Recommended Factors for Triage Categories using Simulation Modelling

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Abstract— **Malaysia is in advancement towards the establishment of effective and efficient energy mix plan within its Nuclear Power Programme (NPP) resulting from current governance acceptance and support. Prior precautions have been inculcated in order to comprehend nuclear energy accountability in striving high income economic growth and energy security. This paper is attempting to prescribe nuclear safety recommendations encompassing radiation and nuclear (RN) event recovery phase within integrated disaster operations management (DOM) activities from Soft System Methodology (SSM) perspective by using Simulation Modelling. Possibly, this method is introduced in order to recommend triage categories for vulnerable population groups which are commonly at-risks during RN emergencies, incidents and disasters. Therefore, this paper will proposed some factors of triage categories which may affect these groups whereby representing an initial system map. It is concluded that prioritized suggestions given could possibly ascertain the characteristics of other interventions involved in order to achieve a sustainable and secure nuclear safety in the future.**

Keywords- vulnerable population groups, soft system methodology, simulation modelling

I. BACKGROUND

Malaysian government is improving its National Fuel Policy by establishing an effective and efficient energy mix plan which holds promise for a significant economic growth [1-3]. In addition, the NPP is placing a significant emphasis on the security issues associated with the sustainability and maintenance of the nuclear power industry [4]. This emphasis is necessary so that the nuclear power regulatory bodies can develop effective nuclear power management standards. Previous case study conducted among Malaysian radiation and nuclear (RN) emergency plan stakeholders identified that two major elements are affecting the success of the considered Nuclear Power Programme (NPP). They are focusing on the enhancement on safety legal and regulations framework, and also improvement of Malaysian safety culture. These elements can be best transformed by highlighting public community preparedness education and awareness programmes on RN events. Meanwhile, human resources development is also highly recommended in preventing any human error or failure [5]. Therefore, it could produce convincing public resilience enforcement especially in dealing public compensation due to loss and major RN event hindrances [6-11].

II. KEY OBJECTIVES

The purpose of pursuing the issues mentioned is related to chaos prevention and enhancing casualties' chance of survival which are resulting from the hospital short-term failures. Fawcett and Oliveira indicated that this scenario is slightly more severe than the delayed failures on the overall death rows compared to low impact pre-hospital care [12]. Therefore these two main purposes are preliminary in preventing severe hospital short-term delayed failures. These will lead to the key objectives of this paper as the following:

1. To recommend factors of triage categories those influence the RN disaster recovery framework for vulnerable groups.
2. To analyze required factors and represent it using system map.

III. RESEARCH METHODS

Several studies indicated that NPP safety system is relatively a combination of integrative system components of safety analysis. NPP arrangements required demanding infrastructure of legal, regulatory and safety framework. Desperately, Malaysians are also concerned on the demanding safety issues regarding on this programme [4, 6, 13, 14]. These circumstances are creating interdisciplinary approach as socio-technical system which is dynamically affected one another in a timely fashion. Therefore, *Soft System Methodology* (SSM) is assigned to be used as a lens and research tool to determine conceptual modelling of this research [5, 15, 16]. According to prior studies mentioned, *simulation modelling* is appropriate to demonstrate required recommendations of this research in emphasizing the on-the-scene triage screening which based on the absorbed dose range, and also determining capacity planning in the emergency and healthcare system during RN disaster recovery phase.

A. Soft System Methodology (SSM)

Checkland defines *systems thinking* as a paradigm of holistic thinking involving problems of many disciplines that could be expressed and solved such as the RN disaster recovery phase framework. By using a particular set of ideas and system ideas, systems thinking is to promote understanding of the outside world's complexity interconnecting elements as a whole by showing properties of its components. In doing so, means of the concept of the system can be expressed. More likely, hard system thinking seeks social entities as organizations to achieve goals and information systems in supporting decision-making. Besides that, previously SSM seeks social entities as organizations to achieve goals by focusing the extension of organizational behaviour and management rather than computer science [Davis 1985 cited in 17] however it is slowly evolved by providing information to support the organizational operations, management and decision-making functions. This framework is mainly focusing to address ill-structured and poorly defined problem situations, which possessed other aspects other than technical functionality. Figure 1 is proposing the identified *system dynamics (SD) simulation* approach according to the adapted *LUMAS model* (part of SSM) as cited [15, 16]. SSM is derived from systems thinking paradigm, which was introduced by Checkland (1981, 2000) [18, 19].

Aspects involved in this framework are major human factor elements in nuclear safety that had been recognized and representing human performance, management and organization, and also the regulatory environment. Human performance investigations will consist on the causal model of human error within an unplanned situation. Management and organization elements will be inquired more on the organizational design and culture reliability. Lastly, the regulatory environment will be analyzed according to the development and tracking of key performance indicators. Next, action is taken to identify the interactions between these elements through socio-technical system justification. The result from these investigations will be visualized using simulation and transform it into proposed future Malaysian RN emergency plan framework. Consequently, LUMAS model (see Figure 1) which is emphasized from SSM as the research adaptation on the Malaysian RN emergency plan by acknowledging system dynamics as main research design and analysis methodology recognized from significant literatures as follows-through some recognitions and considerations highlighted by the recognized stakeholders [16, 20].

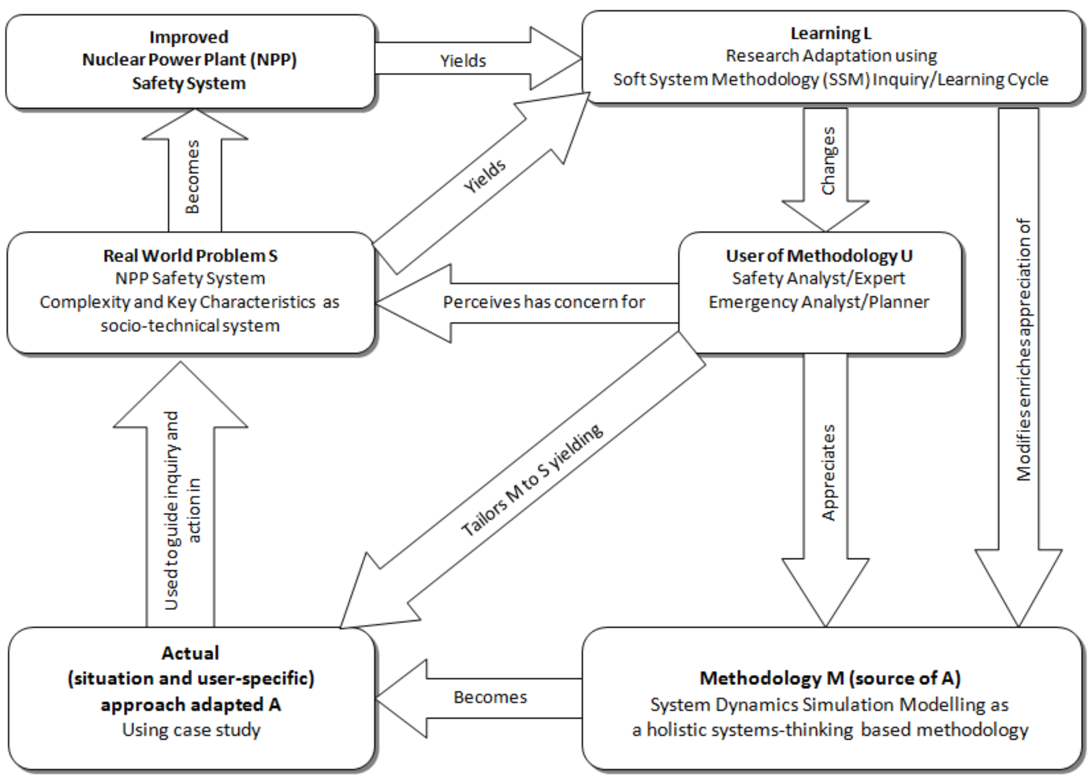

Figure 1. Research Adaptation using the LUMAS Model [19]

B. Simulation Modelling

A simulation is the imitation of the operation of a real world process or system over time. Whether done by hand or on a computer, simulation involves the generation of an artificial history of a system and the observation of that artificial history to draw inferences concerning the operating characteristics of the real system [21].

General definition of simulation emphasized in this research as an imitation of a system as it progresses through time which involved human activity systems that are consciously or unconsciously ordered [18, 22]. In this case, it is preferred as an operating system which configures combined resources parts for the provision or service purpose prevalent for Malaysian RN emergency first responder and regulator, technical support organisation and also, medical emergency services provider. Thus, the variations of this simulation are unpredictable even though it is interconnected as a whole entity [22-24]. Robinson suggested that simulation should be seen as a form of decision support system, that it is supporting decision-making rather than making decisions on behalf of the user. It should be noted, however, that most modern simulation software provide facilities for automating the experimentation process with the aim of finding an optimum scenario [22]. In spite of previous studies recommending SD simulation to further expressing the scenario of this research however several attempts of experimentations indicating that a combination of simulation approaches is pre-occupied.

This paper is proposing that a mixture of SD and *discrete event (DES) simulation* manifesting the key objectives of this research. This proposal is analyzed further in the next section.

IV. Research Analysis and Findings

Main contributions of this research are applied in the nature and scale of the RN event and its interactions with the healthcare infrastructure. Hence, it also is providing some relative feedbacks resulting to the population and other infrastructure sectors. This system map is expressed significantly by delivering an integration of SD and DES simulation (see Figure 2). Furthermore, Figure 3 is attentively displaying the research system boundary as a whole. Initially, proposing five sectors which are interrelated within the dotted line depicted. This finding is improvising from Rosyton *et al.* and Hirsch studies [25, 26].

This research scope is emphasizing two phases of large-scale RN event. Firstly, RN casualties absorbed dose range screening according to the triage categories which resides in the on-the-scene triage. Second, RN event casualties' hospital treatment among vulnerable population groups such as children, pregnant women and elderly in the emergency and healthcare infrastructure. The triage categories of absorbed dose range are producing significant symptomatologies and acute radiation syndromes (ARS) among the victims which range into mild (<0.75 Gray-2 Gray), moderate (2-3 Gray), severe (4-6 Gray) and very severe (6-10 Gray).

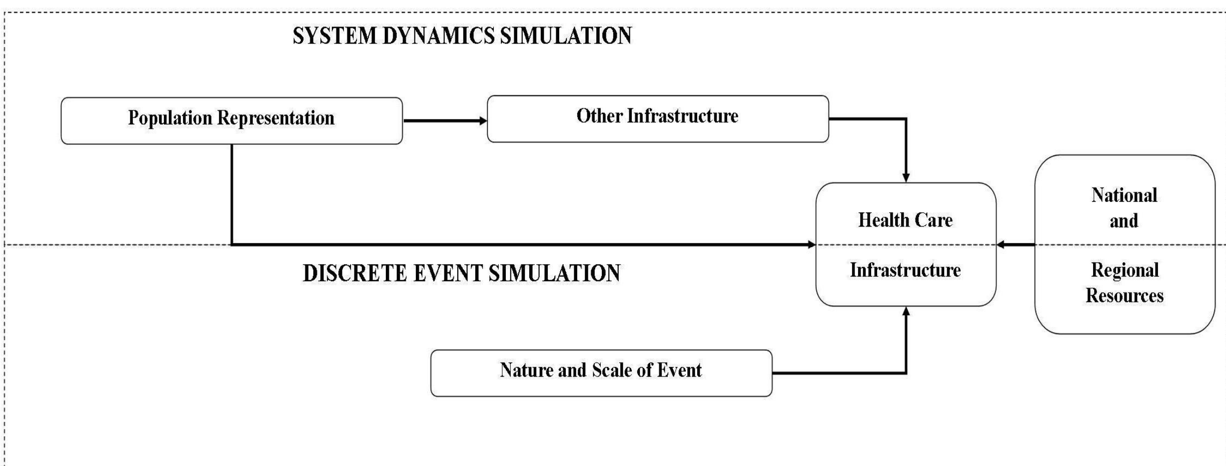

Figure 2. Proposed Integration of SD and DES Simulation System Map

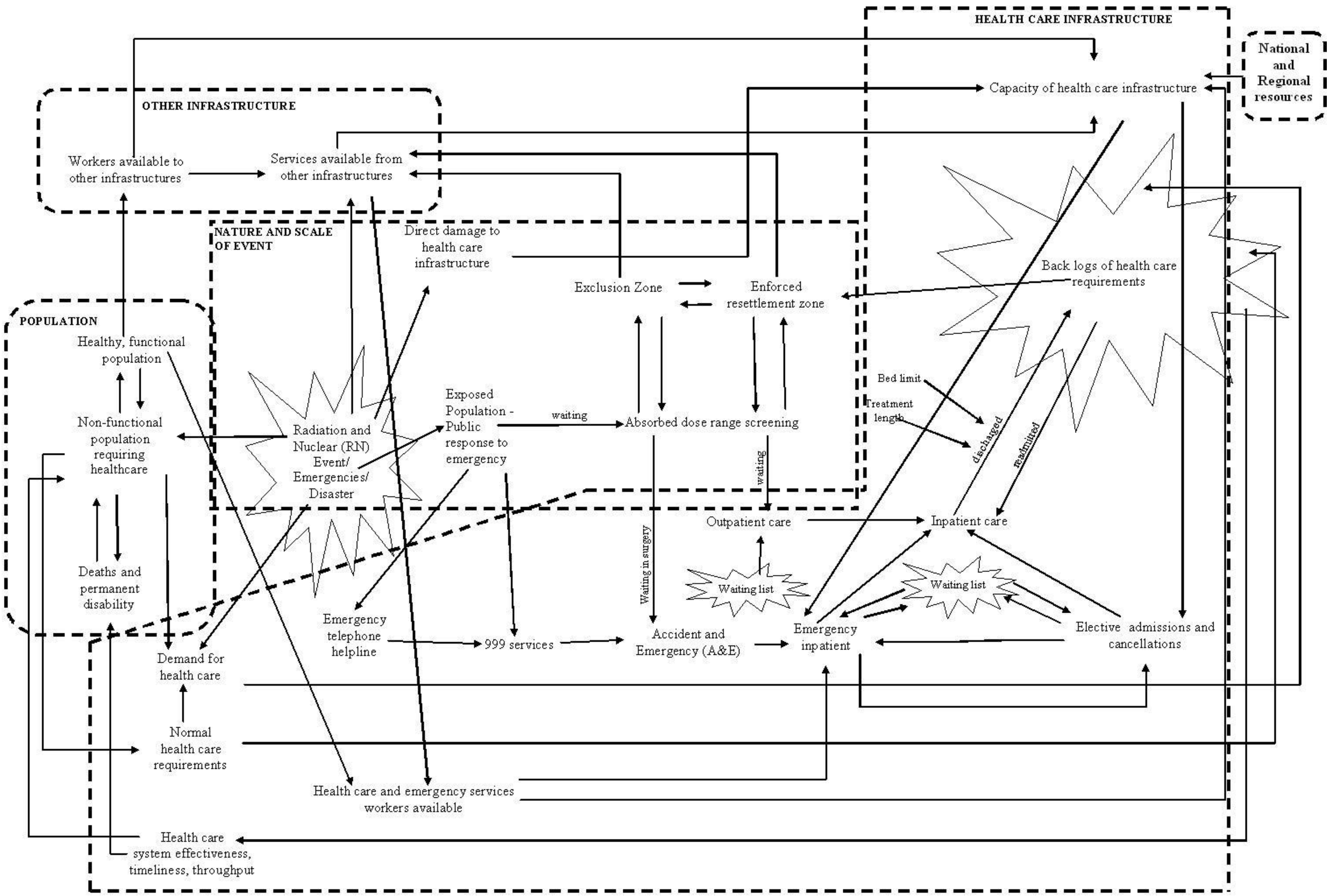

Figure 3. Overview of Radiation and Nuclear Event in Emergency and Health Care System Map [Improvised from 25, 26]

In general, SD simulation is expressing the specification or measurement of the system behaviour in order to understand the dynamics of the system within RN event circumstances, whereby the computerized simulation system will response to the specified relation among the elements by illustrating the particular process estimated [24, 27, 28]. For instance, likewise, systems approach in a NPP implies risk estimation that implicates the plant's design and operations. Therefore, any changes in operating and maintenance practices and other functions will also propose changes in its regulation, management, and operations [4, 6]. The components of the system map are depicted in feedback loop diagram. It is a feedback reinforcement mechanisms according to system behaviour as it structures the computerized simulation model by testing alternative policies and scenarios in a systematic way that answers all "how", "what -if" and "why". This approach depends on the complex understanding interrelationship among these unlikely elements within a system [24, 27]. According to Harrell [29], DES is defined as simulation perspective on system that can be emphasized as entities, activities, resources, and controls. Therefore, in order to establish the modelling objectives, several attempts must be pointed out which begins with the simulation system elements, component list, process or entity flow diagram, logic flow diagram, activity cycle diagram and initial research system map. These could produce the desired conceptual model of the research simulation modelling [21, 29]. These elements comprising the who, what where, when and how of entity processing.

As one of the key objectives of this paper is to produce the system map of its conceptual model which may leads to some combination of both SD and DES conceptual modelling. Most probably, SD conceptual modelling is based on the leading indicators of significant events in a form of 'system archetypes'. It depicted common structural and behavioural states in the dynamics of the system in modelling past events which is also known as feedback or causal loop diagram. This methodology is popularized in nuclear industry for analyzing risk, contingency planning, diagnosis of problems and tests of mitigation actions [30].

Meanwhile, DES conceptual modelling is dealing with mathematical/logical/verbal representation (mimic) of the system developed for the objectives of a research. The conceptual model which is running on a particular computer system to conduct such experimentations is also known as simulation model [31]. This methodology is widely used in healthcare application areas such as operating rooms (ORs), Intensive Care Units (ICUs) or Emergency Departments (EDs) [32].

Consequently, Brailsford further investigated and agreed by Macal and Chan that nonetheless, agent-based (ABS) simulation is most appropriate to this research system boundary as it is hard to define even though it seems self-contained but it is interrelated with wider environment. Main focus is on the determining apparently different but certain aspects of the real-world system that resulting from approach adoption agreed [32-34].

Kasaie added that ABS model is also a powerful tool in describing structured epidemiological processes involving human behaviour and local interactions. ABS models computational capacity allows large-scale model development of epidemics which is flexible in displaying detailed and complex characteristics of a real system. It is commonly used to simulate epidemics and assess policy options through macro and micro levels of system behaviour representation and investigations [35].

Besides that, other advantages of ABS are using databases which are organized in microscopic level. Therefore micro-data can support micro-simulations. Last and most importantly, advancing and rapid development of large-scale micro-simulation modelling applications is thriving ABS itself [32, 34]. Possibly, a hybrid of SD and DES approaches which is known as ABS simulation and modelling is best expressing the conceptual model of this research. As a concluding remark, ABS is generally defined as interacting autonomous agents in simulation systems in order to identify, explain, generate and design emergent behaviours [33, 34].

V. Conclusion

In conclusion, future research directions regarding on research adaptation according to *ABS simulation modelling* given could possibly determine the characteristics of other interventions involved in order to achieve a sustainable and secure nuclear safety in the future. These will be further investigated and most probably, these findings are relying on the model analysis and validation to justify the most reliable interventions and its accuracy that need more attention in this study.

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