applied sciences

Article

Evaluation of Barriers to Deployment of Information and Communication Technologies to Sustain Information and Communication Flow in Floods

Izza Anwer [1], Muhammad Irfan Yousuf [2,*] and Susan Grant-Muller [3]

[1] Department of Transportation Engineering, University of Engineering and Technology, Lahore 54890, Pakistan; engr-izza@uet.edu.pk or engr_izza@hotmail.com
[2] Department of Computer Science, University of Engineering and Technology, Lahore 54890, Pakistan
[3] Institute for Transport Studies, University of Leeds, Leeds LS2 9JT, UK; s.m.grant-muller@its.leeds.ac.uk
* Correspondence: irfan.yousuf@uet.edu.pk

Abstract: A sustainable information and communication flow (ICF) supports lifelines in floods, especially transport systems. A detailed insight into barriers regarding effective ICF through the implementation of information and communication technologies (ICTs) in the lifecycle of floods was given for evolved and evolving economies, i.e., York and Head-Marala, with sample sizes of 240 and 300 experts, respectively. All experts responded on an ethically approved questionnaire with further information notes that were used whilst discoursing the factors. ICTs were segregated into two groups, ranging from simple to advanced technologies. KMO and Bartlett's tests confirmed high sampling adequacy with values ranging from 0.679 to 0.823 ($\geq$0.5) with *p*-values $\leq$ 0.05. An amended version of Q-Methodology was used to identify nine factors in total. Each factor with an Eigenvalue $\geq$1 was retained, and all factors were highly reliable with values between 0.89 and 0.96. Factors were explained through communalities, factor loadings, pattern and structure matrices, and notes from experts. Results showed that under-evolved economies have limited technological resources and under-developed flood coping plans compared to evolved economies. Also, the unacknowledged possibility was uncovered that ICF can certainly be sustained if all possibly available ICTs are engaged through a thorough deployment plan of action. Authorities needed to make ICT engagement plans simple and efficient through effective coordination among different institutions. Though authorities were trained and equipped with modern tools, equipment, and technologies, dense and dependent populations overwhelmed the rescue capabilities. Other than VMS, social media pages, and radio, other ICTs were not tried and tested in floods for the exchange of transport–flood ICF. These findings are useful for stakeholders from all communities, transport planning institutions, and flood managers who are not fully benefiting from the extended use of ICTs to manage travel activities in floods.

Keywords: developed and developing countries; floods; information and communication flow; information and communication technologies; transport systems

check for updates

Citation: Anwer, I.; Yousuf, M.I.; Grant-Muller, S. Evaluation of Barriers to Deployment of Information and Communication Technologies to Sustain Information and Communication Flow in Floods. *Appl. Sci.* **2024**, *14*, 592. https://doi.org/10.3390/app14020592

Academic Editor: Alessandro Lo Schiavo

Received: 15 November 2023
Revised: 13 December 2023
Accepted: 14 December 2023
Published: 10 January 2024

1. Introduction

World Bank reports that the damages caused by the 2022 floods in Pakistan might exceed 14.9 billion USD, whereas total economic losses reach about 15.2 billion USD. Also, an approximate estimation of 16.3 billion USD is needed for reconstruction and rehabilitation, even though it does not include many basic needed assets [1,2]. Alone, the transport and communication sector suffered significant damages of about 3.3 billion USD. The damages to the transport and communication sector further cause unimaginable damage to human life-saving activities, infrastructure, and emergency and rescue (ER) operations. Therefore, it is worthy to understand the sustainability and roles of information and communication technologies (ICTs) for the exchange of transport-associated information and communication flow (ICF) in the life cycle of a flood.

There is no direct study that involves the measure of life and material losses due to lack of communication. The study of such losses is of a subjective type and requires attention and precise methods to estimate losses due to specific variables. Floods pose dynamic challenges to both evolving and evolved countries but how floods are responded to in order to minimize the damages that they can cause entirely depends on the disaster risk management policies, strategies, resources, and expertise that each individual country holds [3,4]. In recent years, the Yokohama framework following the Sendai framework of disaster risk reduction (2030) emphasized the inclusion of technology in coping with the deadly impacts of disasters, yet they considerably lacked technological details and action plans [5,6].

By keeping in view the variable capacities of different economies, the technology involvement definition varies too and is under-explored [7,8]. The role of ICTs in disasters has been under discussion recently, and there are many aspects that have not yet been thought about to engage ICTs in disasters [9]. ICTs in developing countries are under-adopted and the community requires training to engage ICTs effectively in various aspects of life [10]. As countries have different absorptive capacities toward ICTs [11], therefore, it is important to investigate the challenges faced by evolving and evolved economies regarding technological advancements and their subsequent applications.

In recent years, transport systems [12], disasters [13], and technological [14] research domains have advanced and their applications too. This research has brought three of these major research domains together [14] and the overall system has become complex. Conventional discrete methods are insufficient to capture and address the real-time challenges caused within the frame of these three domains due to floods. Therefore, new methods are required to apprehend the integrated effect of floods on multiple systems and offer practical solutions to them. In addition, there exist insufficiently comprehensive methods to analyze the dynamics of a disaster [6].

Often, disasters and their impacts are studied either through quantitative [15,16] or qualitative [17,18] methods, which are often ineffective in grasping the flood systems' dynamics [19–22]. In recent years, big data [23], wireless sensors for alerts [24], ICT-based education programs [25], empirical methods [26,27], machine learning methods [28], and analytical methods [29] have been widely used. However, there exists a need for a comprehensive analysis method that captures the qualitative aspects of ICTs and disasters and interprets them in a quantitative manner. This is because humans are the first affected and the respondents to disasters who carry subjectiveness in the form of opinions, observations, and experiences [30].

Anwer [31,32] has developed a new approach named Q–Likert methodology, which is applied to disaster-affected evolving economies to understand the hurdles faced by experts in using ICTs. Q–Likert methodology holds the maximum possible evidence through quantitative measures of qualitative data approaches. The Q–Likert methodology from [31,32] is used in this paper to draw a comparison between evolving and evolved economies facing disruptions in ICTs' deployment in floods. The work builds upon the study of [31] by extending its scope, enhancing the sample size, performing an in-depth analysis, and adding another case study.

Among other disasters, floods are historically one of the major deadly disasters [33,34]. Floods are foreseeable but when they occur, they cause much damage to ICF among others. The interrupted ICF cuts all sorts of transport lifelines such as search and ER operations [35]. It is suggested that to sustain the lifelines in floods, transport–flood management systems should be sustained through the smooth flow of information through ICTs to prevent life and property damages [14,36].

It is important to deal with the extensive losses caused by floods due to poor communication at the time of need. Other than property and infrastructure losses, broken communication linkages cause fatalities and leave people seriously disabled and traumatized for the rest of their lives. This research is a part of an expanded study, and this paper is important to highlight the perspectives of experts (i.e., transport and flood management authorities) to identify the flaws in the system due to which required information was not conveyed to people and people could not convey their sufferings to the authorities to ask for general or specific help for survival. The negative impacts of floods are massive and restoring the linkages between communities and authorities will help reduce these negative impacts and help in achieving earlier restoration of the system.

This paper is a part of an extended study. Initially, when specific data on information and communication gaps that caused missed and poorly timed information related to transport and travel-related activities in floods were approached, there was no definite answer. Therefore, different experts were approached for discussion to get a hold on the possible reasons for ICF failures. An initial survey was conducted with experts by asking three questions focusing on the objective of whether there exists any difference regarding the choice of ICTs used by communities and experts that leaves gaps in information, and if advanced technologies (accessed by experts only) are included in the system, will they be useful in eliminating those gaps?

The results gave a clear indication that experts believe that there exists a considerable difference in the usage of similar ICTs between communities and authorities. The results showed that the use of similar ICTs will bridge the gap between communities and authorities; in addition, advanced ICTs will fill in the left-over gaps in actions and information. Figures 1–3 show the three case studies, two from Pakistan (EQP = Earthquake Pakistan), FP = Floods Pakistan) and one from the UK (FUK = Floods UK) and two disasters, i.e., floods and earthquakes; experts agreed with more than 50% of data results that the ICTs used by communities and experts were not the same and therefore, the transmission of information was not fruitful. More than 80% of experts agreed that if similar ICTs were used in times of disasters, there would be a greater chance of survival, efficient search and rescue operations, and emergency transport activities including evacuations. Also, a considerable percentage showed strong agreement towards the inclusion of advanced ICTs, e.g., radars, sensors, satellites, etc., to gather unsaid information and estimate the extent of damaged infrastructure to avail the opportunities of timely life-saving actions.

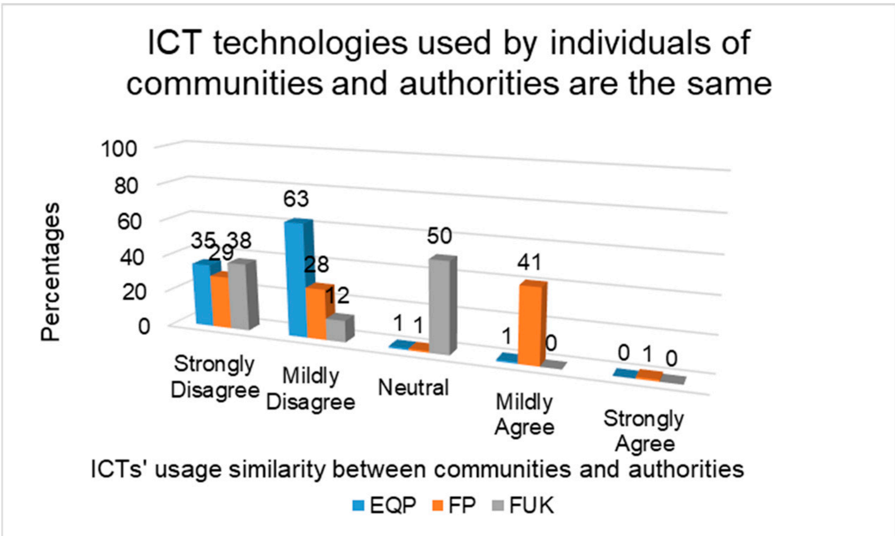

Figure 1. ICTs used by communities and authorities are same to provide two-way communication.

These results prepared certain grounds for the study by the thorough investigation of ICTs and their usage among community members and experts, including the discrepancies in the systems of management, operation, and implementation.

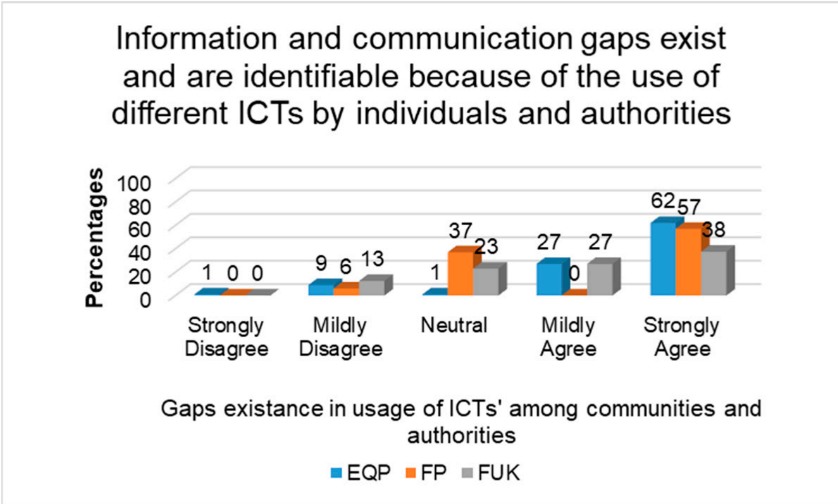

Figure 2. Information and communication gaps exist between communities and authorities.

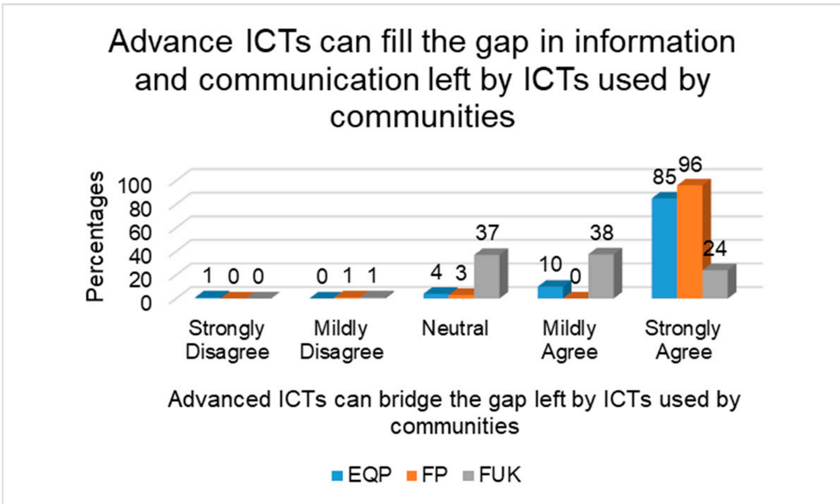

Figure 3. Advanced ICTs used by experts can bridge the gap left by ICTs used by communities.

Therefore, one step ahead of that, this study focuses on answering the following research questions: (i) how the actions of transport–flood management institutions are challenged on technological grounds, and (ii) from a big list of ICTs, which technologies can survive and effectively play an active role in the pre-, during, and post-flood phases? Anwer [14] has discussed the effectiveness of ICTs in floods from the perspective of communities in detail and this study investigates the perspectives of experts, which is a major gap in the current literature.

2. Methodology

This study was ethically approved by the ethical committee of the University of Leeds, Leeds, UK. It includes two case studies from evolving (Head-Marala, Pakistan) and evolved (York, UK) economies to understand the differences of barriers in implementing ICTs. A wide range of ICTs (Table 1) were investigated to understand the barriers to implementing technological resources in the life cycle of a flood. Table 2 shows the institutions and designations of experts from both case studies who deal with the barriers.

Table 1. Information and communication technologies (ICTs) used for information and communication flow (ICF) in floods.

ICTs	ICF Technologies Used by Communities and Institutions
ICTs-1: used by people and experts	Newspaper, newsletters/brochures Landline/mobile phones/smartphones Newsletter (mobile phone- and email subscription-based) Smartphone earthquake and flood site-specific information application Smartphone communication applications (Skype) and messengers (Viber, WhatsApp, Line) Social media websites: Facebook and Twitter with geo-tags (earthquake and flood information pages) Information websites/blogs (specific disaster websites and information pages to offer help and flood and earthquake-related information) News channels, both national and international Pictures or videos on YouTube, Web technologies/contributory websites (Google Maps, Google Media) Radio Variable message signs
ICTs-2: used by experts	Remote sensing technologies (satellite images/Radar, Lidar) Airborne technologies (airplane and helicopter) Small drones Bluetooth technology (wireless and non-wireless) Navigation system (GPS).

Table 2. Recruited experts from different institutions.

ID.No.	Institutions	Participants
	York	
1	Department of flood control and resilience, Yorkshire	Senior officer, front-line officers, and team members
2	Metrological office and civil contingencies, West Yorkshire	Metrological officers, advisors, and team members from civil contingencies
3	Department of flood risk and planning, York	Flood risk planning managers, advisors, and team members
4	Office of Intelligent Transport System (ITS), York, UK (macro-scale)	Head of professional services and team members
5	University of York	Flood experts and visiting researchers
6	Environment Department	Senior environmental engineer and staff members
7	ITS unit, Transport for London (macro-scale)	ITS managers and team members
8	ITS unit, Transport for London (micro-scale)	ITS managers and team members
	Head-Marala	
1	Development authorities, Pakistan	Town planners and geological information system experts
2	Transport Planning Unit, Government Departments.	Project directors, ICT and ITS experts
3	Meteorological Department, Research and Development Division, Islamabad.	Chief and other meteorologists
4	Rescue and Logistics operations division, National disaster management authority (NDMA)	Director and member operations wing
5	Environmental Protection Agency, Sialkot.	Director General and agency experts
6	District and emergency offices, Sialkot.	District and Emergency Officers
7	Disaster Monitoring Division, Pakistan Space & Upper Atmosphere Research Commission (SUPARCO), Islamabad.	Disaster-monitoring managers and experts
8	Rescue and rehabilitation divisions, NDMA	Director, officials, first-line rescue officers, and staff
9	Geotechnical and environment divisions, National Engineering Services Pakistan (NESPAK)	Head and team members
10	City Traffic Police, Department Punjab Police officers, Islamabad	SSP and other staff members

The methodology used involved that, first, through the participation of communities and experts, ICTs that were used by the community and experts that were similar or different so as to bridge the gap in information were identified. Also, ICTs of an advanced nature that could only be used by experts to provide untold information, such as satellite images to identify damaged lands where rescue teams could be sent to save lives, were identified. Further, the factors that cause broken information exchange linkages are identified, which were mainly focused on in this paper. This would help in aligning the information technological resource deployment plans.

It is assumed that information exchange through these ICTs is related to transport and floods and the language is local language and easy to understand.

2.1. Case Studies and ICT Technologies

York is a developed city with an evolved economy and Head-Marala (HM) is a town with an evolving economy. The overflowing of the rivers Ouse and Chenab cause massive frequent floods in York and HM, respectively. Both are densely populated, flooded in the same manner, and well equipped with modern tools, technologies, and skilled human resources. Both communities have had floods for decades but are still vulnerable. There is a massive loss of life, infrastructure, and economy [37–41].

There is evidence, shared by York City Council's website https://www.york.gov.uk/ (accessed on 12 September 2023) [42], that shows that different departments work in coordination with each other and the front-most coordinator is the city police. York City Council takes care of the city, is responsible for all of the city activities [42], and works in collaboration with different stakeholders to manage the city whenever required. It has been revealed that despite authorities' claims that they were ready to cope with floods of any severity, any time but the floods in the last decade showed that these claims were exaggerated [43].

A range of all possible ICTs were investigated from experts' perspectives. ICTs were grouped into two, ICT-1 and ICT-2 (Table 1). ICTs-1 are accessible to people and experts whilst ICTs-2 only to experts.

2.2. Survey Form, Sample, and Sample Size

A survey was designed to collect data from experts in transport, smart technologies, and disaster management authorities. The survey was piloted, ethically approved, and conducted through the recruitment of expert data collectors.

The survey was designed carefully in a concourse where statements were in a consecutive thematic manner called Q-sorts [44]. Q-sort contained 116 statements, out of which 71 belong to ICT-1 and 45 to ICT-2. The sampling method was chain and snowball, through which experts from related fields were approached, recruited, and interviewed following their consent. In total, 240 experts from York and 300 from HM were recruited. The experts belong to development authorities, planning and engineering departments, government sectors, police and emergency departments, etc. (Table 2).

2.3. Data Collection and Analysis Technique (Q–Likert Methodology)

The modes of data collection were through telephonic conversations and in-person visits. Along with the survey form, additional notes were taken to explore the underlying problems. These notes are also discussed while interpreting results.

According to ref. [32], Q–Likert methodology is a refined form of Q-methodology and Likert scales with intact principles of Q-methodology. Q-methodology and its amended versions are widely used in psychology, attitude, and perception-based studies; however, it is under-applied in technology, disaster, and transport system-related research [45–48]. The nature of this study demanded a mixed-methods approach to deal with qualitative and quantitative data; hence, Q–Likert methodology was the most suited method to select, collect, analyze, and interpret data.

Each statement on the survey form is called a Q–Likert statement and a set of statements called Q–Likert sorts. Data was collected on five-point Q–Likert sorts from each expert separately. Inverse factor analysis was applied to the collected data in which experts are variables and responses against each Q–Likert statement are attribute values.

3. Data Analysis and Result Interpretation

Though Q–Likert methodology has the potential to take small sample sizes and extract massive information but this research has employed a massive sample size [32,45,49].

3.1. Sample Adequacy Test of Kaiser–Meyer–Olkin (KMO) Measure and Bartlett's Test

With respect to the number of statements and the adequacy of sample size, KMO and Bartlett's sampling adequacy test were conducted. The KMO values are greater than 0.5 and closer to 1. Also, Bartlett's test shows $p \leq 0.05$, which is statistically significant evidence to show that the sample is strongly adequate to draw meaningful results, Table 3.

Table 3. Kaiser–Meyer–Olkin measure and Bartlett's test for sampling adequacy validity.

Case-Study ICTs	No. of Statements	(KMO)	Bartlett's Sig.	Sampling Adequacy
HM (ICT-1)	71	0.816	0.000	Great
HM (ICT-2)	45	0.679	0.000	Mediocre
York (ICT-1)	71	0.760	0.000	Good
York (ICT-2)	45	0.823	0.000	Great

3.2. Extracted Factors through Factor Rotation Using Q–Likert Methodology

Q-Factor analysis, particularly the principal component analysis extraction method [50,51] was used for both ICT groups of York and HM; analysis was run to calculate latent variables. As a result, scree plots were obtained based on Eigenvalues (<1 = factor ignored, $\geq$1 = factor retained) (Figure 4).

Communalities for each expert set were calculated to understand the explained and unexplained information for each extracted factor. Ranging between 0 and 1, the values closer to 1 showed that extracted factors have significant information in explaining all the data Table A1. For York ICT-1, expert set 4 extracted the lowest (0.441) whilst set 8 extracted the highest (0.691) information share, and for ICT-2, expert set 1 extracted the lowest (0.145) whilst set 8 extracted the highest (0.983) information share. For HM ICT-1, expert set 8 extracted the lowest (0.170) whilst set 5 extracted the highest (0.912) information share, and for ICT-2, expert set 9 extracted the lowest (0.242) whilst set 10 extracted the highest (0.746) information share.

The next step was factor rotation, the purpose of which was to analyze existing relationships but from different angles (perspectives) to unveil further details and make details less ambiguous and more explainable. There are two types of rotations that can be performed, i.e., Orthogonal and Oblique. The former rotates the factors by keeping them independent of each other, whilst the latter allows factors to co-relate with each other. Oblique rotation is very complicated compared to orthogonal rotation because correlations are permitted to happen in oblique rotation. Another compelling aspect of preferring oblique over orthogonal rotation was that the variables in this analysis are humans (experts) and the nature of their professional commitments might correlate with each other rather than being totally independent. This fact should not be ignored and was taken into account while analyzing data.

Factors were rotated by using the complex method of Oblique rotation to support oblique correlations. Further to Oblique rotation, the method of rotation used was Direct Oblimin with default Delta (▲) value = 0 so as not to influence the actual correlation that exists among the factors.

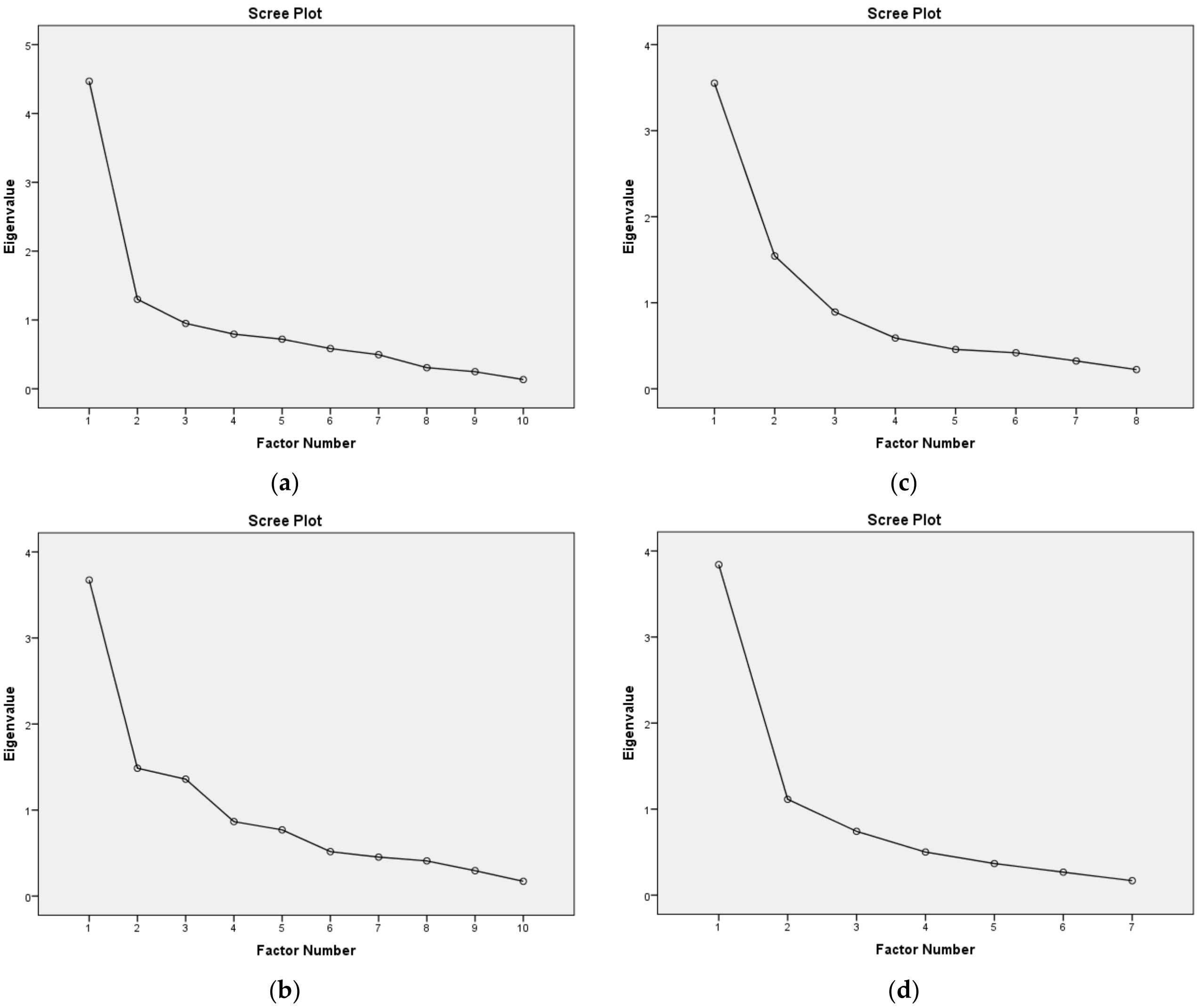

Figure 4. Eigenvalues show retaining of factors for (**a**) York-ICT-1, (**b**) York-ICT-2, (**c**) Head-marala-ICT-1, and (**d**) Head-Marala-ICT-2.

Pattern and structure matrices were calculated through factor rotation. The pattern matrix (PM) presented factor loading whilst the structure matrix (SM) presented the relationship between the obtained factors. The PM indicated the loading contributed by individual variables on each factor. Each set of Q-statements (array) and the related loadings were further interpreted with respect to the calculated and standardized scores supported with additional information taken from experts as notes. Q–Likert sorts resulted in three different types, i.e., significant, bipolar, and confound during PMs' development. Each type of Q–Likert sort was dealt with as per its nature.

Table A2 shows the number of retained factors and the contribution of information shared by each expert set. For York ICTs-1 and 2, two factors were identified, and for HM ICT-1, two, whilst for ICT-2, three factors were identified. For York ICT-1, factor one was heavily loaded by set eight and two by set one. For ICT-2, factor one was heavily loaded by set five and factor two by set eight. For HM ICT-1, factor one was heavily loaded by set six and factor two by set five. For ICT-2, factor one was heavily loaded by set eight, factor two by set ten, and factor three by set two.

Table A3 shows the relationship strengths between factors and expert sets. For York ICT-1, factor one has a strong relationship with responses from expert set eight whilst factor two has a strong relationship with set seven. For ICT-2, set five and factor one have a strong relationship, whilst set eight has a strong relationship with factor two. For HM, ICT-1, set six and factor one have a strong relationship, whilst set three and factor two have a strong negative relationship. For ICT-2, set eight and factor one have a strong relationship, set ten and factor two have a strong relationship, whilst set two and factor three have a strongly negative relationship.

The PM loadings and their subsequent relationships from SM helped to calculate the standardized loadings. The standardized loadings, loading scores, and additional information gathered through notes from experts were interpreted.

3.3. Q–Likert Factor Scores

After factor extraction, the details of the factors and their association with the variables were calculated and expressed through factor loading plots and matrices. Each Q–Likert sort and its elements had a different relation with each identified factor. The significance of factor loading in PM was determined through the standard error (SE) of factor loadings, where N = number of statements.

$$SE = \frac{1}{\sqrt{N}} \tag{1}$$

Expert sets with loadings greater than 2.58 (SE) were considered statistically significant at the level of 0.01, which showed a strong relationship between the Q–Likert sort and the identified factors. The loadings greater than 0.31 (ICT-1) and 0.38 (ICT-2) were statistically significant at the 0.01 level.

1. Standard error of factor loading for (ICT-1) 71 statements = $2.58(1/\sqrt{71}) \geq 0.31$
2. Standard error of factor loading for (ICT-2) 45 statements = $2.58(1/\sqrt{45}) \geq 0.38$

The weights of each factor were calculated and multiplied by the respective array of statements of experts' responses. It followed the standardization of all arrays of respective experts relating to each factor. For standardizing the array of responses from experts for each factor, first, Q–Likert sort factor loadings (f) from the PM for each extracted factor were separated. After separation, w (weight) was calculated through Equation (2).

$$W = \frac{f}{(1 - f^2)} \tag{2}$$

The weighted values of each Q–Likert sort were then multiplied with each statement of the array (raw responses from the experts) of that respective Q–Likert sort. Afterward, the sum of each statement score was calculated, for which Z-scores for each statement were computed by Equation (3), where 'T' is the total of each weighted statement and 's' is the standard deviation of the Total (T).

$$Z = \frac{T - \overline{X}}{S} \tag{3}$$

The Z-scores were used to compare and standardize the effect of different statements in different arrays to reflect the effect on each factor. The index used was (−2 to +2), which was compatible with the Likert scale used during data collection. Each statement was discoursed according to its scores. If any statement had a similar score but with reverse signs, then both possibilities about the concourse were provided. In other cases, higher loading was preferred over lower loading to interpret the results.

3.4. Q–Likert Factor Interpretation

Prior to interpreting the factors, it is important to check the reliability of each identified factor. Table 4 shows that all factors are highly reliable, with reliability values ≥ 0.89. The final step towards Q–Likert factor analysis was interpreting the factors. The objectively focused concourse statements were discoursed with interpretations. It was conducted in two ways; first, the discourse and discussion on identified name-called factors along with explanatory notes from experts. Second, the comparison of ICTs engaged by experts in the pre-, during, and post-flood phases (Table 5).

Table 4. Reliability check for identified factors for ICT groups 1 and 2 from York and Head-Marala.

Factors	r = 0.80(p)/(1 + (p-1)0.80), r = Reliability of Factors (Ranges from 0 (Not Reliable at All) to 1 (Extremely Reliable)), p = Number of Persons (Experts) Defining a Factor	
	York: ICT-1	HM: ICT-1
1	r1 = 0.94, p1 = 120	r1 = 0.96, p1 = 210
2	r2 = 0.94, p2 = 120	r2 = 0.92, p2 = 90
	York: ICT-2	HM: ICT-2
1	r1 = 0.95, p1 = 150	r1 = 0.96, p1 = 180
2	r1 = 0.89, p2 = 90	r2 = 0.90, p2 = 60
3	-None-	r3 = 0.90, p3 = 60

Table 5. Expert's perspectives: the effectiveness of ICTs through the life cycle of a flood for York and Head-Marala (where U = used, NU = not used, NS = not sure (ambiguous), and MU = moderately used or somewhere in the middle).

ICT-1	York	Head-Marala	ICT-2	York	Head-Marala
Newspaper			Navigation system (GPS)		
Pre	NS	U	**Pre**	MU	NU
During	NU	NS	**During**	NU	NU
Post	NU	NS	**Post**	NU	NU
Newsletters and brochures			**Variable message signs (VMS), diversions, loudspeakers for evacuations**		
Pre	NS	U	**Pre**	U	U
During	MU	NS	**During**	U	U
Post	MU	NS	**Post**	U	U
Landlines/smartphones (call and text)			**Remote sensing technologies (satellite images/RADAR, LIDAR)**		
Pre	NS	NU	**Pre**	NU	NU
During	MU	NS	**During**	NU	NU
Post	NU	MU	**Post**	NU	NU
Newsletter/email subscriptions			**Airborne technologies (airplanes and helicopters)**		
Pre	NU	NU	**Pre**	MU	MU
During	NU	NU	**During**	U	U
Post	NU	NU	**Post**	U	U
Information websites			**Small drones**		
Pre	NS	NU	**Pre**	NU	NU
During	NU	NU	**During**	U	NU
Post	NU	NU	**Post**	U	NU
Flood/earthquake site-specific application			**Technology-equipped boat**		
Pre	NU	NU	**Pre**	NU	U
During	NU	NU	**During**	U	U
Post	NU	NU	**Post**	U	U
Smartphone communication applications			**Bluetooth technology (wireless and non-wireless), LOOP detectors, and CCTV cameras**		
Pre	U	U	**Pre**	U	NU
During	U	U	**During**	MU	NU
Post	U	U	**Post**	U	NU

Table 5. *Cont.*

ICT-1	York	Head-Marala	ICT-2	York	Head-Marala
Social media dedicated information pages					
Pre	NU	NU			
During	NS	NU			
Post	NU	NU			
Images and videos on YouTube (or similar)					
Pre	NU	NU			
During	NS	NU			
Post	NU	NU			
Web technologies					
Pre	NU	NU			
During	MU	NU			
Post	NU	NU			
Radio					
Pre	U	MU			
During	U	MU			
Post	U	U			
News channels					
Pre	U	U			
During	NU	NU			
Post	NU	NU			

The next section presents the identified factors following an elaborate discussion on each one of them.

4. Identified Factors and Discoursed Discussion

Figure 5 shows the identified factors' loading plots for both case studies and respective ICT groups. Factor loading plots, PM, and SM are used to understand the clusters of information, loaded by expert sets. Also, additional notes of information from experts were utilized to interpret results and reinforce information.

4.1. Factors: York ICT-1

Figure 5a shows that (a) York ICT-1 expert sets 8, 7, 4, and 2 loaded factor one with a maximum PM of 0.864 and SM of 0.824, whereas 1 and 3 loaded factor two with a maximum PM of 0.843 and SM of 0.773 (Tables A2 and A3). Likewise, sets 6 and 5 influenced both factors one and two.

4.1.1. Technology-Led Management of Transport System Network Operations in Floods

It was revealed that there was a lack of technology-led transport system management in floods, which caused haphazard, unguided, and panicked evacuations by the transport–flood-affected people. The lack of timely information showed a clear gap in ICF between people and authorities. Authorities believed that only a few people used ICTs, e.g., smartphones, to provide transport–flood information and the data generated by those ICTs were not accessible by the authorities and, thus, could not be used for ER needs.

Experts shared that the life and property losses could be avoided if those affected and ER teams were informed on time with relevant physical transport network and operation information but often, it was not happening, especially in floods. Therefore, it is the need of the hour to incorporate ICTs in the transport system and York is not yet ready to meet the pace of changing trends in transport and technologies. To date, it is required to revisit all the policies from time to time with a focus on the deployment of a variety of technological resources while making decisions to deal with future challenges such as climate change.

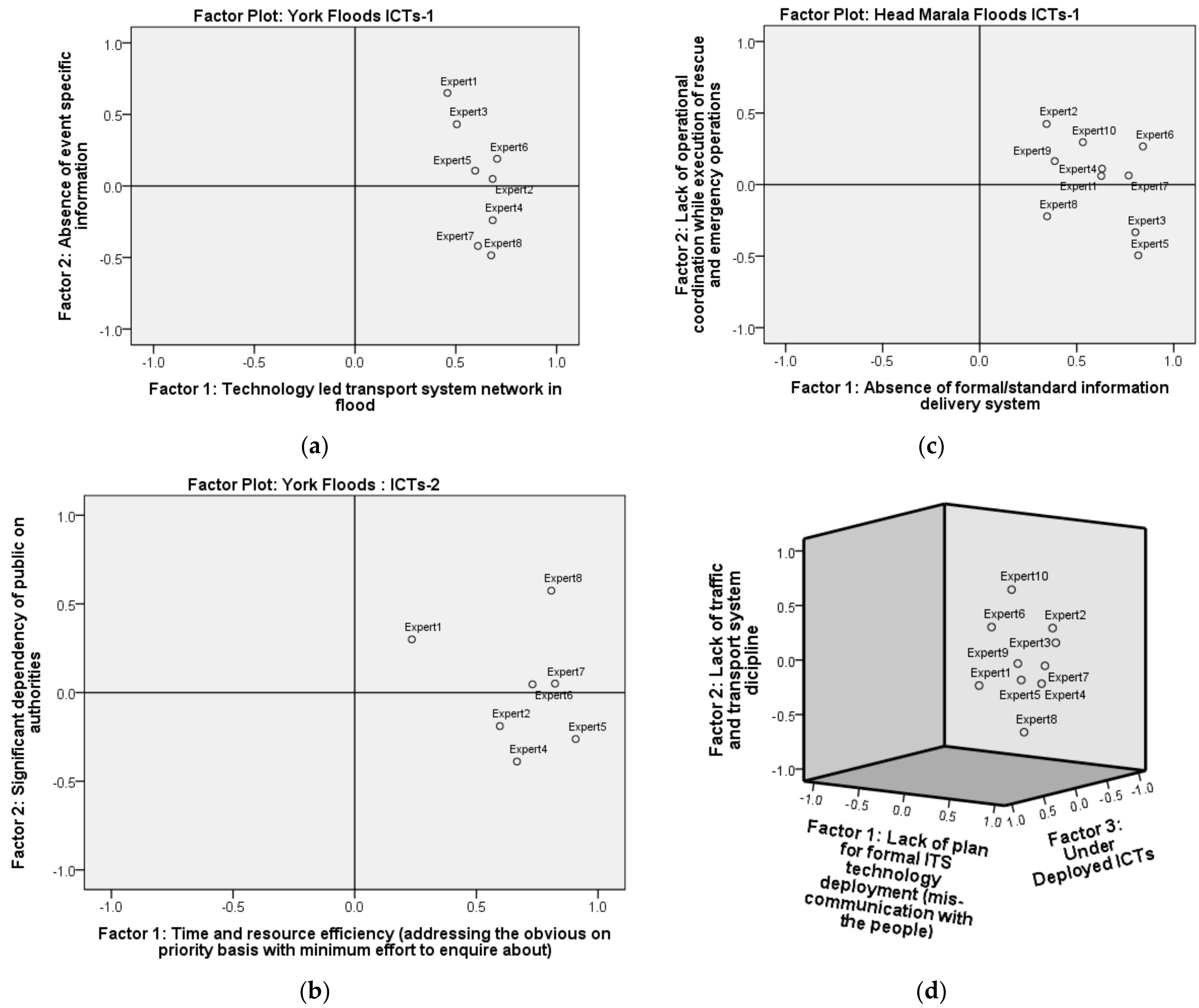

Figure 5. Factor loading plot in rotated factor space for (**a**) York ICT-1, (**b**) York ICT-2, (**c**) Head-Marala ICT-1, (**d**) Head-Marala ICT-2.

4.1.2. Absence of Event-Specific Information

York is different in nature. The significant reason was the lack of sharing of event-specific information among authorities and flood victims. The issue is the origin of many issues such as loss of valuable time to figure out what went wrong, where it went wrong, who was the victim, how to help, what plan to adopt, etc., which in turn caused uncertainty and delays in the execution of operations by the authorities. Also, the spread of misinformation and miscommunication happened among those vulnerable, which made the situation worse, and trust in authorities was lost. Even though there was a possibility of a weak connection (bond of trust) between authorities and people during floods, unfortunately, that was not shown. For example, when York's Foss barrier and pumping station were overwhelmed by flood water, a sudden decision was made to raise the barrier [52] and immediate amendments to the flood prevention plan were executed. This caused more than 600 properties to flood [53] and hundreds of people to evacuate because neither people nor authorities were expecting this situation.

Authorities probably had the resources and plans to tackle any challenging situations, but people did not. Therefore, in such situations, the exchange of event-specific information is necessary to utilize the best possible efforts to deal with unpleasant circumstances. For example, someone is unable to evacuate their house, is stuck in a building, their car is flooded with water and they cannot come out of it, has taken a wrong turn on the road and is unable to recognize the way out [37,54,55], and similar. It is only possible when we deploy every possible ICT available and effective in that area in an optimum manner and monitor it to improve transport systems' resilience in floods. This can be conducted to bridge the gap between individuals of communities and authorities through the sharing of information. The resilience can be monitored by further creating response maps of that particular area that identify the rate of participation in information pools.

Experts revealed that the main activities from previous floods, e.g., the time schedule for past floods' coping activities, were reviewed by authorities to improve the system for the future [40,56] but new challenges arose every time because each flood is unique and brings its own provocations.

4.2. Factors: York ICT-2

Figure 5b shows that two factors were identified, for which expert sets 7, 6, 2, 5, and 4 loaded factor one with a maximum PM of 0.928 and SM of 0.944, whilst sets 1 and 8 loaded factor two with a PM of 0.882 and an SM of 0.972 (Tables A2 and A3). It should be noted here that responses from set 3 showed "zero" variance.

4.2.1. Time and Resource Efficiency: Addressing the Obvious on Priority Basis Whilst Putting Minimum Effort to Enquire about the out of Sight

York experts showed concern that although authorities had enough resources vs. a controllable number of flood victims in the flooded area, even then it was a challenge for them to decide where to start rescuing people. The usual practice was that after every flood, the data of each vulnerable person were acquired and added to a record and each activity was evaluated [40,42] to utilize time and resources in a better way next time.

The identified factor indicated information about the provision of EM to the people by using different resources including ER vehicles. Authorities usually did not try to reach the far-flung flooded regions by themselves, but rather addressed the obvious and easy-to-access areas to utilize time and resources efficiently. This leaves a few gray areas in the system that cause either loss of life, property, or other resources.

This situation could be avoided by engaging ICTs to provide easy options to investigate and help neglected flood victims who probably could not engage in any contact with anyone by themselves. For example, if a local community group of flooded people was created on any social media, then the absence of someone's response may indicate that the person was in trouble or had no access to any communication sources. Also, while evacuating, sharing of vehicles and other necessary transport–flood information might improve the safety of the citizens and develop community strength.

4.2.2. Unrealistic Expectations of Public from Authorities

Two aspects were discoursed simultaneously; first, flood victims were significantly dependent on the authorities and expected them to take every initiative and measure to help them in floods. The second aspect was that there was very little community strength observed as a result. There emerges a need for balance between both aspects. The reverse trend was observed in the case of floods in HM.

It is practically impossible that authorities do everything in extreme flood situations, especially if there is a rapid change in flood dynamics. For example, the removal of defense barriers from River Foss because of a quick decision by authorities caused a huge loss. Strong community strength and lesser dependence on the authorities could have enhanced efficient use of resources and time because otherwise, it creates an extra burden on the authorities. Engagement of ICTs can help reinforce community strength as well as rectify the overwhelming dependency of flood victims on authorities.

It was also observed that in the during and post phases of floods, the implementation of flood management plans practiced by the authorities was often not very compatible with flood-affected people. This was because those affected were not taken into consideration while designing plans and strategies for them; also, advanced ICTs were used by authorities without the prominent inclusion of the public.

4.3. Factors: Head-Marala ICT-1

Figure 5c shows that two factors were identified for which expert sets 6, 2, 10, 7, 4, 1, and 9 loaded factor one with a maximum PM of 0.748 and SM of 0.857 and expert sets 3 and 8 loaded factor two with a PM of −0.956 and an SM of −0.859 (Tables A2 and A3). Bipolarity in the Q–Likert sort is obvious.

4.3.1. Absence of Formal and Standard Information Delivery System

Power cut-out is the first thing that happens in floods even when the flood has not arrived yet. It happened in York too but only when the flood was severe. The power cut-out paralyzed most of the ICF such as TV broadcasts but there were still many options available that needed to be considered but were not. HM is not developed compared to York, yet people had considerable access to smart gadgets. It came out that the grassroots-level ICF was quite weak.

HM showed strong community strength and lesser dependency on authorities, which was reversely observed in York. The reason was that HM's people understood and accepted the ground realities that the population was denser compared to the facilities that authorities had. This compelled people to manage their own escape and safety measures. In such scenarios, the minimum help that people expected to obtain from authorities was a constant supply of transport–flood-related ICF. Thus emerged a strong need to establish a standard format of ICF utilization to keep people updated with constant standardized and customized information sharing.

For this purpose, a specific set of ICTs should be engaged in floods but there is also a need to standardize the plans to practice ICTs for effective communication among communities and authorities. This information sharing requires timely management; otherwise, the useful information may get lost or outdated with the heterogeneous use of different ICTs.

4.3.2. Lack of Operational Coordination among Different Institutes during Execution of Emergency and Rescue Operations

In HM, contrary to York, a weak operational coordination among different institutions was observed during the execution of ER operations. It is out of the question that authorities used their efforts and expertise in the best possible way that they could but due to the lack of an effective operational framework, tasks were either overlapped or unattended and there was ambiguity in setting addressable jobs' priorities. Also, hesitation in taking initiative while overseeing a particular operation, either due to political or other administrative pressures, caused weak operational coordination.

The inclusion of stakeholders seemed a critical problem to consider. For example, metrological and environment departments conveyed up-to-date information to other institutions but not directly to the public, who were the first line affected. Experts shared that while managing floods, transport system-managing authorities were usually not taken into consideration, which results in poor handling of transport systems in floods. Also, many possibilities of engaging ICTs for effective communication were neglected. This triggered loss of time, resources, and people's trust in authorities. Contrary to HM, the authorities in York worked in a more coordinated manner, which is why the public trusted authorities more compared to their own selves.

This can be avoided by practicing two things. Firstly, engaging a variety of ICTs [57] in the ER operational system for fast and timely communication among different stakeholders of the society who face transport system problems in floods. Secondly, there is a need for a suitable coordination system to execute plans with clear definitions and distribution of layer-wise responsibilities and roles of each authority. The incorporation of ICTs will optimize the strategies to tackle transport systems in different flood scenarios.

4.4. Factors: Head-Marala ICT-2

Figure 5d shows that three factors were identified for which expert sets 8, 4, 7, 5, 1, and 9 loaded factor one with a maximum PM of 0.965 and SM of 0.86, sets 10 and 6 loaded factor two with a PM of 0.850 and an SM of 0.829, and set 3 loaded factor three with a PM of −0.709 and an SM of −0.741 (Tables A2 and A3).

4.4.1. Lack of Formal ICT Deployment Plan: A Reason for Miscommunication with the People

Experts from HM mentioned that the information system's ability to convey information about floods, their occurrence, expected severity, and flood water flow was in a very immature phase. Only when the bulk of water overflowed and flooded the region were floods announced in mosques and these were the only warnings with no further details. There was a lack of formal plans to cope with the flood's impacts. Rescue was provided to those who were stuck in floods; females and children were preferred though.

It was revealed that to manage floods and gather information to assess the progression, an important neglected aspect was the absence of an advanced ICT deployment plan, especially in the time of flood management operations. Each ICT can play a different role in managing transport systems, e.g., traffic accident avoidance systems in certain prevailing situations. Therefore, a holistic plan and a framework are required to take all ICTs on board to consider every possible worst scenario that people and authorities may encounter.

It was emphasized to establish an understanding with the community people [57,58] but it was not given due importance. Through a comprehensive ICT deployment plan, communities can effectively be engaged in their own capacity to deal with the challenges offered by floods. For example, communities can offer sharing of resources, such as technological gadgets to get into contact with other community members in need, vehicles and transport services that can be shared in floods, and ICTs through which ICF can be sustained.

Even though advanced ICTs can only be handled by experts, there was an intense need to involve flood-vulnerable and -affected people and their concerns, views, experiences, and practical involvements to make realistic plans and achievable targets. It requires a rich data bank to investigate detailed transport systems in flods. In contrast to York, so far there exists no specific data related to HM but this can be achieved by deploying multiple ICTs through which the required data can be collected.

4.4.2. Lack of Traffic and Transport System Discipline

If transport systems under floods are effectively managed and smoothly run with minimum accidents, delays, and congestion then the negative impacts of floods can efficiently be coped with. The usual trend observed in the traffic and transport system was a lack of discipline, especially during floods. Two types of traffic behaviors were brought into notice by the experts working for HM flood management and there exists no case-specific study to date.

The first type of behavior was that while flooding, the water level in HM rose and people from the nearby areas started traveling towards the flood-affected area to see rising water. This was rather a recreational activity and adventurous spot without realizing the complex nature of dangerous floods' effects, which was never observed in York. An opposite flow of traffic towards the flooded area interrupted mainstream evacuation and ER traffic and caused delays in ER search operations. The authorities' attention was divided due to irresponsible behavior, the infrastructure being overburdened, and many lives being exposed to danger.

The second type of behavior was from evacuating traffic, in which no discipline was followed, and each driver drove their vehicle with almost no safe distance from the leading and following vehicles. Drivers, wherever they found a space, inserted their vehicles without realizing the consequences in the form of congestion, delays, accidents, and disruptive flow. Experts highlighted that emergency vehicles, i.e., fire brigades and ambulances, could not pass through such traffic, which was very disappointing. In contrast, Yorkshire authorities advised drivers to double the headway distance, which was followed by evacuees.

Due to these behaviors, authorities could not consume their optimum efforts and resources, and the effectiveness of the potential deployment of ICTs was compromised. Hence, the need emerged for a thorough plan to tackle transport systems in floods well integrated with different information systems and with the involvement of all possible influencing sectors of society.

4.4.3. Under-Deployed ICTs

The results showed that the existing ICTs were under-deployed compared to their potential because the practical applications of ICTs were not experienced in floods. Also, there was room to exploit already-in-practice ICTs by expanding their application perspectives in various complicated flood scenarios.

To date, there is no significant research and data on the use of ICTs in evolving flood-prone countries like Pakistan. Refs. [57,58] suggested flood management authorities on multiple forums to integrate a variety of ICTs into the flood management and relief operations without integrating transport systems.

Table 5 shows that from ICT-1, social media information pages were used in both York and HM, whilst radio was used in York for all phases of floods. From ICT-2, evacuation VMS were engaged for all phases and airborne technologies and technology-built boats for the during and post phases for both case studies. The rest of the ICTs were not tried or tested for specific scenarios and their possible potential remained unknown.

ICTs play a vital role in managing travel activities, especially in the time of floods because guided and timely information is supportive of rescue, emergency search operations, and evacuations. For example, when HM was flooded with huge infrastructure destruction and life losses, there was no local driver available who could drive injured people to nearby hospitals for medical aid and there was no road left to define the path. Drivers imported from other localities were brought to the area to drive vehicles with inbuilt ICTs. GPS systems and phones helped the drivers to take people out of the damaged region toward the nearby aid camps and hospitals.

It is to be noted that Table 5 shows the use of ICTs for flood warnings, coping strategies, and instructions for the three stages of floods, pre, during, and post. It is assumed that the information provided through these ICTs must be in the local language and easy to understand; therefore, for this paper, the language of messages was not stressed but rather the mode of information sharing, which was or was not operative in certain circumstances (Table 5). The particular focus was on the exchange of transport, travel, evacuation, rescue and search operations, and any other transport- and flood-related information.

In summary, it was found that both York and HM faced challenges related to the lack of technology-led management in transport systems during floods even though York is very advanced with technology, resources, and infrastructure. The unrealistic expectations of the public and the need for efficient time and resource management were common concerns in both locations too. Both regions emphasized the importance of incorporating ICTs for effective communication, community engagement, and improving resilience to floods.

As a point of difference between both case studies, HM exhibited stronger community strength and lesser dependency on authorities compared to York. The issues related to power cut-out and weak ICF were more pronounced in HM, indicating the lack of resources.

York emphasized the need for revisiting policies and deploying a variety of technological resources, while HM focused on the absence of a formal and standard information delivery system and weak operational coordination among different institutions during emergency and rescue operations.

5. Conclusions

The conclusions and identified factors are drawn from the opinions of experts, authorities, and managers of transport- and flood-related institutions to understand why information exchange fails; why despite having significant ICT resources, timely actions do not happen; and how to bridge the gap of information between experts and communities.

It is concluded that in both evolved and under-evolved economies, ICF related to transport systems under floods is a challenge at all times. The role of ICTs is overlooked, yet carries a huge exploitable potential to sustain lifeline systems during floods. To understand the barriers to implementing ICTs in floods, responsible factors were identified. The input information came from samples of expert sets, 240 (York) and 300 (HM). KMO and Bartlett's test confirmed high sampling adequacy with values ranging from 0.679 to 0.823 (i.e., $\geq$0.5) with p-values ≤ 0.05. All factors with Eigenvalues $\geq$1 were retained whilst those ≤ 1 were neglected. For York, two factors emerged for both ICT-1 and ICT-2, and for HM, two factors for ICT-1 and three factors for ICT-2 emerged. These factors were highly reliable with values ranging between 0.89 and 0.96.

Factors were explained based on communalities with repeated iterations that show the information contribution of each drawn factor. Factor rotation uncovered PM and SM to show the strength of relationships between information sources and obtained factors. Extracted communalities showed that in York, all factors were contributed with information from micro-scaled ITS managers, i.e., set 8 with values 0.691 for ICT-1 and 0.983 for ICT-2. In HM ICT-1, all factors contributed information from environmental protection agencies, i.e., set 5 for ICT-1 with a value of 0.912, and city traffic police, i.e., set 10 for ICT-2 with a value of 0.746.

ICT-1 was a group of technologies used to exchange and dispatch information among people and authorities. Factors related to ICT-1 in York and HM were nearly of a similar nature. In York, the transport system network required an integrated system of ICTs to regulate ICF during floods so that people and authorities could communicate effectively. The ICF particularly needed event-specific information with which anyone can benefit from the information they require to manage evacuation and ER operations. Similarly in HM, the information to be delivered to people was unstructured and shapeless. It required formal and standardized information, especially in the local language so flood-affected people can understand. Also, operational coordination among different institutions was absent, which did not support the ER operations even if information from ICT-2 was gathered. The extended delays and laborious and unneeded extended procedures caused many affected people left out to die.

ICT-2 included highly technical devices used by the experts only and based on these technologies, informed decisions were made. Identified factors highlighted a difference in the behaviors of communities. In York, people were overly dependent on authorities in terms of ER and no significant resilient behavior was observed compared to HM. Likewise, authorities in York approached people who were easy to approach and despite critical challenges to the lives of people, fewer efforts were observed to approach far-resided people even though highly precise information from ICT-2 was available in most of the instances. In HM, gray areas were identified in which the lack of formal ICT-2 deployment plans and laborious procedures to use ICTs caused prolonged delays and inefficiencies in ER operations. Considerable ICTs-2 were not even deployed to attain required information. Also, community people over-burdened the transport system through contraflow towards the flooded area, which distracted and troubled ER teams.

An evaluation of ICTs-1 and 2 in three phases of floods was conducted by experts and it came out that many ICTs-1 and 2 were not even considered to be deployed for the ICF of transport–flood-related information among people and experts. Radio, social media information pages, VMS, technologically equipped boats, and airborne technologies were used to some extent but the rest were not. For stakeholders of both case studies, it is a valuable baseline that York emphasized the need for revisiting policies and deploying a variety of technological resources, while HM focused on the absence of a formal and standard information delivery system and weak operational coordination among different institutions during emergency and rescue operations. Therefore, both experts and authorities from both case studies should work on the gray areas highlighted in this research to improve the transport–flood systems.

A flood index-inspired, priority-based use of ICT plans/frameworks is recommended to effectively help manage transport systems, especially during ER operations. It will improve ICF among authorities such as ICT and flood ICF managers, institutions, and vulnerable people. Improvement in the transport system's resilience could be ensured by addressing the identified factors and maintaining the traffic flows on roads. Meanwhile, the public should be given awareness about ICTs and their potential use, and law enforcement agencies should take strict actions against those causing ill-discipline in floods. It is also recommended that to monitor the transport system's resilience in floods, fast revival of information and transport services is required. Apparently, it could be measured over time; therefore, data recording is an important aspect that needs to be maintained and trends could be checked over time to measure the progress.

The strengths of the study include a thorough research approach with the inclusion of 240 to 300 samples in the respective case studies that adds robustness and diversity to it by capturing a broader range of perspectives. The ethical approval enhanced the credibility, and KMO and Bartlett's test confirmed a high sampling adequacy that adds a quantitative dimension to reinforce the validity of the findings. Also, the high reliability values of the identified factors suggest a consistent and dependable measurement of the variables under consideration. The limitations include that the study does not cover the potential cost implications of implementing the recommended ICT deployment plans, which could be a crucial factor for stakeholders and authorities considering the adoption of these strategies.

Further studies require multiple methods to attain a better understanding of ICT deployment plans in floods, which is carried out in forthcoming publications from this study. Also, onwards from this paper is the assessment of criteria with respect to the effectiveness of ICTs under various scenarios in making comprehensive plans.

Author Contributions: Conceptualization, I.A.; Methodology, I.A. and M.I.Y.; Software, I.A.; Validation, I.A. and M.I.Y.; Formal analysis, I.A.; Investigation, I.A.; Resources, I.A.; Data curation, I.A. and M.I.Y.; Writing—original draft, I.A.; Writing—review & editing, M.I.Y.; Visualization, M.I.Y.; Supervision, S.G.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This work was partially funded by the Korea Institute of Science and Technology (KIST) under KIST School Partnership Project for its alumni.

Institutional Review Board Statement: The study is reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and the decision was favorable, reference code is AREA 14-073, 2015.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data are not publicly available because it involves high-profile experts' personal responses and most of them did not want data taken from them to be shared.

Acknowledgments: We highly acknowledge the cooperation of all the experts from various institutions who spared their time and contributed their wisdom and honest opinions to this study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Communalities of ICTs-1 and 2 from York and HM.

York (ICT-1) Communalities			HM (ICT-1) Communalities		
Expert Sets	**Initial**	**Extraction**	**Expert Sets**	**Initial**	**Extraction**
1	0.431	0.632	1	0.387	0.396
2	0.443	0.468	2	0.314	0.298
3	0.409	**0.441**	3	0.760	0.754
4	0.526	0.523	4	0.428	0.410
5	**0.395**	0.367	5	**0.767**	**0.912**
6	0.458	0.533	6	0.663	0.779
7	0.588	0.547	7	0.611	0.593
8	**0.618**	**0.691**	8	0.280	**0.170**
			9	**0.176**	0.176
			10	0.427	0.370
York (ICT-2) Communalities			**HM (ICT-2) Communalities**		
Expert sets	**Initial**	**Extraction**	**Expert sets**	**Initial**	**Extraction**
1	**0.189**	**0.145**	1	0.332	0.319
2	0.394	0.391	2	0.449	0.576
4	0.504	0.596	3	0.447	0.558
5	**0.750**	0.893	4	0.605	0.561
6	0.525	00.536	5	0.294	0.259
7	0.701	0.680	6	0.555	0.711
8	0.610	**0.983**	7	0.511	0.540
			8	0.605	0.818
			9	**0.279**	**0.242**
			10	**0.622**	**0.746**

Table A2. Pattern matrix showing factor loadings by using Oblimin with Kaiser Normalization as factor rotation for ICTs-1 and 2 from York and HM.

York (ICT-1)			HM (ICT-1)			
Expert Sets	**1**	**2**	**Expert sets**	**1**	**2**	
8	**0.864**	−0.113	6	**0.748**	−0.236	
7	0.765	**−0.084**	2	0.610	0.206	
4	0.672	0.122	10	0.596	**−0.027**	
2	0.440	0.392	7	0.508	−0.389	
1	−0.200	**0.843**	4	0.475	−0.263	
3	**0.008**	0.661	1	0.423	−0.310	
6	0.343	0.536	9	0.384	−0.069	
5	0.333	0.403	5	**−0.001**	**−0.956**	
			3	0.146	−0.791	
Rotation converged in 9 iterations.			8	−0.012	−0.417	
			Rotation converged in 11 iterations.			
York (ICT-2)			**HM (ICT-2)**			
Expert sets	**1**	**2**	**Expert sets**	**1**	**2**	**3**
5	**0.928**	0.039	8	**0.965**	−0.226	0.160
4	0.830	−0.177	4	0.674	0.087	−0.149
7	0.623	0.338	7	0.551	0.203	−0.241
2	0.622	**0.008**	5	0.486	**−0.035**	−0.125
6	0.552	0.301	1	0.412	0.188	0.356
8	0.213	**0.882**	9	0.376	0.168	**−0.102**
1	**−0.039**	0.395	10	−0.157	**0.850**	−0.210

Table A2. *Cont.*

York (ICT-1)	HM (ICT-1)			
Rotation converged in 5 iterations.	6	**0.111**	0.809	0.209
	2	0.144	0.053	**−0.709**
	3	0.342	0.133	−0.554
	Rotation converged in 18 iterations.			

Table A3. Structure matrix showing factorial relationship strengths by using Oblimin with Kaiser Normalization as factor rotation for ICTs-1 and 2 from York and HM.

York (ICT-1)			HM (ICT-1)			
Expert Sets	**1**	**2**	**Expert Sets**	**1**	**2**	
8	**0.824**	0.189	6	**0.857**	−0.582	
7	0.735	**0.183**	7	0.688	−0.624	
4	0.714	0.357	10	0.608	−0.302	
2	0.577	0.546	4	0.596	−0.482	
1	**0.094**	**0.773**	1	0.566	−0.505	
3	0.239	0.664	2	0.515	**−0.076**	
6	0.53	0.655	9	0.415	−0.246	
5	0.473	0.519	5	0.44	−0.955	
			3	0.512	**−0.859**	
			8	**0.181**	−0.412	
York (ICT-2)			**HM (ICT-2)**			
Expert sets	**1**	**2**	**Expert sets**	**1**	**2**	**3**
5	**0.944**	0.433	8	**0.86**	**0.09**	**0.046**
7	0.766	0.602	4	0.728	0.35	−0.269
4	0.755	**0.175**	7	0.661	0.438	−0.361
6	0.679	0.535	5	0.493	0.158	−0.195
2	0.626	0.272	9	0.452	0.318	−0.189
8	0.587	**0.972**	1	0.423	0.275	0.26
1	**0.129**	0.379	10	**0.177**	**0.829**	−0.327
			6	0.365	0.814	0.057
			2	0.274	0.222	**−0.741**
			3	0.476	0.346	−0.63
Extraction method: principal axis factoring. Rotation method: Oblimin with Kaiser normalization.						

References

1. Nazeer, M.M. Review of World Bank Two Most Terrible Moves Resulting in All Ever Increasing, Terrible Climate Calamities over the Entire Earth Globe along with Continuous Huge Disasters in Pakistan. *Open Access Libr. J.* **2020**, *7*, 1. [CrossRef]
2. The World Bank. *Pakistan: Flood Damages and Economic Losses Over USD 30 Billion and Reconstruction Needs Over USD 16 Billion—New Assessment*; The World Bank: Washington, DC, USA, 2022.
3. Haer, T.; Botzen, W.W.; Aerts, J.C. Advancing disaster policies by integrating dynamic adaptive behaviour in risk assessments using an agent-based modelling approach. *Environ. Res. Lett.* **2019**, *14*, 044022. [CrossRef]
4. Heydari, M.; Lai, K.K.; Fan, Y.; Li, X. A Review of Emergency and Disaster Management in the Process of Healthcare Operation Management for Improving Hospital Surgical Intake Capacity. *Mathematics* **2022**, *10*, 2784. [CrossRef]
5. Busayo, E.T.; Kalumba, A.M.; Afuye, G.A.; Ekundayo, O.Y.; Orimoloye, I.R. Assessment of the Sendai framework for disaster risk reduction studies since 2015. *Int. J. Disaster Risk Reduct.* **2020**, *50*, 101906. [CrossRef]
6. Chmutina, K.; von Meding, J.; Sandoval, V.; Boyland, M.; Forino, G.; Cheek, W.; Williams, D.A.; Gonzalez-Muzzio, C.; Tomassi, I.; Páez, H. What We Measure Matters: The Case of the Missing Development Data in Sendai Framework for Disaster Risk Reduction Monitoring. *Int. J. Disaster Risk Sci.* **2021**, *12*, 779–789. [CrossRef]
7. Munawar, H.S. Flood disaster management: Risks, technologies, and future directions. *Mach. Vis. Insp. Syst. Image Process. Concepts Methodol. Appl.* **2020**, *1*, 115–146.
8. Ben Youssef, A.; Dahmani, M.; Ragni, L. ICT use, digital skills and students' academic performance: Exploring the digital divide. *Information* **2022**, *13*, 129. [CrossRef]

9. D'Andrea, A.; Grifoni, P.; Ferri, F. Discussing the role of ICT in sustainable disaster management. *Sustainability* **2022**, *14*, 7182. [CrossRef]
10. Zhang, C.; Khan, I.; Dagar, V.; Saeed, A.; Zafar, M.W. Environmental impact of information and communication technology: Unveiling the role of education in developing countries. *Technol. Forecast. Soc. Chang.* **2022**, *178*, 121570. [CrossRef]
11. Afawubo, K.; Noglo, Y.A. ICT and entrepreneurship: A comparative analysis of developing, emerging and developed countries. *Technol. Forecast. Soc. Chang.* **2022**, *175*, 121312. [CrossRef]
12. Guerrero-Ibáñez, J.; Zeadally, S.; Contreras-Castillo, J. Sensor technologies for intelligent transportation systems. *Sensors* **2018**, *18*, 1212. [CrossRef] [PubMed]
13. Botzen, W.W.; Deschenes, O.; Sanders, M. The economic impacts of natural disasters: A review of models and empirical studies. *Rev. Environ. Econ. Policy* **2019**, *13*, 2. [CrossRef]
14. Anwer, I.; Yousuf, M.I. Mapping Undermined Role of Information and Communication Technologies in Floods. *Transp. Telecommun.* **2022**, *23*, 168–179. [CrossRef]
15. Shrestha, B.B.; Kawasaki, A. Quantitative assessment of flood risk with evaluation of the effectiveness of dam operation for flood control: A case of the Bago River Basin of Myanmar. *Int. J. Disaster Risk Reduct.* **2020**, *50*, 101707. [CrossRef]
16. Aroca-Jiménez, E.; Bodoque, J.M.; García, J.A.; Díez-Herrero, A. A quantitative methodology for the assessment of the regional economic vulnerability to flash floods. *J. Hydrol.* **2018**, *565*, 386–399. [CrossRef]
17. Weerasinghe, K.M.; Gehrels, H.; Arambepola, N.; Vajja, H.P.; Herath, J.; Atapattu, K. Qualitative flood risk assessment for the Western Province of Sri Lanka. *Procedia Eng.* **2018**, *212*, 503–510. [CrossRef]
18. Török, I. Qualitative assessment of social vulnerability to flood hazards in Romania. *Sustainability* **2018**, *10*, 3780. [CrossRef]
19. Marchezini, V. "What is a sociologist doing here?" An unconventional people-centered approach to improve warning implementation in the Sendai framework for disaster risk reduction. *Int. J. Disaster Risk Sci.* **2020**, *11*, 218–229. [CrossRef]
20. Syahrin, M.; Rukmana, G.; Rachman, D.; Harakan, A.; Tadjine, F. Sister city bottom up collaborative model plan as a major flooding mitigation in Samarinda. In Proceedings of the 1st Workshop on Environmental Science, Society, and Technology, WESTECH 2018, Medan, Indonesia, 8 December 2018.
21. Lyu, H.-M.; Shen, S.-L.; Zhou, A.; Yang, J. Perspectives for flood risk assessment and management for mega-city metro system. *Tunn. Undergr. Space Technol.* **2019**, *84*, 31–44. [CrossRef]
22. McClymont, K.; Morrison, D.; Beevers, L.; Carmen, E. Flood resilience: A systematic review. *J. Environ. Plan. Manag.* **2020**, *63*, 1151–1176. [CrossRef]
23. Freeman, J.D.; Blacker, B.; Hatt, G.; Tan, S.; Ratcliff, J.; Woolf, T.B.; Tower, C.; Barnett, D.J. Use of big data and information and communications technology in disasters: An integrative review. *Disaster Med. Public Health Prep.* **2019**, *13*, 353–367. [CrossRef] [PubMed]
24. ur Rahman, M.; Rahman, S.; Mansoor, S.; Deep, V.; Aashkaar, M. Implementation of ICT and wireless sensor networks for earthquake alert and disaster management in earthquake prone areas. *Procedia Comput. Sci.* **2016**, *85*, 92–99. [CrossRef]
25. Uchida, O.; Tajima, S.; Kajita, Y.; Utsu, K.; Murakami, Y.; Yamada, S. Development and implementation of an ICT-based disaster prevention and mitigation education program for the young generation. *Inf. Syst. Front.* **2021**, *23*, 1115–1125. [CrossRef]
26. Vogt, M.; Hertweck, D.; Hales, K. Strategic ICT alignment in uncertain environments: An empirical study in emergency management organizations. In Proceedings of the 2011 44th Hawaii International Conference on System Sciences, Kauai, HI, USA, 4–7 January 2011; pp. 1–11.
27. Stute, M.; Maass, M.; Schons, T.; Kaufhold, M.-A.; Reuter, C.; Hollick, M. Empirical insights for designing information and communication technology for international disaster response. *Int. J. Disaster Risk Reduct.* **2020**, *47*, 101598. [CrossRef]
28. Linardos, V.; Drakaki, M.; Tzionas, P.; Karnavas, Y.L. Machine learning in disaster management: Recent developments in methods and applications. *Mach. Learn. Knowl. Extr.* **2022**, *4*, 446–473. [CrossRef]
29. Kaur, A.; Sood, S.K. Analytical mapping of research on disaster management, types and role of ICT during 2011–2018. *Environ. Hazards* **2019**, *18*, 266–285. [CrossRef]
30. Kumar, A.; Joshi, S.; Sharma, M.; Vishvakarma, N. Digital Humanitarianism and Crisis Management: An empirical study of antecedents and consequences. *J. Humanit. Logist. Supply Chain Manag.* **2022**, *12*, 570–593. [CrossRef]
31. Anwer, I.; Grant-Muller, S.; Lai, F. Factors Limiting the Scope of Intelligent Transport System Technologies in Disaster Relief Operations. In Proceedings of the European Transport Conference 2016 Association for European Transport (AET), Barcelona, Spain, 5–7 October 2016.
32. Anwer, I. Application of Q-Likert Methodology to Find Factors Affecting Information and Communication Flow Related to Transport-Earthquake Problems. 2016. Available online: https://vixra.org/pdf/1910.0189v1.pdf (accessed on 12 September 2023).
33. Timothy, L. *6 of the World's Deadliest Natural Disasters*; Encyclopedia Britannica: Chicago, IL, USA, 2022.
34. Cornwall, W. *Europe's Deadly Floods Leave Scientists Stunned*; American Association for the Advancement of Science: Washington, DC, USA, 2021.
35. Khan, A.; Gupta, S.; Gupta, S.K. Multi-hazard disaster studies: Monitoring, detection, recovery, and management, based on emerging technologies and optimal techniques. *Int. J. Disaster Risk Reduct.* **2020**, *47*, 101642. [CrossRef]
36. Anwer, I.; Grant-Muller, S. The use of ITS technologies to manage transport in disasters. In Proceedings of the 12th ITS European Congress, Strasbourg, France, 19–22 June 2017.

37. BBC (NEWS). York Homes Flooded as River Ouse Rises. 2012. Available online: http://www.bbc.co.uk/news/uk-england-york-north-yorkshire-19732741 (accessed on 12 September 2023).
38. Ferreira, A.; Marsden, G.; Shires, J. *Report on York Floods 2012, Transport Resilience to Surface Water Flooding, Report of the Disruption Project*; Institute for Transport Studies: Leeds, UK, 2014; Available online: http://www.disruptionproject.net (accessed on 10 September 2023).
39. Kulemeka, O.; Sheehan, D.; Thwaites, J.; York, B.; Lee, J. How People Affected by Disaster Use the Internet: A study of Facebook Usage during the 2014 Hazelwood Mine Fire in Victoria. *Australas. J. Disaster Trauma Stud.* **2014**, *18*, 2.
40. City of York Council. Floods in York Key-Facts, City of York Council. 2016. Available online: https://www.york.gov.uk/downloads/file/8807/floods_in_york_-_key_facts (accessed on 10 July 2017).
41. Today, P. Govt Decides to Install Computerised Flood Warning System at Head Marala. REPORT. 2015. Available online: http://www.pakistantoday.com.pk/2015/07/15/city/lahore/govt-decides-to-install-computerised-flood-warning-system-at-head-marala/ (accessed on 15 August 2022).
42. City of York Council. 2015. Available online: https://www.york.gov.uk/ (accessed on 15 March 2022).
43. ITV (NEWS). Environment Agency Defends Decision to Open York Flood Barriers. 2016. Available online: http://www.itv.com/news/tyne-tees/2016-01-04/ea-defends-decision-to-open-york-flood-barriers/ (accessed on 13 December 2021).
44. Gaito, J. Force and Free Q Methodology. 1961. Available online: https://www.scribd.com/document/92246042/History-and-Principles-of-Q-Steven-Brown (accessed on 10 October 2023).
45. Brown, S.R. The history and principles of Q methodology in psychology and the social sciences. In Proceedings of the Red at the British Psychological Society Symposium on, A Quest for a Science of Subjectivity: The Lifework of William Stephenson, University of London; 1997. Available online: https://journals.copmadrid.org/historia/archivos/fichero_salida20220923110918125000.pdf (accessed on 12 August 2023).
46. Barry, J.; Proops, J. Seeking sustainability discourses with Q methodology. *Ecol. Econ.* **1999**, *28*, 337–345. [CrossRef]
47. Van Exel, J.; de Graaf, G. Q Methodology: A Sneak Preview. 2005. Available online: http://www.qmethodology.net/PDF/Q-methodology (accessed on 12 August 2023).
48. Watts, S.; Stenner, P. Doing Q methodology: Theory, method and interpretation. *Qual. Res. Psychol.* **2005**, *2*, 67–91. [CrossRef]
49. Brown, S.R. Bibliography on Q technique and its methodology. *Percept. Mot. Ski.* **1968**, *26*, 587–613. [CrossRef] [PubMed]
50. Danesh, N.A. qfactor: A command for Q-methodology analysis. *Stata J.* **2018**, *18*, 432–446. [CrossRef]
51. Akhtar-Danesh, N. Impact of factor rotation on Q-methodology analysis. *PLoS ONE* **2023**, *18*, e0290728. [CrossRef]
52. Emily, G.; Finnigan, L. York Floods: Why Did the Foss Barrier Fail? 2015. Available online: http://www.telegraph.co.uk/news/uknews/12072220/York-floods-Why-did-the-Foss-Barrier-fail.html (accessed on 19 June 2022).
53. Taylor, M. Hundreds Evacuated after Further Flooding in Northern England. Published by The Guardian. 2016. Available online: https://www.theguardian.com/environment/live/2015/dec/27/hundreds-evacuated-flooding-northern-england-latest-updates (accessed on 29 March 2022).
54. BBC (NEWS). UK Weather: Homes and Transport Hit by Flooding. 2012. Available online: http://www.bbc.co.uk/news/uk-19709952 (accessed on 12 April 2021).
55. BBC (NEWS). UK Floods: Homes at Risk as Misery Continues. 2012. Available online: http://www.bbc.co.uk/news/uk-19725625 (accessed on 27 May 2023).
56. City of York Council's High Level Overview of the Events between 23 and 31 December 2015, Weekly Report. 2015. Available online: https://www.york.gov.uk/StatementOfAccounts (accessed on 27 May 2023).
57. Awan, S.A. *The Associated Programme on Flood Management*; Technical Support Unit: Lahore, Pakistan, 2003; Available online: https://www.floodmanagement.info/about/reports/APFM_2003-2004_AnnualReport.pdf (accessed on 27 May 2023).
58. Awan, S.A. *Pakistan: Flood Management—River Chenab from Marala to Khanki*; Flood Forecasting Division, Pakistan Meteorological Department: Lahore, Pakistan, 2003; Available online: https://www.floodmanagement.info/publications/casestudies/cs_pakistan_chenab_full.pdf (accessed on 27 May 2023).