A Methodology of Building Workflow for Search and Rescue Operation with UAV

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A Methodology of Building Workflow for Search and Rescue Operation with UAV

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***Abstract*— The development of Unmanned Aerial Vehicles (UAVs) is progressing rapidly. Many efforts, such as capturing images immediately after the disaster, grasping building damage, and calculating the amount of debris are proposed for disaster mitigation and disaster response. Fire bureaus (FBs) in Japan also have installed UAVs, and the practical utilization of UAVs is demanded in actual activities. In the previous paper, we presented the utilization of UAVs with Wi-Fi sensing function for search and rescue (SAR) operation. However, it was difficult for us to deploy in the field because practitioners could not appreciate the relationship between new operations and existing operations. In practice, practitioners in FBs learn many skills through exercise and training and get experiences through practical operations. In this paper, to support the smooth installation, we propose a methodology of building workflow for SAR operation including UAV tasks. We visualize the workflow of new operations with UAVs and existing operations by using Work Breakdown Structure (WBS) with practitioners, and then we confirm the validity of the workflow using the Data Flow Diagram (DFD). WBS is a deliverable oriented hierarchical decomposition of the work to be executed by the project team. This paper presents the manual of SAR operation including UAV tasks as a reference model, and also describes a strategic planning process based on workflow. It is essential for practitioners to share current information for situational awareness and make an intelligent decision.**

***Keywords*— Unmanned Aerial Vehicle, Workflow, Search and Rescue, Work Breakdown Structure, Situational Awareness**

I. Introduction

The development of Unmanned Aerial Vehicles (UAVs) is progressing rapidly, and then the utilization in various fields such as disaster response, agriculture, and delivery is expected. The utilization of UAVs in the disaster mitigation field is strongly desired as one of the promised fields. At present, in Japan that has a rapidly aging population and various disasters, installing UAVs in fire bureaus (FBs) is a matter of great urgency for enabling sustainable activities. According to the report by Fire and Disaster Management Agency (FDMA) in Japan [1], as shown in Table 1, the installation of UAVs to FBs is a trend towards an increase in the recent three years. With the increase of retention, the practical utilization of UAVs is demanded in actual activities as the next step.

TABLE 1: UAV retention rate of FBs in Japan (as of 1st June 2019) [1]

	2017	2018	2019
# of retention FBs	70	116	201
# of non-retention FBs	662	612	525
UAV Retention rate	9.6 %	15.9 %	27.7 %

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However, to realize efficient and practical activities with UAVs in an actual spot, we need to solve various problems because UAVs are a growing technology and systematic operation has not been decided yet. First, pilot training is necessary for utilization. In the future, as various types of UAVs such as micro and fixed-wing UAVs will be spread, FB has to consider how practitioners acquire skills for operating UAVs safely at a spot. For the problem, as the first attempt, we proposed a UAV operation drill that composing the essential skills [2]. As the drill makes the contents clean and concise at a necessary minimum so as that everyone could learn, it would be helpful as a reference model of UAV training.

Then, FB needs to consider how to put UAVs to practical use in a spot, but each FB has different incidents such as search and rescue (SAR), fire accident, a water-related accident, and damages by earthquake and flood. Thus, FB needs to make an operation with UAV tasks that meet the actual circumstances because the role of UAVs is different for each incident. However, at present, there is no systematic operation with UAV tasks. For instance, in [3], in addition to the camera-based function, we proposed to utilize an aerial Wi-Fi sensing function (Wi-SF) to enhance the effectiveness of a SAR operation. Wi-SF captures Wi-Fi beacons broadcast from Wi-Fi terminals, e.g., smartphone and handheld game console, which a missing person carries, and it displays the spots where Wi-SF captured the Wi-Fi beacons. Although we proposed a new function of UAV for a SAR operation, it is not very easy to operate it at a spot promptly. Because, as FB has been following a conventional operation, it needs to carefully consider how to include UAV tasks in the existing operation. In actuality, when installing new equipment, Plan-Do-Check-Act (PDCA) is required because it may change tasks, cooperation, and so on in the existing operation.

In this paper, we propose a methodology of building workflow for SAR operation, including UAV tasks. An operation has been managed by each organization so far, but it is essential to make an operation visible for the smooth installation of new equipment and PDCA. In our approach, we first create a workflow by making tasks and relations of each unit clear via Work Breakdown Structure (WBS), and then we confirm the validity of the workflow via the Data Flow Diagram (DFD). The approach has the following two main contributions. First, as our approach can make a workflow visible, practitioners can continuously maintain a productive workflow according to the current circumstances. It is then helpful for collaborators such as researchers to reasonably propose a new function and so on by understanding the actual workflow. The paper also focuses on SAR operation, including UAV tasks as an example, and then makes a detailed explanation of a procedure for building a workflow. The paper also presents the manual of SAR operation, including UAV tasks as a reference model. Finally, this paper also describes a strategic planning process based on workflow. It is essential for practitioners to share current information for situational awareness.

II. Building Workflow for Search and Rescue Operation with UAV

As mentioned in Section I, FBs have been required to utilize UAVs to accomplish their operations effectively. When introducing new technologies like UAVs, it is necessary to consider how they relate to existing operations or how they can be improved. However, it is generally difficult to modify it because practitioners in FBs have skills through exercise and training, and have experience and knowledge through the practical operation. That is, they do not have a manual of operations. In other words, they implement operations based on their implicit knowledge. In this section, firstly, we describe the model of knowledge management to transfer implicit knowledge to explicit knowledge and define the process of this research. Secondly, we describe a methodology that practitioners participated in building workflow for SAR operation with UAV.

A. Model of Knowledge Management to Transfer Implicit Knowledge to Explicit Knowledge

Nonaka et al. referred to the Socialization, Externalization, Combination, and Internalization (SECI) model for knowledge management [4]. In this model, there are two types of knowledge, i.e., implicit knowledge and explicit knowledge, and new knowledge is created by the constant conversion and transfer among individuals, groups, and organizations. The SECI model illustrates the four processes of transferring implicit knowledge and explicit knowledge. Figure 1 shows the process of the SECI and this research.

- Socialization: The process of acquiring and transmitting implicit knowledge through shared experiences. In this research, we had a workshop in which practitioners with different tasks participated and clarified tasks of SAR operation.
- Externalization: The process of converting the obtained implicit knowledge into explicit knowledge so that they can be shared. In this research, we clarified organizations and tasks of SAR operation and described cards about existing operations and new operations with UAV.
- Combination: The process of creating new explicit knowledge by combining existing explicit knowledge. In this research, we created SAR with the UAV manual by using WBS and DFD.
- Internalization: A process in which individuals acquire new implicit knowledge through making explicit knowledge available. In this research, practitioners designed actual exercise and demonstrated it.

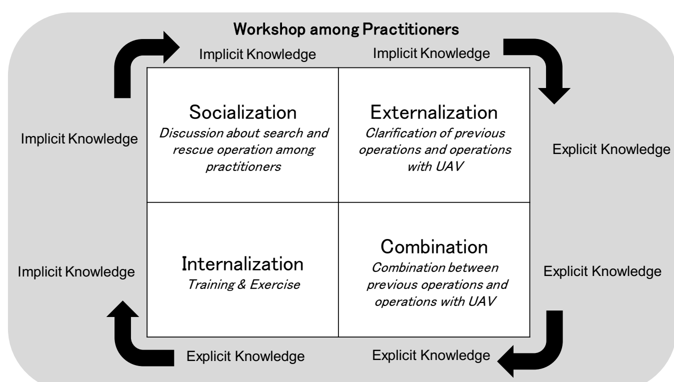

Fig. 1 the Process of the SECI

B. Building Workflow for Search and Rescue operation with UAV

In this section, we describe practical process to build a workflow for Search and Rescue operation with UAV.

We organized a workshop that practitioners with different tasks participated as shown below.

- Date: July 2nd and 3rd, 2018

- Participations: two practitioners with UAV operation, one practitioner with command operation, and researchers
- Purpose: Visualization of existing and new operations, and creating WBS with UAV for SAR operation
- Method: Workshop with WBS and DFD as shown in Fig. 2

We visualized the workflow of new operations with UAVs and existing operations by using WBS with practitioners. WBS is a universal standard project management tool used to define and group a project's discrete work elements to help organize and determine the overall project work scope, and representing the project as a hierarchy of deliverables and services the project is to produce [5, 6]. Creating manuals for effectively implementing post-disaster operations has issues that formats and methods depend on personal skills, and the manual is not widely known among practitioners. To solve some issues for creating manuals, the method of creating a manual for disaster response by using WBS is proposed as a practical process [7].

Fig. 2 : Workshop with Practitioners for SAR

Firstly, we discussed the organization and teams of existing operations for SAR operation. The organization consists of "Incident Commander," "Command Team," "Rescue Team," "First-aid Team," "Regional Fire Brigade," "Helicopter Team," and "Logistics." Incident Commander mainly has the responsibility for decision making for executing operations effectively and safely. Rescue Team mainly has the responsibility for searching and rescuing missing people. The first-aid Team mainly has responsibility for first-aid and takes the injured person to the nearest hospital. Regional Fire Brigade mainly has the responsibility for supporting practitioners in FBs. The members of the Regional Fire Brigade are citizens in each region for jurisdictional boundaries. Helicopter Team mainly has the responsibility of searching for missing people by helicopter. Logistics Team mainly has the responsibility for preparing physical resources. New operations add UAV Team to existing operations. A WBS-based manual is created through workshops with practitioners in different affiliations reflecting individual experiences and knowledge, and producing visualized solutions in some steps:

- Inputting information about tasks to task card for each team
- Examining hierarchical relationships between task cards
- Creating temporary WBS in discussion
- Simulating relationships between tasks using DFD as follows
- Making feedback to temporary WBS and completing WBS

Table 2 shows one of the operations in the UAV Team. Regarding task about searching for missing people, the task can be divided into five sub-tasks: "Consider the details of a flight plan," "Determine the takeoff and landing point and move to a spot," "Search for missing people with UAV," "Report current information," and "Report information of rescuer." In addition to the process from temporary WBS to WBS, we employ DFD and check workflow. DFD is utilized to develop information systems and graphically represent the functions, or processes, which capture, manipulate, store, and distribute data between a system and its environment and between components of a system. We utilized DFD in order to check relationships between tasks, as shown in Fig. 3. A task begins with a trigger and continues in the next task. There is information or physical resources between tasks. Immediately after arriving at Incident Command Post (ICP), UAV Team determines the details of a flight plan based on the previous flight plan. Typically, the ICP is located in the vicinity of the incident site and is the focus for the conduct of direct, on-scene control of tactical operations. Next, UAV Team prepares UAV ready and determines the takeoff and landing point and moves to the point. Next, UAV Team pilots UAV according to the UAV operation drill and searches for missing people. UAV Team receives images from UAV with cameras and sensors and regularly reports the status of information to Command Team by FBs wireless system. When UAV Team finds missing people, they also report current information to Command Team soon. We can not only check the logical relevance of tasks, but it will also be clear relationships between teams because DFD described communicators and recipients. Practitioners can simulate operations through the process of creating DFD.

TABLE 2: An Example of WBS (UAV team Operation)

Search missing people	6-3-1	Determine the details of flight plan
	6-3-2	Determine the takeoff and landing point and move
	6-3-3	Search missing people with UAV
	6-3-4	Report current information
	6-3-5	Report information of rescuer

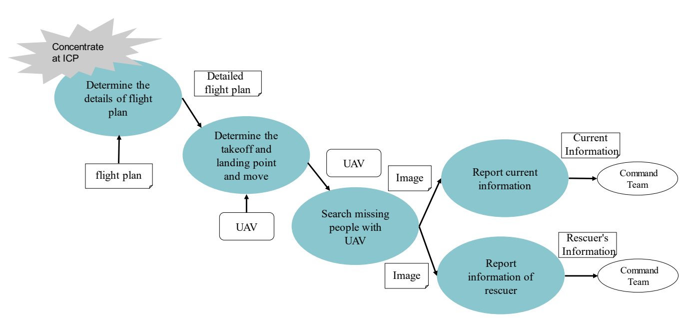

Fig. 3 : An Example of DFD (UAV team Operation)

TABLE 3: Entire WBS for SAR

	Team	Tasks Level1		Tasks Level2	
1	Incident Commander	1-1	Receive reports from citizens		
		1-2	Determine the type of disaster		
		1-3	Command and dispatch		
		1-4	Grasp the current information		
		1-5	Report to police department		
2	Command Team	2-1	Excute initial response	2-1-1	Understand the command contents
				2-1-2	Dispatch to the site
				2-1-3	Establish a Incident Command Post(ICP)
				2-1-4	Collect Information on site
				2-1-5	Determine the action plan
				2-1-6	Instruct rescue activity units
		2-2	Manage Incident	2-2-1	Manage current information
				2-2-2	Instruct rescue activity units based current information
				2-2-3	Report to Incident Commander
				2-2-4	Instruct rescue activity units after requirement
		2-3	Require human resouces	2-3-1	Require First-aid Team
				2-3-2	Require Regional Fire Brigade
				2-3-3	Require Regional UAV Team
				2-3-4	Require Regional Helicopter Team
				2-3-5	Require Regional Logistics Team
		2-4	Contact to police department	2-4-1	Share current information
		2-5	Respond to media	2-5-1	Make a press release at ICP
		2-6	Demobilization	2-6-1	Declaration to complete an incident
				2-6-2	Demobilization
3	Rescue Team	3-1	Concentrate certain place	3-1-1	Understand the command contents
				3-1-2	Dispatch to the site
				3-1-3	Concentrate at ICP
		3-2	Search missing people	3-2-1	Determine the details based on action plan
				3-2-2	Begin to search missing people
		3-3	Report the current situation	3-3-1	Require physical resouces
				3-3-2	Report current information
		3-4	Rescue people	3-4-1	Determine the action plan
				3-4-2	Report the action plan
				3-4-3	Rescue people
		3-5	Take rescuer to certain place	3-5-1	Take rescuer to certain place
4	First-aid Team	4-1	Concentrate certain place	4-1-1	Understand the command contents
				4-1-2	Dispatch to the site
				4-1-3	Concentrate at ICP
		4-2	Give first aid to rescuer	4-2-1	Move to the location of the rescuer
				4-2-2	Give first aid to rescuer
				4-2-3	Take the injured in ambulance
		4-3	Take the injured to the nearest hospital	4-3-1	Select the nearest hospital
				4-3-2	Take the injured to nearest hospital
5	Regional Fire Brigade	5-1	Concentrate certain place	5-1-1	Understand the command contents
				5-1-2	Dispatch to the site
				5-1-3	Concentrate at ICP
		5-2	Search missing people	5-2-1	Determine the details based on action plan
				5-2-2	Begin to search missing people
		5-3	Report the current situation	5-3-1	Determine the action plan
				5-3-2	Report the action plan
				5-3-3	Rescue people
		5-4	Take rescuer to certain place	5-4-1	Take rescuer to certain place
6	UAV Team	6-1	Create a flight plan	6-1-1	Simulate flight range
				6-1-2	Create a flight plan
		6-2	Concentrate certain place	6-2-1	Understand the command contents
				6-2-2	Dispatch to the site
				6-2-3	Concentrate at ICP
		6-3	Search missing people	6-3-1	Determine the details of flight plan
				6-3-2	Determine the takeoff and landing point and move
				6-3-3	Search missing people with UAV
				6-3-4	Report current information
				6-3-5	Report information of rescuer
		6-4	Inform location of rescuer	6-4-1	Confirm location of rescuer
				6-4-2	Hover the UAV over the rescuer
				6-4-3	Confirm status of rescue
7	Helicopter Team	7-1	Concentrate certain place	7-1-1	Dispatch to the site
				7-1-2	Contact to ICP
				7-1-3	Concentrate at ICP
		7-2	Search missing people	7-2-1	Determine the details based on action plan
				7-2-2	Search missing people
				7-2-3	Report current information
		7-3	Rescue people	7-3-1	Rescue people
		7-4	Take the injured to hospital	7-4-1	Select the nearest hospital
				7-4-2	Take the injured to nearest hospital
8	Logistics Team	8-1	Prepare physical resources	8-1-1	Understand the command contents
				8-1-2	Prepare physical resources
				8-1-3	Send physical resources to ICP

Table 3 shows the entire WBS involved all operations. From the table, we can describe all tasks hierarchically and visibly about SAR operation in WBS. It is helpful for collaborators such as researchers to reasonably propose a new function and so on by understanding the actual workflow. The followings are comments from practitioners through the workshop.

- We were able to visualize the experience and knowledge gained through training and field activities.
- The relationship of mutual tasks became clear through the process of building workflow.
- The methodology of building workflow can be used for new employee training.

III. Future work for sharing situational Awareness

As shown in Section II, WBS is crucial for practitioners to share current information to execute a SAR operation. We propose a way to share information by using Geographic Information System (GIS). GIS is a framework for gathering, managing, and analyzing spatial data. GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps. With this unique capability, GIS reveals more in-depth insights into data, such as patterns, relationships, and situations. GIS helps users to make smarter decisions [8]. GIS is also called a problem-solving tool, as shown in Fig. 4 because GIS can collect data effectively, integrate data, and have potent functions that "Visualization," "Retrieving and Analysis," and "Sharing Information." These functions can support reasonable decision making and action for practitioners.

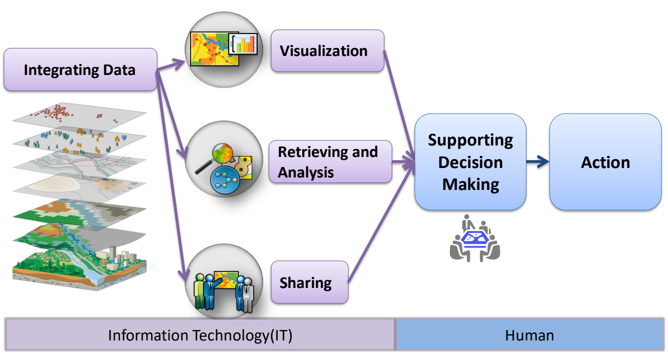

Fig. 4: The Decision Making Process by Utilizing GIS

Regarding sharing situational awareness, a tool called Common Operating Picture (COP) will be created by practitioners. COP is a single identical display of relevant disaster information shared by more than one command. A COP facilitates collaborative planning and combined execution and assists all practitioners to achieve situational awareness. GIS is a powerful tool to build a COP.

Figure 5 shows the process from decision-making to action. The command team make a decision about strategy, and COP helps our intelligent decision. After decision making, the incident objectives are defined in the operational period (OP), and we create Incident Action Plan (IAP), which involves tactics to manage incidents. Federal Emergency Management Agency (FEMA) in U.S.A publishes FEMA Incident Action Planning Guide [9]. The IAP is a written plan that defines the incident objectives and reflects the tactics necessary to manage an incident during an operational period. The IAP is developed through the incident action planning process. An operational period is the period of time scheduled for executing a given set of operational actions as specified in the IAP. The length of the operational period, typically 12 to 24 hours at the beginning of the incident requiring extensive response efforts, is established during the initial response and subsequently reviewed and adjusted throughout the life cycle of the incident as operations require. Finally, necessary human resources and physical resources are provided to the incident area, and the operation is executed.

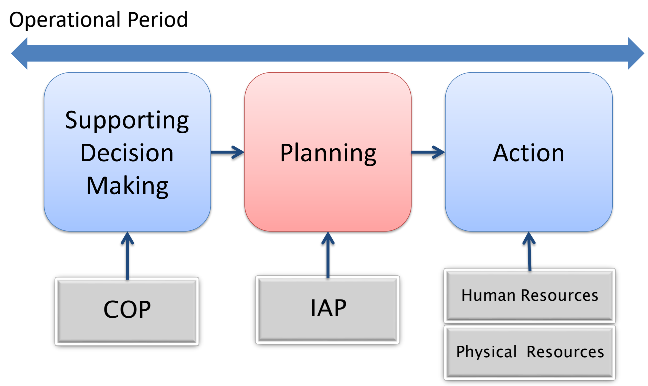

Fig. 5: The Process from Decision Making to Action

The incident action planning process consists of the following five phases, i.e., (1) Understand the situation, (2) Establish incident objectives, (3) Develop the plan, (4) Prepare and disseminate the plan, and (5) Execute, evaluate, and revise the plan, and called "Planning P" as shown in Fig. 6.

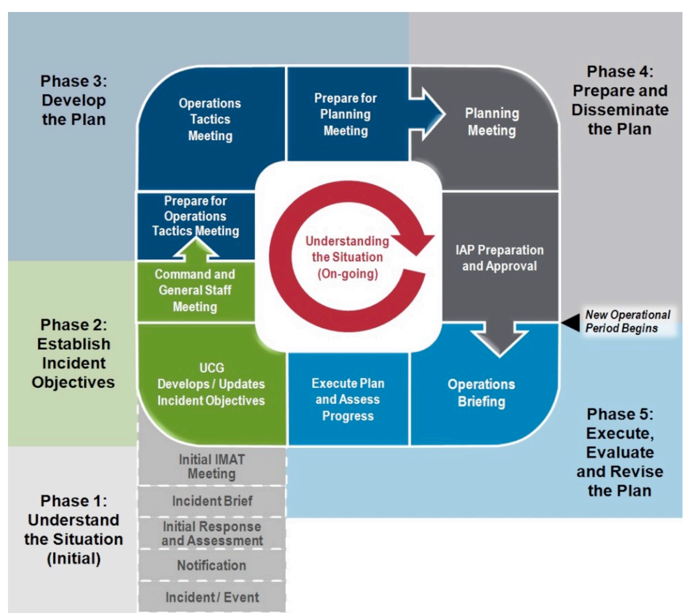

Fig. 6 : Planning P

The center of “Planning P” describes sharing situational awareness to understand the situation (ongoing). To create COPs for sharing situational awareness, we propose to discuss essential elements of information (EEIs) among practitioners. Effective decision-making is contingent upon communities of interest in collectively defining and codifying their operational information requirements for various missions. These collections of pre-defined operational information requirements are EEIs [10]. In the EEIs design process, practitioners need to discuss EEIs requirements discussion for themselves. Operational information requirements for SAR operation are considered as follows, and practitioners should discuss and pre-define EEIs.

- Static Information
  - Terrain Data
  - Ortho Image
  - Knowledge Data (Places where people are likely to be missing)
- Dynamic Information
  - Information from UAV
  - Location of ICP
  - Location of Staging Area (Base for gathering resources)
  - Searching Route

IV. Conclusion

This paper presented a methodology of building workflow for search and rescue operations with UAV and the importance of COP to share current information for situational awareness. We mentioned that practitioners in FBs have skills through exercise, training, and practical operation. It is said that their skills are implicit knowledge for themselves. To introduce new technologies like UAVs, it is necessary to consider how they relate to existing operations or how existing operations can be improved. We examined the practical processes to build the workflow for SAR Operation with UAV to transfer implicit knowledge to explicit knowledge. We created a workflow involved tasks via WBS, and then we confirmed the validity of the workflow via DFD. The methodology does not only make workflow hierarchically visible but also is helpful for collaborators such as researchers to discuss for obtaining the same purpose. This paper also describes the importance of sharing situational awareness and how to create COP involved EEIs. As future works, we will discuss EEIs for SAR with practitioners and develop an application for sharing situational awareness-based cloud GIS. Finally, we expect that our methodology is adopted when FBs install UAV for their operational excellence.

References

[1] Fire and Disaster Management Agency, Japan, https://www.fdma.go.jp/publication/ugoki/items/rei0202_11.pdf, (in Japanese)(Accessed on 1st March 2020)

[2] S. Kashihara, A. Yamamoto, K. Matsuzaki, K. Miyazaki, T. Seki, G. Urakawa, M. Fukumoto, and C. Ohta, “Towards Practical Utilization of Unmanned Aerial Vehicle in Disaster Mitigation - UAV Operation Drill -,” Proc. of 2019 IEEE Global Humanitarian Technology Conference (GHTC), pp. 414−415, October 2019.

[3] S. Kashihara, A. Yamamoto, K. Matsuzaki, K. Miyazaki, T. Seki, G. Urakawa, M. Fukumoto, and C. Ohta, “Wi-SF: Aerial Wi-Fi Sensing Function for Enhancing Search and Rescue Operation,” Proc. of 2019 IEEE Global Humanitarian Technology Conference (GHTC), pp. 423−426, October 2019.

[4] I. Nonaka and H. Taguchi, “The Knowledge-Creating Company,” Oxford Univ. Pr., 1995.

[5] P. S. Royer, “Project Risk Management: A Proactive Approach,” 2002.

[6] G. T. Haugan, “Effective Work Breakdown Structures,” 2002.

[7] G. Urakawa and H. Hayashi, “How Business Flow Diagram’s Improve Continuity of Operations Planning,” Journal of Disaster Research, Vol. 5, No. 5, 2010.

[8] ESRI, USA, https://www.esri.com/en-us/what-is-gis/overview (Accessed on 1st March 2020).

[9] EMA, FEMA Incident Action Planning Guide, January 2012.

[10] National Information Sharing Consortium, Essential Elements of Information Publication Guidance, March 2015.