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Geospatial Data and Technology Application Towards Managing Flood Disaster in the Context of Industrial Revolution 4.0 (IR4.0)

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Abstract - Recent years have seen the revolution towards Industrial Revolution 4.0 (IR4.0) in which data acts as an important driver. To date, efforts on providing a comprehensive study on the application of geospatial data and technology for flood disaster management in the context of IR4.0 are still lacking. This paper intends to address this gap by investigating previous research in applying geospatial data and technology to manage flood disasters. The comprehensive reviews on recent geospatial and IR4.0 based flood models, applications and simulations were carried out. Several research agendas have been proposed to provide possible research areas in the context of geospatial data acquisition and integration. It is discovered that the perspective of the Internet of Things (IoT), Big Data, Cyber-Physical Systems (CPS), and Cloud Computing has made a significant contribution to the dissemination of GIS-based geospatial data processing for flood prediction, mitigation, visualisation, and management of sophisticated Spatio-temporal analytic capabilities with the emergence of IR4.0. This article can serve as a starting point for future advancements in flood disaster prediction, analysis, and response.

Keywords - Flood Disaster, Industrial Revolution 4.0, Geospatial Data, Geospatial Technology, Geographic Information System (GIS)

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1.0 Introduction

Nowadays, respective industrialists, scientists and researchers are evolving towards the IR4.0 agendas, which offers more significant influences on the way people live, work and connect. IR4.0 is an attempt to integrate human and machine roles with the invention of new technologies (Phuyal, Bista and Bista, 2020). This evolution offers new challenges for government, businesses and society as the institutions are forced to reinvent the ways they do their business to adapt to technological advancement (Ricker and Thatcher, 2017; Supekar et al., 2019). The governments and industries globally have observed this movement, and many of them have acted to gain benefits over this revolution wave Liao, Deschamps, Loures and Ramos (2017). Some of the government agendas (Kuo, Shyu and Ding, 2019) that being implemented include:

In the United States of America (USA) – National Network for Manufacturing Innovation (NNMI) is proposed as "an initiative to accelerate U.S. advanced manufacturing by catalysing the development of new technologies, educational competencies, production processes, and products via shared contributions from the public and private sectors and academia" (Advanced Manufacturing National Program Office, 2013);

In Germany – IR4.0 is one of the strategic initiative of the German High-Tech Strategy 2020 Action Plan with the attempt to foster the idea of Intelligence Manufacturing aiming to "leverage the market potential for German manufacturing industry through the adoption of a dual strategy comprising the deployment of Cyber-Physical Systems (CPS) in manufacturing on the one hand and the marketing of CPS technology and products to strengthen Germany's manufacturing equipment industry on the other" (Kagermann et al., 2013);

In China – Inspired by Germany's IR4.0 Plan, "Made in China 2025" has been developed to accelerate the Chinese manufacturing industry, making it more efficient and integrated by focusing on ten key sectors, i.e. "New advanced information technology; Automated machine tools & robotics; Aerospace and aeronautical equipment; Maritime equipment and high-tech shipping; modern rail transport equipment; New-energy vehicles and equipment; Power Equipment; Agricultural equipment; New materials; and Biopharma and advanced medical products" (Kennedy, 2015; Ma et al., 2018).

In Malaysia – A training programme under the public-private sector initiative has been conducted in 2016 that cover five technology pillars for the IR4.0, which are horizontal and vertical integration, industrial Internet of Things, cybersecurity, cloud and big data analytics to make the future workforce more IR4.0 ready (Ganapathy-Wallace (2017); Ismail et al., 2020). However, the programs and initiatives mentioned above are more specific to the manufacturing industry. Entering the IR4.0 world delivers an escalation in the latest technologies for the geospatial industry. A drastic transformation in the geospatial field is necessary due to the roles played by geospatial technology as the prime mover for newer applications in a wide range of industries, facilities, infrastructures, utilities and the military. As stated by Li et al. (2020), geospatial technology refers to all of the technology used to acquire, manipulate and store geographic information. Examples of typical geospatial technologies include Geographic Information System (GIS), Global Positioning System (GPS), Remote Sensing, unoccupied aircraft systems, location-based services and virtual reality (VR) devices (Todd et al., 2020).

For instance, companies like Uber and Grab have been part of the geospatial industry as they are users of geospatially based transportation access. Therefore, as the world experiences these dynamic changes, it is vital for the geospatial industry to keep pace and persevere with the new technological advancement. The geospatial industry in the IR4.0 era is no longer like its traditions which involving data collection, map construction, model building and providing information and services to consumers. The geospatial world today is about how and how much data being generated and captured, specifically regarding a movement from offline data analysis to a more sophisticated technique in real-time processing data (Todd et al., 2020; Syarul and Puspita, 2021). In addition, there may be an increase in the problem of managing the complexity of large geospatial datasets (Li et al., 2020). Therefore, the ability of the geospatial experts to come out with the most sophisticated new technologies is crucial, especially in managing abundant data systematically and efficiently.

As stated by Tsai et al. (2021), one of the key areas that drive the geospatial industry is natural disaster management. Among the varieties of natural disasters, flooding is one of the major catastrophic disasters hampering the world since the past centuries (Kia et al., 2012; Curebal et al., 2016; Liu and Li, 2017; Siahkamari et al., 2017). Over the last three decades, the number of flood events has increased significantly (Tabari, 2020), and it was further expected that more frequent and catastrophic floods would occur in the future from Simonovic, Kundzewicz and Wright (2021). As a result of this concerning tendency, numerous programmes and models have been developed to help mitigate or prevent flood occurrences. However, these disasters still occur, and the impacts are worsening. Taking into account that geospatial data and technology are essential in flood disaster management, the extent to which the role of this technology in managing flood disasters is vital to be investigated.

Therefore, this paper addresses to what extent the role played by the geospatial field in dealing with this issue. Efforts to provide an intensive literature review on the application of geospatial data and technology for flood disaster management still lack, especially in Asian regions. Considering the IR4.0 taking place around the world, this paper intends to address the preparedness of geospatial data and technologies to meet IR4.0 pace by stressing on:

a) What are the geospatial data and technologies currently applied in managing flood disasters?

b) Why the geospatial data and technology are essential in the IR4.0 era?

c) How the geospatial data and technology should be utilised towards managing flood disasters in the IR4.0 era?

This paper provides a review regarding the application of geospatial data and technology in managing flood disasters. Following that, there will be a discussion of the key components of IR4.0 and the integration of geospatial-based flood data and equipment.

2.0 Geospatial technology: Absolute feeder for flood disaster management

In the past decades, billions of gigabytes of geospatial data have been produced and made available to the public by government agencies and other stakeholders (Li et al., 2014; Dold and Groopman, 2017). As information technologies being developed dramatically, geospatial technologies emerged as one of the most promising tools that shaped a modern approach to problem-solving. Geospatial technologies such as Remote Sensing, GPS, GIS and VR, integrated with valuable near/real-time field information, can provide a comprehensive platform for emergency management (Yong et al., 2020). Among them, GIS is increasingly seen as indispensable in supporting disaster management activities because of its advantages over conventional maps (Shi et al., 2020; Thomaszewski et al., 2020; Curebal et al., 2016; Bhanumurthy et al., 2015; Pattusamy and Purusothaman, 2014; Tran et al., 2009). GIS is a system designed to capture, store, manipulate, analyse, manage and ultimately present all types of geospatial data. In the simplest terms, GIS is the merging of cartography, geodesy, statistical analysis and database technology (Foote and Lynch, 2014).

In disaster management, GIS has the ability to retrieve information of the areas affected by disaster and presenting the information on the map, thus allows the key players to take effective decision-making. As managing disaster is a complex task, specific data are required for specific stages of disaster management (pre-, current- and after-event). Hence, the use of GIS offers huge advantages on the ability to integrate multiple sets of data into a single framework that suits to capture each disaster management stage (Shi et al., 2020). To find out the most appropriate and relevant methods as well as to empirically prove the importance of GIS in flood disaster management, the procedures, applications, strengths, weaknesses and other relevant issues regarding the numerous techniques were discussed and compared in this paper. The review on the application of geospatial technologies in managing flood disaster was characterised into four categories, namely (i) GIS for flood risk studies; (ii) GIS for flood mitigation studies; (iii) GIS for flood evacuation study; and (iv) GIS for flood recovery study.

3.0 GIS for flood risk studies

GIS has been proven to be a useful medium in evaluating areas that are vulnerable to flood risk (Cai et al., 2021; Mukherjee and Singh, 2020; David and Schmalz, 2020; Feloni et al., 2020; Khaleghi and Mahmoodi, 2017; Al-Abadi et al., 2016; Al-Saady et al., 2016; Basahi et al., 2016; Khosravi et al., 2016; Masoud, 2016; Tien et al., 2016). David and Schmalz (2020) studied the traditional method of modelling single ran fall-runoff events using HEC-HMS and HEC-RAS hydrological model. The integrated approach in the HEC-RAS model resulted in detailed flood inundation maps within the sub-basin. Hence, implementing the integrated approach towards urban, pluvial and flash floods in small basins is recommended. Ramachandran et al. (2019) used ArcGIS software to produce flood inundation maps of 2, 5-, 10-, 50- and 100-year return periods in Adyar catchment. An increase of 1m to 4m flood depth is discovered around the Adyar river and thus indicates Ramapuram, Saidapet, Mudichur, and Kotturpuram is highly vulnerable to flooding. Khaleghi and Mahmoodi (2017) were able to identify flood hazard areas of the Lighvan catchment based on the maps that were developed using GIS. The areas were divided into five classes which are very low, low, moderate, high and very high. They further make a suggestion for managers and planners to immediately implement flood hazard mitigation and flood control to those areas. Meanwhile, Siahkamari et al. (2017) were able to evaluate the potential of flood hazard in the Madarsoo watershed, Golestan Province, Iran based on the application of the frequency ratio and maximum entropy models for flood susceptibility mapping in GIS setting.

Moreover, Rasn et al. (2021), in their study of the Wasit area, Iraq, through the integration of Remote Sensing data and GIS system, were able to divide the flood-prone zones into five categories which are very low, low, medium, high and very high flood risk area. This research claimed that such an attempt resulted in over 60% of the study area prone to high and very high susceptibility of flooding and helped decision-makers to improve flood management planning. Al-Saady et al. (2016) used the Lesser Zab River Basin located in Iraq and Iran as a case study to evaluate the flood risk level of the sub-basins. The researchers were able to separate the sub-basins into seven classes using remote sensing and GIS mapping techniques, which are critical, very high to critical, high to very high, medium to high, low to medium, very low to low, and lowest. Masoud (2016), in a study of the Wadi Qanunah basin in Saudi Arabia, was able to classify the sub-basins into three groups based on the degree of hazards (i.e. high, medium and low) through the integration analysis between physiographic features and GIS techniques. Khosravi et al. (2016) used GIS application to prepare 211 flood locations in Iran. The locations were then modelled and validated through four models, which are Frequency Ratio (FR), Weights-of-Evidence (WofE), Analytical Hierarchy Process (AHP) and Ensemble of Frequency Ratio with AHP (FR-AHP) to develop flood susceptibility maps. In the Indian setting, Manjusree et al. (2015) conducted satellite-based observations, which is combined with hydrological data and found 15.85 thousand hectares of the evaluated areas are vulnerable to flood events in which North Bihar area is the most vulnerable one.

Jun et al. (2015) were able to construct a spatial information database using GIS and integrating geography, hydrology, geology, and forestry evaluates slope stability of the affected areas using SINMAP (Stability Index Mapping), analyses spatial data that have a high correlation with selected landslide areas using Likelihood Ratio. It prepares landslide predictions of the mountainous regions that are vulnerable to disasters. Their results were very useful in determining suitable flood disaster mitigation strategies. A case study in Saudi Arabia has come out with a proposal of the suitable areas for urban development based on the geological, geomorphological, and geographical characteristics of the study area as well as flash flood risks which obtained by integrating the AHP method, Multicriteria Decision Analysis (MCDA) and GIS (Abdelkarim et al., 2020). Moreover, the researchers were able to find case studies in Malaysian settings, which Zaman and Mustapha conduct, Tehrany et al. (2015), Kadir et al. (2016) and Pourebrahim et al. (2014). For example, Pourebrahim et al.

(2014) analysed data of Landsat TM for the years of 1988, 1991, 1996 and 2010 obtained from the Malaysian Remote Sensing Agency (MRSA) and able to highlight the current unsustainable pattern of growth that may increase the flood risk and emphasises the urgent need for a sustainable development plan.

On the other hand, Tehrany et al. (2015) conducted a study in Kuala Terengganu to assess and evaluate the flood susceptibility areas through a GIS-based Support Vector Machine (SVM) technique. The study found that the method is reliable and efficient in assessing flood susceptibility areas which then lead to better flood mitigation implementation. To determine the areas that are vulnerable to flood in Kelantan, Zaman and Mustapha (2016) try to delineate the Kelantan watershed and divide the watershed into several sub-basins. Their experiment using an open-source MapWindow GIS integrated with Soil and Water Analysis Tool (MWSWAT) has successfully divided the 9,755.55 km^2 of the watershed into 18 sub-basins. In Batu Pahat, Malaysia, Kadir et al. (2016) used Interpolation Inverse Distance Weighted (IDW) method to develop rainfall maps for a period of 10 years. It revealed that the highest rainfall occurred in 2006 and 2007 when the years of significant floods occurred in Batu Pahat. It is proved that rainfall analysis using GIS application is efficient in gaining information of rainfall patterns associated with flood risk.

4.0 GIS for flood mitigation studies

GIS also has been proven to be used in the process of identifying the areas suitable for developing the flood mitigation systems as well as evaluating the effectiveness of the available flood mitigation systems (Puttinaovarat and Horkaew, 2020; Darabi et al., 2019; Munir and Iqbal, 2016; Madadi et al., 2015; Youssef et al., 2015; Patel and Srivastava, 2013). Research by Puttinaovarat and Horkaew (2020) addressed assisting flood disaster mitigation via an internetworking system using the Remote Sensing, GIS and Deep Learning (DL) approach (Figure 1). Such an approach enables flood notifications and verification in real-time, thus reducing significant time on the investigations. Darabi et al. (2019) applied the machine learning algorithms to predict flood-prone areas in Amol City, Iran using geospatial predictor variables. Distance to channel, land use and run-off generation was identified as the primary causes of flood hazards. The obtained vulnerability map indicates the need for flood mitigation planning in high-risk areas. Patel and Srivastava (2013) integrated the satellite and GIS datasets to develop the mapping of flood zones in Surat district, Gujarat, India. Based on high-resolution

Indian Remote Sensing images (IRS-1D), topographical maps combined with hydraulic analysis and DEM, the researchers were able to divide the study areas into seven flood-prone zones. They suggested several mitigation measures such as developing alternate routes for natural drainage to flow and diverting the high-risk river into other rivers or storing water in polders, cut-off and reservoir.

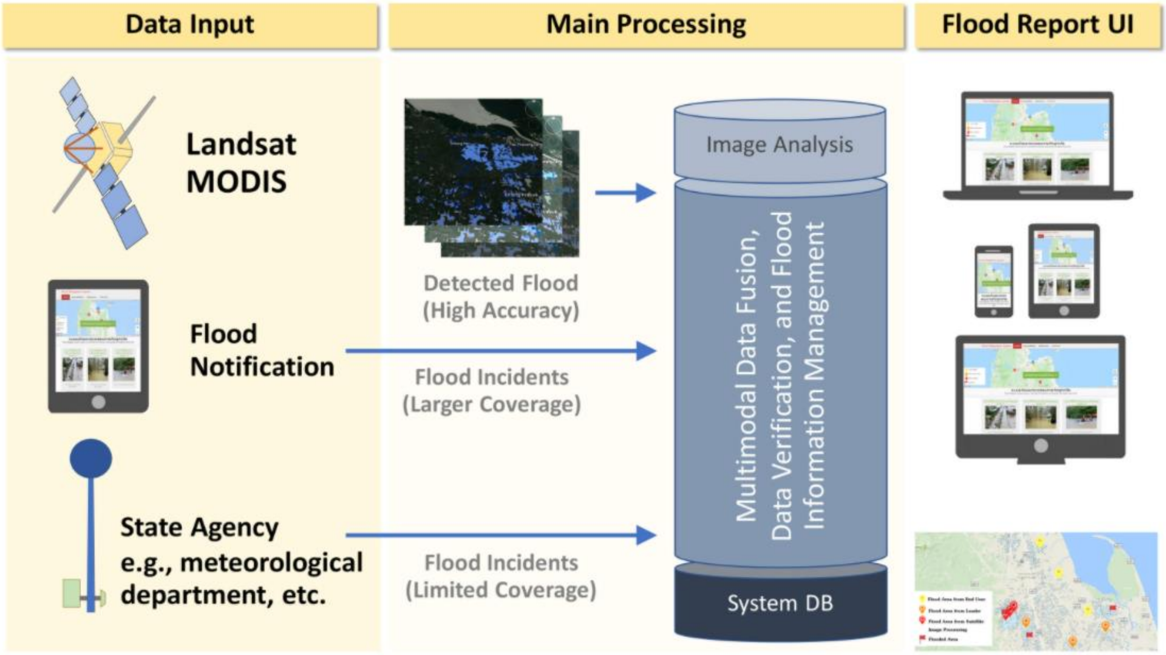


Figure 1: Schematic Diagram of online flood information management system by Puttinaovarat and Horkaew (2020).

Kamarudin et al. (2014) used GIS to overlay and digitise the topographic maps that show the history of meander changes from the climatic condition perspective at the Pahang River. Based on their findings, several solutions for future flood mitigation were suggested, such as “regulate the land-use change development by providing some mitigation measures such as tightening the laws of the Environmental Impact Assessment (EIA) rules; banning the large-scale deforestation at highland areas; establishing buffer zone areas for deforestation and restricted zones for the main river (500m to river banks); monitoring and applying the development of the river erosion control; and establishing the applications of sediment management to all types of development, such as sediment traps, sediments pond, and others”. Venkatesh and Anshumali (2019) used GIS to investigate the spatial variation of geological, hydrological, and topographical properties. They used the Shuttle Radar Topography Mission digital elevation model (SRTM DEM) and topographical maps. The mean bifurcation ratio

(4.61) indicated that structural problems did not affect the drainage pattern. The drainage texture analysis revealed coarse texture, low run-off, low erosional potential, permeable subsurface material, high vegetation cover, and low relief as the dominant characteristics. These findings could be used in watershed management, agricultural land-use planning, forestry management, and the design of environmentally friendly industrial buildings.

Madadi et al. (2015) evaluate the effectiveness of the Narmab Dam in Iran as a flood mitigation system. In this study, inflow hydrographs for different return periods were routed through the Pulse method using the integration of ArcView GIS and HEC-RAS. The results confirmed the high ability of Narmab Dam on flood control, especially for floods with a shorter return period. Youssef et al. (2015) were able to identify suitable locations for flood control dams' development. Taking one of the areas that have been experiencing severe flooding in 2009, which is Wadi Qus, Saudi Arabia, the researchers applied remote sensing-based in conjunction with field data strategy in their study. Similarly, Munir and Iqbal (2016) in their study in Dera Ghazi Khan City, Pakistan, were able to find suitable sites for dam construction using remote sensing and GIS application. The researchers further claimed that the integrated approach applied in their study is valuable for the responsible bodies in designing mitigation strategies for the flood hazards and can be used in other parts of the world. Santillan et al. (2016) make an effort to generate additional flood characteristics layers through the integration of Remote Sensing, GIS and HEC RAS 2D numerical modelling approach, which include flood velocities, arrival times, recession times, inundation duration, and per cent time inundated. The new flood characteristic map would help in formulating preparedness, evacuation as well as mitigation strategies for flood disaster management. Sindhu and Durga Rao (2017) on the other hand, proved the importance of the combination between remote sensing data and GIS in developing a model parameter for surface run-off estimation. Using a high-resolution digital elevation, namely ALTM, has improved the model and inundation map accuracy, thus developed an effective non-structural method of flood damage mitigation which is flood alarms for the Brahmani–Baitarani River Basin, India.

5.0 GIS for flood evacuation studies

Previous researchers also have utilised GIS in evaluating and identifying suitable evacuation centres for flood victims (Sritart et al., 2020; Masuya et al., 2015; Mustaffa et al., 2015). For example, Sritart et al. (2020) proposed a methodology for spatial assessment and evaluation of the area and vulnerability of the evacuation shelters and the residents of Mabi Town, Japan. According to the recommended strategy, the flood threatened 54.55 per cent of the allocated evacuation shelters and 59 per cent of the overall population. Using GIS maps, the results show that the total shelter capacity was significantly reduced to 43.86 per cent. The result evaluation focused on specific vulnerable shelters and the disparity between demand and resources available at each top. As a result, this study offers valuable information and a useful reference for assisting local governments and stakeholders in improving catastrophe planning, prevention, and preparedness in the future.

Dano et al. (2019) used GIS, analytic network process (ANP), and RS generated variables to assess flood susceptibility in Perlis, Malaysia, to mitigate and manage flood impacts on people and the environment. To ensure their stability, the results were subjected to a one-at-a-time (OAT) sensitivity analysis, with 6 of the 22 flood scenarios correlating with the simulated geographical evaluation of flood vulnerability. This precise identification of flood-prone locations could serve as an early warning system, and it might be repeated in cities experiencing floods to identify flood-prone areas for more efficient flood catastrophe mitigation.

In addition, Masuya et al. (2015) used GIS as a tool and have successfully identified a total of 6,342 buildings that are suitable to be used as evacuation centres for Dhaka’s flood victims. Besides, the researchers also evaluate available flood emergency centres and found that most of the centres unable to provide shelters for the victims due to several problems, such as located far from the vulnerable areas and did not have enough capacity to support the vulnerable residents. In Malaysia, Mustaffa et al. (2015) applied Remote Sensing couple with GIS techniques to determine the suitable flood evacuation centres for flood victims in Batu Pahat areas. Like Masuya et al. (2015); Mustaffa et al., (2015) study also evaluates the current flood evacuation centres and found that only 8 out of 16 centres were suitable for emergencies. However, the researchers were then able to suggest ten new suitable evacuation centres for Batu Pahat areas. The findings are valuable to the organisations involved in flood management in the decision-making process and would benefit society.

6.0 GIS for flood recovery studies

The flood has brought severe damage to the country's social and economic situation. However, the extent to which the damage should be investigated. For that reason, researchers took the approach to identify the effects of flood events so that the recovery actions should be proper implemented. GIS has been proven to be an essential platform in facilitating the measurement of the effects of flood disaster events. For example, flood indicators such as slope, elevation, land use, Normalized Difference Vegetation Index (NDVI), topographic wetness index (TWI), drainage density and rainfall were utilised by Ullah et al. (2020) to identify flood-prone zones in the Panjkora River Basin (PRB), Pakistan using GIS-based Analytic Network Process. The model's outputs were determined to be reliable, with the area under curve values of 82.04 per cent for success and 84.74 per cent for prediction rate, respectively. The findings of this study can be used by the local disaster management authority, researchers, planners, local government, and line agencies involved with flood risk management in the target region to help control flood hazards.

Twumasi et al. (2020) also identified flood-prone locations in Southeast Louisiana to assist decision-makers in developing appropriate adaptation measures and flood prediction and mitigation. The findings highlighted the majority of the research area is low-lying or very low-lying land below sea level. For the study region, a policy proposal was given in the form of the need to design and develop a comprehensive Regional Information System (RIS) with full government assistance in periodic inventorying, monitoring, and assessment.

Yang et al. (2017) used GIS in conjunction with the loss estimation model to improve the loss assessment procedure efficiency and effectiveness, leading to better long-term flood control planning and preparedness. On the other hand, the combination of GIS and DEM in Liu et al., (2013) study has improved the effectiveness of flood damage assessment, leading to better flood control decision making. In their study, Kawamura et al. (2014) focus on constructing a mobile communications network after the flood occurs in Tsukuba City, Japan, through the integration of ZigBee and GIS technologies. The constructed wireless network could respond to the extent of damage after a disaster and ensure adequate communications between the investigators, evacuation centres, and victims.

7.0 The industrial revolutions

The industrial revolution has been classified into four phases: the first, second, third, and fourth revolutions (Figure 2). The first industrial revolution (IR1.0), which involved mechanisation and water and steam power, began around the end of the 18th century. IR1.0 determined the transition from the commercial city, which expanded based on the trading of agricultural goods and services, to the industrial area, which expanded based on greater productivity. The second industrial revolution (IR2.0), which involved mass production, assembly lines, and electricity, began around the turn of the 20th century (Gajdzik et al., 2021; Sima et al., 2020; Mohajan, 2019; Lu, 2017). The third industrial revolution (IR3.0), which began in the 1970s, saw computers and factory automation. IR3.0 saw a shift from the planned city to the fragmented city, with industries gradually distancing themselves from markets, resulting in new economic systems and production methods. A new economic-social order emerged, further distancing homes from the job, customers, city life, and research and development institutes. With the conclusion of information technology growth, internet penetration in all realms of business, development of the IoT ecosystem, and related artificial intelligence (AI) and neural network technology, the fourth industrial revolution, dubbed IR4.0, is underway (Gulin and Uskov, 2017). Other terms appearing along with IR4.0 are the convergence of technologies and societal trends like Cyber-Physical Systems, IoT and Cloud Computing.

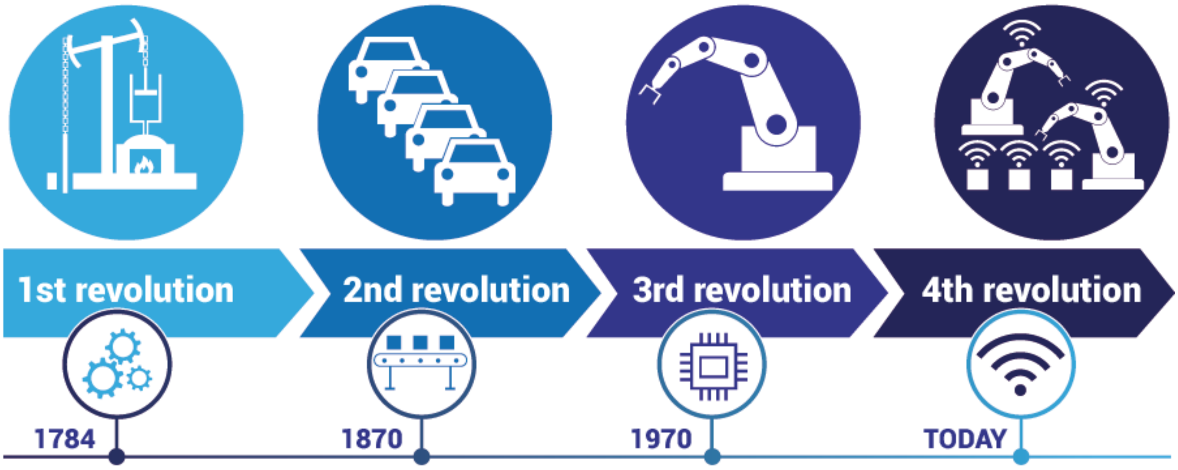


Figure 2: The industrial revolution era (source: https://www.criotherm.com/en/industry-4-0/)

The first three revolutions were propelled forward by the productivity of the industry itself. As a result of the widespread invention and use of social networks with smart devices, the rapid changes in today's society are driving the IR4.0 development (Sima et al., 2020; Schuh et al., 2015). IR4.0 is a dramatic overhaul of the entire industrial manufacturing process that combines digital and internet technology with traditional methods. As stated by Stăncioiu (2017), the IR4.0 is the next phase of revolution in the industry, as machines begin to take over the majority of human tasks. The current changes will undoubtedly result in the creation of a more connected and intelligent society. The adoption of IR4.0 has revealed that the network of connections between persons, systems, and things have grown more complex, dynamic and real-time optimised. The IR4.0 develops on the technological transformation by combining computation, networking, and physical processes in the manufacturing process to increase flexibility, shorten lead times, personalise with small batch quantities and lower prices (Lu, 2017). This revolution entails transforming entire systems, governments, companies, industries and societies from the outside (Gulin and Uskov, 2017). Some of the essential technologies and concepts for the IR4.0 development are briefly presented in this context, such as Cyber-Physical systems (CPS), the Internet of Things (IoT), big data and cloud computing.

8.0 The Components of IR4.0

There is a huge potential as more intelligent technologies are integrated into industrial systems and processes. Connected machines will communicate, visualise the production chain, and make decisions on their own. The geospatial technology and application field is fast evolving due to the rising adoption of cloud computing, augmented reality (AR), and the Internet of Things (IoT). The dominant key technology drivers for the IR4.0 developments are CPS, IoT and Internet of Services (IoS), Big Data and Cloud Computing (Gajdzik et al., 2021; Zambon et al., 2019). Each component is described in the following subsections.

8.1 Cyber-Physical Systems (CPS)

Cyber-Physical Systems (CPS) is a system that incorporates computation, networking, and physical processes. Physical and software elements are deeply interconnected, each operating at various levels of abstraction, exhibiting multiple and unique behavioural mechanisms, and interacting with one another in various contexts (Yan and Sakairi, 2019). Different components can interact with each other in various ways to communicate information using CPS (Zhong et al., 2017). Moreover, CPS is a network-connected mechanism that allows it to collect data from the environment and then analyse it before changing its location (Tamás & Illés, 2016). It can be thought of as systems that bring about major shifts and revolutions in how the physical and virtual worlds interact. (Hofmann and Rüsch, 2017; Kim and Park, 2017). It is not a unique app but rather a mixture of distributed calculation, real-time integrated systems, and wireless sensor networks based on old technology. Leveraging data management and communication technology would offer CPS towards managing effective resources effectively. Hence, CPS offers cost reduction, improve infrastructures and high-quality services. Issues regarding air resistance, consumption and the number of accidents in the traffic could be reduced significantly by connecting the cars; and reduces manufacturing waste by coupling the manufacturing system's elements, in the formation and actuation of supply chains (Kim and Park, 2017). In addition, the integration of CPS and GIS system is successfully worked out by Rogach et al., (2020) by integrating them in oil and gas industry as illustrated in Figure 3.

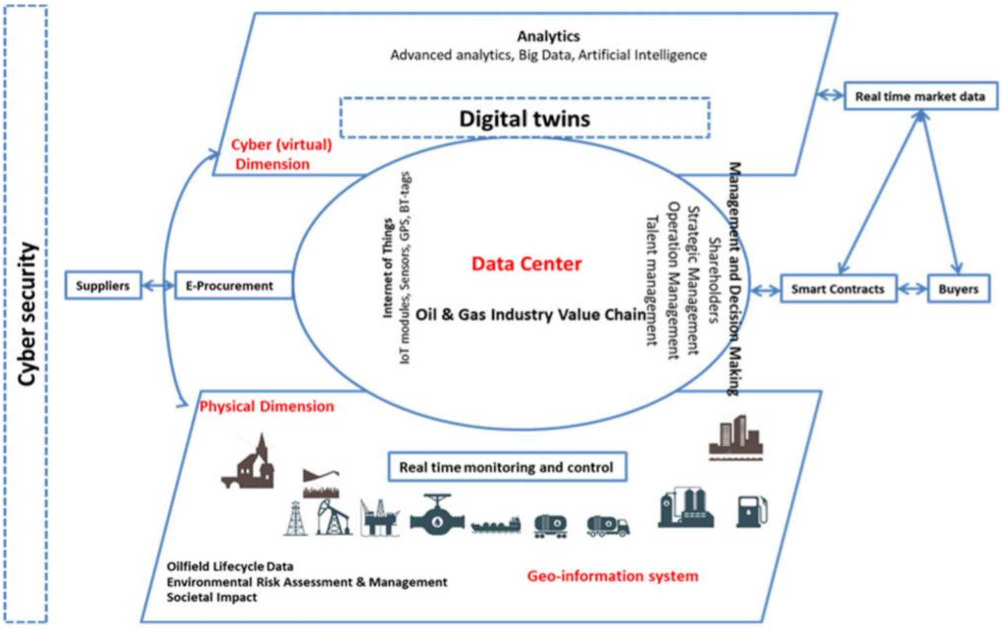


Figure 3: Conceptual framework of GIS and CPS integration (Rogach et al., 2020).

8.2 Cyber-Physical Systems (CPS)

IoT combines different technologies and approaches based on the connection between physical things and the internet (Sarwat, 2020; Pereira and Romero, 2017). IoT data is created on the device and then transferred to a centralised database system (for example, the cloud) that organises and analyses it for use by a wide range of applications, including but not restricted to home automation, smart city, industrial internet, integrated autos and linked wellbeing. The IoT enables the access of different equipment from physical objects using a computer network or accelerated wireless connections (Pavlik et al., 2020; Li et al., 2020; Tamás and Illés, 2016; Dilberoglu et al., 2017). As stated by Zhong et al. (2017), IoT can be referred to as the Internet connection in which various objects are embedded with electronic sensors, actuators, or other digital devices so that they can be networked and connected to collect and exchange data. At the same time, an enormous amount of data will be obtained.

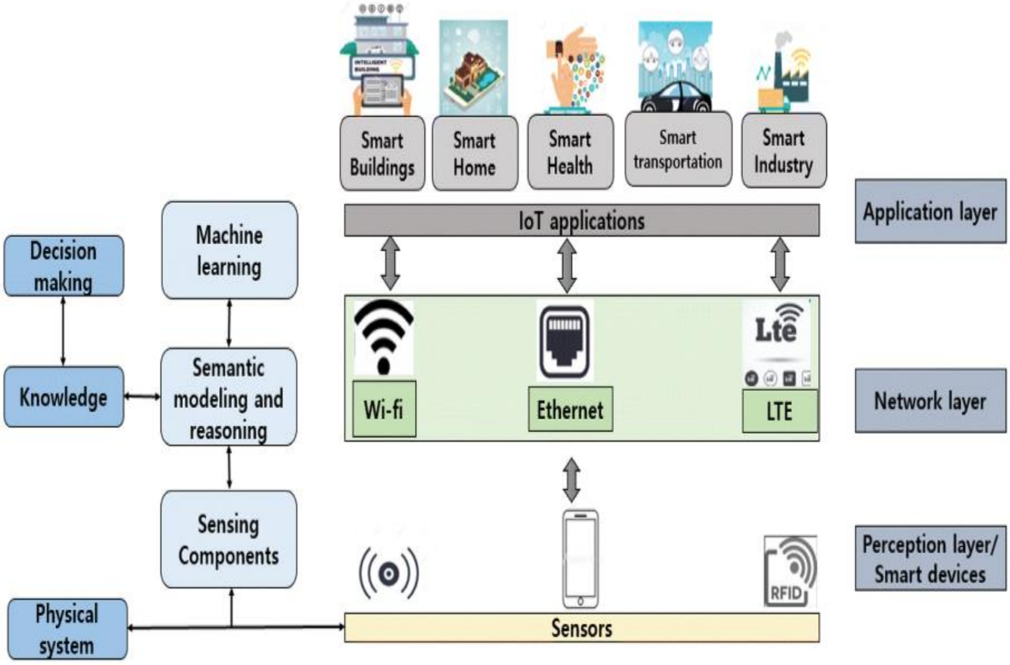


Figure 4: IoT Architecture (Park et al., 2019)

According to Pavlik et al. (2020), IoT is a fundamentally new technique in which wired or wirelessly connected systems are physically located in remote geographical regions. Many industries can interact with one another using common Internet-based protocols. As IoT techniques advance and become more widely used, machine-to-machine communication between systems in different locations will become possible within a systematic architecture framework, as depicted in Figure 4. It can deliver the data required to tackle internet-scale challenges that have been too difficult to gather and harness (Georgakopoulos and Jayaraman, 2016). It entails integrating potentially billions of sensors into cloud data centres, such as cameras, industrial machines, displays, cellphones, and other smart communication devices, allowing for real-time computation and distribution of high-value information anywhere (Georgakopoulos and Jayaraman, 2016). Consequently, IoT can have many impacts and positives to several fields. It brings several opportunities for users, manufacturers and companies to become smarter, more reliable and more autonomous, enabling added-value products and services (Pereira and Romero, 2017).

8.3 Big Data and Cloud Computing

Big data refers to a large amount of valuable precise, and uncertain data that can be easily captured and delivered at a fast rate in various real-world applications. The volume and diversity of large Earth data are quickly growing, posing substantial challenges for the data management cycles of storing, computing, analytics, visualisation, exchange and applications (Li et al., 2020; Yang et al., 2019; Santos et al., 2017). It comprises technology and techniques for gathering, processing, analysing, and extracting meaningful knowledge from enormous amounts of structured and unstructured data created at rapid speeds by many sources (Hajirahimova, 2017). Sensors, digitisers, scanners, numerical modelling, cell phones, the Internet, movies, e-mails, and social networks contribute to the flow of digital data known as big data. Texts, geometries, photos, videos, sounds, and combinations of these data kinds are among the data kinds (Yang et al., 2017). The data can be directly or indirectly related to geospatial information. For example, Yang et al. (2019) discovered the popularity of mobile devices is highly associated with colossal data transmission constantly and provides a creative way of collecting disaster-related data. These data deliver geographic information such as time, location, temperature, water vapour, wind speed and others, crucial for geohazard disaster mitigation.

Furthermore, big data has five characteristics: volume, velocity, variety, veracity, and value (Uthayasankar et al., 2017). The magnitude of the data for processing and analysis is referred to as volume. Data collecting from social networks, an extensive array of sensors from the micro (atomic) to the macro (global) level, and data transfer from sensors to supercomputers and decision-makers are all examples of velocity. The term "variety" refers to the various data formats and formats in which model and structural data are stored. The correctness of the results and the analysis of the data is referred to as veracity. Value is the added value and contribution offered by data processing and analysis (Snášel et al., 2017). Big data, including big geographical data, has the potential to help a wide range of social applications, including climate change, disease surveillance, disaster response, vital infrastructure monitoring, and transportation, among others. It has been one of the most popular terms in recent years, but its benefits to society are usually limited by issues like data privacy, confidentiality and security (Li et al., 2016).

Ramalingam and Mohan (2021) stated that deployment models define the cloud's function and the nature of the cloud's location. The four deployment models are public cloud, private cloud, community cloud, and hybrid cloud. A slew of new cloud service providers has entered the market, each with its own set of features that help service developers collaborate and migrate services across various cloud service providers to meet the diverse needs of cloud users. Furthermore, cloud computing is a highly effective security solution based on conceptual technology. The fundamental difficulty in cloud architecture and environment is data retrieval and data security (Saeed and Khan, 2015). It gives us a platform to leverage a wide range of internet-based services to deal with our industry operations and various information technology services. Moreover, it allows individuals and businesses to use services without installing anything and retrieving or accessing personal files or data (Paul et al., 2013). Cloud computing is a natural extension of the widespread acceptance of virtualisation, service-oriented architecture, and utility computing. To put it another way, cloud computing is nothing more than the use of the internet for all computer needs.

9.0 Enduring issues, gaps and opportunities in geospatial data and technology studies for flood disaster management in the IR4.0 era

9.1 Endeavour Geospatial Data and Technology in the IR4.0 Era

IR4.0 encourages the integration of intelligent production systems and advanced information technologies that have fundamentally changed society and the economy. In this context, it is obvious that geospatial data and technology in IR4.0 are becoming very important. One of the geospatial data and technologies is the combination of GIS and IoT for decades. Such an approach enables a device’s location with its status and other dynamic surrounding information. Moreover, IoT is gaining increased attention beyond its traditional home in GIS communities, and it penetrates deeper and broader into society. Object sensors will provide accurate location information. As a result, analytics that rely on knowing where something will be fine-tuned to a considerably higher resolution yield far more refined results. It may also create real-time maps using time and location data and perform a variety of analyses integrating artificial intelligence (AI) and geospatial calculations to improve decision-making in a variety of sectors. To develop quantitative resistance evaluations, system dynamics simulation is performed. Incorporating simulation processes at various spatial locations and then integrating them to create a dynamic map may illustrate the temporal (computation in time) and spatial (inclusion in space) quantitative characteristics of the stability measure. The measurement approach can readily be extended to analyse perseverance's spatial pattern.

Cloud computing provides broad-spectrum of services to users across the globe. The users can exploit to increase the assistance, making the organisations business and easy to manage the geographic data since they have limited time to maintain data storage and computing hardware (Muzafar and Razef, 2011; Snášel et al., 2017). As a result, cloud computing can be used to tackle and overcome issues in GIS applications. It demonstrates a method for providing GIS computing or storage capacity as a web service and application hosting to make organisational, geographic data easily accessible, publishable, and consumed. Cloud computing also helps GIS become imperative to understand the underlying architecture of GIS (Muzafar and Razef, 2011).

Big data is a no less important aspect for geospatial data design and development. By utilising the big data idea to develop geographical data structures, the volume and format of data collected would grow, posing issues in storing, managing, processing, analysing, displaying and confirming data quality (Li et al., 2016). For example, from a societal aspect, the smart city concept has clearly seen the outfitting of cities over the previous decade, with smart card ticketing systems, vehicle tracking devices, CCTV, toll systems, induction loops, and other sensor systems offering vast volumes of real-time data. Furthermore, big data is getting a lot of interest since it allows users to analyse massive amounts of geographic data (Lee and Kang, 2015). IR4.0 provides significant opportunities and improvements in the digital earth arena regarding how people exist, think and perform (Yang et al., 2017). Yang et al. (2019) investigated fine-grained public emotional data from Chinese social media big data to aid catastrophe research by looking at an earthquake in Ya'an, China in 2013. Combining this with additional geographic information data (such as population density distribution data and Point of Interest (POI) data, the study has further aided in assessing impacted populations, examining emotional movement law, and the maximisation of disaster mitigation techniques.

More catastrophe-related information, such as various groups of disaster loss data, can be pulled from social networks as data mining techniques advance. This essential information can play a more significant role with the help of GISs' sophisticated Spatio-temporal analytic capabilities.

9.2 Geospatial data and technology towards managing flood disaster in the IR4.0

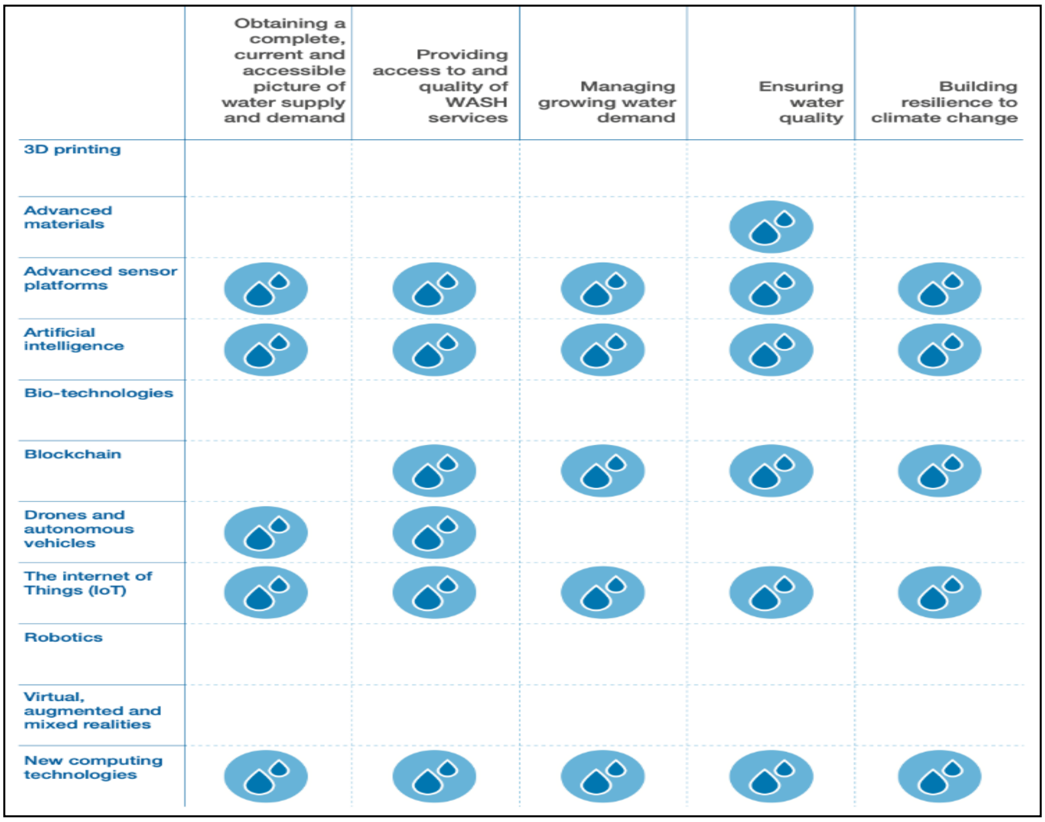
The emergence of state-of-the-art technology and systems in the IR4.0 era unlocks vast potential and opportunities in improving the disaster management system. For many elements of social life, this era change will have various beneficial effects and outcomes. IR4.0 improves adaptability, resource efficiency, and the integration of supply and demand systems. As a result, factories, manufacturing, cities, and potentially intelligent equipment and objects all become smart. It equips production with sensors, actors, and autonomous systems in the IR4.0 age, making factories more intelligent, flexible, and dynamic (Lu, 2017).

A resilient approach is required whether responding to floods or a pandemic (Simonovic et al., 2021). Accepting that the event will occur and ensuring that resilience is increased and consequences are minimised is what this means. It also entails accepting that the socioeconomic system will not necessarily return to pre-existing conditions but rather adjust to a "new normal." In addition to defence, planning is essential. The respective entities must have strategic plans and command structures in place, and the public must be included in the talks so that they are aware of the extent of resistance and the reasons for the measures they must take to raise it. This means that flood control studies must remain to incorporate geophysical and environmental science and behavioural science, and risk management.

In flood disaster management, the development of geospatial technology combined with IR4.0 components eases flood data access, volume data transformation, cloud-based platform independence, less additional hardware/software requirement and better visualisation and cost-effectiveness (Kulkarni et al., 2014; Pendyala and Vijayan, 2018). In IR4.0, The GIS tool is commonly utilised in disaster management applications in both pre-and post-disaster activities. Mitigation and preparedness initiatives are linked to pre-disaster applications. Mitigation refers to efforts that lessen a society's vulnerability to the effects of a disaster, whereas readiness refers to actions that make it easier to prepare for a disaster's aftermath. Response and recovery efforts are linked to post-disaster applications. Recovery refers to operations to restore communities to pre-disaster conditions, such as reconstruction, whereas response refers to the immediate and short-term consequences of a disaster. It is the trend and direction for the new IR4.0 (Lu, 2017). The GIS approach is often used to analyse Remote Sensing data, allowing for the knowledge of processes as well as the identification of standards and correlations between variables. The GIS in IR4.0 help in real-time monitoring, early warning and quick damage assessment of flood disasters. GIS can assist floodplain managers in identifying flood-prone areas in their community more efficient and effective. Moreover, current geospatial data indexing technologies are unable to manage geographical big data streams because their efficiency decreases as new spatial data streams exceed the spatial data index's capability for expansion. Thus, it would offer significant attempts of utilising geospatial data indexing design and development for flood prediction, mitigation and management in the extended dimension of space, namely 3D GIS-based data structure.

Figure 5 addresses the water challenges based on the development of IR4.0 technology. Nevertheless, such challenges enable the possible research areas on managing flood disasters. For instance, the application of advanced sensor platforms would offer possible identification of future flood events involving the enhancement of the sensor technology embedded in satellite devices. The transmitted signals could be converted into a real-time geospatial data structure for determining heavy rainfall events. The combination of AI in geospatial data structure delivers possible 3D visualisation of possible flood coverage based on estimated rainfall volume and intensity.

Moreover, Blockchain offers the latest approach for storing flood information in blocks. Such blocks enable sufficient database and spatial coverage to be stored for easier flood disaster information searching, updating and filtering. Researchers may explore the possible 3D spatial indexing of the flood geometry coverage in such offerings, enhancing spatial operators for intersecting complex solid objects on the earth surface. Such findings may combine with AI features to deliver real-time zonation of safe, moderate and high flood-prone areas. Analysing flood water quality are easily performed by referring to the emitted signals from sensors using drones and autonomous vehicle.



	Obtaining a complete, current and accessible picture of water supply and demand	Providing access to and quality of WASH services	Managing growing water demand	Ensuring water quality	Building resilience to climate change
3D printing					
Advanced materials				●	
Advanced sensor platforms	●	●	●	●	●
Artificial intelligence	●	●	●	●	●
Bio-technologies					
Blockchain		●	●	●	●
Drones and autonomous vehicles	●	●			
The internet of Things (IoT)	●	●	●	●	●
Robotics					
Virtual, augmented and mixed realities					
New computing technologies	●	●	●	●	●

Figure 5: Development level of Fourth Industrial Revolution technology applications that address water challenges. (source: World Economic Forum, 2018)

Thus, the creation of IoT, cyber-physical systems and big data is expected to offer promising solutions to transform the operation and improvement of geospatial data to become more flexible and reconfigurable. As proposed by Santos et al. (2017), big data is required to support the data requirements for geospatial data envisioned and presented by incorporating numerous layers and aspects for data collection, storage, processing, analysis, and distribution. Then to provide an integrated environment that facilitates decision-making at various levels of strategic planning. The IoT enables the integration of geospatial data structure, equipped with sensing, identification, processing, communication and networking capabilities. These terms are drivers that dominate geospatial data and increase the digitisation of geospatial data. As a result, IR4.0 increases time efficiency and improves product quality, associated with the enabling technologies, methods, and tools towards managing flood disasters.

10.0 Concluding Remarks

Geospatial data and technologies have emerged as a powerful tool to deal with various aspects of flood management in the prevention, preparedness and relief management of flood disasters. GIS is one of geospatial technology ideally suited for various floodplain management activities such as base mapping, topographic mapping and post-disaster verification of mapped floodplain extents and depths. In the context of IR4.0, GIS is built as a highly flexible production model of personalised and digital products and services, with real-time interactions between people, products and devices during the production process. It illustrated that geospatial data and technology, combined with IR4.0 components, will benefit our lives and future. Thus, this study shows that the importance of geospatial data and technology application for managing flood disasters in the future. As a result, it can be stated that geospatial technology in IR4.0 has the greatest potential for analysing and providing the data necessary for rapid and effective flood decision-making.

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