Statement :** All previous statements under multi-model automation are applicable to HydroGIS tool too
DV 8.2: Suitable Framework for HydroGIS Tool Development	**Question:** According to your experience, are there any suitable framework existing to utilize in the HydroGIS tool development?
DV 8.3: Comment on Existing Frameworks	**Question:** Can you provide a comment on the answer to the above question?
DV 8.4: Best Hydrology-GIS Integration Method	**Question:** According to your experience, what is the best Hydrology-GIS integration method for urban flood management decision making tool ?
DV 8.5: Additional Satisfaction Factors in Automation	**Question:** What else you feel to be satisfied when automating a Hydro-GIS /or any other integrated process?

Table 40: Results of perspectives on Applicability of Multi-Model Automation concepts evaluated in previous question to HydroGIS tool development.

Professional Category	Average agreement on DV 8.1
Software Management	4.04
Software Technical	3.97
Average for both categories	4.02

9) Averages for Independent Variables The differentiation of the Management and Technical perspectives in eight independent variables (IVs) related to urban flood management automation are shown in Figure 11.

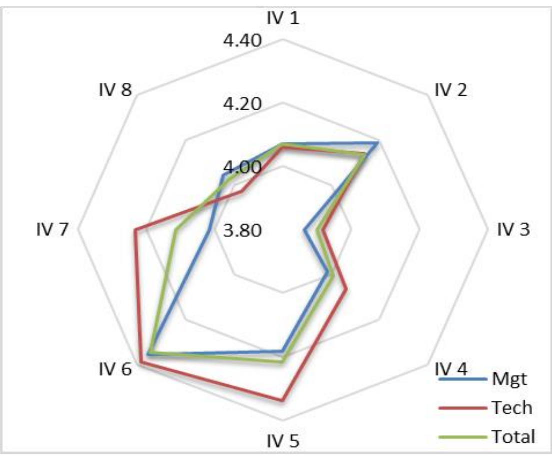

Figure 11. Acceptance of Professional categories to the IVs

IV. RESULTS AND DISCUSSION

A survey was conducted to explore the diverse perspectives of computing professionals regarding multi-model automation, particularly when the models span across different disciplines (referred to as multi-disciplinary models). The primary focus of the study was to understand how computer professionals undertake development tasks under the guidance of the Modeller, who serves as the project sponsor. Additionally, the survey assessed the feasibility of implementing multi-model automation and the availability of the HydroGIS tool framework for software professionals.

A. *Perspective on "Stakeholder" and "The role of Sponsor"*

Based on the responses from the Likert scale, both the Management (Mgt) and Technical (Tech) categories share the belief that the term "Stakeholders" refers to the end users of the software (DV 1.1). They also agree that the project sponsor (or multi-disciplinary model builder-modelers) should play a crucial role in clarifying the business rules, logic, and computation algorithms. Additionally, both Mgt and Tech professionals believe that end users (decision-makers) can represent the requirements of individuals who have not used the software but have benefited from it or encountered problems as recipient stakeholders during the requirement acquisition stages (DV 1.2 and 1.3). However, it is worth noting that Mgt professionals have a slightly lower level of agreement compared to the Tech professionals in this regard. One Mgt professional suggested that it is the responsibility of the Business Analyst to identify the relevant requirements, while three others disagreed with this viewpoint.

B. *Responsibility on the Model*

Both management (Mgt) and technical (Tech) professionals exhibit a shared preference for assigning the responsibility of providing calibrated business logic with well-defined inputs to the modelers (DV 1.4 and 1.5). However, computing professionals acknowledge their expertise in effectively preparing inputs using the data provided by users or other models/modelers, as this aligns with the intended automation work of the tool development.

Furthermore, both groups of computing professionals believe that modelers should clearly define the output, including its formats, behaviours, and other pertinent details, in order to enhance tool development (DV 1.6). However, it is noteworthy that Tech professionals display a slightly lower level of agreement compared to Mgt professionals regarding this notion.

Nevertheless, both Tech and Mgt professionals accept the responsibility of converting outputs into the required formats as demanded by the intended recipients, whether they are users or other models/modelers (DV 1.7).

C. Enabling Seameless Interaction Between Users and Models/ Modelers

The Mgt and Tech category slightly agreed to accept the responsibility to foster effective communication between users and different models/modelers, as well as between different models themselves(DV 1.8).

D. Maage the Dynamic Nature of the Model

The Mgt and Tech category agreed to accept the responsibility of design the tool to accommodate changing business rules, but they require end users (decision makers in this scenario) to educate them about those points and ensuring that automation aligns with them (DV 2.1, 2.2 and 2.3). However, a Mgt respondent states that this responsibility also to be taken by the Business Analyst.

E. Concern on Advanced Models

Both the Mgt and Tech professional agreed that it should be automate the all the advanced models (DV 3.1). As well, they expect to have the modeller to be with them to calibrate and verify the automated models (DV 3.2). However, both the professionals are showing slight lower agreement to the automation of all the advanced models. Further, the Mgt professionals slightly agreed that they have the responsibility to make interface to facilitate this advanced communication between models and users (DV 3.2). However, the Techs do not agree to the idea and in a neutral mode. However, the bot the professionals agreed to responsibility to utilize adequacy, formative, summative and acceptance testing methods to automate advanced processing tool (DV 3.4).

F. Model Calibratio Verification

Both the professional have a clear perspective that calibration of the model is a responsibility of modellers and own-responsibility is to automate it (DV 4.1 and 4.2). However computing professionals took the responsibility of show the required parameters once it automates to check the accuracy of the models to the modeller or required users (DV 4.3).

G. Usability and Security

The computing professionals positively agreed to the requirement of develop the tools following not only the general usability guidelines, but also to follow specific guidelines to the scenario (DV 5.1. and 5.2). As well they agreed to the security to achieved through all the possible ways such as data security, access control on role-based authentication as the processes are handled by multiple users (DV 6.1, 6.2 and 6.3).

H. Process Automation

The responsibilities of understating the entire process steps, gather the data and convert as per the process requirement, generate the outputs and convert them to the receiving end-requirement are accepted by the computing professionals (DV 7.1 and 7.2). However professionals are agreed with slight reluctant to above data manipulation responsibility.

I. HysroGIS Tool Framework

The computer professionals were agreed to have the same perspectives they have paid to general multi-model automations when in the HydroGIS tool development too (DV 8.1).

The specific highlight regarding the HydroGIS framework, is the 75% of the compositing professional complained that According to your experience, there are no suitable framework existing to utilize in the HydroGIS tool development. As well another 23% state that they are not sure or don't have enough experience of HydroGIS tool development frameworks. However 2% stated that there are framework for HydroGIS tools, but it indicate that such tools are either GIS software such as ArcGIS, QGIS or GRASS or developed models like HEC-HMS.

J. Independent Varaiables

According the overall picture (Figure 11), it appears that management and technical professionals have a shared understanding of the roles and responsibilities of stakeholders and software professionals in multi-model automation. There is general agreement among both groups on the importance of business rules, multi-model automation, calibration and verification of different models, usability and security.

However, there are some differences in opinion between management and technical professionals on certain topics. Technical professionals have a stronger consensus on the importance of usability, security, utilization of multiple models in a single tool scenario, and the factors contributing to the satisfaction of automating a Hydro-GIS or integrated process. On the other hand, management professionals have a slightly higher level of agreement on the development framework of a Hydro-GIS tool.

Overall, these findings suggest that both management and technical professionals recognize the importance of collaboration and coordination in software development processes, and that a shared understanding of the roles and responsibilities of stakeholders and software professionals is essential for effective multi-model automation.

V. CONCLUSION

The study aimed to investigate challenges and perspectives of computing professionals regarding the automation of urban flood management, focusing on issues like data integration, interdisciplinary requirements, and usability for non-technical users. A survey-based analysis was conducted to explore stakeholders' responsibilities, business rules, multi-model automation, model calibration and verification, usability, and security, along with other independent variables. The findings revealed varying levels of agreement among computing professionals with different job roles concerning these variables. Consensus was observed among participants regarding the need for clear definition of inputs and outputs, as well as automated communication facilitation for stakeholder responsibilities. However, disparities arose in opinions regarding collaboration with modelers and the requirement acquisition process, indicating existing gaps in current practices. Additionally, the study highlighted the absence of a Hydro GIS tool development framework as a significant hindrance to the creation and implementation of automated tools that effectively support non-technical decision makers in managing urban floods. Overall, this research provides valuable insights into the practices and perspectives of computing professionals in urban flood management automation, informing the development of automated tools and improving urban flood management.

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