Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 210 (2022) 133–140

Procedia Computer Science

www.elsevier.com/locate/procedia

The 12th International Conference on Current and Future Trends of Information and Communication Technologies in Health care (ICTH 2022)
October 26-28, 2022, Leuven, Belgium

A Framework for Constructing Discrete Event Simulation Models for Emergency Medical Service Policy Analysis

Saeid Amouzad Mahdiraji[a,]*, Johan Holmgren[a], Ala'a Alshaban[a], Radu-Casian Mihailescu[a], Jesper Petersson[b,c], Jabir Al Fatah[a]

[a]*Department of Computer Science and Media Technology, Malmö University, Malmö 21119, Sweden*
[b]*Department of Healthcare Management, Region Skåne, Malmö 21428, Sweden*
[c]*Department of Neurology, Lund University, Lund 22242, Sweden*

Abstract

Constructing simulation models can be a complex and time-consuming task, in particular if the models are constructed from scratch or if a general-purpose simulation modeling tool is used. In this paper, we propose a model construction framework, which aims to simplify the process of constructing discrete event simulation models for emergency medical service (EMS) policy analysis. The main building blocks used in the framework are a set of general activities that can be used to represent different EMS care chains modeled as flowcharts. The framework allows to build models only by specifying input data, including demographic and statistical data, and providing a care chain of activities and decisions. In a case study, we evaluated the framework by using it to construct a model for the simulation of the EMS activities related to acute stroke. Our evaluation shows that the predefined activities included in the framework are sufficient to build a simulation model for the rather complex case of acute stroke.

Keywords: Model construction framework, Care chain, Simulation model, EMS.

* Corresponding author. Tel.: +46-40-6657110.
E-mail address: saeid.amouzad-mahdiraji@mau.se

1877-0509
10.1016/j.procs.2022.10.129

1. Introduction

The use of simulation models has become increasingly common for analyzing healthcare systems [1], particularly for the analysis of emergency medical services (EMS) systems, which are emergency services responsible for prehospital stabilization, treatment, and transport of severely injured and sick patients. Simulation models in the healthcare domain are applied to, for example, staff scheduling, allocation of human resources, patient flow management inside emergency rooms, hospital bed utilization, and prehospital healthcare service management [2]. Simulation models are often useful for analyzing complex systems, allowing to evaluate the performance of a system under different configurations and to assess decision policies before being implemented. Discrete event simulation (DES) is a simulation modeling paradigm frequently used to analyze dynamic and complex systems in different areas, such as healthcare. It models the behavior of a system as a sequence of discrete events that occurs over time, where each event takes place at a specific time. The key feature of the DES paradigm is that it only models the points of time where events occur, which can be contrasted to the fixed-increment time simulation approach, where each time step is explicitly simulated.

A policy is typically referred to as a series of activities in the form of guidelines that aims to assist decision-makers in making decisions on a specific problem. Policy assessment in healthcare contributes to identifying the policies that have the potential to help achieving the intended goals and allow the decision-makers to improve the design and implementation of current healthcare policies, leading to an enhanced level of the patients' health and healthcare services. For example, the expected time to treatment is a key factor in certain medical conditions, such as stroke. One of the major objectives of using simulation is to assess healthcare policies that aim to reduce the expected time to treatment for the patients.

A modeling framework typically provides a general structure for modeling a real system and reusable components that can be used and combined in a way that is specified by the user. Modeling frameworks usually provide some types of graphical user interface for constructing models, for example, in the form of an activity diagram. In a framework, a set of activity types are typically integrated to enable activity chains to be modeled as flowcharts or activity diagrams. Activity diagrams or workflow diagrams are behavioral diagrams that represent the workflow of activities from a start point to an endpoint, typically with the support of decisions. Modeling frameworks have been applied in several problem domains, for example, in the transport domain [3-6] and the healthcare domain [7, 8]. As an example of using a model construction framework in the healthcare domain, Nasir and Kuo [7] contribute a decision support framework to analyze home healthcare (HHC) service delivery decisions of the aging society, allowing to create simultaneous schedules and route plans for both HHC staff and home delivery vehicles. Traoré et al. [8] present a framework for multi-perspective modeling and holistic simulation of healthcare systems. The included perspectives are resource allocation, health diffusion, population dynamics, and individual behavior. Traoré et al. also propose an integrative approach for the interactions between the models of different perspectives and a stratification of the levels of abstraction into multiple perspectives. To the best of our knowledge, no prior study explicitly contributes a modeling framework for the analysis of EMS policies with the focus on prehospital healthcare.

In this paper, we contribute a modeling framework that can be used to build simulation models for EMS policy analysis for different diagnoses. In the rest of the paper, we refer to it as the *model construction framework*. The model construction framework aims to simplify the generation of specific EMS simulation models, by providing an intuitive image of the model to the user, and by providing reusable components that can be used to construct different models. In particular, the framework includes a series of building blocks, which are used to construct care chains modeled as flowcharts. Since decision policies and behaviors of entities are also included in the framework, the framework reduces the need to write code when constructing a new model. To enable the construction of advanced simulation models, we made use of a complex scenario, that is, acute stroke, to identify the components to include in the framework.

The rest of the paper is organized as follows. In Section 2, we describe the proposed model construction framework for constructing EMS simulation models, followed by the scenario study in Section 3, where we applied the proposed framework to build a simulation model for the stroke care chain. Eventually, we conclude the paper in Section 4.

2. The model construction framework

In this section, we present our model construction framework, which can be used to construct EMS simulation models for different medical conditions. The framework is a micro-level approach, meaning that it can be used to build models where each patient is simulated individually.

In general, it is complicated to build one simulation model that captures all aspects of the EMS domain, and a model therefore typically needs to be created for the purpose of analyzing only one or a few aspects; for example, the analysis of patient admission process policies [9], dynamic ambulance dispatching policies [10], stroke-related policies [11, 12], or prediction of medical workforce supply [13]. However, different EMS models share many aspects; hence, it is often a good idea to build models using a reusable framework rather than building them from scratch. The framework enables to create a model only by specifying the care chain and providing input data. Hence, the framework simplifies the generation of specific models and reduces the complexity of the model construction activities.

A schematic overview of our model construction framework is presented in Fig. 1. The framework is an integrated approach, in the sense that it contains both a model construction phase and a model execution phase. The user provides different types of input, which are used to configure the framework and to provide the necessary specifications for the modeled entities. In other words, the model construction framework utilizes input, such as statistical data, demographic data, and a care chain specification, including activities and decisions, to build EMS simulation models, which are then automatically run using the input data. Examples of output generated by the framework are the times to diagnosis and treatment for each patient, and the total service time of the ambulances.

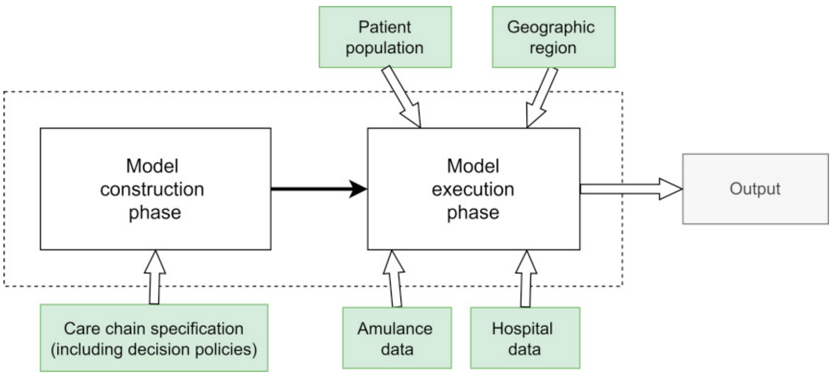

Fig. 1. Overview of the proposed model construction framework, which is an integrated approach where the user provides input data that is used to 1) construct the model and 2) run the model.

We studied typical EMS care chains to include the most common activities in our framework. The identified activities include, for example, *choose destination hospital*, *transport patient*, and *diagnose patient,* and each model activity is connected to one of the modeled actors, that is, *emergency call center*, *ambulance*, and *hospital*. See Table 1 for a complete list of the general activities provided by the framework. Using the provided activities, we argue that the framework can be used to construct most chains of main activities and decisions from when the emergency call center receives an emergency call until the patient receives treatment.

We regard an activity as a key task that should be executed as part of completing a process. Each activity has its corresponding actor and input, functionality, and output. Each activity in a chain of activities typically also requires some specific prerequisites to be triggered, that is, the previous activity must be completed, and a possible condition for starting that activity might need to be fulfilled. There are two categories of activities: decision-making activities, for example, for the ambulance or hospital selection, and pure task activities, for example, *transport* and *diagnosis*.

The framework makes use of different types of input, that is, geographic region, patient population, ambulance data, hospital data, and a care chain specification. In the following, we describe each type of input in detail.

Geographic region: A model for the analysis of EMS care chains needs to explicitly model a geographic region, which is populated by hospitals, patients, and ambulances. The framework assumes that the geographic region is divided into smaller subregions, where each subregion is represented by its id and its centroid coordinates (longitude,

Table 1. List of general care chain activities that are included in the framework.

Activity	Actor	Description
Emergency call	Emergency call center	The emergency call center receives a call concerning an emergency incident.
Preassessment	Emergency call center	The emergency call center performs preassessment over the phone. Based on the description of the patient symptoms, an ambulance priority and a set of possible diagnoses are determined.
Select ambulance	Emergency call center	If an ambulance is required, the emergency call center decides which ambulance should be dispatched to provide service to a patient.
Transport	Ambulance	In general, an ambulance may travel using three different paths in the EMS care chain: - Travel from the ambulance current location to the patient scene. - Travel from the patient scene to a hospital. - Travel from a hospital to an ambulance site.
Patient scene assessment	Ambulance	The ambulance paramedics examine the patient at the patient scene, determine a set of possible diagnoses, or/and exclude some diagnoses.
Load patient	Ambulance	The patient is loaded into the ambulance.
Choose destination hospital	Ambulance	Based on the patient symptoms, the paramedics' diagnosis, and predefined policies, the paramedics choose to which hospital the patient should be transported.
Unload patient	Ambulance	The patient is unloaded from the ambulance.
Diagnosis	Hospital	The patient is examined at the hospital.
Treatment	Hospital/Ambulance	The treatment is initiated either in the hospital or in the ambulance.

latitude). It is also assumed that all inhabitants residing in a subregion are represented by its centroid, where the centroid is the core of all activities of the subregion it represents.

Patient population: The simulation is driven forward by patients appearing at different times and locations in a geographic region. The patient population can be real or synthetic, where each patient is specified using attributes such as age, sex, incident time (day and hour), location (coordinates), and symptoms.

Hospital and ambulance data: Hospital data includes hospital locations (coordinates). Ambulance data contains ambulance site locations (coordinates) and expected traveling times between 1) ambulance sites and patient locations, 2) patient locations and hospital locations, and 3) hospital locations and ambulance sites.

Care chain specification: The framework uses building blocks to construct care chains of EMS activities modeled as flowcharts. The building blocks are general reusable activities representing both decision-making and non-decision-making activities. The flowchart approach provides an intuitive way for the user to construct complex care chains, where the care chain flowchart used in our approach consists of boxes, arrows, an ellipse, and conditions, where two consecutive blocks are connected to each other using an arrow. As an example, in Fig. 2, we show the chain of EMS activities for a suspected stroke patient, where each block specifies an activity and its corresponding actor. An arrow represents the order of activities, and the ellipse represents a trigger to start the care chain, which in the considered scenario is the emergency call. A condition specifies a condition that must be met to go from one activity to another, here shown by a note connected to the arrow. For example, the note *Condition: patient.worst_case_diagnosis_code* between the *preassessment* and *select ambulance* activities in Fig. 2, implying that if an ambulance assignment is decided, the *select ambulance* activity will begin; otherwise, the care chain for the corresponding patient will be stopped when the *preassessment* activity is executed. At runtime, the framework constructs a specific simulation model, where the provided care chain specification is applied for each of the simulated patients.

We have also included parallel activities that typically occur in the EMS care chains, shown by the blue arrows in Fig. 2. For example, after unloading the patient from the ambulance (*unload patient* activity), the patient will be prepared for the diagnosis at the hospital, and the ambulance will simultaneously return back to its station.

The major decisions currently modeled in the framework, and which are included in the care chain example in Fig. 2 are 1) which ambulance should be dispatched towards the patient? and 2) to which hospital should the patient be transported? In a typical situation, the above decisions can be made by assigning the closest available ambulance for

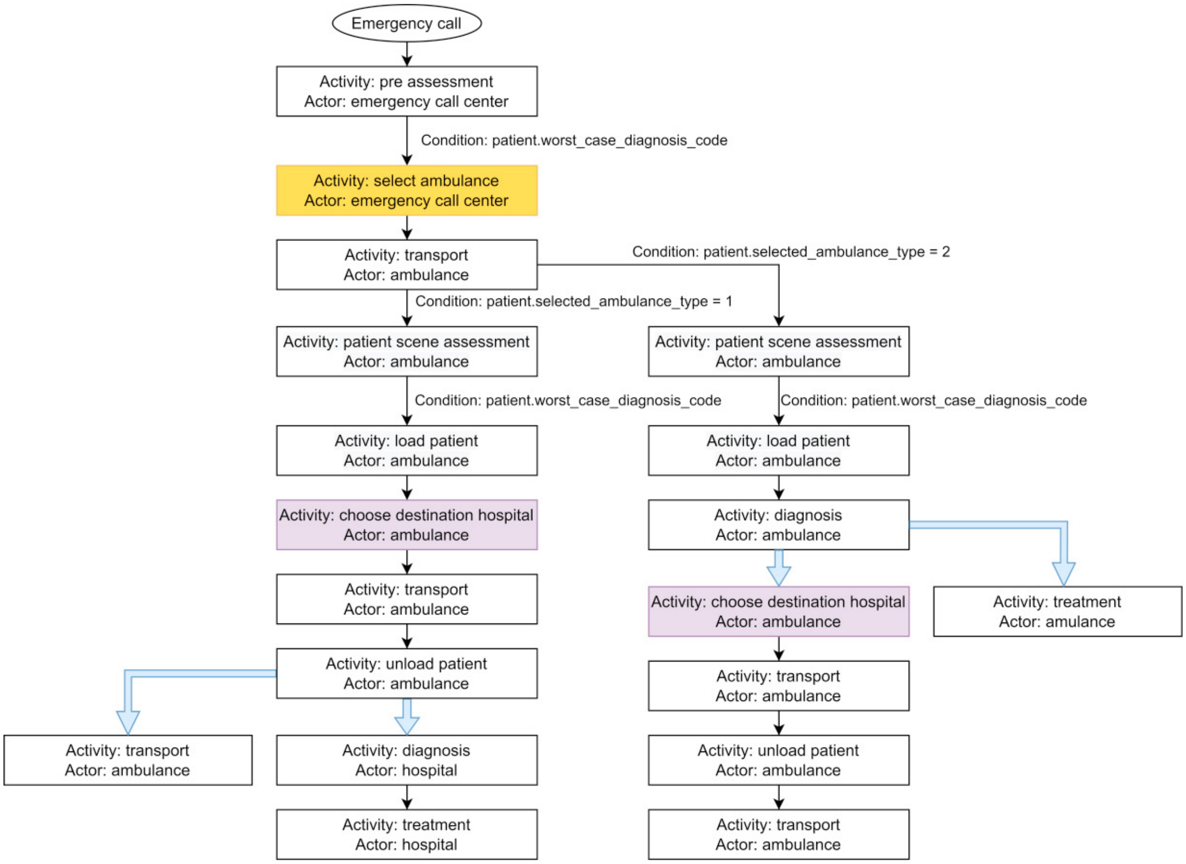

Fig. 2. Care chain of the EMS activities for a suspected stroke patient, where the colored boxes demonstrate the decision-making activities and the blue arrows represent the parallel activities.

the operation and transporting the patient to the nearest hospital from their current location. However, there may be exceptions, for example, when a special type of ambulance is required based on the preassessment over the telephone by the emergency call center. In such a case, a special ambulance needs to be dispatched instead. Or, after the patient scene assessment by paramedics, the patient needs to be transported to a hospital that can provide specific treatment. In this case, the patient will be directly driven to the special clinic. Based on the above reasoning, we included a set of different policies for selecting ambulance and hospital, which is discussed in more detail below.

The ambulance selection policies aim to choose an emergency vehicle (EV) and its type by minimizing 1) the expected time to patient, 2) the time to diagnosis, or 3) the time to treatment, represented using the following policies:

- **Time to patient policy:** An EV is chosen to minimize the expected time from symptoms onset until the EV arrives at the patient location.
- **Time to diagnosis policy:** An EV is chosen to minimize the expected time from when an incident happens until the diagnosis is initiated at the hospital or patient location.
- **Time to treatment policy:** An EV is chosen to minimize the expected time from when an incident happens until the patient receives treatment at the hospital or at the patient location.

There are typically different types of EVs available, which makes it reasonable to also include the type of EV in the ambulance selection decision. Each ambulance selection policy enables choosing the EV that can provide the fastest service for the patient. By conducting a set of simulation runs, it is then possible to compare different decision policies to observe from which policy the patient is expected to benefit most. It should be highlighted that the time to diagnosis and the time to treatment policies are made using assumptions based on the emergency call center preassessment.

To decide where to transport the patient (to which hospital), the following policies are included in the framework:

- **Closest hospital policy**: The patient is transported to the closest hospital from their location.
- **Direct to special clinic policy**: The patient is transported directly to the closest special clinic that can provide specific treatment based on the outcome of the patient scene assessment.

It should be emphasized that the abovementioned policies are the policies currently coded into our framework to choose an ambulance and hospital for a patient. If other policies are needed, they can be easily added to the framework.

As an example, in Fig. 2, the decision for selecting an EV and its type is made in the *select ambulance* activity colored by orange, using the predefined ambulance selection policy. The decision for choosing the destination hospital is made in the *choose destination hospital* activity, colored by purple, using the predefined hospital selection policy.

We established our framework on the principles of the DES paradigm, meaning that the framework, based on the specified entities, constructs a DES model for the analysis of the EMS care chain. Each activity in the care chain is represented using two events, that is, a start event and an end event, enabling to simulate activities that are non-instantaneous. Upcoming events are sorted in a queue based on the time of occurrence, meaning that the next event is always the first event in the queue. Once an event occurs, the simulation clock is moved forward to the time of that event, where it represents either the start or the end of an activity. As shown in Fig. 2, the care chain of activities for each patient is initiated by creating an *emergency call* activity. At the end of an activity, the start event for the next activity is typically created and added to the event queue. For example, when the *emergency call* activity is handled, the model creates the start event for the *preassessment* activity and adds the new event in the right place in the queue. When an event has been processed, it is removed from the queue. The simulation will terminate once the event queue is empty or when the simulation end-time has been reached.

3. Scenario study

We evaluated our framework by constructing a model for the simulation of EMS care chain activities for stroke patients. In this section, we initially provide a brief introduction to stroke, and we then present the application of our framework to construct a simulation model for the stroke care chain.

Stroke is one of the deadliest diseases and a major cause of disability around the world. Thrombolysis is the standard treatment for ischemic stroke, which is the most common type of stroke. It is generally agreed that the time to treatment is the most crucial factor for the possibility of stroke patients to recover. However, logistical issues typically make it difficult to provide treatment fast enough, as stroke patients traditionally need to be transported to an acute hospital for diagnosis and treatment However, it has been shown that it is possible to reduce the time to treatment for stroke patients by utilizing so-called Mobile Stroke Units (MSUs), which are special ambulances equipped with a CT scanner, allowing to both diagnose stroke patients and provide thrombolysis inside the MSU [14]. As mentioned earlier, the use of simulation can help us choose decision policies that lead to reduced expected time to treatment for stroke patients. For the case of MSUs, an important decision policy concerns where to locate the MSUs to provide the best possible service for the inhabitants in a geographic region.

We chose acute stroke for our scenario study since we consider the stroke care chain to be rather complex in comparison to the EMS care chain for many other diagnoses. An important reason for this is that the use of MSUs introduces multiple decisions that should be taken as there might be different types of EVs available to provide service to the patient. Furthermore, decisions often need to be taken based on incomplete information, for example, since the patient cannot be diagnosed until after conducting a CT scan on the brain of the patient, it is challenging to decide where to transport the stroke patient, that is, the closest hospital or special clinic.

In our scenario study, we used both regular ambulances and MSUs in the EMS care chain for stroke patients in need of thrombolysis. The considered care chain, which is illustrated in Fig. 2, is triggered when the emergency call center receives a call concerning an emergency incident, and the subsequent activities will be activated during the simulation. Each activity is triggered once the preceding activity is accomplished and in case the possible condition on the incoming arrow is met. Otherwise, the care chain terminates after the current activity. For example, the conditioned arrow with the note *Condition: patient.worst_case_diagnosis_code* between the *patient scene assessment* and *load patient* activities indicates that the paramedics determine whether the patient should be transported to the hospital for treatment based on the worst-case code given based on the patient symptoms. If it is decided to transport the patient, the patient is loaded into the ambulance (*load patient* activity), and the following care chain activities will be executed. Otherwise, the care chain for the corresponding patient will be stopped after the *scene assessment* activity has been executed. Then, the patient is left at their current location, and the ambulance returns back to its station.

When an MSU is dispatched for a potential stroke case, the diagnosis and treatment (thrombolysis) can be performed at the patient scene. In this case, the time to diagnosis/treatment is the expected time from when a stroke happens until the patient receives diagnosis/treatment inside the MSU. However, when a regular ambulance is dispatched, the patient should be transported to a hospital for diagnosis and treatment. After unloading the patient at the hospital, the EV returns to its station, and once it arrives there, it becomes available for the next operation.

In the stroke care chain, there are two situations when activities happen in parallel, represented by the blue arrows in Fig. 2. When a regular ambulance is assigned for an operation, there is one pair of parallel activities, which is described in Section 2. There is also a pair of parallel activities when an MSU is assigned for an operation, see the blue arrows in the right side of Fig. 2, showing that after performing the diagnosis inside the MSU, the treatment is initiated at the same time as the paramedics choose the destination hospital, followed by the MSU starting to drive towards the hospital.

In our scenario study, we constructed a model for the EMS care chain of stroke patients in Sweden's Sothern Healthcare Region (SHR) and conducted a set of simulation runs using the constructed model. In the simulation runs, we considered all of the decision policies described in Section 2. The constructed simulation model takes as input geographic region data, patient population, and hospital and ambulance data. We also provided data related to the acute hospitals and special clinics that can perform thrombectomy treatment. We used the same input data, MSU locations, and assumptions as we did in a previous study [11]. The geographic region is the SHR, where all patients, ambulance sites, and hospitals are located, and the geographic region is divided into 1×1 km squares. The stroke patient data is a synthetic population of patients distributed over the SHR, and it was generated using a Poisson distribution (see Amouzad Mahdiraji et al. [11] for details). We assumed that all modeled patients are suspected stroke patients, which need to be transported to a hospital. The scenario study included three different scenarios: a baseline scenario (including only regular ambulances) and two MSU scenarios (MSU1 and MSU2), each including three MSUs. It was assumed that the MSUs in MSU1 are located in Hörby, Markaryd, and Tingsryd, and the MSUs in MSU2 are located in Lessebo, Hyltebruk, and Kristianstad (see Amouzad Mahdiraji et al. [15] for details).

In Table 2, we present the simulation results for the constructed model, in the form of expected times to treatment (in hours), for each scenario and each of the ambulance and hospital selection decision policies described in Section 2. As expected, the simulation results show that the use of MSUs, compared to the baseline scenario, enables to provide better service for stroke patients in the SHR by reducing the expected time to treatment for both of the considered MSU allocations. In particular, when the decision for the choice of an EV is made using each of the *time to diagnosis* and *time to treatment* policies. The improvement is more considerable when the hospital selection policy is *direct to special clinic*; especially, the expected time to treatment is expected to be reduced from 2.020h for the baseline scenario to 1.571h and 1.602h for the MSU1 and MSU2 scenarios, respectively, considering the *time to diagnosis* policy.

For the *closest hospital* policy, the share of patients who are expected to receive treatment within an hour is approximately doubled and tripled for the MSU1 and MSU2 scenarios, respectively. In addition, the share of the patients who are likely to receive a diagnosis within an hour is expected to increase from 3.65% for the baseline to 90.91% and 88.05% for MSU1 and MSU2, respectively. Considering our assumption that a regular ambulance drives

Table 2. Comparison of the average expected time to treatment (in hours) obtained from simulation model of stroke care chain for the whole SHR for each scenario and decision policy. The numbers within the curly brackets show the ambulance site IDs. See our prior paper [15] for details.

Scenario	MSU sites	Direct to special clinic			Closest hospital		
		Time to patient	Time to diagnosis	Time to treatment	Time to patient	Time to diagnosis	Time to treatment
Baseline	-	2.020 h	2.020 h	2.020 h	1.347 h	1.347 h	1.347 h
MSU1	{11, 27, 36}	2.017 h	1.571 h	1.584 h	1.346 h	1.279 h	1.274 h
MSU2	{15, 18, 24}	2.014 h	1.602 h	1.618 h	1.346 h	1.291 h	1.287 h

faster than an MSU, the results in Table 2 suggest that when the decision to select an EV depends on the *time to patient* policy, the use of a regular ambulance is a more effective choice. The results presented in Table 2 are similar to the results presented in our prior paper [11], where we employed a DES model to evaluate MSU-related policies in the stroke care chain, demonstrating that the constructed simulation model for the stroke care chain functions as intended.

4. Conclusions

In this article, we proposed a model construction framework that can be used to simplify the construction of EMS simulation models. The framework is based on the idea of modeling EMS care chains using standard flowcharts consisting of connected activities and decisions, and it includes a set of general activities that can be used to represent most EMS care chains. As the framework includes activities and policies modeled on a general level, the framework can construct models only by specifying input, such as geographic region, patient population, hospital data, ambulance data, and the care chain. We evaluated our framework by applying it to construct a simulation model for the analysis of EMS activities for the stroke care chain, which we argue is rather complex in comparison to the typical EMS care chain. The reason we argue that the stroke care chain is more complex is that including an MSU in the prehospital stroke care chain creates multiple decisions that need to be taken with incomplete information; for example, decisions related to EV selection, diagnosing the type of stroke, and hospital selection. After applying the required data to the generated simulation model for stroke patients, the simulation output analysis showed that the included activities in the framework were sufficient to build EMS simulation models, representing complex diagnoses such as stroke.

Acknowledgements

This work is partially financed by Sweden's Southern Regional Healthcare Committee and The Kamprad Family Foundation for Entrepreneurship, Research & Charity.

References

[1] Davahli, M.R., Karwowski, W., Taiar, R.: A system dynamics simulation applied to healthcare: A systematic review. International Journal of Environmental Research and Public Health 17 (16), 5741 (2020).
[2] Almagooshi, S.: Simulation modelling in healthcare: Challenges and trends. Procedia Manufacturing 3, 301-307 (2015).
[3] Deng, Q.: A general simulation framework for modeling and analysis of heavy-duty vehicle platooning. IEEE Transactions on Intelligent Transportation Systems 17 (11), 3252-3262 (2016).
[4] Holmgren, J., Davidsson, P., Persson, J.A., Ramstedt, L.: TAPAS: A multi-agent-based model for simulation of transport chains. Simulation Modelling Practice and Theory 23, 1-18 (2012).
[5] López-Neri, E., Ramírez-Treviño, A., López-Mellado, E.: A modeling framework for urban traffic systems microscopic simulation. Simulation Modelling Practice and Theory 18 (8), 1145-1161 (2010).
[6] Abdelghany, K.F., Mahmassani, H.S., Abdelghany, A.F.: A modeling framework for bus rapid transit operations evaluation and service planning. Transportation Planning and Technology 30 (6), 571-591 (2007).
[7] Nasir, J.A., Kuo, Y.H.: A decision support framework for home health care transportation with simultaneous multi-vehicle routing and staff scheduling synchronization. Decision Support Systems 138, 113361 (2020).
[8] Traoré, M.K., Zacharewicz, G., Duboz, R., Zeigler, B.: Modeling and simulation framework for value-based healthcare systems. Simulation 95 (6), 481-497 (2019).
[9] Kang, H., Nembhard, H. B., Rafferty, C., DeFlitch, C. J.: Patient flow in the emergency department: a classification and analysis of admission process policies. Annals of emergency medicine 64 (4), 335-342 (2014).
[10] Jagtenberg, C. J., Bhulai, S., van der Mei, R. D.: Dynamic ambulance dispatching: is the closest-idle policy always optimal?. Health care management science 20 (4), 517-531 (2017).
[11] Amouzad Mahdiraji, S., Holmgren, J., Mihailescu, R.C., Petersson, J.: A Micro-Level Simulation Model for Analyzing the Use of MSUs in Southern Sweden. Procedia Computer Science 198, 132-139 (2022).
[12] Al Fatah, J., Alshaban, A.A., Holmgren, J., Petersson, J.: An agent-based simulation model for assessment of prehospital triage policies concerning destination of stroke patients. Procedia Computer Science 141, 405-412 (2018).
[13] Lopes, M. A., Almeida, Á. S., Almada-Lobo, B.: Forecasting the medical workforce: a stochastic agent-based simulation approach. Health care management science 21 (1), 52-75 (2018).
[14] Ebinger, M., Winter, B., Wendt, M., Weber, J. E., Waldschmidt, C., Rozanski, M., Kunz, A., Koch, P., Kellner, P. A., Gierhake, D., Villringer, K., Fiebach, J. B., Grittner, U., Hartmann, A., Mackert, B.-M., Endres, M., Audebert, H. J.: Effect of the use of ambulance-based thrombolysis on time to thrombolysis in acute ischemic stroke: a randomized clinical trial. Jama 311 (16), 1622-1631 (2014).
[15] Amouzad Mahdiraji, S., Dahllöf, O., Hofwimmer, F., Holmgren, J., Mihailescu, R. C., Petersson, J.: Mobile stroke units for acute stroke care in the south of Sweden. Cogent Engineering 8 (1), (2021).