GEOSPATIAL METAMODEL FOR LANDSLIDE DISASTER MANAGEMENT IN MALAYSIA: CURRENT PRACTICES

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Abstract:

Most of time, landslide in Malaysia was triggered by heavy rainfall during monsoon season. Landslides disaster in Malaysia are managed by Public Work Department (JKR) via Slope Engineering Branch (CKC), Department of Mineral and Geosciences (JMG), and Malaysian Space Agency (Agensi Angkasa Malaysia). JKR was critically engaged in slope remediation activities and the establishment of slope management. JMG and MYSA contribution was informing the government areas prone to landslides via landslide mapping. National Institution, expert practices, and researcher in landslide management in Malaysia is actively engaged in disaster management (DM) activities through the implementation National Slope Master Plan 2009 – 2023 (NSMP 2009 – 2023). With due respect, some issues such as no evasive approach where experts might use for decision-making process according to site suitability, and appropriate mitigation measure, lack of study in landslide disaster management practices in Malaysia, and the availability landslide historical data. Hence, this paper systematically reviews the current practices of geospatial metamodel for landslide disaster management in Malaysia. Findings show that, only few researchers deeply explore the potential of geospatial metamodel in facilitating landslide management and monitoring activities in Malaysia. Geospatial metamodel gives a benefit in determined the completeness of any landslide DM activities either before, during, or after the incident.

Keywords:

Geospatial Metamodel, Landslide Disaster Management, Landslides, Malaysia.

Introduction

Despite knowing, Malaysia are not steep countries (mountains and hills compose for less than 25 % of the topography areas) landslide and slope failure still arise (Qasim, Harahap, & Osman, 2013). Landslide are amongst the most common geo-hazard disaster event in tropical monsoon countries like Malaysia (Tan, Bai, Zhou, Hu, & Qin, 2021). Most of time, landslide in Malaysia are triggered by heavy rainfall during monsoon season beginning May to September (Southwest Monsoon) and November to March (North-Eastern Monsoon) (Majid, Taha, & Selamat, 2020). Majid et al. (2020) also state, since 1961 until today Malaysia has experienced a few major landslide events and reported high number of casualties. For example, major landslide incident at "Ringlet, Cameron Highlands, Pahang in 1961 claims 16 people lives (Alnaimat, Jaafar, & Lam, 2018; Ismail, 2017; Muaz Abu Mansor Maturidi, Kasim, Abu Taib, Nur Aifa Binti Wan Azahar, & Husain Husain, 2020), Highland Towers, Ulu Klang, Selangor in 11th December 1993 killed 48 people and injured two people (Akter et al., 2019; Disaster Preparedness and Prevention Center, 2020; Majid et al., 2020; National Slope Master Plan, 2009), Post Dipang near Orang Asli Settlement, Kampar Perak in 29th August 1996 take out 44 people lives (Abdul Rahman & Mapjabil, 2017; Izumi et al., 2019; Majid et al., 2020; National Slope Master Plan, 2009), and landslide incident at Kg Pampang, Limbawan, Kandang Ayam, Gunung Emas, Keningau, Sabah in 26th December 1996 killed 302 people (Alnaimat et al., 2018; Izumi et al., 2019; National Slope Master Plan, 2009; Sardi & Razak, 2019).

Landslide in Malaysia are managed and monitored by government entities such as JKR via CKC, JMG, and MYSA (Abdul Rahman & Mapjabil, 2017). JKR are the foremost government unit in Malaysia which essentially responsible in activities such as slope remediation (active action) and the development of slope assessment and management work in Malaysia (Abdul Rahman & Mapjabil, 2017). For the meantime, the role of JMG and MYSA is to notify government areas prone to landslide via landslide susceptibility, hazard, vulnerability, and risk mapping activities (Abdul Rahman & Mapjabil, 2017). Those maps are broadly used by other government agency as a guidelines in planning proper action and SOP for the development at hilly and slopes areas (Jamaludin & Hussein, 2006). Hence, it's required dedicated action and skilfully manpower from both entities to serve and visualized accurate landslide information to other government agency.

As an initiative, both JMG and MYSA correspondingly developed an application system known as "National Geospatial Terrain and Slope Information System (NaTSIS)" (Department of Mineral and Geoscience, 2016b) and electronic slopes (e – Slopes) (Agensi Angkasa Malaysia, 2021). The system aims to monitor and visualize landslide information using geospatial technology such as Aerial Photography (AP), Airborne Light Detection and Ranging (LiDAR) and High-resolution of satellite imagery. JKR was also develop an early warning system known as "Landslide Warning System (LWS)" in 2013 (Abdul Rahman & Mapjabil, 2017). The system offers an early warnings at minimum two hours before landslide occur to a public and currently was tested and validated at Tapah – Cameron Highlands Road, Pahang and Ulu Klang – Bukit Antarabangsa, Selangor regions (Abdul Rahman & Mapjabil, 2017). Both areas considered one of Malaysia's landslide high sensitivity regions besides Kundasang, Sabah and other areas (Abdul Rahman & Mapjabil, 2017).

Presently, national institution partnering with landslide expert practices was actively engaged in landslide disaster management activities via the execution of NSMP 2009 – 2023 across the countries (Alnaimat et al., 2018). NSMP was established by JKR in 2004, same year with

establishment of Slope Engineering Branch (CKC) and one year after rock slide incident at North Klang Valley Expressway (NKVE) near Bukit Lanjan, Selangor in 2003 (Abdullah, 2013). The plan was totally endorsed by government of Malaysia in 2009 and aim to reduce risk and losses due to landslide nationwide since 2009 until 2023 (Abdullah, 2013) via the engagement at entire level in both public and private sector (Abdul Rahman & Mapjabil, 2017).

The plan outlines ten (10) specific components of robust and comprehensive national policy, strategic and action plan to mitigate landslide events in Malaysia (Abdul Rahman & Mapjabil, 2017; Abdullah, 2013; Tajul Anuar Jamaludin, 2015). The components were address in detailed in three volumes sectoral report. Volume I comprise of policy and institutional framework as well as hazard mapping and assessment activities (National Slope Master Plan, 2009; PreventionWeb, 2009). Volume II entails another four specific components of NSMP which is early warning, and real-time monitoring system, loss assessment, information, collection, interpretation, dissemination, and archive (PreventionWeb, 2009). Volume III comprises remaining component such as public awareness, , loss reduction measures, emergency preparedness, response, and recovery, as well as research and development (R&D)(PreventionWeb, 2009).

In terms of landslide mitigation strategies, JKR contributed most in hazard mapping and assessment, early warning system and real-time monitoring, and public awareness program (Alnaimat, Lam, & Jaafar, 2017). Hazard mapping and assessment is a realistic approach in determine the risk of living in specific regions and assist civilian become alert in areas subject to slope failure incident (Alnaimat et al., 2018). Figure 1 below indicates Volume I Sectoral Report of NSMP 2009 – 2023 document published by Government of Malaysia and Public Work Department (JKR).
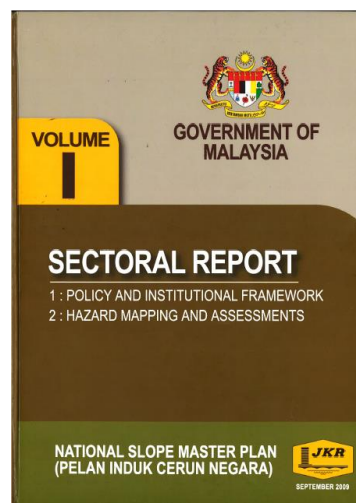
Figure 1: Volume I Sectoral Report of National Slope Master Plan
(NSMP 2009 – 2023) published by Government of Malaysia and JKR

Source: (National Slope Master Plan, 2009)

Nevertheless, several issues has been arisen lately. Although, Malaysia does have national slope management very much like NSMP 2009 – 2023, there is no unified strategic approach where experts and researcher could use for decision making based on site suitability, causal factor, and adequate mitigation measure (Alnaimat et al., 2018). For that reason, each landslide

location has a different characteristic of topographic surface, geology, lithology, geomorphology, vegetation cover, causal, and anthropogenic factor. Hence, it's vital for experts and researcher to own one inclusive approach that can be fitted to any landslide location in Malaysia for decision making process.

The second issues related to lack of study in landslide disaster management practices, which greatly emphasis on spatial prediction and mapping areas of landslide. By considering record from Web of Science (WOS), most of the research on landslide disaster management in Malaysia was greatly focus on preparedness phase (50 %), but less emphasize on landslide mitigation, management and resilient development (12 %) (Akter et al., 2019). This because landslide or slope failure management in Malaysia is fairly in the initial phase which numerous things need to be considered particularly on landslide inventory and data acquisition of slopes for efficient planning purposes (Alnaimat et al., 2018). Things get worse, when JKR hard to convince government to supply financial resources for mitigation actions instead of paying much for repair activities (Alnaimat et al., 2018; Mezughi, Akhir, Ghani Rafek, & Abdullah, 2012).

Lastly, issues linked to availability of landslide historical data. According to Alnaimat et al. (2018), current landslide historical database only present a subtle information and understanding of landslide event at Peninsular Malaysia, Kuala Lumpur, and it's nearby areas. Incomplete landslide historical record due to absence of appropriate and systematic landslide inventory is a main roots those issues had arisen lately (Akter et al., 2019; Rodeano, 2019). Although the records of landslide are existed, the information is not comprehensive and widespread (Rodeano, 2019). For example, landslide event at Ringlet, Cameron Highlands, Pahang on 11th May 1961 which killed 16 people and injured 35 people. The detailed information about that tragedy is quite limited since the incident was occurred about six decades ago. Although it was available, the source of information is from online blogpost which can be argued later. Hence, decision making on landslide disaster management become problematic to implement and executed at all level of jurisdiction(Abdullah, 2013; Komoo, Abdul Ghani Aziz, & Lim, 2011). When it comes to this situation, search and rescue (SAR) activities turn out to be challenging task to carry out, and resulting more damage to the public residents (Nasir & Abdul Khanan, 2018).

To counter it, a systematic, comprehensive, and unifying data model known as "Geospatial Metamodel" has been highlighted in this paper. Beforehand, metamodel concept will be briefly introduced and explained in "Literature Review" section to give a better understanding "how metamodel work in disaster management?", as well as their advantages and disadvantages in terms of disaster management.

Literature Review
There are five points will be discussed in literature review (LR) which is metamodel concept, disaster management metamodel, geospatial metamodel, current practices of geospatial metamodel for landslide disaster management.

Metamodel
Metamodel can be defined as model of model or model that contains statements about model itself (Jeusfeld, 2009). Much like model are representation some reality, metamodel are depiction of models itself (Jeusfeld, 2009). As stated by D. I. Inan, Beydoun, and Pradhan

(2018), metamodel is made up of class concept and relation that defined the domain explicitly. For instance, by some disaster event, stakeholders / government entities can have a deeper understanding on how to mitigate the impact and attain disaster management (DM) resiliency by defining an appropriate concept classes in metamodel (D. I. Inan et al., 2018). Class concept was referred to activity / task in disaster management (DM) phase beginning from prevention, mitigation, preparedness, response, and recovery. The activity of designing and creating metamodel known as "Metamodeling"(Abd Sahrin & Abdul Khanan, 2021; Jeusfeld, 2009) and typically follows a strict and systematic methodology (Whittle, Hutchinson, & Rouncefield, 2014). It's comprise the specification of model and define the syntax and semantics of domains (S. H. Othman, Beydoun, & Sugumaran, 2014). Metamodel also allowed the creation of information repositories with distinct interface (Kaptan, 2014; S. H. Othman et al., 2014). Beydoun et al. (2009) outlines eight steps of "Metamodeling Creation Process" beginning from model collection and preliminary study domain, identifying sets of models, extraction of concept in model, short listed candidate definition, reconciliation of definitions, designing concept, identification of relationship, and validating metamodel. Later, the step was adopted by S. Othman and Beydoun (2010) for the development of disaster management metamodel (D. I. Inan et al.).

Metamodel Framework
Object Management Group (OMG) Standards classified metamodel into Unified Modelling Language (UML), Interface Definition Language (IDL), Meta-Object Facility (MOF), Common Warehouse Metamodel (CWM), and XMI (XML Metadata Interchange) (Picka, 2004). Picka (2004) also state that, metamodel based on OMG Standards follow four level metadata architecture which is information layer, model layer, metamodel layer, and meta-metamodel layer. MOF follow this architecture and each level is represent as M0 (real world domain), M1 (model), M2 (metamodel), and M3 (meta-metamodel) (D. Inan, Beydoun, & Opper, 2017; D. I. Inan et al., 2018; S. H. Othman & Beydoun, 2016). MOF also commonly used in the development of disaster management metamodel (DMM) due to flexible exchange between conceptual and real world and vice versa (Abd Sahrin & Abdul Khanan, 2021; D. I. Inan et al., 2018). It means that the knowledge / information of disaster management can flexibly exchange between low and high level and vice versa in MOF framework. As supported by D. Inan et al. (2017), lower level of MOF should conform to its higher level and higher level instantiate model to lower level (D. Inan et al., 2017). Figure 2 and 3 below shows an example of Nuclear Disaster Model at M1 level and Fukushima Nuclear Disaster Model at M0 level respectively.
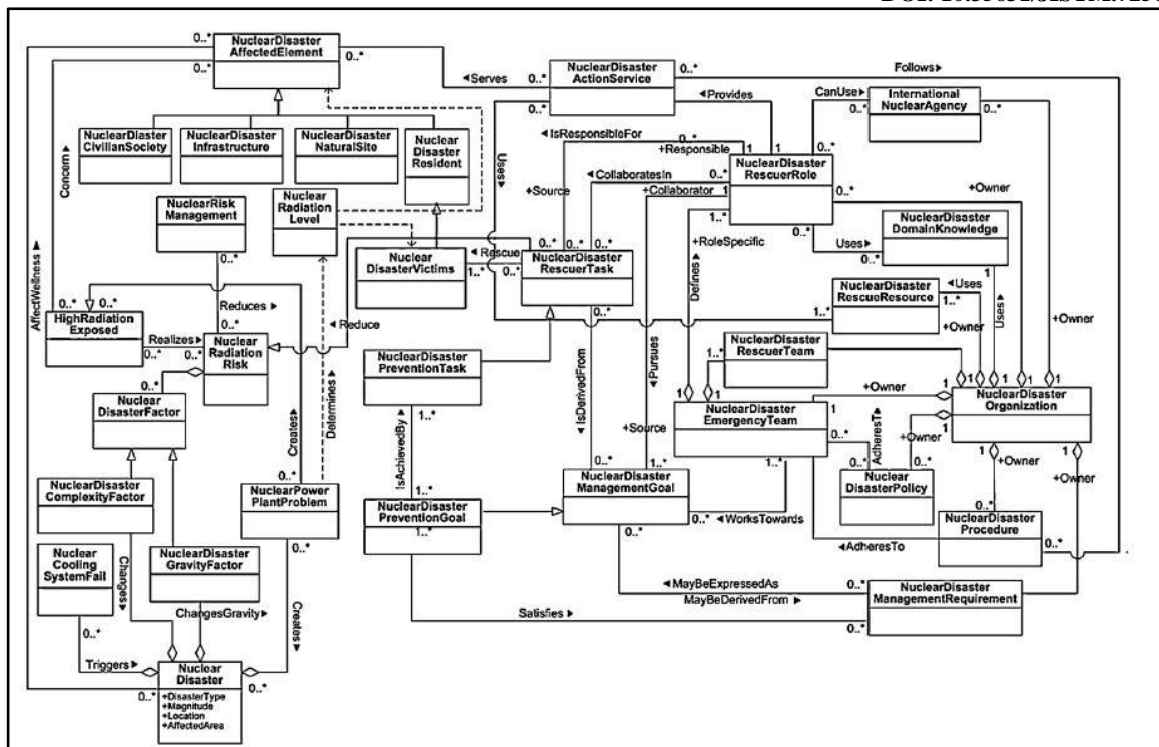
Figure 2: Nuclear Disaster Model at M1 level based

Source: (S. H. Othman & Beydoun, 2013)
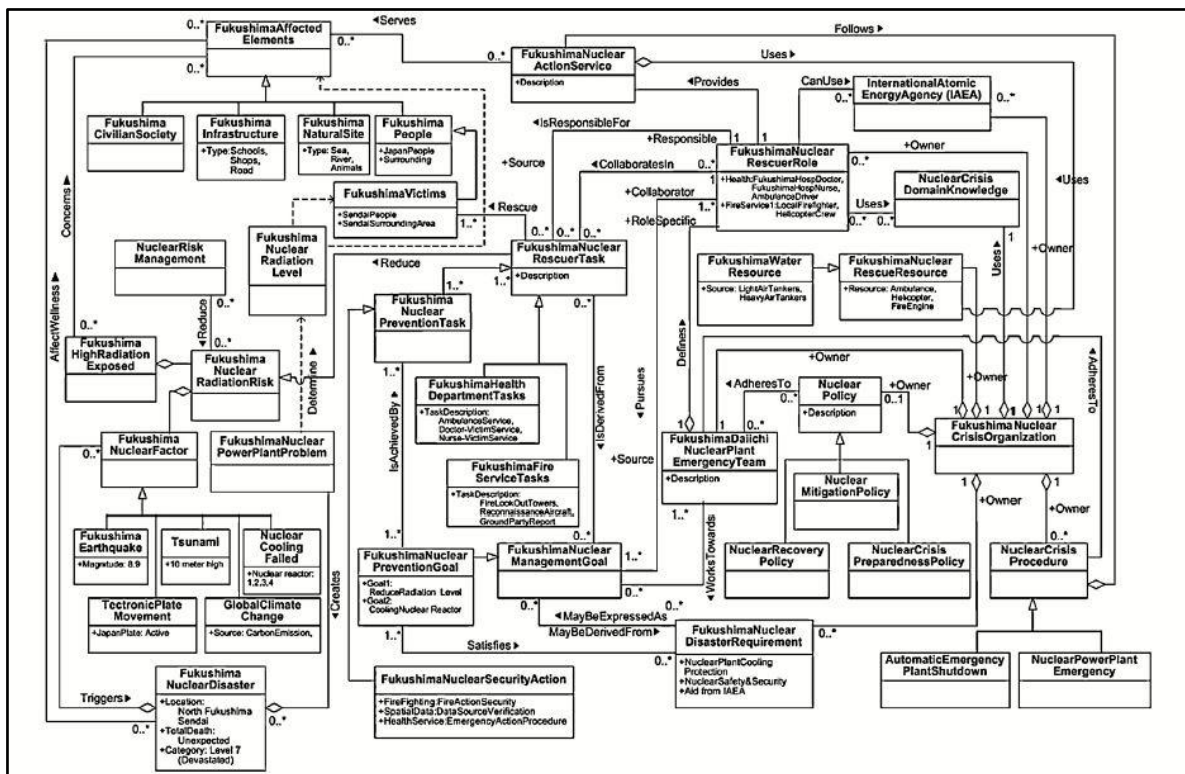
Figure 3: Fukushima Nuclear Disaster Model at M0 level

Source: (S. H. Othman & Beydoun, 2013)

Based on Figure 2 and 3, Fukushima Nuclear Disaster Model at M0 level was instantiated by Nuclear Disaster Model at M1 level. This in line with MOF framework, lower level must instantiated by high level, and high level must conformed by lower level (D. Inan et al., 2017). In other words, higher level (M1) to lower level (M0), model are allows to inherit as many as possible class concept from the model above level to developed a new disaster specific-model (D. Inan et al., 2017). Same goes to other, M2 level could also inherit class concept at M3 level. For example, for the Nuclear Risk Management, the concept is being instantiated to be the new concept known as Fukushima Nuclear Disaster at M0 level. Nuclear disaster concept at M1 level visualized attribute information such as disaster type, location, magnitude, and affected areas. Meanwhile, class concept Fukushima Nuclear disaster instantiate the attribute information concept at M1 level into real case study of nuclear disaster at Japan. Hence, it's proved that concept at high level model can be inherited to low level model and low-level model comply with model above them.

Disaster Management Metamodel (DMM)

Specific domain metamodel for disaster management (DM) is known as Disaster Management Metamodel (DMM). As supported by Abd Sahrin and Abdul Khanan (2021); D. Inan et al. (2017); S. H. Othman and Beydoun (2016), DMM is a specific model that supported disaster management tasks and phases by utilising a specific metamodel framework known as MOF. DMM also represented the cohesive perception of unique management process with collective standard operational procedure (SOP) and response-oriented applied in several disaster (Sardi et al., 2021). The goal of DMM was to gather a complicated feature of DM activities and deliver it in a way that non-experts could easily grasp (Betke, Hofmann, & Sackmann, 2013). This supported by D. Inan et al. (2017), DMM aims to acquire the characteristic of DM activities and present to the user who doesn't have expertise effortlessly understand the flow process. DMM also allow user to simply form specific DM solution model according to their particular disaster challenges (S. H. Othman & Beydoun, 2013). By this, it speed up the decision making process by endorsing and providing DM knowledge sharing amongst numerous DM communities (S. H. Othman & Beydoun, 2013).

Briefly, DM encompasses collaborative decision-making activities across time, space, and people (S. H. Othman & Beydoun, 2013; S. H. Othman et al., 2014). Weighting bulk of information in the earlier phase of decision-making activities is quite challenging when it comes to race against time (S. H. Othman & Beydoun, 2013). This because DM activities comprises numerous co-operating element such as publics, stakeholders, authority, emergency teams, resources, standard operating procedures (SOP), indefinite environmental states, and many more (S. H. Othman & Beydoun, 2016). The process become worse when a decision must consider the specific interest of victims, governments, NGOs, and emergency teams (S. H. Othman & Beydoun, 2013). Hence, the development of DMM gives a benefits in terms of providing clear representation of DM solution model to stakeholder and public (S. H. Othman & Beydoun, 2013). By this, it can help DM user such as emergency managers, federal, state, and local government, emergency service teams in creating better communication among DM practitioners and become an effective platform for sharing and integrating DM knowledge from various sources (Beydoun et al., 2009; S. H. Othman & Beydoun, 2013; S. H. Othman et al., 2014).

Furthermore, DMM act as steering data model which permitted interoperability of DM solution model between government agency and expertise and used as a tool to clarify and monitor the completeness of any DM solution by illustrating numerous DM activities and desired outcomes (S. H. Othman et al., 2014). This supported by Abd Sahrin and Abdul Khanan (2021), the development of DMM was a solution to issues of disaster such as data interoperability amongst expert groups and government agency. As matter of fact, it can assist appropriate decision making by concatenating and matching distinctive DM activities in response to the disaster scenario at hand (S. H. Othman et al., 2014).

DM activities frequently extend across numerous government sectors, non-governmental organizations, either from federal level down to state or provincial level, as well as individual (S. H. Othman & Beydoun, 2016). It's often unclear the exact tasks and responsibilities of government agency and disaster practitioner before, during, and after disaster strikes (S. H. Othman & Beydoun, 2016). DMM through five phases of disaster management (DM) cycle offer an inclusive picture to government agency, and expert of how all DM activities are executed (S. H. Othman & Beydoun, 2016). With better awareness and understanding the entire DM activities at each stage, numerous benefits can be derived such as enable better decision-making process, decrease time, and cost of SAR operation, and allow DM knowledge sharing between government agency and expert (D. Inan et al., 2017; S. H. Othman & Beydoun, 2016; S. H. Othman et al., 2014). By this, DM activities turn out to be an efficient management (Nasir et al., 2018). Therefore, it's possible to justify that DMM gives a benefit in terms of make a better engagement between disaster practitioner, experts, and government agency in mitigating the impact of disaster to the public through a series of DM activities which cover the entire stages DM cycle. By this, data sharing and transfer of knowledge and technology between both parties could be occur since both expert and government agency clearly know their own role and function when the disaster strikes to the public. Hence, decision-making process grow into faster and efficient disaster management and directly mitigating the number of casualties of public affect by disaster.

However, like other information system, DMM also have their drawback and issues. For instances, issues such as inadequate geospatial element such as map exists in DMM itself (Nasir & Abdul Khanan, 2018). The map will visualize historical event of disaster (inventory), potential area / location of disaster (susceptibility), probability of time for disaster to return (hazard), possible area impact of disaster to people, social, and environmental (vulnerability), and risk area of disaster (risk). By this, task of decision-making, search, and rescue (SAR), and resources supplies to victim become faster and efficient since the location is already know.

Geospatial Metamodel
Geospatial metamodel was adopted the definition of metamodel itself, which defines model about model but with additional geospatial information and element such as map. At present, there is no precise definition in roughly describe the concept of geospatial metamodel. By taking case study of Wang, Li, Chen, Chen, and Wang (2016), geospatial metamodel is known as geospatial decision metamodel which describes as metamodel layer, basic metadata modules, metadata content, and information description structures along with set of uniform rubric and metadata framework that must be followed by geospatial metamodel itself. Figure 4 visualizes geospatial metamodel based on MOF framework.
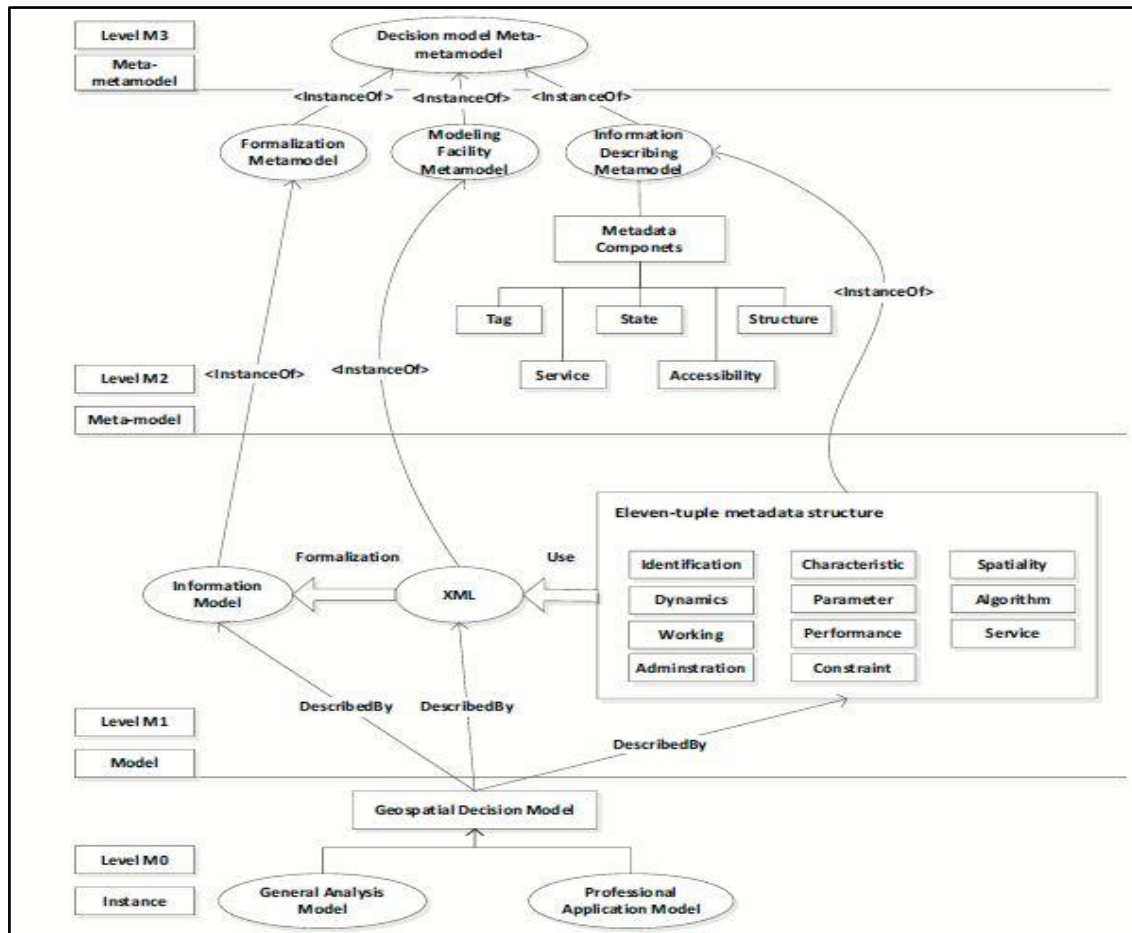
Figure 4: Geospatial Metamodel Structure Based on MOF Framework

Source: (Wang et al., 2016)

Figure 4 above, visualized the geospatial metamodel structure based on MOF framework. Metamodel framework was described as "Metamodel layer" and could be classified into UML, MOF, XMI, CWM, and IDL (Picka, 2004). However, Wang et al. (2016) proposed to use "Meta-Object Facility (MOF)" framework in the development of geospatial metamodel for city-wide decision-making process and transportation planning. Same goes to metamodel itself, geospatial metamodel with MOF architecture was made up of four hierarchy level (M0 to M3 level) (D. Inan et al., 2017; Wang et al., 2016). Model at the higher level is an instantiation a model at lower level, while model at lower level are conformance model at higher level (D. Inan et al., 2017; Wang et al., 2016). By referring figure 4, "Geospatial Decision Model" at M0 level was conform to model at M1 level. Geospatial decision model at M0 level was described by three model at M1 level which is "Eleven-tuple metadata structure", "XML", and "Information Model". This means that the information language and metadata of Geospatial Decision Model was defined and represented as a model at M1 level (Abd Sahrin & Abdul Khanan, 2021; Wang et al., 2016).

According to Wang et al. (2016), the five metadata modules consists of tag, state, accessibility, structure, and services. Those modules were defined in "Information Describing Metamodel" at M2 level and was instances of "Eleven-tuple metadata structure" at M1 level (Wang et al., 2016). Same goes to "XML" and "Information Model" which was described into "Modelling Facility Metamodel" and "Formalization Metamodel" respectively. The information above is important in recognizing and selecting proper geospatial model rapidly and precisely which fulfilled the demands in geospatial decision problem (Wang et al., 2016).

Hence, by take up case study of Wang et al. (2016), which implement geospatial metamodel for city wide decision making process and transportation planning application, some justification can be made. Geospatial metamodel used Meta-Object Facility (MOF) framework to define their metamodel structure based on four hierarchy level (M0 level until M3 level) (Wang et al., 2016). Commonly, single real-world model at M0 level was described until M2 level (metamodel) and probably extend to M3 level (meta-metamodel) if more than one model involved. Similarly, to landslide disaster management, the geospatial metamodel may possibly extend to M3 level if included more than one case study.

Geospatial Metamodel for Landslide Disaster Management in Malaysia

More than a few scholar, like N. Chen, Du, Song, and Chen (2015); D. Inan et al. (2017); D. I. Inan et al. (2018); Nasir et al. (2018); S. H. Othman and Beydoun (2013, 2016); S. H. Othman et al. (2014); Sardi et al. (2021); Wang et al. (2016) has discovered the potential of MOF framework in assisting the development of Disaster Management Metamodel (DMM). Those were tested and validated based on real natural disaster case study in the world such as flood (N. Chen et al., 2015; D. Inan et al., 2017), landslides (Nasir et al., 2018; Sardi et al., 2021), volcanic eruption (D. I. Inan et al., 2018), bushfire (S. H. Othman & Beydoun, 2016; S. H. Othman et al., 2014), earthquake and nuclear crisis (S. H. Othman & Beydoun, 2013). However, the concern is the studies by (Nasir et al., 2018; Sardi et al., 2021) which their case study based on real landslide event at Malaysia in Kundasang, Sabah and Taman Idaman, Serendah, Selangor respectively. Both studies use geospatial metamodel approach to manage and monitor landslide disaster management activities in Malaysia.

Nasir et al. (2018), endorsed MOF framework in the development of geospatial metamodel for landslide non-structural mitigation activities in Malaysia. The activities may cover from visualizing SOP for landslide risk assessment and mapping landslide inventory in specific areas (Nasir et al., 2018). Landslide non-structural mitigation activities aim to mitigate the impact of landslide disaster via law regulation, policy, public awareness between government agency and community, training, research and development (R&D), and education (Khanna, 2005; Nasir & Abdul Khanan, 2018).

Landslide inventory map is an example of non-structural mitigation activity (Khanna, 2005; Nasir & Abdul Khanan, 2018) and the root of landslide risk assessment (Castellanos, 2008; W. Chen et al., 2018; Hervas & Bobrowsky, 2009). The map was created using the data from Airborne Light Detection and Ranging (LiDAR) and Aerial Photograph (AP) via visual image interpretation approach and validated all through existing landslide inventory map. The map together with SOP for landslide risk assessment was visualized into centralized user interface (UI) repository application known as "Geospatial Metamodel for Non-Structural Mitigation of Landslides (GeoMet)" (Nasir et al., 2018).

Sardi et al. (2021), utilized geospatial metamodel concept through the development of metamodel known as "Metamodel-based Geospatial Multi Disaster Risk Prototype System (MGeoMR). The metamodel was formed according to National Security Council (NSC) Directive No.20 disaster plans and SOP for flood and landslide in Selangor (Sardi et al., 2021). Landslide event at Serendah, Selangor in 2016 was chosen to test and validate the geospatial metamodel during "Full Scale Exercise (FSX)" landslide disaster mock-up drill (Sardi et al., 2021). FSX is a Malaysia first landslide simulation utilizing "Information and Communication Technology with Geospatial (ICT-Geospatial) data at the district level (Sardi et al., 2021). The simulation drill was aims to enhance the efficiency of the search and rescue (SAR) taskforce and boost the local community contribution in giving out early warning of landslide disaster and at the same time forming disaster resistant communities (Sardi et al., 2021).

Review Findings

The finding indicates that, the current practices of geospatial metamodel for landslide disaster management in Malaysia is quite new and limited to explore by researcher and some disaster management practices. The studies by Nasir et al. (2018); Sardi et al. (2021), proves that the potential of geospatial metamodel in facilitating monitoring and managing landslide management activities in Malaysia could be further explore and bring into real world crisis not just as prototypes system.

Nasir et al. (2018), visualized the SOP workflow for landslide risk assessment together with landslide inventory map in one comprehensive metamodel user interface application known as "GeoMet". GeoMet visualizes the entire workflow which indicates the general process of landslide risk assessment beginning the item from desk study until recommendation together with the model for each item (Nasir et al., 2018). For each item the activity was entailed based on MOF three hierarchy level (M0 level to M2 level) after the user click on item. The model visualized the workflow process step by step procedure together with map once the user click on it (Nasir et al., 2018). Figure 5,6 and 7 below visualizes the overall GeoMet interface, disaster solution data based on MOF metamodel three hierarchy level and example of the model of landslide inventory map.
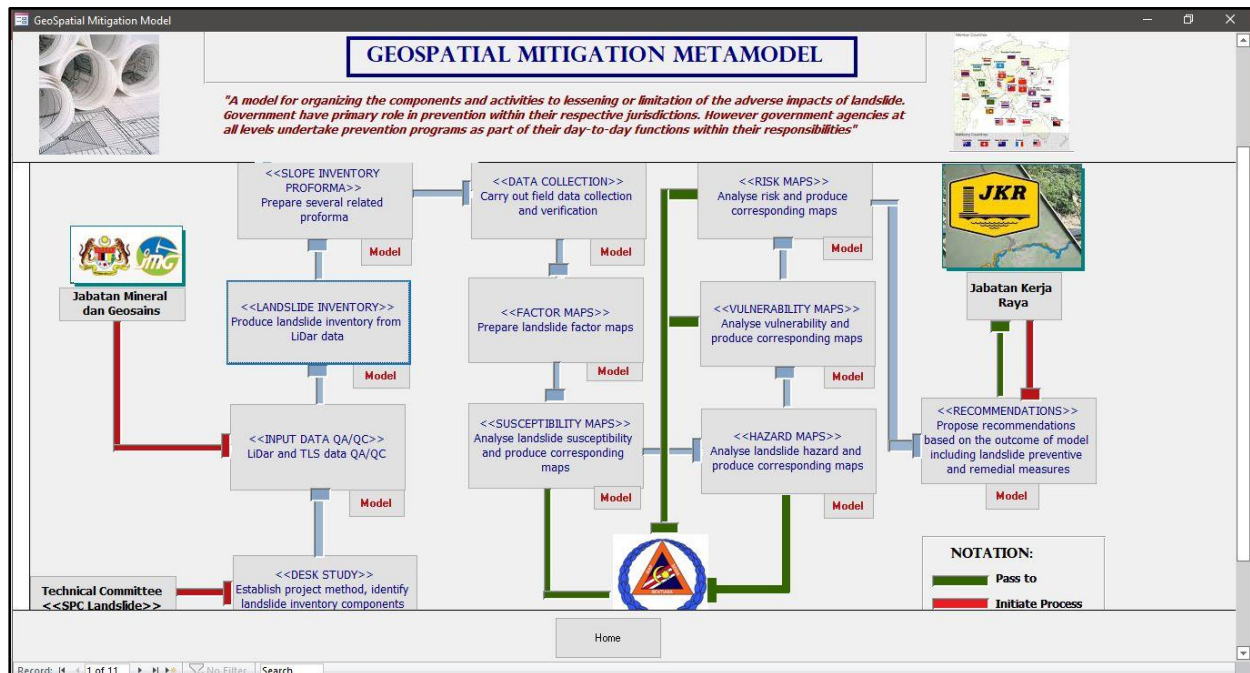
Figure 5: Geospatial Metamodel for Landslide Non-Structural Mitigation

Source: (Nasir et al., 2018)

Figure 6: Disaster Solution Data Based on Landslide Inventory Task in Geomet According to MOF Framework Three Hierarchy Level

Source: (Nasir et al., 2018)
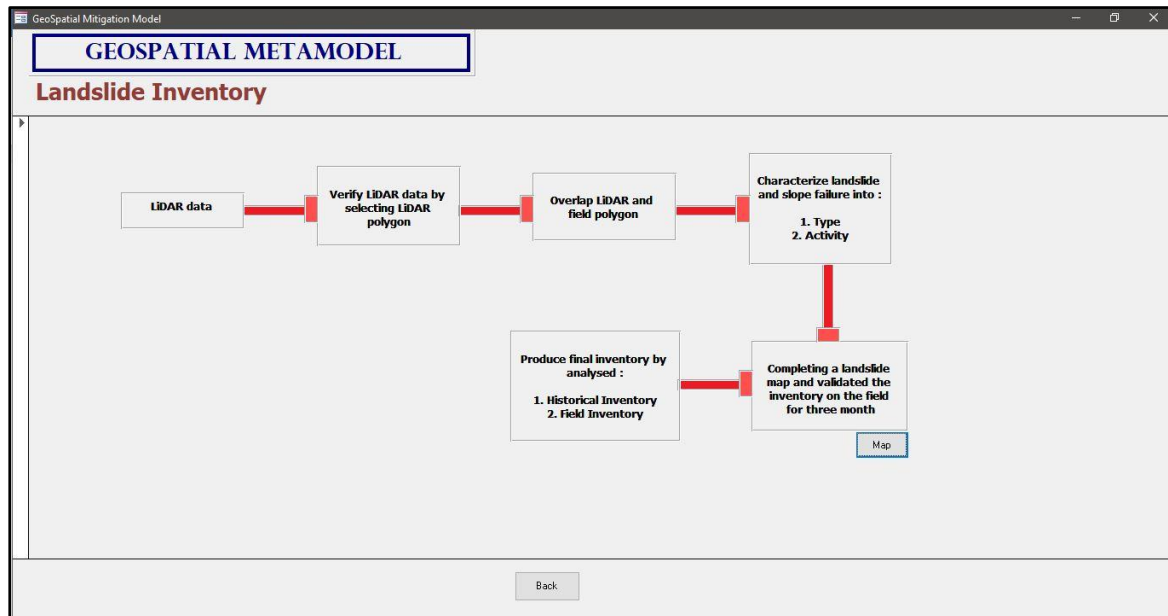
Figure 7: The Model of Landslide Inventory Map Activity in Geomet

Source: (Nasir et al., 2018)

By referring to figure 7 above, the model of landslide inventory map activity was also part of landslide risk assessment process visualizes in GeoMet on figure 5 and figure 6. The model indicates the workflow for generating landslide inventory map at Kundasang, Sabah using LiDAR and Aerial Photograph (Nasir et al., 2018). Landslide inventory map gives a benefit such as potraying the landslide location with reliable information about type, activity, size and volume, relative age, date of occurrence, features and causes (Department of Mineral and Geoscience, 2016a; Nasir et al., 2018) and assist in landslide risk assessment process especially in validating the accuracy and reliability of landslide susceptibility and hazards map (Castellanos, 2008; W. Chen et al., 2018; Hervas & Bobrowsky, 2009). GeoMet serves as a proposed solution by informing the users about the impact of landslides via the landslide inventory map (Nasir et al., 2018). Geospatial metamodel couple with landslide inventory map presents an advantages in terms of mitigating landslides hazard impact by providing the information about the landslides to the responsible government agencies either before, during, and after disaster hit for further action (Nasir et al., 2018).

However, GeoMet still have some issues and limitation. Issues such as limited record of landslide historical event for the purpose of information dissemination to the public and related government agencies still occur. In terms of landslide disaster management, historical record of landslide is crucial to government agencies is useful for planning, monitoring, and managing the subsequent action in disaster management stages. GeoMet can be enhanced by adding landslide risk register into geospatial metamodel. According to Lee and Jones (2014), landslide risk register is kind of document / database which set out all the recognized risk at a particular location and decision that was taken on how to monitor it. This in line with NADMA needs to develop disaster risk register and repository for evaluating the possible impact of natural disaster risk in Malaysia and utilize it as decision-making platform for disaster mitigation programme, development project, and SAR operations (Bernama, 2020).

Sardi et al. (2021), visualized the landslide model interface covering four main phases of disaster management beginning from (i) initial warning, (ii) actions, (iii) response, and (iv) evidence-based scenarios which interpreted into situations for simulations. The simulation drill encompass the entire District Management Committee (DDMC) and State Disaster Management Centre (SDMC) (Sardi et al., 2021). Figure 8 indicates the Disaster Management Metamodel (DMM) for Serendah landslide model interface.
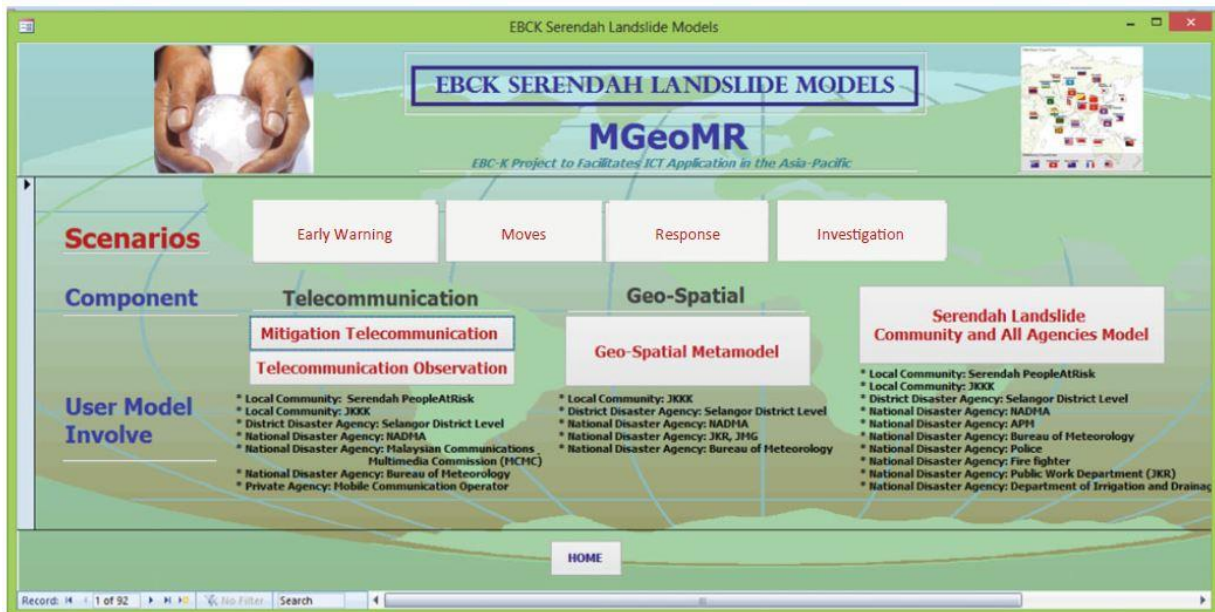
Figure 8: Disaster Management Metamodel (DMM) For Serendah Landslide Model Interfaces

Source: (Sardi et al., 2021)

Based on figure 8, those four main phases was visualized in MGeoMR prototype system which aids as domain information delivery platform for landslide drill simulation (Sardi et al., 2021). For the entire phase, the duties and tasks of local communities was associated based on landslide features and geomorphological process (Sardi et al., 2021). The local community are responsible becoming the first responder for monitoring and managing evacuation process before relief team and government agency arrived to gives a help in search and rescue (SAR) operations (Sardi et al., 2021). Sardi et al. (2021) also states, appropriate and precise communication is vital during emergency since the informer tend to use quick approach either direct call, short message services (SMS), and smartphone application to inform the event to disaster operation centre and rescue teams. This is what we call as bottom-up approach which strengthening the local community knowledge and involvement in disaster management. Therefore, the process of SAR and decision making by disaster management can be shortened, reduce the bureaucracy, and mitigating the impact of disaster (Sardi et al., 2021).

MGeoMR prototype system couple with landslide drill simulation gives a benefit in terms of understanding the natives shapes of landslide risk, and enhance the local community and government agency and authority preparedness to deal with crisis in an appropriate manner (Sardi et al., 2021). Hence, indirectly promoted and strengthening local "Disaster Risk Reduction (DRR)" initiatives and programme to local community and local authority when

disaster hit. Nevertheless, there is some issues and limitation regarding to this study. Metamodel framework that used during the development of MGeoMR not clearly stated in the study. By time, it could possibly develop based on MOF framework, due to MOF was commonly used in DMM development and flexible exchange between conceptual model and real-world model (D. I. Inan et al., 2018).

Conclusion

This paper gives a review on the current practices of geospatial metamodel for landslides disaster management practices in Malaysia. Landslide disaster in Malaysia was manage by government agency such as JKR via CKC, JMG, and MYSA (Abdul Rahman & Mapjabil, 2017). JKR are the leading technical department which greatly contributed in slope remedial work (active) as well as slope assessment and management inclusion National Slope Master Plan 2009 -2023 (NSMP 2009 – 2023) (revised in 2016) (Abdul Rahman & Mapjabil, 2017). JMG and MYSA contribution was informing the other government agency of areas prone to landslides via landslide hazard and risk mapping (Abdul Rahman & Mapjabil, 2017).

Several researchers have explored the topic of DMM for specific natural disaster such as N. Chen, Du, Song, and Chen (2015); D. Inan et al. (2017); D. I. Inan et al. (2018); Nasir et al. (2018); S. H. Othman and Beydoun (2013, 2016); S. H. Othman et al. (2014); Sardi et al. (2021). However, simply two studies from Nasir et al. (2018); Sardi et al. (2021) discovered the potential of DMM for landslide disaster management practices in Malaysia. Both studies use geospatial metamodel approach to develop a metamodel application for landslide management known as GeoMet and MGeoMR respectivey. GeoMet and MGeoMR was tested and validated based on landslide case study at Kundasang, Sabah in 2015 and Taman Idaman, Serendah, Selangor in 2016.

However, both metamodel application have their own issues and limitation. The issues such as limited record of landslide historical for the purpose of information dissemination was occurred in GeoMet. To counter those issues, it's possible to add landslide risk register which set out the entire risk at particular location and decision that was taken on it. Adding landslide risk register with geospatial metamodel is a right decision, since NADMA wishes to develop those disaster risk register to assess the impact of disaster and use as decision-making platform. Meanwhile, MGeoMR have an issues of specific metamodel framework used during the development of metamodel application not clearly stated in the study. Commonly, MOF framework was used in the development of DMM due to flexible exchange between real world and conceptual model. Hence, it's possibly MGeoMR was develop using the same framework.

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