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Developing Reusable COVID-19 Disaster Management Plans Using Agent-Based Analysis

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Abstract: Since late 2019, the COVID-19 biological disaster has informed us once again that, essentially, learning from best practices from past experiences is envisaged as the top strategy to develop disaster management (DM) resilience. Particularly in Indonesia, however, DM activities are challenging, since we have not experienced such a disaster, implying that the related knowledge is not available. The existing DM knowledge written down during activities is generally structured as in a typical government document, which is not easy to comprehend by stakeholders. This paper therefore sets out to develop an Indonesia COVID-19 Disaster Management Plan (DISPLAN) template, employing an Agent-Based Knowledge Analysis Framework. The framework allows the complexities to be parsed before depositing them into a unified repository, facilitating sharing, reusing, and a better decision-making system. It also can instantiate any DISPLAN for lower administration levels, provincial and regency, to harmonise holistic DM activities. With Design Science Research (DSR) guiding these processes, once the plan is developed, we successfully evaluate it with a real case study of the Manokwari Regency. To ensure its effectivity and usability, we also conduct a post-evaluation with two authorities who are highly involved in the Indonesia task force at the regency level. The results from this post-evaluation are highly promising.

Keywords: COVID-19; disaster management; agent-based models; disaster management knowledge; knowledge analysis

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1. Introduction

In a learning process, knowing that we know that we do not know leads us to strive to improve our understanding about domain problems, from the conceptual to empirical level. However, in the COVID-19 biological disaster that struck the world in late 2019, we are mostly in the position that we do not know what we do not know about the disaster management (DM) domain [1]. This is not surprising as, in the modern era of DM, we have not experienced this particular event [2]. This disaster demonstrates once again that there is no one person or country that fundamentally can prevent, prepare for, or respond effectively to a disaster [3]. What we can do is manage it effectively, to reduce the impact of the loss of properties and lives [4,5]; this is what we call developing resiliency, that is, a capability to bounce back from unforeseen stress and/or adapt to the situation [6].

Particularly in Indonesia, in response to this disaster, the President acknowledged the first case of COVID-19 on 2 March 2020 [7], and correspondingly established a national task force commanded by the head of the national disaster management agency (BNPB) to manage related DM activities. However, it was soon realised that DM disaster comprises complex activities involving various roles, and their inherently different responsibilities, resources, etc., which need to be interacted, communicated, and coordinated. An amendment to the President's first decree was made in only one week [8]. In the updated decree, the emphasis is that more ministry offices are involved, and they need to be proactive and responsive in all DM activities. As there is no prior knowledge facilitating the learning process, unknown factors are still dominant, and following the existing manual can be risky [9]. This is not to mention that, as COVID-19 is an event-driven disaster, the trade-offs between health and economic issues have been a primary government concern during decision making.

Following the previous President's decree to respond to this disaster, other President's instructions and Ministries' regulations were issued as responses to evolving situations, ranging from operationalisation of essential and critical sectors related to public services, to Large-Scale Social Restrictions (LSSR) and the Imposition of Restriction on Community Activities (IRCA) [10]. These all demonstrate that, essentially, we have no knowledge in place that is ready to be reused and shared at any point of the timeline of the response phase for the task force, at any government administration level. However, over time, of all the efforts that have been put in place in response to the disaster, it appears that the IRCA perhaps guide DM activities relatively well. This is signified by the fact that no other guidance was issued to follow this up until now. Moreover, it is customisable to provincial and regency/municipality levels, as the confirmed positive, inpatient, and death rate of COVID-19 cases decreased significantly [11] during the implementation.

This paper sets out to contribute to DM resilience endeavours by developing an Indonesia COVID-19 DISPLAN. The DISPLAN essentially constitutes a collection of best practices related to COVID-19 knowledge. However, instead of only populating and structuring the existing knowledge used by authorities, we approach it by disentangling its complexities into empirical knowledge elements, facilitating it to be understood more easily, and depositing it into a unified DM repository to be later shared and reused, for better decision-making processes. This is a crucial and challenging task, as the knowledge used in DM activities is mostly written in the government specification format, in which most parts of the document have nothing to do with DM activities, prohibiting it from being easily understood, particularly in real-world activities [12]. Our initial review of related COVID-19 knowledge documents from formal resources revealed that they are written in a semi-structured format, where the focus is on the roles played by government authorities and their responsibilities. This format can only be useful in an office with permanent structure and function.

However, in DM activities, the first and foremost concern should be achieving the main goal [13]. This means all resources required, roles involved, interaction, communication, and coordination between roles and scenarios to be achieved should be maintained and harmonised in order to pursue the desired goals [14]. Put simply, for an effective DM, all sectoral egos need to be subdued to be able to see the bigger picture; that is, accomplishment of a main and shared goal. For instance, once COVID-19 cases escalate and community movement restrictions are activated, the police will ensure that people comply with this. The culture and education office needs to coordinate with schools and universities regarding online learning. Shopping centres and traditional markets will be managed by the corresponding government office regarding their open and close hours and so forth. All these activities are aimed to accomplish the main goal: that community restrictions are well managed. In addition, the knowledge needs to be understood and applied to the provincial and regency/municipality levels. Therefore, the COVID-19 DISPLAN aimed to be developed should also have an ability to generate and instantiate plans for these administration levels; this is essentially required, as anytime improvements are made in the template, they can be synchronised efficiently with the new generated and instantiated plans. On the other hand, if the instantiated plans need to be more contextualised with local wisdom knowledge, they can also be incorporated easily into their DISPLAN.

As this research is part of our larger work to contribute to the DM resilience endeavours, we employ the Disaster Management Knowledge Analysis Framework Version 2.0 (hereafter refers to as DMKAF) [15] to guide these tasks. Our DMKAF is a framework in which knowledge written in the government document will be analysed and modelled using Agent-Based models (ABMs): the goal, role, organisation, interaction, environment, and scenario models, subsequently transferring it to the repository to be used later. ABMs are used in the analysis and modelling stages, as they lend themselves to representing the empirical knowledge know-how, -when, -where, -who, -why and -what of DM activities [16]. Thus, as earlier described, a COVID-19 DISPLAN template is developed, first based on the ABMs as a foundation to instantiate plans for lower administration levels. Subsequently, the instantiated plans are transferred into the repository, to be accessed and reused in DM activities. As this research is guided by the Design Science Research (DSR) methodology [17], an evaluation with a case study from Indonesia will be managed, as the knowledge analysis framework has already been developed. The evaluation is to ensure the efficacy of the framework, as described in developing the Indonesia COVID-19 DISPLAN. The paper is structured as follows: Section 2 reviews relevant existing literature. Section 3 describes the DSR methodology employed to guide this research. Section 4 discusses the evaluation of the new framework with a real case study. Section 5 discusses the research, and Section 6 outlines the conclusions, limitations, and future research directions.

2. Literature Review

In DM, resiliency is essentially determined by the level at which the affected communities have the necessary resources, and their ability to manage them during disaster situations [18]. Like other typical disasters with cascading effects [19] in which one event drives another, these almost always occur suddenly and unexpectedly; however, the COVID-19 disaster is extremely unique, as we have no prior knowledge about it to learn from. As a consequence, we approached this particular disaster with a "trial and error" path, which might hinder an effective DM resilience endeavour [3]. This does not mean that for other recurring disasters, such as floods and earthquakes, management is easier. In fact, no two disasters are identical, which means there is no generic solution for similar DM cases [20]; however, learning from experience is still envisaged as the best source to develop DM resilience [21].

However, knowledge from the best practice of experiences is not always available; even if it is, it is mostly scattered in experts' minds. If written down, it is generally formatted in the typical government document or business specification structure, which is not easy to comprehend and in fact most knowledge elements in it have nothing to do with the DM activities, particularly for those who are on the ground [22]. These issues have been of concern to various scholars in the DM domain [23–25]. Albris et al. [20] echo these concerns by identifying gaps: the epistemological, institutional, and strategic gaps in DM activities. These gaps, essentially, inform that there is an urgent need to formally formulise evidence-based DM knowledge, employing scientific approaches to facilitate effective learning processes. This includes synthesising knowledge elements from best practices and transferring them into a formal structure, to allow them to be accessed and reused [26].

Scholarly interests in the aforementioned include developing strategies to provide DM authorities with adequate and representative information in a timely manner, and enhancing the decision-making process during catastrophic situations [24,27]. Due to the unique nature of each disaster, it is hard to develop a uniform policy that would be effective in all DM scenarios. It is vital to address the dissemination of DM information that pervades all PPRR stages (prevention/mitigation/planning, preparedness, response, and recovery). This is performed by grasping [28] and delivering [29,30] as much relevant best practice information as feasible for DM implementation as a requirement for DM resilience efforts.

Additionally, DM information must be deconstructed and made accessible, to facilitate the development of more effective decision-making systems [5].

To begin, we established [13] and modified our Disaster Management Knowledge Analysis Framework 2.0 (DMKAF2.0) [15] to analyse and model disaster management knowledge, prior to storing it in a single repository based on the Disaster Management Metamodel (DMM) [31]. The repository's distinguishing characteristic is that it foregoes a chronological viewpoint in favour of unlimited access to all stages of PPRR. The DMM is a set of comprehensive ideas and their relationships that facilitates the representation of organizational knowledge and processes in DM activities. It was first constructed in accordance with a structure that comprehensively reflects the DM domain, using OMG's three modelling layers [32]: M0-M1-M2, which represent the actual world object, the model, and the modelling language, respectively. Agent-Based Models (ABMs) are used in a DMKAF to extract the greatest lessons learned from the DISPLAN via analysis and modelling. ABMs lend themselves to being useful tools for representing the COVID-19 DM knowledge pieces in a way that is more easily comprehended.

Subsequently, these elements are deposited into a unified DM repository for sharing and reuse by other stakeholders effectively and efficiently. The knowledge structure in the repository also allows it to be used as a decision-making mechanism in DM activities. We have demonstrated such a process in our prior study of the volcano eruption DM of Mt. Agung in Bali, Indonesia [33]. Here, the knowledge structured in the DMM-based repository facilitates the decision-making process, making it more efficient and effective. For instance, decision-making can be constructed using a bottom-up approach; the data and information from the planning and operationalisation levels supply the decision to be concluded. However, decisions can also be developed based on a top-down approach; this approach is only possible if the structure of the unified repository allows it. The repository itself is a metamodel-based form that constitutes collections of the most relevant and vital DM concepts and their relations in a way that demystifies DM decision-making processes. Put simply, decision-making processes based on both approaches allow the knowledge to be conformed and instantiated based on the needs of the stakeholders at each level and at any point of the DM timeline easily (please see our previous paper [33] for more detail).

Essentially, existing research has recognised the critical role played by ABMs to facilitate more understanding of the COVID-19 pandemic [34,35]. The most compelling benefit brought by an ABM is that it lends itself to represent complex and interrelated phenomena in a dynamic setting such DM activities. Moreover, it can also mimic behavioural and goal driven rational entities (for e.g., individuals, organisations/institutions, government organisations, etc.) in dynamic situations [36,37]. ABMs have been used to study social and economic effects in social restriction scenarios [37,38]. Compared to other approaches (e.g., a mathematical model), ABMs can describe complex DM situations in more natural ways [39]. ABMs can equip DM stakeholders with useful and relevant knowledge for better decision-making mechanisms of social intervention through different simulations.

Indeed, the use of ABMs to create simulation tools to comprehend the COVID-19 phenomena has been embraced by many scholars. For instance, it is used to understand the supply chain disruption caused by the pandemic [40], the assessed effectivity of full and partial stay-at-home orders, face mask usage, and contact tracing [41], the COVID-19 transmission rate, and the impact of public health measures [42–44]. These scholarly works have demonstrated that ABM can be used prescriptively to improve our understanding and ability to predict various scenarios during the COVID-19 pandemic.

Agent-Based Models are used to disentangle domain knowledge from the domain's complicated features [45]. They are derived from the domain of Agent-Oriented Software Engineering (AOSE). ABMs are used descriptively to untangle the entangled knowledge in DISPLANs, with the components in each representative model serving as a point of reference. The ABMs are developed using the FAML (Framework for Agent Modelling Language) meta-model [46]. Thus, the conversion of ABMs to DMM is calculated theoretically using FAML and DMM and is constructed as a model transformation [47,48]. OMG [32] has documented this conversion procedure in detail using the Meta Object facilities (MOF) framework. Thus, adopting the MOF serves two purposes: (1) leading the conversion phases of ABMs to the unified repository, and (2) giving a clear-cut view of the information organized in ABMs as it is used in decision-making processes, planning, and real-world objectives [13]. The repository's knowledge may subsequently be accessed by other DM stakeholders. The knowledge pieces of the MOF's layers are related based on their semantic knowledge, since they fundamentally have the same meaning but are used in various scenarios. While prior assessments effectively assessed the usefulness and effectiveness of the proposed framework, they also identified more opportunities for process improvement. There is room to improve the analysis' efficiency and to guarantee that it applies to sources other than the DISPLANs; both are addressed in this work.

3. Research Methodology

Our endeavour is a Design Science Research (DSR) endeavour [17,49,50], as we aim at solving the disaster knowledge management issue in the case of the COVID-19 disaster in Indonesia. Thus, we employ the DSR methodology to demonstrate analysis and model the DISPLAN COVID-19, employing Agent-Based Models. We contribute to this issue by demonstrating the construction of the COVID-19 Disaster Management Plan in the Indonesian context. DSR lends itself to be the most relevant and suitable methodology for this study, for instance as demonstrated in here [51]. The output of the process is an information system artifact guiding the detailed activities in each stage.

As this study is part of a larger project aimed to contribute to DM resilience endeavours, to guide the construction process, instead of formulating it from scratch, we employ a validated Disaster Management Knowledge Analysis Framework Version 2.0 (DMKAF) [15]. The DMKAF is a knowledge analysis framework that has been successfully developed based on ABMs as a guideline for knowledge analysis and modelling [13]. Once the knowledge is analysed and modelled, it is then transferred into a DMM-based unified repository to be later used by stakeholders in DM events; for instance, for a decision-making system. As is the case with the DSR technique, once constructed [52], assessment is the first step. The intention is to ensure that the created artifact is not only intended to answer the specified challenges, but also to contribute to domain knowledge. The concept is that the generated artifact must also address a larger class of concerns, not simply the one at hand [15].

Additionally, we instantiate the established framework in a web-based interface to facilitate these assessment procedures. This tool is basically a proof of concept designed to explain the fundamental ideas of techniques, modelling, and framework construction. Our DMKAF has been experiencing a suite of successful validations using two real case studies of flood DM from SES New South Wales [13,52] and a real case study of flood DM in Victoria State, Australia [15]. We also have demonstrated the effectivity of the framework as a decision-making system in DM of the Mt. Agung Volcano Eruption in Indonesia [33]. Put simply, the DMKAF has been rigorously developed and evaluated so that it is ready to be used in analysis and modelling of our knowledge of DM activities.

In addition to the evaluation stage, there is a need to ascertain the usability of the developed DISPLAN. As such, a post-evaluation is sought. To be able to do that, we directly communicate with two authorities who are categorised as planners and highly involved in COVID-19 task force activities in each of their regencies in Indonesia. They, basically, are the leaders of their sectors, and have authority to plan and mobilise resources from their offices and communicate and coordinate with the task force commander. We used Venable et al. [53]'s assessment technique to determine why, when, how, and what to evaluate. This assessment technique is designed to guarantee that the created artifact is evaluated thoroughly and consistently with the specified issues. The objective is to ensure that the functionality and usability of the system are compatible with the organization, as well as other associated quality aspects [17].

Disaster Management Knowledge Analysis Framework Version 2.0 (DMKAF 2.0)

The DMKAF procedure used in this research consists of three stages: (1) customizing Agent Based Model templates, (2) creating a unique DISPLAN, and (3) storing the DISPLAN in the repository. The framework's detailed components are provided in Figure 1. The following is a breakdown of each stage:

Stage 1: Creating customized ABM templates. As inputs to the system, a DISPLAN knowledge template and corresponding external references from COVID-19 are employed. At this stage, a DM specialist with an understanding of the agent-oriented paradigm (or a knowledge engineer with extensive DM experience) analyses and models the input, which is then structured into six (6) representative ABMs: the goal, role, organization, interaction, environment, and scenario models. These generate the six ABM templates that correspond to the COVID-19 DISPLAN template.

Stage 2: Developing the customized DISPLAN. The customised ABMs are the result of Stage 1. They then become the ABMs responsible for generating the COVID-19 DISPLAN for a certain area. As an example, the modified ABMs are used to develop a COVID-19 DISPLAN for the Manokwari Regency in Indonesia's West Papua Province.

Stage 3: Transferring the DISPLAN into the repository. In this step, the six ABMs detailing a specific DISPLAN are transferred into the unified repository (as an example from Stage 2, the DISPLAN developed for the Manokwari Regency of West Papua Province, Manokwari regency, Indonesia). The transferred ABMs comprise the analysis and modelling of external source specification.

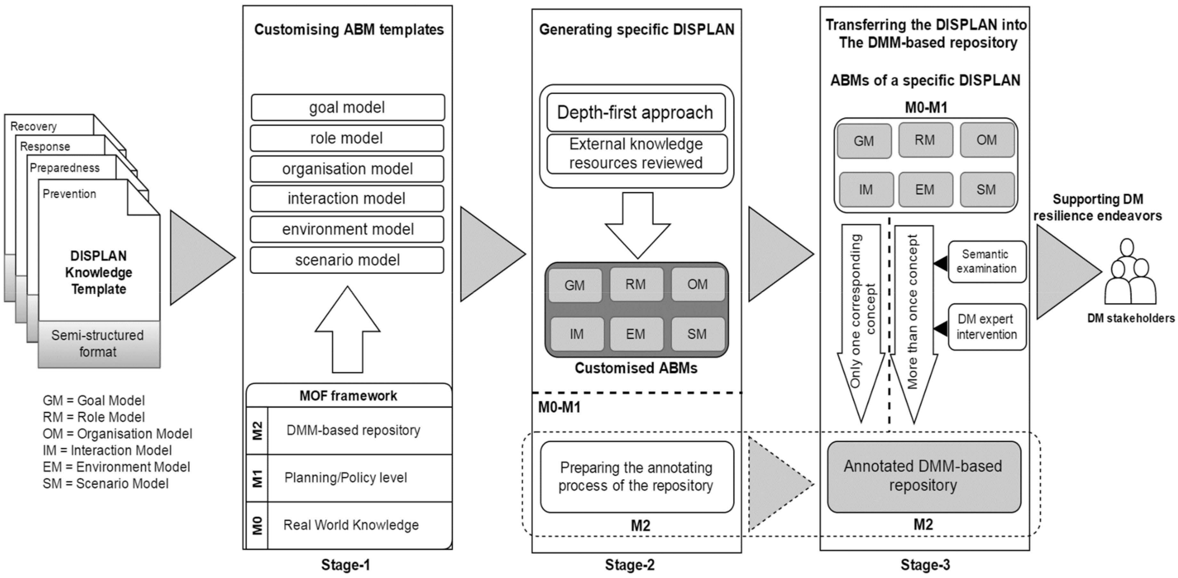

Figure 1. The Disaster Management Knowledge Analysis Framework 2.0.

4. Evaluation

4.1. The Manokwari Regency Case Study

Manokwari is one of thirteen regencies in West Papua and is the capital of the West Papua province. Similar to other regencies in Indonesia, it also had experienced the highest level (Level 4) of the Imposition of Restrictions on Community Activities (IRCA) up to 20 September 2021, based on Instruction of Home Affairs Minister Number 40 Year 2021 and now its level is reduced to Level 2 since 5 October 2021, based on Instruction Number 54 Year 2021 (all the instructions of the Minister of Home Affairs related to the IRCA can be found on the ministry's website: https://ditjenbinaadwil.kemendagri.go.id/halaman/detail/instruksi-menteri-dalam-negeri, (accessed on 17 October 2021). We employ the case of the Manokwari Regency to demonstrate the knowledge analysis and modelling, as this is a regency in the West Papua province that is among the two most eastern provinces in Indonesia. We aim to demonstrate that although the regency is among the farthest regencies from the central government, the enactment of the IRCA level can be instantiated efficiently using the same template as issued by the Minister of Home Affairs. However, the empirical knowledge to be understood in the activities directly by the relevant stakeholders remain challenged as is clearly articulated in the template. However, this is regulated by the Person in Charge (PIC) in the administration level, the regent, or the governor. Moreover, we evaluate the effectivity of the developed DISPLAN with a case study from the regency level in Indonesia, based on Law Number 23, Year 2014. After the central government, only the regency administration has territory. The provincial government is a representative of the central government.

The level of IRCA itself is ratified by the Minister of Home Affairs based on these three indicators: (1) a confirmed positive case of COVID-19, (2) an inpatient of COVID-19 at the hospital; and (3) the death rate in the regency. These are measured per 100 thousand population in a regency per week. These assessment levels are adopted and adapted from the WHO's guideline (WHO, 2020). For instance, the level 4 of IRCA will be applied to a regency once: (1) confirmed positive COVID-19 are more than 150 cases, (2) inpatients caused by COVID-19 are more than 30 cases, and (3) the death rates are more than 5 cases. Table 1 presents the IRCA levels in Indonesia. The data of these three indicators are supplied by the local hospital in each regency. Once the IRCA level is authorised to the provinces and regencies, the governor and/or the regent issue IRCAs using the same template but for their administrations.

Table 1. Level, indicator, and the IRCA of COVID-19 DM in Indonesia.

Level of IRCA	Indicators			Imposition of Restrictions on Community Activities (IRCA)
	Confirmed Positive	Inpatient	Death Rate	
1	<20	<5	0	(1) Non-essential sectors: 75% WFO if vaccinated. (2) Essential sectors: 100% WFO in two shifts with tight protocol. (3) Shop and supermarket can open with 75% capacity. (4) Traditional market can open to 75% capacity. (5) Shopping centre: mall and plaza can open to 75% capacity until 21:00. (6) Street vendors, barbershop, and such can open until 20:00. (7) Food stall, street food, and snack stall can operate up to 75% capacity until 21:00 and their customers can dine in 30 min. (8) Restaurant in enclosed space can open to 75% capacity. (9) Education sectors: 50% online and 50% offline. (10) Worship place can open with 50% capacity and tight protocol.
2	20–50	5–10	<2	(1) Non-essential sectors: 50% WFO if vaccinated. (2) Essential sectors: 100% WFO in two shifts with tight protocol. (3) Shop and supermarket can open with 75% capacity until 21:00. (4) Traditional market can open with 75% capacity until 21:00. (5) Shopping centre: mall and plaza can open to 50% capacity until 20:00. (6) Street vendors, barbershop, and such can open until 20:00. (7) Food, street food and snack stalls can operate up to 50% capacity until 20:00 and their customers can dine in 30 min. (8) Restaurant in enclosed space can open to 50% capacity. (9) Education sectors: 50% online and 50% offline. (10) Worship place can open with 50% capacity and tight protocol.

Table 1. *Cont.*

Level of IRCA	Indicators			Imposition of Restrictions on Community Activities (IRCA)
	Confirmed Positive	Inpatient	Death Rate	
3	50–100	10–30	2–5	(1) Non-essential sectors: WFH. (2) Essential sectors: 100% WFO in two shifts with tight protocol. (3) Shop and supermarket can open with 50% capacity until 20:00. (4) Traditional market can open with 50% capacity until 15:00. (5) Shopping centre: mall and plaza can open with 25% capacity until 17:00. (6) Street vendors, barbershop, and such can open until 20:00. (7) Food stall, street food, and snack stall can operate with 25% capacity until 20:00 and their customers can dine in with time limit of 30 min. (8) Restaurant in enclosed space for take away/delivery only. (9) Education sectors: 100% full online. (10) Worship place can open with 25% capacity and tight protocol.
4	>150	>30	>5	(1) Non-essential sectors: WFH. (2) Essential sectors: 50% WFO in one shift and 100% WFO for critical sectors with tight protocol. (3) Shop and supermarket can open with 50% capacity until 20:00. (4) Traditional market can open with 25% capacity until 15:00. (5) Shopping centre: closed except for pharmaceutical and drug stores. (6) Street vendors, barbershop, and such can open until 20:00. (7) Food stall, street food, and snack stall can operate until 20:00 and only three customers can dine in 30 min. (8) Restaurant in enclosed space for take away/delivery only. (9) Education sectors: 100% full online. (10) Worship places are closed.

This includes adjustments for the roles played by the government's bodies in both administrations' levels, based on the Person in Charge (PIC) authorities in each region. It is worth noting that in the COVID-19 case in Indonesia, at regency level, the PIC forms a one-off Task Force (TF) lead by a Task Force Commander (TFC) to manage all the IRCA, and reports to the PIC during DM. In DM common terminology, the TF is an Emergency Management Team. In the COVID-19 disaster in Indonesia, the TFC is a role played by the District Military Commander in each region and the Local Disaster Management Agency (BPBD) will be part of the task force.

The IRCA described in Table 1 will be for guidance, for the TF to conduct the operation and uphold the health protocol based on their role. For instance, in the IRCA level 4 (the highest), while the essential sectors are Work From Office (WFO) up to 50% of the capacity in one shift only, the critical sectors are 100% WFO with tight protocol. While the essential and critical sectors are those which are directly related to basic needs, for instance, health, food supply, information and communication technology, and the stock market, the non-essential sectors are those that are not directly related to basic needs, such as higher education, university, and school, therefore these sectors are Work From Home (WFH) 100%. To ascertain that these sectors adhere to COVID-19 protocol and the prescribed IRCA, the relevant roles in the TF that are responsible to each of the sectors will plan, supervise, evaluate, and coordinate them. For instance, in Level 2 of the IRCA, for the non-essential sector: 50% for each online and offline in the educational sector will be the responsibility of, and planned, coordinated, and supervised by, the education and culture office and welfare division of the regency secretariat.

In the evaluation, we choose a COVID-19 IRCA case study of the Manokwari Regency, the capital of the West Papua province, to demonstrate the analysis and modelling using the DMKAF. Eventually, the output is the analysed and modelled COVID-19 DISPLAN for the Manokwari Regency, to be deposited into the repository and reused as the basis of the decision-making mechanism for all stakeholders. We will visualise this using a web-based tool we developed for this purpose. The next sections concentrate on the extensive assessment conducted in this article using the case study.

4.1.1. Stage 1: Customising the Template of Six ABMs

In this stage, we use the template of the instruction of Ministry of Home Affairs for the IRCA level. It is then customised based on six ABMs. We analyse and model the template using each of the corresponding ABMs. The result is the six customized ABM DISPLAN IRCA templates of the Manokwari Regency. These six customised ABMs will be the foundation to develop any local plan for the province or regency level. In this paper, we generate the COVID-19 DISPLAN of the Manokwari Regency. The details are elaborated next.

Customising the *Goal Model*

The purpose of customizing the *goal model* is to create a COVID-19 DISPLAN *goal model* that is unique to the individual, as illustrated in Figure 2.

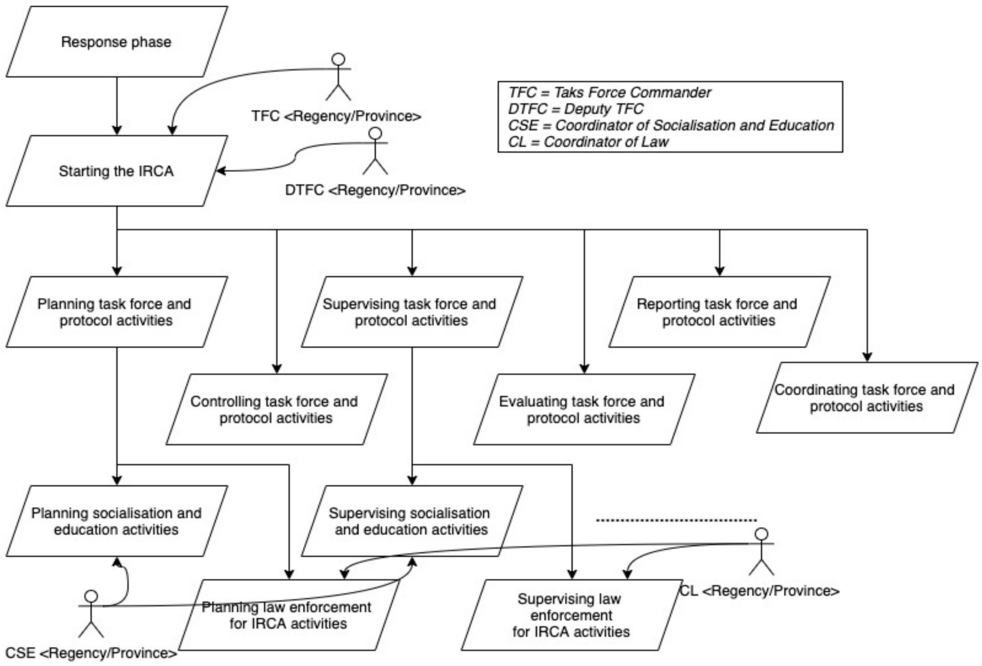

Figure 2. A customized *goal model* of the <Regency> DISPLAN for a main goal: "starting the IRCA".

These activities are conducted by a knowledge engineer. The customised *goal model* produced in this evaluation will be the basis to compose a *goal model* for any province and/or regency DISPLAN in Indonesia, as the template used is based on the instruction issued by the Minister of Home Affairs. A main goal "starting the IRCA" is identified as an example for the *goal model*. Having identified the main goal, the <Regency> TFC is identified as the role that is responsible to it. All the sub-goals and the roles for each of them are next to be identified. For instance, a sub-goal "planning socialisation and education activities" and the roles responsible for are <Regency> TFC, DTFC, CSE, and CL. Once it is completed, the knowledge engineer categorises each of the knowledge elements in this model based on the MOF framework, be it M0 or M1.

Customising the *Role Model*

The *role model* is customised in accordance with the customized *goal model*. Thus, the role model provided in Table 2 has been customised in accordance with the customised *goal model* illustrated in Figure 2. The purpose of this section is to explain each of the Regency's jobs and their associated duties. Finally, the knowledge engineer assigns an M1 or M0 value to the knowledge items in the *role model*. The role model for role *R3*: <*Regency*> TFC is provided in Table 2.

Table 2. Customized *role model* of the <Regency> COVID-19 DISPLAN template.

DMM-Based Repository	
Role Knowledge	
Role ID	R3
Role Name	Task Force Commander the Regency of <Manokwari>
Description	Task Force Commander (TFC) is a role played by District Military Commander of the <Manokwari>
Responsibility	1. Planning task force and protocol activities. 2. Controlling task force and protocol activities. 3. Supervising task force and protocol activities. 4. Evaluating task force and protocol activities. 5. Reporting task force and protocol activities. 6. Coordinating to the related parties.
Constraint	These responsibilities are for the Regency <Manokwari>

As this is the customised role model, any instance of this model for any regency can then be generated efficiently and effectively from it, as they conform to this customised model.

Customising the *Scenario Model*

Due to space constraints, we present only three customised ABMs in this study, out of a total of six. The last three models are scenario-based models. Except for the trigger, pre-condition, and post-condition components, which are based on other customised models, the customised scenario model's knowledge elements are based on other customised models, as indicated in Table 2. Thus, the knowledge engineer must revisit the Minister of Home Affairs' initial directive to identify and organize the important knowledge pieces that have not yet been analysed and modelled in the first five ABMs. Once this model is complete, all knowledge items are labelled M1 or M0, corresponding to knowledge at the policy/planning level or in real-world activities.

4.1.2. Stage 2: Generating the Customised Six ABMs

In this stage, the analysed and modelled ABM templates from the previous stage instantiate a particular regency out of them. In this study, that is the ABMs of the COVID-19 DISPLAN of the Manokwari Regency. As such, knowledge elements specifying local wisdom characteristics of the regency that are useful to the stakeholders in DM activities can be incorporated into the main DISPLAN. The details of the processes are described next.

Generating the *Goal Model*

In this stage, the customised *goal model* of the COVID-19 DISPLAN, as in Figure 2, generates the same model, but for Manokwari regency. The process is as drawn in Figure 3.

All knowledge elements in the customised *goal model* instantiate the same elements into the *goal model*, but specifically for the Manokwari regency. These processes are conducted by a DM expert who has ABM understanding or an engineer who has DM expertise background. For any local characteristics that are relevant and useful for stakeholders in case of DM, the knowledge engineer needs to identify and explore them from external resources to complement the instantiated *goal model*. As in Figure 3, all roles now have been specified for the Manokwari regency. Nonetheless, for more detail and related knowledge elements, the knowledge engineer needs to identify and structure them into the corresponding role. For instance, for the goal "planning task force and protocol activities", for describing details of activities for this goal, subgoals are structured, such as "planning socialisation and education activities, "planning law enforcement for IRCA activities". The roles that are responsible for the subgoal include the roles from the goals.

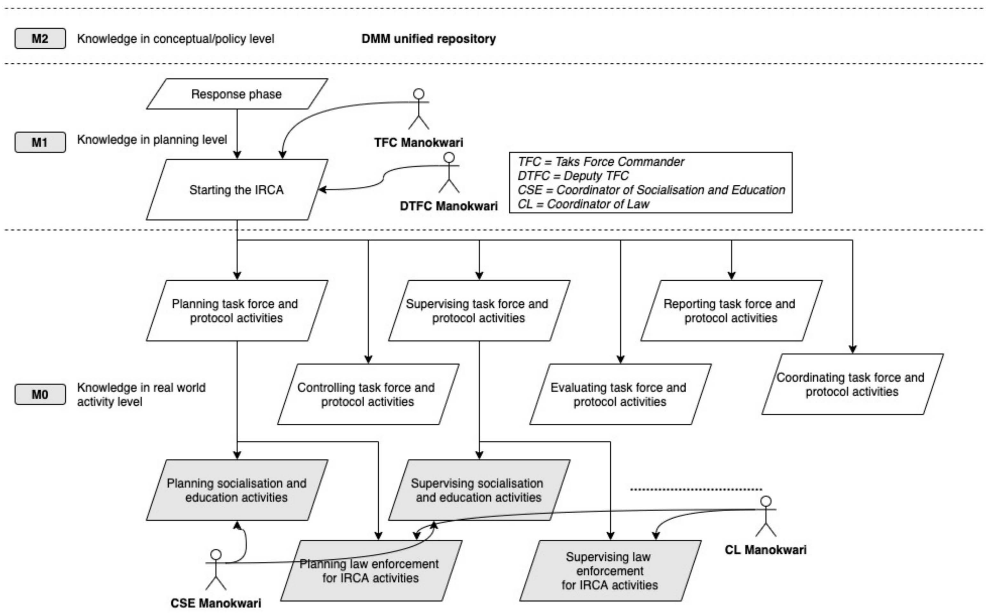

Figure 3. The *goal model* of the flood DISPLAN of the SES Moira Shire Municipality.

Generating the *Role Model*

Generating a specific *role model* is undertaken by substituting all the general knowledge elements in the model template to the roles representing the Manokwari Regency. In Table 3, the *role model* of the COVID-19 DISPLAN knowledge of the Manokwari Regency is provided. It describes role R2: Task Force Commander (TFC) and all its responsibilities.

Table 3. The *role model* of COVID-19 DISPLAN of the Manokwari Regency.

DMM-Based Repository		**M2**
Role Knowledge		**MOF Layer**
Role ID	R3	M1
Role Name	Task Force Commander the Regency of <Manokwari>	
Description	Task Force Commander (TFC) is a role played by District Military Commander of the <Manokwari>	
Responsibility	1. Planning task force and protocol activities. 2. Controlling task force and protocol activities. 3. Supervising task force and protocol activities. 4. Evaluating task force and protocol activities. 5. Reporting task force and protocol activities. 6. Coordinating to the related parties.	M0
Constraint	These responsibilities are for the Regency <Manokwari>	

Generating the *Scenario Model*

The last to generate is the *scenario model*. Table 4 illustrates the generating process to produce the *scenario model* of the COVID-19 DISPLAN of the Manokwari Regency. A knowledge engineer examines all elements in the *scenario model* template to substitute with ones representing this regency.

Table 4. The *scenario model* of COVID-19 DISPLAN of the Manokwari Regency.

DMM-Based Repository					**M2**
Scenario Knowledge					**MOF Layer**
Scenario		S2			
Name		Executing the IRCA operation			M1
Goal		Executing the IRCA operation on the regency of <Manokwari >			
Initiator		Task Force Commander (TFC)			
Trigger		Protocol and operation of IRCA are activated by the PIC <Manokwari>			
Pre-condition		IRCA is authorised			
Post-condition		Starting the task force role			
Description		As the PIC <Manokwari> has given the approval for the IRCA operations and the protocol, it is followed by executing them by TFC.			
Condition	Step	Activity	Role	Environment Entity	
Sequential	1	Planning task force and protocol activities	R1–R2	E1, E2, E3	M0
	2	Controlling task force and protocol activities	R1–R2	E1, E2, E3	
	3	Supervising task force and protocol activities	R1–R2	E1, E2, E3	
	4	Evaluating task force and protocol activities	R1–R2	E1, E2, E3	
	5	Reporting task force and protocol activities	R1–R2	E1, E2, E3	
	6	Coordinating to the related parties	R1–R2	E1, E2, E3	

4.1.3. Stage 3: Transferring the DISPLAN into the Repository

Transferring the generated DISPLAN into the repository comprises two stages: (1) preparing the repository, and (2) transferring the generated ABMs of the Manokwari Regency COVID-19 DISPLAN to it. Figure A1 in Appendix A illustrates the repository. As earlier explained, the repository is based on DMM comprising DM concepts and their relations in ways, so they inform other related concepts to be considered once a concept is processed. For instance, if Coordination <<activity>> is to be performed, all resources <<EnvironmentEntity>> about Aid, the Incident <<Event>> and all roles played by agents in the EmergencyManagementTeam <<Agent>> also need to be catered for as they are related directly to the <<activity>>.

As all activities are carried out by corresponding stakeholders in DM, then all the concepts describing resources they need, other parties they need to interact, coordinate, and communicate with, and other activities to be performed need to be laid out. This is what Figure A2 in Appendix B and Figure A3 in Appendix C aim for, to inform other concepts that are related to the involved stakeholders. The figure also demonstrates how COVID-19 DISPLAN knowledge is structured in the repository. The initiator, pre- and post-condition, trigger, and all the scenario activities for a particular main goal are laid out. The activities are also informed whether they need to be performed parallel, sequential, or interleaved. Each of them is accompanied by the roles involved and the resources needed.

In this section, we have evaluated the effectivity of the construction of the COVID-19 DISPLAN for the Manokwari Regency, based on the DMKAF. We began by exhibiting analysis and modelling the ABM templates of COVID, generating the ones for the Manokwari Regency, subsequently transferring them into the unified repository successfully. However, to ensure the framework's usability to its DM stakeholders, a post-evaluation is sought. This post-evaluation is performed by the authorities who are highly involved in the task in the regency administration. This is discussed in the following section.

4.2. Post-Evaluation of the COVID-19 DISPLAN of the Manokwari Regency Case Study

As earlier described, post-evaluation is aimed to ensure the usability of the COVID-19 DISPLAN deposited into the unified repository. Particularly, this post-evaluation is conducted with the aim to ascertain that the new knowledge representation in the DMM-based repository is unchanged and reusable by the stakeholders as a decision-making mechanism. We pursue this post-evaluation with two authorities in the regency levels. They are (1) second assistant for development and economic sectors of the Manokwari Regency West Papua Province who plays a role as field coordinator of economic sector of the regency task force of the COVID-19 and (2) secretary of planning and development office of Kaimana regency West Papua Province who are also part of the task force in the Kaimana regency. Both are from the same province to ensure that their regencies conform to the same template of IRCA level effectively issued by the Minister of Home Affairs. We conduct the post-evaluation with two authorities to validate the interrater reliability of both for the same issue. We conducted this post-evaluation in Indonesia Language and translated it into English. This post-evaluation is guided by the DSR literature [53]. The prototype GUI interface built for this study is used to perform this post-evaluation. By 'clicking' on the knowledge items organized in the repository, the prototype enables people to simply access and explore them.

We begin this post-evaluation by determining if the resulting knowledge items and their relationships within the repository are consistent with those described in the original instruction. This is crucial to ensuring the repository's continued usefulness and utility to DM stakeholders. This is verified for each of the six ABMs that were used in this study. Both authorities have given good comments in this respect. For instance, the authority from the Manokwari Regency declares in the target model assessment that "*yes, the knowledge meaning in the goal model and regent instruction is still the same*". The authority of Kaimana Regency replied "*yes, it is. Knowledge elements in [the] goal model and document have still the same meaning although they get reworded in some parts*" for our purpose of determining if the information associated with the objectives pursued by each authority in the *goal model* and the DM has not been altered, that the document has not been altered. Both authorities reach similar conclusions for the remaining five ABMs: *role*, *organisational*, *interactional*, *environment*, and *scenario models*.

However, although both authorities acknowledge that the analysed and modelled knowledge elements in the ABMs and in the instructions have not changed, there are two concerns from one of them about the effectivity of the communication during the activities of IRCA, as stated: "*yes, they are still the same. The default responsibility of each of [the] authorities ease the identification; for instance, all activities related to education are the domain of education and cultural office. Thus, all relevant activities will be interacted with the office automatically*". The concern to be considered is related to the effectivity of formal communication, interaction, and coordination between authorities. However, it is also revealed that the concern is not about the efficacy of the ABMs employing in the analysis and modelling activities; instead, it is related to the incomplete knowledge elements in the instruction issued by the regent as mentioned by the authority of Kaimana Regency in the scenario evaluation that "*these knowledge elements are crucial. However, they are not always ready and explicitly described in the instruction. In the real situation, the trigger is mostly based on non-formal instructions*". This concern informs that identifying missing and incomplete knowledge is possible with our developed knowledge analysis framework. In other words, this is essentially a feature offered by our framework, which facilitates the users to identify the inconsistencies of knowledge elements from the DISPLAN. Thus, for the authoritative agency that is responsible for developing such relevant knowledge, identifying the most suitable tool to help develop as complete the knowledge as possible is crucial.

ABMs also lend themselves to identifying incomplete knowledge elements systematically of the DISPLAN, this post-evaluation is also noted further by both authorities. In this context, while the authority of the Manokwari Regency mentioned that "*yes, they can. By utilising these ABMs, we can easily identify what knowledge elements are missing and incomplete from the instruction. The knowledge structured based on this model is easier to understand*", the authority of Kaimana Regency echoed that "*yes, they can. As authorities who are highly involved in the real situation, knowledge elements from the instruction that are structured employing ABMs are far easier to understand. The models also allow us to identify the incomplete knowledge elements easily and quicker*", addressing the topic of whether the DM document's deficient knowledge pieces can be discovered systemically. Following that, this post-evaluation considers additional criteria: (1) whether novel knowledge representations may aid authorities in better comprehending their actions, and (2) whether the repository structure facilitates the identification of knowledge gaps, and (3) whether the created framework contributes to the advancement of the DM resilience agenda at the regency level. In general, the professional responses to this post-evaluation are uniformly good. The post-evaluation is detailed in Table A1 of Appendix D.

5. Discussion

This paper contributes to the development of COVID-19 Disaster Management Plan (DISPLAN) in Indonesia. It is driven by the fact that since the pandemic struck the world, not one person nor country has prior experience for mitigating/preventing, preparing, or responding to such a biological disaster. In fact, we are still quite far from the recovery phase, as we all still struggle to find and implement the best formula that fits for each of us to combat this disaster. The effort toward this issue becomes even more difficult in the absence of prior experience that might equip us with relevant and useful knowledge. What we know from reviewing the related literature of disasters history is that prior DM knowledge is critical for our resilience [20,54].

Since this COVID-19 disaster emerged in late 2019, every government in the world have been "learning by doing" in response to what is best for their country, including Indonesia. Therefore, in this paper, we demonstrate how the best lesson learnt from the "learning by doing" processes can be formally analysed and modelled and subsequently deposited into a unified repository effectively. To allow this to happen, we employed the DMKAF that has been previous developed [13] and experienced a suite of validation [15,33]. In this paper, we evaluated the development of a COVID-19 Disaster Management Plan (DISPLAN) as a knowledge template based on the imposition of restriction on community activities issued by the Minister of Home Affairs. We then instantiated efficiently the DISPLAN of COVID-19 of the Manokwari Regency from it. All these stages are guided by the DSR methodology.

However, to ensure the usability of the generated DISPLAN, we conducted a post-evaluation engaging two authorities who are highly involved in the COVID-19 task force activities. From the post-evaluation, although they both agree with the effectivity and usability of the COVID-19 DISPLAN generated using the DMKAF, they also noted an interesting insight from the post-evaluation. They commented that the DMKAF are also capable of identifying the incomplete knowledge element from the generated DISPLAN. This is not too surprising, as ABMs employed as tools in analysis and modelling activities have unique characteristics for each of them to parse the empirical knowledge elements normally intertwined in a disaster management document; for instance, the one used as a case study in this report. Utilising the ABMs, only relevant knowledge elements from the DM plan will be analysed and modelled to each of the corresponding models. For instance, in the *goal model*, only the main goals, their subgoals, and the roles responsible for each of them are structured. In other words, all the complex knowledge of DM that is mostly written in a business specification format [13] can be disentangled using the ABMs.

To our knowledge, this paper sheds more light on how a COVID-19 DISPLAN of a government administration in Indonesia, developed by employing the DMKAF, can be used to pursue DM resilience endeavours. Particularly in issuing IRCA instruction by the Minister of Home Affairs, having a COVID-19 DISPLAN template of the central government in place facilitates the instantiation of one for any lower administration level, to guide COVID-19 DM activities. We particularly do not only recognise but also provide an empirical solution to the issue raised here [20], to contribute to the gap between acknowledging DM concepts and being able to channel them empirically, facilitating a transfer mechanism for the stakeholders to be used in DM activities. This evaluation reveals that the COVID-19 DISPLAN of the Manokwari Regency has merit to ease the stakeholders to comprehend DM activities. We have also demonstrated the development process using a web-based prototype to guide the use of the system.

In addition, development of a COVID-19 DISPLAN template is extremely crucial as there is a tendency that we expect a third wave of COVID-19 in the near future [55], while, up to now, it appears that we have no formal knowledge that can be reused and shared under the same level administrations in COVID-19 DM activities. The contribution of the paper is also basically a response to our concern, as we noted in our previous work [33], that a DISPLAN template of any disaster should be developed and in place in the central government to be instantiated efficiently for the government at the province and regency levels as part of their DM resilience endeavours. Moreover, once there is an amendment in the policy level for instance, as [11], the knowledge can be propagated to the lower-level administrations easily.

Particularly for developing countries, where a DISPLAN is less commonly used, our developed COVID-19 knowledge analysis framework also facilitates learning processes to be more efficient. This is conducted by allowing the customisation process of the DISPLAN in which it can be suited to the available resources and local wisdom of the administrative levels that it is aimed for. Thus, once a template of a customised DISPLAN for a COVID-19 DISPLAN is developed at the first place for the national level, for instance, it can be adjusted to all provinces and municipalities/regencies efficiently, based on their contexts. In other words, once developed, the template of the customised COVID-19 DISPLAN can be mixed and matched to where it will be adopted and adapted. For developing countries with diverse resources across the regions yet in the same administration levels, (e.g., province vs province or regency vs. regency, particularly between Western vs. Eastern), harnessing a template of customised DISPLAN is crucial to ensure an efficient learning process. Put simply, for developing countries, the requirement for efficient but still effective work throughout DM processes should be fully considered due to the limited resources. Utilising the COVID-19 template for learning from best practices and past experiences of such, as DM lends itself, to materialise it, given its features.

We are cognisant that context-awareness in practical reuse of knowledge is critical. Empirical knowledge facilitates the work of those on the front line to be more effective in responding to each DM activity. Delineating and underlining context dependency is another feature of our developed framework. The framework facilitates the integration of relevant external knowledge based on local wisdom. Because identical disaster management activities and concerns exist in various regions of the globe with distinct populations, geographic features, and so on, it is vital to recognise the local specificities where a catastrophe happens to harness the potential of reuse. This may guarantee DM stakeholders effectively adopt that information for use at all administrative levels of the organisation. We have demonstrated this feature, as validated by our disaster management knowledge analysis framework that was just recently published [15]. This feature applies to the context of the research, as the development of the COVID-19 DISPLAN is formulated based on the developed plan described here [15]. In other words, the knowledge elements describing the local wisdom at any particular place or situation is recognised as the most empirical element that requires no interpretation for the disaster management stakeholders by the time they need it. Our developed framework can facilitate their integration into the instantiated

DISPLAN. We have demonstrated and validated this process in our enhanced knowledge analysis framework, as described here [15]. In our framework, we recognise the tacit knowledge and local situation as external knowledge that immensely complemented the main knowledge elements previously analysed and modelled from the formal DISPLAN. As the knowledge analysis framework in this paper is based on the one we validated [15], this feature is also inherited from the enhanced one.

It is also worth noting that the DM unified metamodel-based repository facilitates stakeholders to predict the decisions for various interrelated activities. This is because the repository constitutes a collection of interrelated essential DM concepts that will guide stakeholders in providing more complete decision-making processes (for instance, as demonstrated in Figure A1 for the response-phase). This provides them a complete view of "what-if" in DM, along the related set of concepts and their relationships.

6. Conclusions, Limitations and Future Research Directions

As earlier described, in a DM, having a DISPLAN in place is one thing. However, for it to be easily understood by the stakeholders is quite another thing. Moreover, understanding as completely as possible the knowledge from the conceptual level to planning and in a real-world context at any point of the DM timeline is extremely important. This is to ensure that the stakeholders are equipped with relevant and useful DM knowledge to guide their activities. In this paper, we have successfully demonstrated the development of the COVID-19 DISPLAN template of Indonesia, which can also be used as a foundation to instantiate plans for regency or provincial governments. We evaluate this process using the DMKAF and COVID-19 instructions issued by the Minister of Home Affairs to generate a COVID-19 DISPLAN for the Manokwari Regency efficiently. A post-evaluation is also conducted to ensure the usability of the result.

Notwithstanding these, some limitations are also noted as feedbacks for our future research directions. First, as noted in the post-evaluation, there is an urgency for the COVID-19 DISPLAN knowledge structured using ABMs to be used in a real-world setting, as stated "*but this will be far better if we can implement this system in COVID-19 disaster management as soon as possible to see its effectivity*". This does not mean we expect the worst in our status of the COVID-19 pandemic. However, the aim is to ensure the effectivity of the COVID-19 DISPLAN of the Manokwari Regency. Second, in the evaluation stage, we generated a COVID-19 DISPLAN of the Manokwari Regency. Although we successfully demonstrated this, another case study, for instance, generating a plan for the provincial level, is sought for the purpose of generalisability of the process we described in this paper. Third, the knowledge presented in the DISPLAN might include spatial elements; for instance, from geographical information systems (GIS). Expanding our framework to integrate such features to make more sense of the decision-making processes will be a focus of one of our future directions for this research.

As we noted in our paper, our post-evaluation aims to assess the usability of the framework in the context of its use. This is following the Design Science Research methodology of Information System research we employ in this study [17]. Although it is sufficient for post-evaluation by an expert with an intimate DM knowledge in this domain [56] (e.g., as illustrated in [33]), we are aware of the interrater reliability issue. Thus, this study instead applies the post-evaluation with two government officials who are the leaders in their institution and part of the COVID-19 government taskforce at the municipality levels. They are highly involved and responsible for day-to-day operations and decision-making processes at their administration levels. They are the most suited candidates for the evaluation. At this stage, the two authorities involved in the post-evaluation are those who are significantly taking part in the COVID-19 task force in their regencies. They are also the decision-makers at the different government offices. Thus, at this stage of the research, we see that they are sufficient to be the respondents for the post-evaluation, as guided here [17,56]. For future research directions, more DM stakeholders and experts will be sought.

It is worth noting that the evaluation methods depend heavily on the work products/Information System artefact resulting from the research activities and the methodologies employed in the study. As our research is guided by the Design Science Research methodology, and the knowledge analysis framework for COVID-19 disaster management is the overarching artefact produced from our research, we sought the post-evaluation based on expert evaluation, as discussed here [53,56]. Nonetheless, a broader variety of evaluation methods will benefit the validation itself and will be considered in future extensions of this research.

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Abbreviations

ABM	Agent-Based Model
AOSE	Agent-Oriented Software Engineering
BPBD	Badan Penanggulangan Bencana Daerah/Regional Disaster Management Agency
CSE	Coordinator of Socialisation and Education
CL	Coordinator of Law
DM	Disaster Management
DMM	Disaster Management Metamodel
DMKAF	Disaster Knowledge Analysis Framework
DSR	Design Science Research
DISPLAN	Disaster Management Plan
GIS	Geographical Information System
IS	Information Systems
IRCA	Imposition of Restriction on Community Activities
LSRR	Large-Scale Social Restriction
OMG	Object Management Group
PIC	Person in Charge
SES	State Emergency State
TF	Task Force
TFC	Task Force Commander
TFD	Task Force Deputy
WFO	Work From Office
WFH	Work From Home

Appendix A

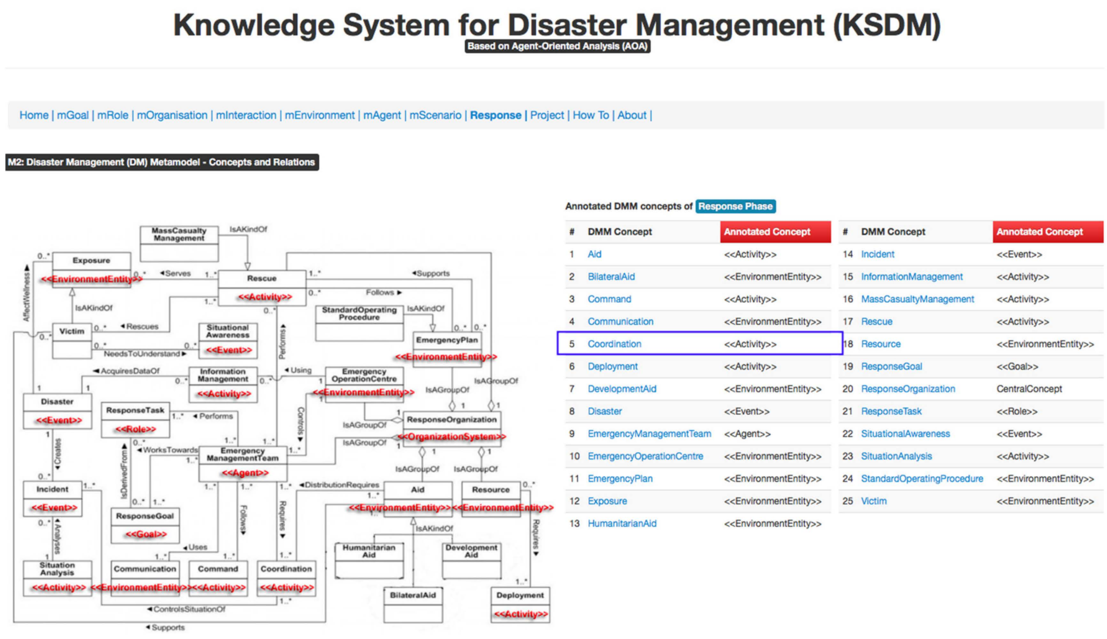

Figure A1. DMM-based repository structure for COVID-19 DISPLAN.

Appendix B

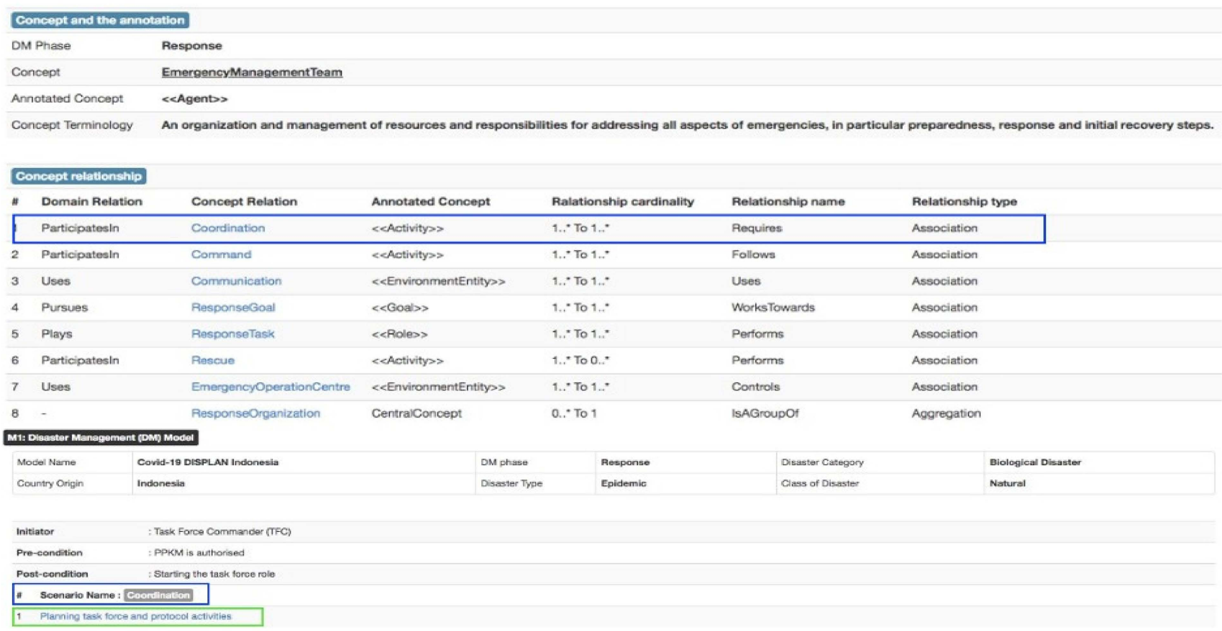

Figure A2. Knowledge elements in M1 level describing <<EmergencyManagementTeam>>.

Appendix C

Figure A3. Knowledge elements in M0 concept describing the ones in M1.

Appendix D

Table A1. Evaluation outcome of usability from confirmatory focus group.

Addressing Criteria	Outcome	Interrater Reliability of Authority Comment
The knowledge included in the goal model and the DM document on the objectives to be pursued by each authority remains unchanged.	Y	Assistant: "Yes, the knowledge meaning in the goal model and regent instruction is still the same". Secretary: "Yes, it is. Knowledge elements in goal model and document have still the same meaning although they get reworded in some parts".
The knowledge-informing functions of each of the authorities participating in the activities continue to exist.	Y	Assistant: "Yes, they are still the same". Secretary: "Yes, the roles and their responsibilities are still the same and can still be easily understood".
The knowledge detailing the organizational structure for the purpose of communicating amongst authority remains unchanged.	Y	Assistant: "Yes, they are still the same. However, informal communication is usually more efficient". Secretary: "Yes, they are still the same but in real situation, communication between authorities is usually looser than it should be".
Knowledge describing to what extent organisations are interacting is not changed.	Y	Assistant: "Yes, they are still the same". Secretary: "Yes, they are still the same. The default responsibility of each of authorities ease the identification, for instance, all activities related to education are the domain of education and cultural office. Thus, all relevant activities will be interacted with the office automatically".
The knowledge base on the resources needed by roles to carry out their DM activities remains unchanged.	Y	Assistant: -idem- Secretary: "Yes, they are still the same. But this needs to be explicitly mentioned so that the roles better prepare them".
In a DM scenario, no knowledge about triggers, pre and post conditions, actions to be performed, or initiating roles is altered.	Y	Assistant: "These knowledge elements will be very useful if they can be defined explicitly in the model". Secretary: "These knowledge elements are crucial. However, they are not always ready and explicitly described in the instruction. In the real situation, the trigger is mostly based on non-formal instructions".
Systematically identifying knowledge gaps in the DM document is possible.	Y	Assistant: "Yes, they can. By utilising these ABMs, we can easily identify what knowledge elements are missing and incomplete from the instruction. The knowledge structured based on this model is easier to understand". Secretary: "Yes, they can. As authorities who are highly involved in the real situation, knowledge elements from the instruction that are structured employing ABMs are far easier to understand. The models also allow us to identify the incomplete knowledge elements easily and quicker".

Table A1. *Cont.*

Addressing Criteria	Outcome	Interrater Reliability of Authority Comment
The new knowledge representation may assist DM stakeholders in comprehending the scenario type in which they find themselves and the other organisations with whom they must deal.	Y	Assistant: "Yes, it can. Particularly in the scenario model, all the activities, the roles that responsible to, the resources needed, the pre- and post-condition, the initiator which allow us to understand the scenario of a particular main goal to be pursued better and easier". Secretary: "Yes, definitely they can. The knowledge represented in the system (framework) help us easily at understanding the activities to be achieved. We can easily identify all activities, the initiator, the pre- and post-condition as well as the roles involved in each of activities and the resources needed. Based on the knowledge structured in the system, we can easily identify what other knowledge elements should be added and involved".
The repository's new information structure assists DM stakeholders in determining the most suitable action at any stage in the catastrophe timeline.	Y	Assistant: "Yes it does. Using the ABMs, we can identify these particular knowledge elements easily". Secretary: "Yes, the structure of the ABMs allows us to identify the relevant knowledge elements easily in any point of the timeline of the activities".
In general, the approach contributes to the agenda for DM resilience.	Y	Assistant: "Yes, definitely. The framework helps us to understand the knowledge required in the activities easily". Secretary: "Yes, it does. But this will be far better if we can implement this system in COVID-19 disaster management as soon as possible to see its effectivity".

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