

Development of HydroGIS Model Development Framework: Research Methodological Perspectives

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Abstract: *The common problem of transdisciplinary research is the acceptable research methodology. The author was questioned with the same when developing a HydroGIS model development framework as it synthesises multiple disciplines. Hence the present work aims to systematically select the methodology options for developing research methodology for the research. For that, it carried out a comprehensive literature review to formulate how ontology, epistemology, and axiology axioms are aligned with the author's thoughts. Then utilising the "Heightening your Awareness of your Research Philosophy" tool and Burrell and Morgan's four paradigm approach it selected and verified the most suited philosophy. Based on such underpinning, it analysed the best-suited theory-building approach and formulated the research steps. Founded on those steps it comprehended the methodological choices available to the research design. Then analysing the findings, it systematically selected the research strategies for operationalising the research design. Finally, it could be able to identify the framework development is in the interpretivism philosophy and explains the subjectivistic truth which is axiologically experienced by the researcher. The deductive approach is identified as the theory-building approach, where the components of the framework are identified through the explanatory science approach while the design science approach verifies the findings. Due to this bidirectional shift, research needs to follow the sequential multi-phase approach of the mixed method. Further, it identified constructivist grounded theory, survey, document research, and Multi-Criteria Decision-Making tools are the best-chosen research strategies to operationalise the research design. Finally, this work demonstrates how to systematically select the research philosophy and formulate research methodology for transdisciplinary research.*

Keywords: *Ontology Epistemology Axiology, Interpretivism, Abduction, Sequential multi-phase approach of the mixed method, Constructivist grounded theory*

1. Introduction

A. Background

The present work based on the PhD research which attempted to understand the present status of hydro-GIS-stakeholder relations to guide the development of

sustainable decision-making tools. Developing a building block framework is necessary to describe the top-level components in phenomena and their relations to explain such a situation to software professionals (Pradeep & Edirisuriya, 2021). Then PhD work expects to develop a building-block framework (hereafter framework), illustrating the current status.

Initially, it found that special attention was paid to calibrate and verify the discovered knowledge as the flood management research works have an inbuilt difficulty of verification. Then, early works show the verification is done through three methods such as (1) Comparison with observed data, (2) Comparison with another model, and (3) Expert judgement (Ford et al., 2019; Malalgoda et al., 2016, 2013; Molinari et al., 2018; Zhong et al., 2020). However, always researches recommended the expert judgment technique as the reliability of the outcome.

Then the foresaid PhD research's expected knowledge should be a clear explanation of the existing urban flood management scenario, hence it needed to develop a framework to explain all the interested components to software development. When consider those components, it found that those are laying in multiple disciplines such as hydrology, GIS, stakeholder management, flood management and computing. Further, as those disciplines need to be integrated in depths as the framework should clearly explain how and what data and process to be shared or keep independently when automations, the research become transdisciplinary work rather than multidisciplinary activity. Then the fundamental challenge in transdisciplinary collaboration is accepted research methodology for each discipline. Hence the initial attention to methodology development faced complexities due to diverse views, terminologies, practises and norms in methodology development. Therefore, it understood that the general discipline-oriented methodology does not applicable to transdisciplinary research.

B. Aim and Objective

Then aim of the present work is to demonstrate how it systematically select the methodology options for transdisciplinary research. Then the objectives of the present research are comprehensive literature review on research methodologies, identify the research options availed and select the appropriate technique.

C. Background study of Knowledge discovery

Hence, this chapter describes and reasons out the research methodology selections. The research philosophy clarifies the knowledge building approach and underpins all the research methodology choices, including strategy, data collection techniques, and analysis procedures (Burrell & Morgan, 1979, pp. 1–5).

Research is to discover knowledge. Due to various viewpoints and arguments on the terminologies, a mind map (DOI:10.13140/RG.2.2.13395.50721) was developed to demonstrate how different activities are involved in such processes by 35 using prominent sources on research theory. The mind map fired the research community and 12 experienced international researchers, representing multiple disciplines such as administration, economics, logistic, operational research, sociology, environmental science, medicine, education, architecture, and computing, critiqued the mind-map. With their reviews it developed the reviewed mind map as shown in. The meaning of ‘knowledge’ and its approach is subjective. This subjectivity can be explained by understanding the research’s ontological, epistemological, and axiological stances. The ontology, epistemology, and axiology collectively form a research philosophy while they influence the development of research questions or hypotheses or a mix of both regarding the problem or the solution. As the research philosophy and questions/hypotheses originate from the same sources, both should be conceptually related. The research design is then formulated to answer those research questions, hypotheses, or a mix of both.

In contrast, the research methodology underpins the research’s ontology, epistemology, axiology, and philosophy. According to Rowley (2002), the research design is referred to the logical coherent of data collection to conclusions as answers to research questions. The research methodology also explains the research plan, the same as the research design. The research methodology/research design guides the researcher to select the research strategy, data collection, and analysis methods (Scotland, 2012). However, selecting the methodological choices, strategies, data collection techniques, and analysis techniques are interrelated decisions. Finally, all these activities resulted in new knowledge. Therefore, as the new knowledge is based on the implemented methodology, any doctoral research should provide a valid research methodology (Malalgoda, Amaratunga, and Haigh, 2013).

2. Materials, Method and Discussion

A. Choosing the Research Philosophy - Interpretivism

This research needed to start clarifying appropriate philosophical continua. However, it examined the history of research concepts for more ground orientation. This section provides a brief historical preamble to general research

assumptions and demonstrates how it systematically utilised available tools to select the most suited research philosophy.

1) *Brief History*: Two prominent diversities could be observed in research philosophies: Western thinking and Eastern thinking. Das (1952) stated that Eastern concepts are intuition, while Western’s are postulation and need proof. Eastern philosophies are primarily practical, while Western ones are theoretical (Das, 1952, p. 631).

Having lived with Lord Buddha’s philosophical teachings for 48 years, the researcher’s axiological ontology is more positivistic and trust that only single truth exists regarding life. Nevertheless, the present research follows Western philosophy since the study problem is primarily a practical observation and research is conducted for academic qualifications.

Western philosophy has different thinking families. In history, the *Sophists* – people with gifted communication capability – believed no absolute right or wrong, but Socrates (469 -300 BCE) started arguing that absolute right and wrong exist (Rankin, 1983). Such *Socratic method* can be considered a modern Western philosophy cornerstone that believes in *Inductive* reasoning for knowledge. Further developments of the induction method were observed, such as the *Dialectic method* of Plato (427-347 BCE), *Four causes of knowledge* by Aristotle (384 -322 BCE), and *“Idola Tribus”* (The idols of the tribe) of Francis Bacon (1561-1626). It considered that Bacon’s ideology had formed the inductive approach to the *scientific method*, posing the questions and seeking science-based responses. However, Galileo Galilei (1564 – 1642) and other philosophers’ rival thoughts of *Deductive* reasoning for knowledge discovery developed another branch. The knowledge is derived logically in deductive reasoning, considering the hypothesis or theory-based observations. Since then, many intermediate branches such as *abductive* and *retroductive* arose between the two poles of inductive and deductive reasoning. However, interestingly, all these ideologies are independent as ideas but practically interdependent in different dosages. Therefore, the present work focused on identifying the most suitable research philosophy.

2) *The Philosophical axioms*: The majority of the researchers fail to grasp that their research is firmly based on their own philosophy of knowledge, reality, and understanding. Knowingly or unknowingly, based on philosophy, a researcher gathers data and analyse to find knowledge. If the research has better axioms of philosophy, then the entire data collection and analysis activities can be strongly justified. The term axiom (Latin) refers to the commends itself as import, while the general axiom refers to a statement of self-recognition. Therefore, it is accepted that the philosophical axiom is a self-established truth that does not require interrogation as fundamental beliefs cannot prove (McGregor, 2018).

The research philosophy focuses on the beliefs and assumptions that influence knowledge development. Hence, initially, the present work attempted to evaluate them. These beliefs and assumptions are described mainly under two axioms; ontology and epistemology. However, the present research considered the axiology axiom (the individual perceptions) vital in urban flood management. As it is understood, these beliefs and assumptions affect the research journey (perspectives on existing knowledge/gaps and research works required) and cumulatively shape the new knowledge.

The ontology (theory of being) axiom describes the nature of reality in terms of human thought as the fundamental/basics/truth. Ontology has two ontological assumptions: (1) realism and (2) nominalism. In realism, the realist (a.k.o. positivist) believes such fundamental is independent of the human consciousness. In contrast, the nominalist (a.k.o. interpretivist) believes the truth is has a relationship with humans and finds multiple truths. Epistemology (theory of knowledge) axiom refers to the acceptable and legitimate knowledge among the humans or community. There, the research beliefs are evaluated against the accepted knowledge. Then axiology axiom – the researcher’s values to the research - is essential as the researcher is subjective and not independent from the problem (Malaloda, Amaratunga, and Haigh, 2013; Johnson and Duberley, 2000, p.78; Berryman, 2019; Crotty, 1998).

The main research problem with the present research is an “unknown situation and interdependent research beliefs are arranged according to assumptions, as shown in Table 1.

Table 1: Ontological, epistemological, and axiological axioms of the research

Beliefs in the research	Assumptions		
	Ontology	Epistemology	Axiology
1. Water Flows from high ground to low	√		
2. A flood is a natural event of excessive water	√		
3. Human take actions to their own benefit only	√	?	
4. Humans change the water paths	√	?	
5. Forceful change of water paths unbalances the nature	?	√	
6. Flood in unbalance nature harms humans		√	
7. Flood water can be managed and simulated with hydrological modelling		√	
8. Flood water management should facilitate human needs		√	
9. Flood management decisions that do not align with human needs will not be practically implemented		√	
10. Flood management decisions should satisfy both the humans and nature to become sustainable decisions		√	

11. Such sustainable decisions are complex but are efficient decisions		√	
12. Automated tools should be used for such efficient decision-making		√	
13. Such tools should provide scenario-optimisation capability		√	
14. Proper water and human integrated models should be utilised to develop efficient tools		?	√
15. A model development framework should be utilised to develop such models		?	√
16. System Developers must construct and practise such model development frameworks			√

According to the explanations of Table 1, the ontological beliefs of water and human behaviours (Srl. no 1 to 4) have been well understood for centuries and accepted without conflict. However, apart from the truth of water flow from high ground to low ground, the other three beliefs can be considered socially-constructed multiple truths. Those beliefs are primarily with the nominalism stance. However, the epistemological beliefs of the present research (srl no. 5 to 13) are well accepted, and most flood management stakeholder research utilises them to continue their works. Nevertheless, the axiological assumptions (srl no. 14 to 16) are yet to be explored to greater extents, and the underpinning is totally value-laden to the researcher. In line with the understood epistemological, ontological, and axiological phenomena, the present research is socially constructed and value-laden research. It must select the best suited theoretical research philosophy to decide the exact research steps. The main intention of the present research is to understand the present situation and develop a framework to demonstrate it, which will facilitate building the flood management models with the best mix of stakeholders.

This framework attempts to illustrate the complex integrations of scientific and management needs of flood management with the complex stakeholder perceptions. Hence, this situation cannot be theorised or explained using existing principles, laws, or theories. The philosophical perspective of the present research is mainly with the ontological interpretivist stance, which facilitates researchers to sense the research environment for explanations. Such explanation, in line with present research, will generate how the new framework to be demonstrated with the stakeholders.

B. Select Research Philosophy

The ontological, epistemological, and axiological understanding of the problem suggested that the present work’s research stance is interpretivist. Then it took actions to confirm the theoretical justifications through practical approaches. It revealed that some terms used interchangeably for philosophy as extremes and paradigms. As these terms are utilised in very individual scenarios to broader views, the following subsections show how the present work selected the suitable philosophy for current

research considering five philosophies, two sets of extremes, and one paradigm approach.

1) *Select the Research Philosophy:* The present work initially utilised the Sumner and Tribe (2008, p. 59) classification table to determine the philosophical research directions by selecting the best-suited tendencies for epistemological assumptions (Table A-1). According to the finding, the present research is epistemologically positioned between Relativism and Realism but rejects Positivism.

Table A-1: Present research epistemological assumptions

Epistemological Assumptions	Selected Tendency	Author's reasoning
What reality is?	Multiple realities could be experienced.	The ontological phenomena as described above.
What is the aim of knowledge enquiry?	To describe reality. It is not possible to establish the truth about reality.	Analyse the existence to the present in a clear platform. Further, it is possible only to argue the best method, but it is impossible to prove it.
How does the researcher relate to the research?	The researcher is subjective and not independent of the research.	The researcher is a professional in Information Systems, which is part of the research domain.

Source: (Adopted from Sumner and Tribe, 2008, p. 59) The Sumner and Tribe classification produced mixed results (Table A-1); hence the present work employed a prominently utilised tool for PhD studies, the "Heightening your Awareness of your Research Philosophy (HARP)" reflexive tool. Alexandra Bristow and Mark Saunders developed this tool to clarify individual research philosophy (Saunders, Lewis, and Thornhill, 2019, pp.161–164). Table A-6 presents the filled HARP, and Figure A-1 illustrates the result. According to the HARP, the present research predominantly has an Interpretivism philosophy with a bias to critical realism and pragmatism.

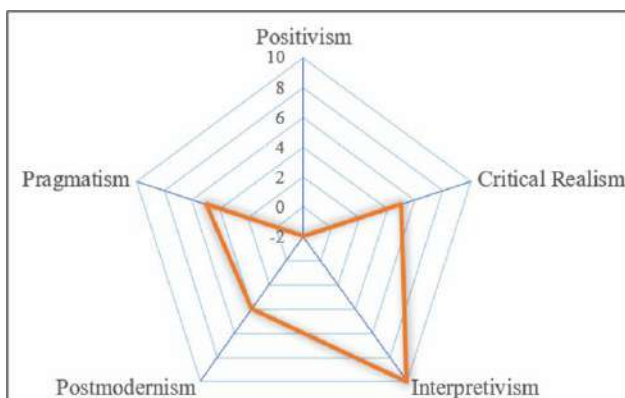


Figure A-1: Web of HARP Results

Source: Author

A1.1.1 Extreme 01 - Objectivism and Subjectivism: Niglas (2010) described that research philosophies are scattered across multidimensional sets of continua from

objectivism to subjectivism, based on the research discipline. According to Burrell and Morgan (2016, p. 3)'s explanation, ontologically, the objectivism approach embraces more *realism* while subjectivism embraces *nominalism* (aka *conventionalism*). When philosophy is at the extreme end of objectivism, the beliefs count the social objects the same as the independent natural objects. Then research is conducted the same way the natural researchers are carrying out, believing that truth exists independently from any. Concomitantly, when research is in the extreme form of objectivism, it believes that the truth is a created concept that depends on single to multiple people, specifically no real truth underneath. However, in a less extreme perception of objectivism, aka *social constructionism*, the research constructs the truth intersubjectively. Then the developing truth is enriched with the opinions, comments, and critics of the social actors and their own beliefs and values. This form of own values cooperation is called *radical reflexivity*. Table A-2 presents the objectivism and subjectivism continua summarised according to the beliefs.

Table A-2: Philosophical Continua with two sets of extremes

Type	Philosophical Continua				Present work
	Objectivism		Subjectivism		
	The extreme form	Less extreme form	Less extreme form (Social constructionism)	The extreme form (Nominalism)	
Ontology	One truth exists external to all available subjects	Truth is external from social actors	Truth is nominal and creates socially and intersubjectively	Truth is nominal and socially constructed	One truth regarding the water; but in management, social constructionism
Epistemology	Adopt assumptions of the natural scientist and truth is measurable Decisions based on Facts, Numbers and Observable phenomena, Analysis are law-like generalisations	Adopt the assumptions of the arts and humanities. Decisions based on Opinions, Written, spoken and visual accounts. Analysis of individuals and			The scientific reasonings of the floods (few) are measurable, but human causes (more) are qualitative
Axiology	As truth is independent, value to the researcher participants	no the or	The truth is Value-bound with the researcher and participants. Radical Reflexivity (incorporation of such to build knowledge) is observed		Radical Reflexivity is required

Source: (Adopted from Saunders, Lewis, and Thornhill, 2019, p.135)

A1.1.2 Extreme 02- Regulation and Radical Change perspectives:

Philosophies can be divided into two extremes based on political and ideological orientation (Burrell & Morgan, 2016, pp. 16–19). When the research discovers new directions based on the status quo, the research is with *Regulation* philosophy. Nevertheless, if the research provides the real solution to the problem that needs to change the status quo, then the philosophy is *Radical Change*.

As the present research believes the status quo is enhanced to add knowledge, the work is more aligned with regulation perspectives.

A1.1.3 Research Paradigm Approach:

According to Burrell and Morgan (2016, p.22), different extremes can be incorporated to develop scenarios for a clear understanding of the continuity and separation of philosophical concepts. The present work used Burrell and Morgan's four paradigms, as shown in Figure A-2.

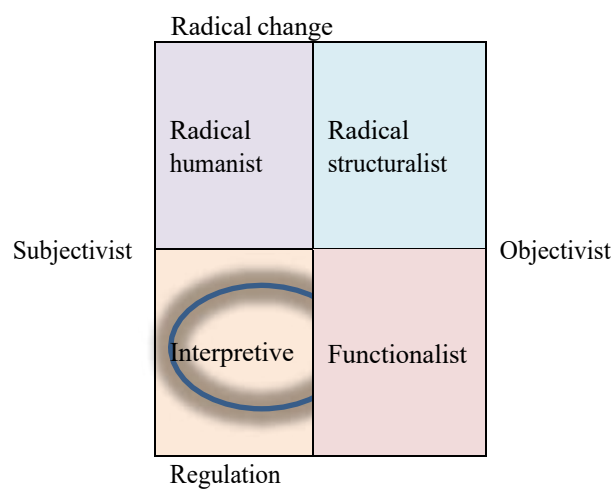


Figure A-2: Burrell and Morgan's four paradigms

Source: (Adopted from Burrell and Morgan, 2016, p.22)

According to the two extremes described above, the present research has subjective and regulation extremes. As per Burrell and Morgan, the suited paradigm is Interpretive, where the research should sense the outside world under a humanistic perspective with the flavours of multiple subjectivities. Kelemen and Rumens (2008) state such research must explain what is going on rather than changing the existence.

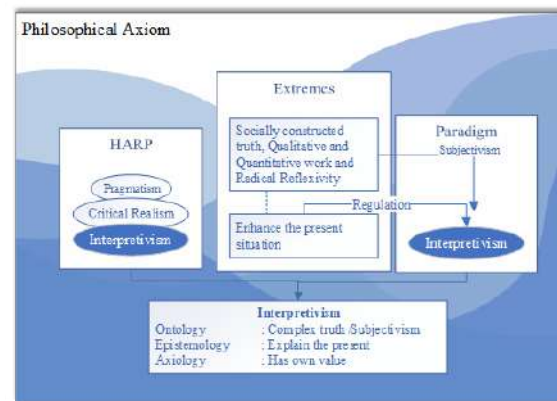
A1.1.3.1 Selected Research Philosophy

The present work compared the available research philosophies and explored the philosophical standpoint during this analysis. Table A-6 describes that interpretivism (10 points) achieved the highest rank and outstanding scores. The results of two extremes (Table A-2) and paradigm analysis (Figure A-2) confirmed this, and Figure A-3 presents the findings' highlights.

Figure A-3: Outputs of philosophical axiom finding

Source: Author

Accordingly, it would be possible to select interpretivism as



the philosophy of the present research logically. As per the accepted philosophical explanations, the ontology of interpretivism is a phenomenon in that reality is being seen as a complex and socially constructed scenario. Further, it considered that the personnel and people interpretation significantly influence such a scenario. Hence, evaluating the diversified meanings, processes, experiences, and practices is necessary. The epistemology of interpretivism is to have a different perspective or novel explanation of reality through the available theories. Then the axiology of interpretivism has a crucial role as the own interpretations and values make more meaning in knowledge debate (Jakubik, 2021).

A1.2 Choosing an approach to theory building - *Abduction*

Once it achieves the philosophical clearance, the next step is to select the approach to theory building.

A1.2.1 Theoretical explanation on theory building

As per the brief history provided, there are two fundamental approaches named *deductive* and *inductive* in theory building. The prime research approach of human thinking is hypothesis-based, i.e., the man predicts the results and carry out the actions. When this thinking maps to the research, it is named *deductive* approach that attempts to match and prove a theory or hypothesis using the research findings. Conversely, in the *inductive* approach, the philosophers discover the theory through data analysis. When it conceptually evaluates these two approaches, the deductive approach divides the whole reason into parts and evaluates, and the inductive evaluates the parts and accumulated to an entire reason (Munro, 1850).

Peirce (1960/1979) introduced *abduction* as the intermediate inference by deviating from both inferences. Abduction explains the situation with a provisional hypothesis that invented surprising phenomena. The inductive and deductive approaches are accumulatively practised in abduction (Flick, 2018; Peirce, 1960, p. 1160). Hence, this becomes an interesting theory-building approach to the present work.

A1.2.2 Practical selection of theory building approach
However, the induction theory building approach always opts for the interpretivism research philosophy. When implementing such an idea to achieve the research objective

of the present work - the development of explanatory HydroGIS model development framework (so-called new theory) – it needs to understand the current phenomena (data). The literature review found ample standalone descriptions, but very few describe the integrated hydrology, GIS, urban flood, and stakeholders concerning the ambitious frameworks. Such a situation is moderately favoured for the inductive approach.

Simultaneously, the well-developed stakeholder and hydrological theories and established understanding of the stakeholder and water management integration facilitates the hypothesis testing (theory), which is inheriting to deductive approach. Again, it creates moderate favouritism for the deductive approach. Nevertheless, if it selects the deductive approach, it needs to falsify or verify the hypothesis, which is impractical and impossible in flood research within a limited period. Therefore, the present study needs to select an intermediate approach, the *abduction*, as the wealth of information available with far less in the researching context and the ambitious framework will be a conscious explanation of existing epistemology in line with the current understanding (theories). Due to this specific scenario, abduction becomes the most suited theory-building approach to selected interpretivism philosophy. Figure A-4 illustrates relations of the reasons for the above decision.

As the present work follows the abduction approach with interpretivism philosophy, the work must explore a phenomenon using data collection. Then it needs to recognise the themes and (clearly) describe the patterns/trends, which requires producing the theory (new/modified) based on such situations. However, this new knowledge needs to be tested with additional data collection (Saunders, Lewis, and Thornhill, 2019, p.160).

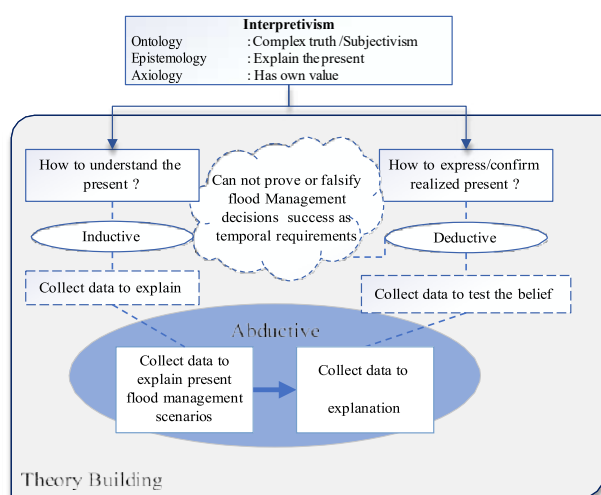
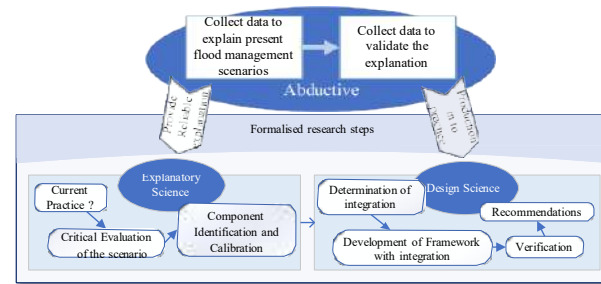


Figure A-4: Reasoning the theory building approach

Source: Author

This abductive approach collectively utilises the research principles of explanatory science and design science. According to Aken (2005), explanatory science's primary

goal is to produce reliable knowledge to realise the natural



or social world for a more precise description/explanation/prediction. The fundamental purpose of design science is to produce information that specialists can utilise design solutions to their issues (Aken, 2005).

A1.2.3 Formalised research steps to theory building The general research steps could be formalised by keeping those concepts in mind, as shown in It was necessary to follow the explanatory science principle initially, which required more qualitative methods, as the little known phenomena (Stebbins, 2001, p. 6) of the integrated hydrology, GIS, urban flood, and stakeholders. Those steps are illustrated as downward rectangles of Figure A-8, where the intended objective is to demonstrate an actual social situation. When it describes more towards the present work, the research should explore the major urban flood management components in the current system setting. Such major components will demonstrate the present information system interactives required by the urban flood management systems.

However, as the demonstration assist the system specialists to solve the issues with stakeholders' perceptions, it must produce supportive knowledge to develop more realistic solutions as per the design science research principle. The next upward steps show (Figure A-8) the so-called design science steps to build the required knowledge to solve the intended problems. As such knowledge development is with design science, it must produce an artefact for specialists to utilise the design solutions to their issues. The intended artefact of the present work is a HydroGIS model development framework with current stakeholder integrations depths. Hence the expected outcome should clearly demonstrate the status quo stakeholder relations, and the depths between the sine-quo-none components have to be considered in system development. This output's epistemological understanding is that it will guide the system specialist to develop more legalistic solutions.

The initial development would be a fully or partially developed framework with depths resulting from the comprehensive study. These depths cannot be validated through implementation or operationalisation but only through expert reviews due to unrealistic time requirements. Since the so-called experts are in different disciplines, the depths and integrations may be differently interpreted and reviewed. Hence validating the framework would be a set of

improvement suggestions. The design science steps will be thus completed with recommendations developed based on the suggestions.

Accordingly, the formalised research steps are linked with the abductive theory building approach, as shown in Figure A-5.

Figure A-5: The relation between the Abductive method and Research Steps

Source: Author

A1.3 Research Methodology – Formulating the research Design

While the ontology and epistemology understanding provides the research foundation, the methodology explains how to find the solutions to research questions in line with the said foundation. “Methodology” is a theory that describes the overall plan of studying the research question/phenomena (Berryman, 2019), and “Research Design” is the descriptive plan of methodology. Research design shows how to answer questions, achieve the questions’ objectives, the reasoning for data collections, and analysis.

A1.3.1 Methodological Choices - *Mixed Research Design*

From the available literature on the methodological choices, the present work started with Saunders, Lewis, and Thornhill (2019)’s suggestion to divide the methodological choices into three research designs, as shown in Table A-3.

Table A-3: Available Methodological Choices

Methodological Choices	Description	Continua
Quantitative Research Design	<ul style="list-style-type: none"> • Mostly with positivism, postpositivist, and deductive • Distinction needs between opinion/results and the respondents/sample’s attribute • Examine the relationship between variables with statistical and graphical techniques • Utilises controls 	Mono method: Single data collection technique
		Multi-method: Multiple data collection techniques
Qualitative Research Design	<ul style="list-style-type: none"> • Mostly with constructivism/interpretivism and inductive • Relationship between opinion and the participants (they are not respondents) • Non-standardised data collection needs classifications and 	Mono method: same as above
		Multi-method: same as above

	analysis through conceptualisation	
Mixed Research Design	<ul style="list-style-type: none"> • Mostly with pragmatism and critical realism • Maybe inductive, deductive, or abductive • Combine quantitative and quantitative methods, either concurrent/convergent, complementary, sequential /multiphase sequential 	Convergent: same question answered by qualitatively and quantitatively Different questions are answered using both methods one after the other (sequentially) or same time (Complementary)

Sources (Berryman, 2019; Flick, 2018; Morgan & Hoffman, 2021; Saunders et al., 2019; Stebbins, 2001; Teddlie & Tashakkori, 2009; Wheeldon & Åhlberg, 2012)

A1.3.1.1 Theoretical Justification

The present work adds several other prominent authors’ explanations to Saunders’s classification. The *description* column of Table A-3 provides general descriptions available for research design types by different authors, while the *continua* column summarised the different methods practised. Even though the literature clearly demonstrates qualitative and quantitative designs, the mixed method explanations are still under development as most researchers in the present day are not following the pure qualitative or quantitative methodology. However, mixed-method is with the pluralistic perceptions; i.e., it tolerates the mixed-use of opposition research designs.

Present research works are primarily abductive research in interpretivism philosophy. According to Table A-3, the interpretivism philosophy should be mainly with the qualitative research design, while the abduction is with the mixed method. However, all research designs prioritise the favouritism of research philosophies, not rejections. Those also show the same attention to inductive, deductive, and abductive reasoning. However, when the researchers are on the mixed method, frequently the explanations describe the relation between abductive and mixed-method as sine-quo-none (Flick, 2018, p. 52; Wheeldon & Åhlberg, 2012, p. 116). Therefore, it is vital to assess the theoretical understanding with the present study scenario.

A1.3.1.2 Justification to a practical approach

Evaluating the present formalised research steps (Figure A-8) over the required undertake and analysis method showed that present research must sequentially employ both methods, as shown in Table A-4. The quantitative analysis of the present research (Serial no. 4 of Table A-4) required to collect data from literature qualitatively, *quantitised* the qualitative data with numerically coding, statistically

analyse the numerical coded data, and get the quantitative output. Further, it is required to *qualitised* quantitative outputs again when validating the framework for easy understanding by the experts in their terms. According to the logic demonstrated in the introduction (under the “Nature of research”), the study combines exploratory, descriptive, explanatory, and evaluative research natures. Therefore, the present research approach should be considered a *sequential multi-phase approach of mixed-method*, based on all these research facts and the theory explanation (Saunders, Lewis, and Thornhill, 2019, p.182). Figure A-6 demonstrates the justification for such selection.

Table A-4: Analysis methods of formalized research steps

Formalised Research Steps	Undertake	Analysis
1. Understand current practice	Literature Review	Qualitative
2. Critical Evaluation of the scenario	In-depth analysis of selected HydroGIS tool, develop guidelines and procedures	Quantitative & Qualitative
3. Component Identification and Calibration	Axiological Use case analysis, Literature Survey, Expert Review	Qualitative
4. Determination of integration	In-depth Literature Survey	Quantitative
5. Development of Framework with integration	Multi Attribute Utility Theory (MAUT) and Weighted Average Programming in Multi-Criteria Analysis (WP – MCA)	
6. Validate Framework	Questionnaire	Quantitative & Qualitative
7. Recommendations	Axiological analysis	Qualitative

Source : Author

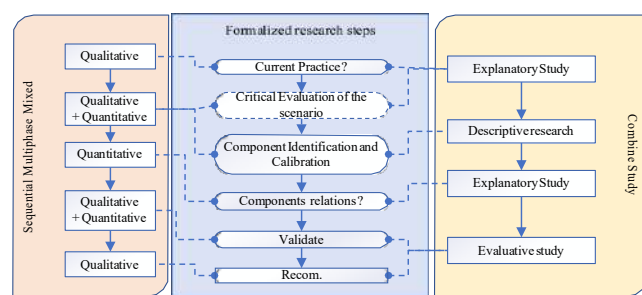


Figure A-6: Relation between mixed method and combine method with research steps

Source: Author

A1.3.2 Purpose of Research – *Combine method study* The research purpose is important in a research design as it clarifies the real research requirement. The present research employs multiple methods, i.e., an *explanatory study* to evaluate the present state-of-art for narrowing down the research to a specific gap, *descriptive research* to identify the themes, an *explanatory study* to explain the relations between themes, and an *evaluative study* to the applicability

of themes and those relations. Error! Reference source not found. demonstrates the justification for such selections. Therefore, the present research facilitates openly reasoning out the rest of the research plan.

A1.4 Chosen Research Strategies – Survey/Doc. Research/Grounded Theory

The research strategy explains the action plan to obtain answers to research questions. Those should be matched with the foresaid philosophy and methodology/design. However, the present research’s philosophy, interpretivism, allows the researcher to develop the research design creatively. It developed a so-called *creative design*, as shown in Figure A-7, which illustrates the relationship to previous decisions.

Figure A-7: Selection of methods aligned with research strategies

Source: Adopted from several authors, indicate them in latter sections

Fundamentally, positivism considers that reality exists independently from humans, but interpretivism explores human reality construed by the social and its actors. The present research is an abductive approach of theory development more biased to interpretivism, but it philosophically agrees to pragmatism. It is identified that this will be mixed-method research and apply both the exploratory science and design science research principles. Therefore, when selecting research strategies, it must be a qualitative and a quantitative research design strategy, and thus, the present research must mix strategies appropriately. The following subsections reason out the suitability of selected strategies and elaborate how to use them in this research.

A1.4.1 Qualitative research strategy – Grounded Theory

A1.4.1.1 Theory explanation

The present research should analyse, interpret, and explain the socially constructed scenario. The said purpose can be achieved by following the Glaser and Strauss (1967) Grounded Theory (GT) methodology, as it discovers “Theory” from “data” collected from the social environment. Even Glaser and Strauss separated later and developed the theory in two directions that fundamentally remains unchanged.

Glaser highlights that the core of the approach needs to be induction; hence he stopped the literature review until data coding, a middle milestone of the process. However, Strauss’s branch of GT, which is induction-focused but allow a systematic approach that emphasises validation, is more in line with the current research requirement (Deterding & Waters, 2021).

This approach is named “constructivist grounded theory”-CGT (Bryant, 2002; Charmaz, 2006, 2016). It incorporates researchers’ and participants’ interpretations to construct the concepts. There, the individual’s positions, roles, backgrounds, and values are recognised. However, the

present research refused the GT derives from positivism as the philosophical selection. Still, the CGT grows into interpretive tradition with more pragmatism continua (Charmaz, 2006), where the present research lies. However, in addition to CGT, the other branches of GT such as Critical Grounded Theory (assists research with a realist perspective - one reality explains how people's interprets are shaped/moderate it) and Situational Analysis (crating situational maps of major elements, their context, and positionalities) also somewhat agree with present work. Therefore, the present work selected the common continua of GT, where the core principles are included. Those core principles are (1) "Grounded" thinking – welcome unanticipated findings, (2) Multiple data capturing to explain the context, (3) Pursuing theory through data – a must close-reading of data, and (4) Theoretical sampling – as conceptual classifications are required. Further, the present work has considered a few myths to exclude, such as (1) The research should produce full-pledged theory, (2) Should not gather literature knowledge/theory at the beginning – Glaser's Argument, and (3) The time taken to coding is extensive (Timonen, Foley, and Conlon, 2018).

A1.4.1.2 GT Suitability

The unexpressed primary data collection for the method is done through interviews and discussions. Those speeches were transcribed, codes constructed, and analysed repetitively until reaching theoretical saturation. The design science approach/development and validation of framework with recommendations (Figure A-8 and Table A-4) could not be incorporated if crudely implemented such methodology for this research. However, GT could be employed in framework construction in the explanatory design steps of component identification and calibration. In line with Strauss's branch of GT, the present research can construct the codes through an axiological use case and literature survey and calibrate through discussion. Table A-5 presents the planned map of the present work and GT steps. Table A-5: Map of Research Steps and GT steps

Extracted Research Steps from Error! Reference source not found.	Undertake	Undertake - Repetitive steps of GT mapping	Repetitive steps of GT (Sharma, Sengupta, and Panja, 2020)
3. Component Identification and Calibration	<ul style="list-style-type: none"> i. Axiological Use case analysis ii. Literature Survey iii. Expert Review 	i – a to c ii and iii – a to d	<ul style="list-style-type: none"> a. Theoretical data sampling b. Conceptual labelling c. Memo creation d. Coding (conceptualisation)

Source: (Sharma, Sengupta, and Panja, 2020)

A1.4.2 Qualitative research strategy – *Documentary Research*

The modified GT can be applied to get the core outcome expected from the descriptive research to identify the themes. However, it required an explanatory study to evaluate the present state-of-art for narrowing the research to a specific gap, hence the need to assess the existing documents developed on the current knowledge areas. As this task is already completed and explained in Chapter 2, this chapter provides no further details.

A1.4.3 Quantitative research strategy – Survey

The remaining research consists of two studies: (1) the explanatory study to explain the relations between themes and (2) an evaluative study to evaluate. In this requirement, the survey strategy provides a well-established practice. It fundamentally agrees with the deductive approach for collecting thoughts and behaviour of a population over the known phenomena (Saunders, Lewis, and Thornhill, 2019, pp.193–194).

It can employ the data collection and analysis techniques aligned with the survey study to the latter part of the present research - design science approach (development and validation of Framework with recommendation shown in Figure A-8 and Table A-4). The survey strategies indicate that it could identify how the component of the present situation is interacting/integrating and evaluating the experts' review to develop a conclusion.

A1.5 Time horizon – Cross-Sectional Study

The present research must understand the existing phenomena rather than how they were developed to the present situation from the historical phenomena. The present research has to be a cross-sectional study. However, as the present research is interested in the temporal based flood, it influences longitudinal studies. Nevertheless, a myriad of research has implemented cross-sectional studies to investigate flood decision making, perceptions, preferences, behaviour, and people responses (Hudson, Thielen, and Bubeck, 2020). Hence, a cross-sectional study is selected for the present research.

Although the research study follows the cross-sectional method, it is interested in considering what period covers the term "cross-sectional" for the present disciplines. It can observe that the perspectives on flood management decision-making have been changing very slowly since it appeared as science. For example, IWRM, a popular theme today; was originated in the 1970s and have been discussed extensively over the years; but it took an average of 40 years to implement practically. As well, hydrology is also a mature science. Undoubtedly, the cross-sectional signifies 30 to 40 years for the present research.

3. Conclusion

As the present work's main objective is to develop HydroGIS model development framework for software professionals, it justified to develop a building block software framework and verify using expert review as described in the of Appendix 2.0. According to the Error! Reference source not found. (p. Error! Bookmark not defined.) description, flood management related

research must plan preciously and creatively as the difficulty in verification. This scenario directed the present research to not to simply follow a ready-made research methodology, but to carryout in-depth study to make the research decisions systematically. Then a comprehensive study was carried out to clear the ontological, epistemological, and axiological axioms and could be able to develop a verified mind-map to illustrate the relations between frequently using terminologies in research. All the related activities are described in section 0 (p. 2) of Appendix 2.0.

Even though the axiological stance of the researcher built the creative research methodology for the research, there are common acceptances on the better research methods according to the discipline. Accordingly, this research is about the conceptual relation between water management and scientific modelling to develop HydroGIS models. Then this study has more managerial perspectives, which most water management and systems development researches have. Therefore, the present research selections were reviewed under the management and information system management perspectives. The current study developed a path map of research design according to the developed mind- map, which answers research questions through identifying the objectives, collecting the intended data, and analysing them with the fundamental understanding of constraints (Error! Reference source not found.). The selected research options for the steps of the path are reasoned out and linked as shown in Table Error! No text of specified style in document.-1.

Table Error! No text of specified style in document.-1
The reasons for selecting conceptual philosophies for the research

Concept	Selecte d	Reason
Philosophic al axiom	Epistemologic al axiology	The socially accepted knowledge is generalised, including the author's belief. The author's extensive experience
Dimension of continua	Social Constructivist - Subjectivism	

Philosophy	Interpretivism	The research inducts the theory as an explanation of the present social status
Approach	Abduction	The knowledge is constructed qualitatively, but the framework is constructed qualitatively; Then framework evaluation conducts qualitatively and quantitatively
Research method and Methodological choice	The sequential multi-phase approach of the mixed method	
Strategies	Constructivist grounded theory	The exploratory phase of the research is based on the situational analysis
	Documentary Research	State-of-art of the subjected areas based on the availed material
	Survey	Construction of framework (the present status) needs to gather data qualitatively and analyse quantitatively
Time Horizon	Cross-sectional	The study analysis the present status

Source: Author

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Author Biographies



RMM Pradeep is a Commissioned officer of Sri Lanka Army where he has been a senior lecturer since 2015 in Faculty of Computing, General Sir John Kotelawala Defence University. His research interests lie in the area of HydroGIS framework, System analysis and design and software modelling & processing. Pradeep has served on roughly twenty-three years in different assignments in arbovirus vector research,

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NT Sohan Wijesekera is a senior professor (Civil engineering) in University of Moratuwa. He is an elegant hydrologist who won the Presidential CVCD Award for his research contribution. Snr Prof Sohan has been served more than forty-one years in the national water resource management industry and teaching in the university. He supervised more than 60 post graduate researches including PhDs. Presently he serves as the Chairman of the Board of Directors, Construction Industry Development Authority, Sri Lanka.

Table A-6: HARP Test of the present research

Your views on the nature of reality (ontology)		Strongly Agree	Agree	Slightly Agree	Slightly Disagree	Disagree	Strongly Disagree	Score
1	Organisations are real, just like physical objects.			x				1
2	Events in organisations are caused by deeper, underlying mechanisms.		x					2
3	The social world we inhabit is a world of multiple meanings, interpretations and realities.			x				1
4	'Organisation' is not a solid and static thing but a flux of collective processes and practices.		x					2
5	'Real' aspects of organisations are those that impact on organisational practices.		x					2
6	Organisational research should provide scientific, objective, accurate and valid explanations of how the organisational world really works.		x					2
7	Theories and concepts never offer completely certain knowledge, but researchers can use rational thought to decide which theories and concepts are better than others.		x					2
8	Concepts and theories are too simplistic to capture the full richness of the world.			x				1
9	What generally counts as 'real', 'true' and 'valid' is determined by politically dominant points of view.			x				1
10	Acceptable knowledge is that which enables things to be done successfully.				x			-1
Your views on the role of values in research (axiology)								
11	Researchers' values and beliefs must be excluded from the research.				x			-1
12	Researchers must try to be as objective and realistic as they can.			x				1
13	Researchers' values and beliefs are key to their interpretations of the social world.		x					2
14	Researchers should openly and critically discuss their own values and beliefs.			x				1
15	Research shapes and is shaped by what the researcher believes and doubts.					x		-2
Your views on the purpose of research								
16	The purpose of research is to discover facts and regularities, and predict future events.				x			-1
17	The purpose of organisational research is to offer an explanation of how and why organisations and societies are structured.			x				1
18	The purpose of research is to create new understandings that allow people to see the world in new ways.		x					2

19	The purpose of research is to examine and question the power relations that sustain conventional thinking and practices.					x			-2
20	The purpose of research is to solve problems and improve future practice.		x						2
Your views on what constitutes meaningful data									
21	Things that cannot be measured have no meaning for the purposes of research.				x				-1
22	Organisational theories and findings should be evaluated in terms of their explanatory power of the causes of organisational behaviour.					x			-2
23	To be meaningful, research must include participants' own interpretations of their experiences, as well as researchers' interpretations.		x						2
24	Absences and silences in the world around us are at least as important as what is prominent and obvious.			x					1
25	Meaning emerges out of our practical, experimental and critical engagement with the world.		x						2
Your views on the nature of structure and agency									
26	Human behaviour is determined by natural forces.					x			-2
27	People's choices and actions are always limited by the social norms, rules and traditions in which they are located.			x					1
28	Individuals' meaning-making is always specific to their experiences, culture and history.		x						2
29	Structure, order and form are human constructions.			x					1
30	People can use routines and customs creatively to instigate innovation and change.		x						2
Research Philosophy		Score	Reflection:						
Positivism (Questions 1,6,11,16,21,26)		-2	1. Have I got an outright philosophical winner? – <i>Yes Interpretivism</i> 2. Why do I think this is? – <i>My epistemological position is most suited to that of relativism and realism</i> 3. Which philosophy do I disagree with most? – <i>Positivism</i> 4. Why do I think this is? – <i>Not a suitable research philosophy for exploratory research</i>						
Critical Realism (Questions 2,7,12,17,22,27)		5							
Interpretivism (Questions 3,8,13,18,23,28)		10							
Postmodernism (Questions 4,9,14,19,24,29)		4							
Pragmatism (Questions 5,10,15,20,25,30)		5							

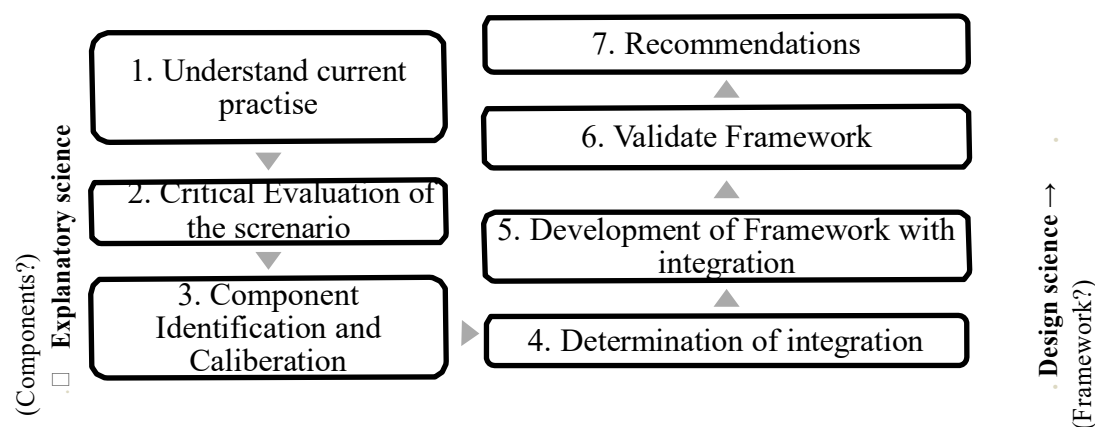


Figure A-8: Formalized Research Steps
Source: Author