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AMS: A NEW PLATFORM FOR SYSTEM DESIGN AND SIMULATION

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Abstract
A new platform for event-based simulation is presented in this work based on a new proposed programming language. The platform supports modelling of any system as stages. The resources reside in what the language calls pools. The language supports topology description of the system as connections between stages and pools. It provides flexibility to choose the needed distribution for every stage, the type of data passed from a stage to another and the output statistics at the end of execution. One of the capabilities of this new platform is to optimize resources needed in the system through multiple simulation iterations. Optimization is based on a previously proposed reward system that balances between three satisfaction factors: patient, owner and resource. Accordingly, new resource allocations are suggested for system enhancement. The compiler of the language takes an English-like text and converts it into a Petri net. A case study is presented to improve the main performance measures of an emergency department located in Lebanon: patient length of stay, utilization rates and queues waiting times.
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Key Words: Optimization, Petri Nets, Programming Language, Satisfaction Factors, Simulation

1. INTRODUCTION

1.1 General

In any business, decision making is approached in order to settle or improve a system. Very often, decision making is restricted and face some limitations related to shortage in resources. Therefore, decision makers struggle to meet the requirements and expectations of the management based on specific goals. To develop managerial decisions, decision modelling is approached. This section is dedicated to highlight the previous work done by the authors which will be integrated into a platform newly developed for hospital management, named AMS.

The focus of this study is the Emergency Department (ED) of a healthcare system since it is referred to be the most critical and complex unit [1]. An ED is a 24/7 service where patients arrive without any prior notice and it covers all type of illness and patients categories. These challenges faced by the ED open the eye on the importance of studying and enhancing such systems [2-5]. As a result of these challenges, staff utilization rates and patient waiting times increase leading to unnecessary costs. In a previous work, an ED located in North Lebanon is studied and simulated using Arena in order to improve the system and enhance patient flow [6]. The main purpose is to prepare the ED and predict bottlenecks ahead of time by suggesting the optimal resource allocation and thus avoiding overcrowding. A study by Dragic and Sorak proposes the need for an efficient tool that allows managers and decision makers to consider the effects of their decisions on the success of small and medium enterprises [7].

Moreover, a new extended type of Petri net was proposed in previous work, called RPN (Resource Preservation Net), aiming to study and formulate the daily flow of patients through the ED [8]. This RPN can be applied to any type of organization where resources are none-consumable, and siphons are controlled. RPN is proved to remain sound for cooperative and non-cooperative units. A framework is developed by Simon et al. where the suitability of DES software for Petri net modelling is investigated [9]. Critical resources and throughput improvement are also discussed by Zupancic et al. [10]. A study conducted by Wang and Chen applies time Petri net modelling and Flexsim simulation to study an industrial system, identify bottleneck problems, and propose optimization methods to improve processes, reduce waste, improve efficiency [11]. A model is proposed by Nie et al. using Petri net theories [12]. In their study, the production plan during deadlocks and bottlenecks is evaluated and corrected using simulation and Petri net. Sena et al. also counted on simulation in order to predict alternative allocations of additional human resources [13].

The main challenges facing the studied ED are the resource shortage, the existence of heterogeneous types of insurance categories and the absence of technology. These factors may result in overcrowding, affecting patient's safety and a loss of potential revenue. Therefore, a comprehensive understanding of the system is needed in order to study potential enhancements. Real data is collected and analysed through conducting interviews with staff and patients. Due to the complex nature of the ED in general, the presence of several acuity levels of patients and the numerous ED processes in particular, simulation modelling is used to build a model that mimics the real system. The designed model is simulated and studied using the new programming platform AMS. Improving the flow of patients in the ED is a must to gain patient satisfaction. Thus, optimization is a must where three satisfaction factors are taken into consideration: patient, employee and owner. The optimization model is called a Reward System (RS) where the three factors are studied, and an optimization algorithm is presented in order to maintain the satisfaction of all parties; always taking into consideration the balance between patient waiting times, cost/revenue and medical resource workloads. The optimization algorithm is called MRA [14]. Lee et al. studied also the flow of an emergency department through simulation where the problem of finding the optimal number of medical staff is considered [15]. A literature review on ED simulations and applications for both normal and disaster cases is presented by Gul and Guneri [16].

To sum up, all the mentioned generic algorithms and models performed by the authors in previous work are the backbone of a platform prototype which is presented in this work based on a new programming language. This platform allows the user to easily describe the system to be studied using English-like statements and then perform simulation in order to study the flow of operations, spot bottlenecks and apply optimization if required.

1.2 Platform objectives

In this paper, a new platform is proposed for healthcare management. The software is a user-friendly interface where any researcher or decision maker can easily learn how to deal with it through its special way of data entry. The software defines a new programming language code that is based on some keywords and statements to describe the industrial system under study. Section 1.1 is dedicated to recall all the work done previously in order to highlight the main contributions integrated in this software. The objective of this platform is to improve the daily operations of a healthcare system, mainly the emergency department of a hospital or any other unit. The stages followed by patients in order to receive the required care are described in the input file and all data such as distribution types, resources categories, resource capacity in the model, salaries, etc. are loaded and fed through the input file. Same, the number of resource under different categories are specified.

As a start, a new programming language is defined to facilitate the way users enter the input data as mentioned before. Once data is fed into the platform, a user interface helps the user to choose what to perform on this data. The user can compile, build, simulate a project or choose to draw the graph corresponding to the system specified. It is a user-friendly platform where the user can easily integrate the stages of the system under study along with the pool of resources as statements written in English. Here, keywords are necessary to be available in the input statements which will be described in detail in the next section. Another feature of this platform is the simulation paradigm. The language core is integrated with a Petri net simulator where all stages cooperate and run concurrently to serve the patient. The simulator validates the model topology fed through the language code by making sure that the system is sound, all connections are valid, and siphons are controlled. The platform supports decision making, priority and concurrency. Stages followed by patients are mapped into transitions in the Petri net engine and the resource pools as well as the input and output pools are mapped into Petri net pools. The input pool represents the arrival patients and the output pool represents patients exiting the system.

The software developed is called AMS. As a result of simulation, statistics such as resource utilization rates, waiting times and total length of stay can be displayed along with identifying bottlenecks. Finally, a very efficient and important advantage of the platform is providing optimization where the optimal resource allocation can be predicted for normal flow or during catastrophic events. The optimization integrated with this platform offers the hospital an opportunity to better serve their patients taking always into consideration patient, employee and owner satisfaction. Recall here, that patient satisfaction reflects decreasing patient length of stay (*LoS*), employee satisfaction reflects decreasing staff workload and owner satisfaction reflects increasing revenue and decreasing potential wastes. The main objectives and advantages of this software are depicted in Table I.

Table I: Platform objectives.

Metrics	**Advantages**
Input Data	New language code based on English statements and keywords
Interface	User-friendly
Simulation	Simulation period can be defined Soundness and critical sections-free are ensured Study the system performance Spot the bottleneck Many experiments can be conducted
Statistics and Outputs	Performance measures: *LoS*, Utilization rates, Service times Identifying bottlenecks
Optimization	Supports the MRA algorithm Calculates satisfaction factors and reward system Suggests optimal allocation of resources

This study is organized as follows: an introduction is presented in Section 1. In Section 2, the new language code, software interface and optimization features are described in detail. Section 3 represents the simulation of the studied ED using the newly proposed platform, where statistics and performance measures are resulted. The socio-economic benefits of AMS are presented in Section 4. Conclusion and future work are illustrated in Section 5.

2. THE NEW PLATFORM: AMS

This section is dedicated to present the new proposed platform defined for hospital's management and used to study the operational flow of a unit or more in the hospital along with calculating satisfaction factors and performing optimization. The optimization phase will suggest new resource allocations for better system performance always guaranteeing a balance between patient, employee and owner satisfaction. All the timings in the software are defined in minutes. A schematic view of AMS is presented in Fig. 1.

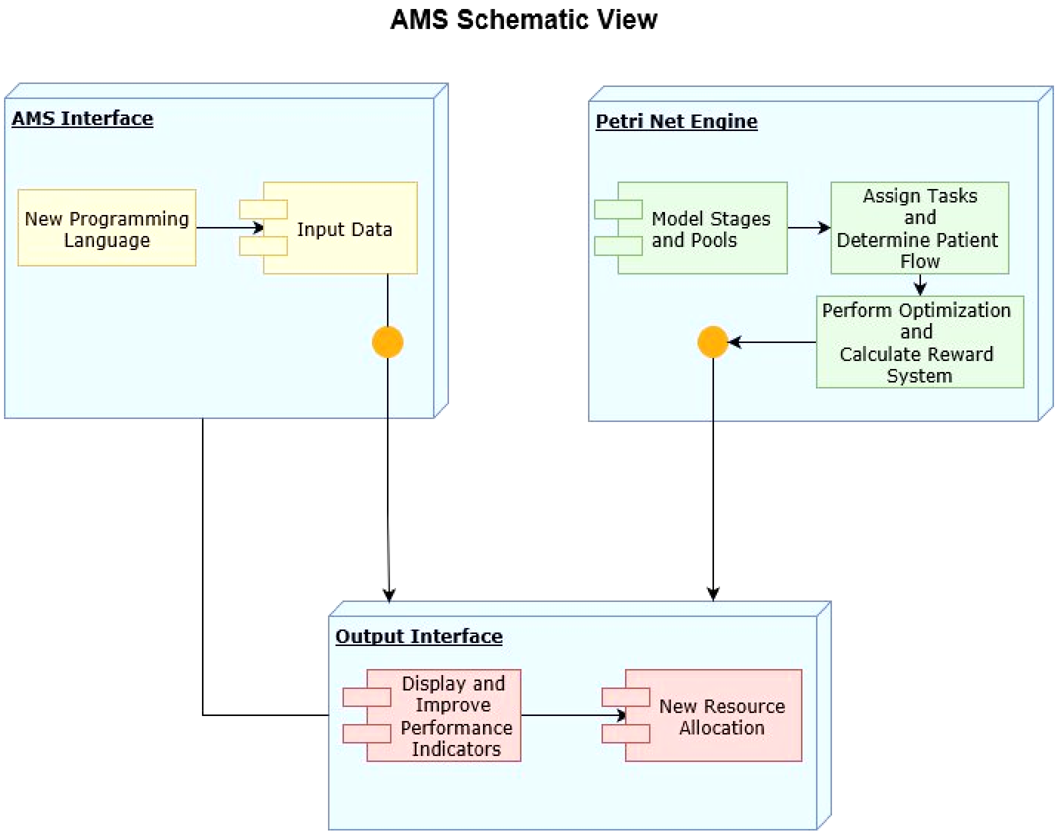

Figure 1: AMS schematic flowchart.

2.1 Language primitives

The language code is a program used to feed data into the software. This is a new user-friendly language code proposed for the first time. It is based on a set of keywords and statements where the user can easily use his English skills only to simulate any complex industrial system such as the emergency department of a healthcare system. The corresponding primitives are presented here to explain to the user how to input the data collected from site visits and hospital's databases to the platform interface. Some important keywords and operators should be illustrated. The operators defined are: = and +. The logic operators are: >, <, ≤, ≥, ≠, %. The % operator is used to add comments anywhere in the code. The keywords are presented in Table II. When the user writes the needed statements in the platform interface, the program searches for the keywords to identify the number of stages, number of pools along with all resource types referred to as tokens and connection types referred to as links. Moreover, the mode can be set to be during normal flow or catastrophic conditions, along with the simulation period of time to be defined as minutes, hours, or weeks. Having these details, the required system can be built and designed to start with simulation. Before simulation and displaying the results statistics, the system is verified and validated using the Petri net engine integrated with the platform. When the system is ready, and bottlenecks are defined, optimization can be applied to the model where new resource allocation can be predicted.

Table II: Language primitives.

Keywords	Description
STAGE	Represents each stage in the system such as Triage, Registration, etc.
POOL	Represents each pool of resources such as DoctorPool, NursePool, etc.
END	Represents the end of each STAGE or POOL
SET	Used to set the input and output pools as well as the satisfaction weights, the threshold during optimization and the mode
MARK	Represents the marking of each pool. The marking of pools is the number of resources available for each type
CONNECT	Used to specify the link between two different nodes
INPUT/OUTPUT	Represents the direction of each link
AS	Used to specify the direction as input or output
PASS	Used with connections to pass the type of token such patient, nurse, etc.
INTERVAL	Represents the time interval of each stage to be executed
FROM	Used with the interval to specify the time interval from and percentage from for each stage
TO	Used with the interval to specify the time interval to and percentage to for each stage
NAME	Used to assign a name for each stage or pool
TYPE	Used to assign a type for each pool such as patient, nurse, etc.
DECISION	Represents the availability of routing the resource to two different locations based on the decision probability
YES	Used to specify that the stage supports decision
NO	Used to specify that the stage does not support decision
PERCENTAGE	Represents the probability percentage of a decision
DISTRIBUTION	Represents the distribution type followed by a stage
ORING	Used to specify if a stage may receive different inputs with different attributes
MODE	Represents the mode of simulation; whether during normal flow or catastrophe events
NORMAL	Represents the normal mode of simulation
CATASTROPHIC	Represents the catastrophic mode of simulation
WORKFLOW	Represents the type of the unit whether A or B or Common for all units
A, B, ALL	Used to set and specify the unit attribute. For example: A referring to unit A, B referring to unit B and ALL referring to a common unit
EMPLOYEE WEIGHT	Represents the weight of employee satisfaction factor
MANAGEMENT WEIGHT	Represents the weight of management satisfaction factor
PATIENT WEIGHT	Represents the weight of patient satisfaction factor
OPTIMIZE	Used to apply model optimization
THRESHOLD	Represents the threshold of the optimization factor
SIMULATE, FOR	2 keywords used to specify the simulation period of time; such as for MINUTES, HOURS or WEEKS
WORKLOAD	Used to set the maximum workload of a resource pool, which reflects the threshold of a resource utilization rate Used with the WEIGHT keyword in order to set the workload weight factor
SALARY	Used to specify the pay amount of each resource pool
MAXIMUM	Used with SALARY and WORKLOAD to specify the maximum pay and maximum workload
CONSULTATION, FEES	2 keywords to represent the consultation fees of each patient visiting the ED used during the optimization phase while calculating the hospital’s revenue needed for the owner satisfaction calculation

WEIGHT	Represents the salary or workload weight factors used during the optimization phase while calculating the employee satisfaction factor for the reward system
OTHER, EXPENSES	2 keywords representing the extra expenses weight factor used during the optimization phase while calculating the owner satisfaction factor for the reward system
EMPLOYEE, IMPACT	2 keywords representing the customer-resource relationship used during the optimization phase while calculating the patient satisfaction factor for the reward system
EXPECTED, LOS	2 keywords representing the threshold or the expectation of *LoS* in the system used during the optimization phase while calculating the patient satisfaction factor for the reward system

2.2 Defining the system

The language preliminaries defined in the previous section are used to describe the system under study. Each line of the language code should end by a semi-column (;). Each stage should end by END STAGE. Each pool should end by END POOL. The steps needed to be added to the input data file are described as per the following:

Defining stages:

Stages are referred to as each stop a patient makes in the ED during his journey in order to receive the required care. The steps to define the stages are:

- A name should be associated to each stage using the keyword NAME and the operator =.
- The Distribution should be set using the keyword DISTRIBUTION and the operator =. It can be set to NONE in case the stage is not a process (does not follow any distribution type).
- The interval time should be set to define the delay. It represents the time each stage takes in order to accomplish a task. Keywords to be used: INTERVAL FROM and INTERVAL TO.
- The stage should either support decision or no, which means a patient can be routed to 2 different ways based on a certain percentage. In case the stage supports decision then the keyword DECISION and the operator = should be used to set it to YES. Otherwise, DECISION should be set to NO. Once the stage is set to support decision, the percentage is set using the keywords: PERCENTAGE TO or PERCENTAGE FROM and the operator =. For example, PERCENTAGE FROM= 0 and PERCENTAGE TO=40 means 40 %.
- In case 2 or more units cooperate, the keyword ORING should be used followed by the operator = and set to YES in case the stage supports ORING. ORING means the stage may receive more than one type of patient coming from 2 different units or more. Therefore, receiving one type of patient only can fire the transition.
- A keyword WORKFLOW must be set to A or B using the operator =, in case two different units are operating for example. WORKFLOW sets an attribute to patients coming from different units.

Defining pools:

Pools are referred to as the resources needed to serve arriving patients. The steps to define the pools are:

- A name should be associated to each pool using the keyword NAME and the operator =. The pool name usually refers to the type of resources associated with these pools.
- The type of resource residing in this pool should be set using the keyword TYPE and the operator =. The patient type refers to the token residing in the resource pool. The input/output pools type is always patient.

- The marking of each pool should be set using the keyword MARK and the operator =. The input pool marking is the number of arriving patients and the output pool marking should be always set to 0 at the beginning since no simulation is performed yet. The marking of pools represents the capacity of resources in the model.
- The salary that each medical resource receives should be entered using the keyword SALARY and the operator =. Salaries represent the actual resource salary in the model.
- The maximum pay each resource is expecting should be entered using the keywords MAXIMUM SALARY and the operator =. The maximum pay is based on the expectation of salaries which resources wish for.
- A utilization rate threshold can be set using the keywords MAXIMUM WORKLOAD and the operator =. This value represents a maximum workload that a resource can handle. Above this value leads to employee dissatisfaction.

Defining the connections:

Connections refer to the links between stages and pools. Connections are set as statements and the steps to define them are presented below:

- Use the keyword CONNECT as the first word in the statement to specify that the links are being defined.
- Use the pool name or stage name as the second word in the statement to specify the link from where the connection starts.
- Use the keyword TO as the third word in the statement.
- Use the pool name or stage name as the forth word in the statement to specify the link where the connection ends.
- Use the keyword AS to be the fifth word in the statement.
- Use the keyword INPUT or OUTPUT as the sixth word in the statement to specify the type of connection to be either input or output.
- Use the keyword PASS as the seventh word in the statement to pass the type of token inside the pool into the stage. Tokens can be either a patient moving across stages or a certain type of resource serving this stage.
- Use the type of token as the last word in the statement. The token type can be either a patient, a doctor, a nurse, etc. These types refer to the type of token residing in the stage.

Defining and setting values:

- To start the simulation phase, a simulation time must be set. Here 2 keywords can be used: SIMULATE FOR and then the number can be specified followed by either MINUTES, HOURS or WEEKS keywords. The statement should start by the keyword SET.
- The input and output pools of the described system must be set by using the keyword SET as the first word in the statement. Then, the pool name can be added as the second word. The third word must be the keyword AS and finally the last word in the statement should be the direction either INPUT or OUTPUT. Here, two separate statements must be defined: one to set the input pool and another one to set the output pool.
- The mode of simulation must be set by using the keyword SET as the first word in the statement. Then, the keyword MODE as the second word followed by the operator =. Finally, the last word must be either the keyword NORMAL or CATASTROPHIC depending on which simulation mode the user desires to run the system through.

Defining the optimization phase:

The last part of the language code data input file is setting the needed factors for the optimization phase. During optimization, many factors need to be set in order to calculate the satisfaction factors: patient, owner and employee. These factors are then used to determine the optimization value which represents the reward system. In order to start with the optimization phase, the keyword OPTIMIZE must be added to the input data file followed by a semi-column (;). Here, some values need to be set in order to apply the optimization algorithm defined in the software and calculate the optimization values. Once these values are set and simulation is started, the software will perform many iterations until the near-optimal solution is achieved. This solution suggests the best allocation of resources for a better performance. Factors that need to be set are as per the following:

- Setting the consultation fees using the keywords CONSULTATION FEES followed by the operator = then the value desired. The values are in US $.
- Setting the pay weight factor by using the keywords PAY WEIGHT followed by the operator = then the value desired. The values are in %.
- Setting the workload weight factor by using the keywords WORKLOAD WEIGHT followed by the operator = then the value desired. The values are in %.
- Setting the extra expenses factor by using the keywords OTHER EXPENSES followed by the operator = then the value desired. Values are in %.
- Setting the customer-resource relationship factor by using the keywords EMPLOYEE IMPACT followed by the operator = then the value desired. Values are in %.
- Setting the expected *LoS* by using the keywords EXPECTED LOS followed by the operator = then the value desired. Values are in minutes.
- Setting the employee weight factor by using the keywords EMPLOYEE WEIGHT followed by the operator = then the value desired. Values are in %.
- Setting the management weight factor by using the keywords MANAGEMENT WEIGHT followed by the operator = then the value desired. Values are in %.
- Setting the patient weight factor by using the keywords PATIENT WEIGHT followed by the operator = then the value desired. Values are in %.
- Setting the optimization threshold by using the keyword THRESHOLD followed by the operator = then the value desired. Values are in %.

3. SIMULATION OF THE STUDIED ED

The studied ED is simulated using the developed platform AMS during normal flow and compared with previous simulations using Arena in order to prove the efficiency and reliability of this platform. A small sample of input data file fed into the software is illustrated in Fig. 2.

```
STAGE
NAME = ARRIVALA;
DISTRIBUTION = EXPONENTIAL;
INTERVAL FROM  1;
INTERVAL TO  20;
DECISION = NO;
WORKFLOW = A;
END STAGE;

POOL
NAME= PATIENTPOOL;
TYPE= PATIENT;
MARK= 140;
WORKFLOW = ALL;
END POOL;

OPTIMIZE;
SET EMPLOYEE WEIGHT = 10;
SET MANAGEMENT WEIGHT =30;
SET PATIENT WEIGHT = 60;

POOL
NAME= DOCTORPOOLA;
TYPE= DOCTOR;
MARK= 1;
WORKFLOW = A;
MAXIMUM SALARY= 2100;
SALARY= 2400;
MAXIMUM WORKLOAD= 80;
END POOL;

SET PATIENTPOOL AS INPUT;
SIMULATE FOR 24 HOURS;
SET MODE = NORMAL;

CONNECT PATIENTPOOL TO ARRIVALA AS INPUT PASS PATIENT;

CONNECT ARRIVALA TO REGISTRATIONA AS INPUT PASS PATIENT;

SET THRESHOLD = 80;
SET CONSULTATION FEES=35;
```

Figure 2: Sample of the input data file loaded into AMS as a language code.

The studied hospital is located in Lebanon, having two buildings: a charitable suite building called ER A and a private suite building called ER B. During overcrowding and bottlenecks, the two emergency rooms cooperate together to serve any patient in need. Almost 215 beds are distributed in different units of the hospital with a 24/7 ED that serves more than 40,000 patients yearly. The main human resources available in the ED are: Doctor, Registered Nurse, Nurse, Transporter, Physician, Technician, Accountant and Receptionist. The none-human resource is called Facilities and refers to all medical equipment, beds, materials, etc. needed during a medical care activity.

3.1 Simulation during normal flow

The ED is first simulated during normal flow; therefore, the keyword NORMAL as the mode is added to the input data file created to describe this system. The marking of the input pool is 140 arriving patients. The output statistics are illustrated in section 3.2. Simulation was run for 24 hours.

Fig. 3 shows the initial marking of resource pools as fed to the platform through the input data file. Fig. 4 shows the system number out after simulation which is found to be equal to 53. This value refers to the number of patients exiting the system from ER A and ER B.

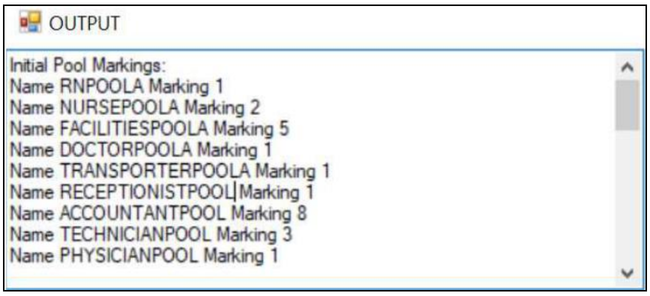

Figure 3: Initial pools marking.

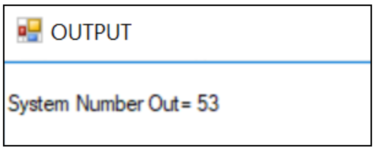

Figure 4: System Number Out.

Fig. 5 shows the number of patients waiting in some queues where the highest is found to be 51 and refers to the transporter queue. The transporter is responsible for transferring the patient from the ED to the radiology unit in case a facility is requested or to admission in case admission to the hospital is needed. It is noticed here that the transporter queue is suffering from bottleneck due to a shortage in the transporter pool and thus need to be optimized. Therefore, the transporter is highlighted by the software to be the bottleneck.

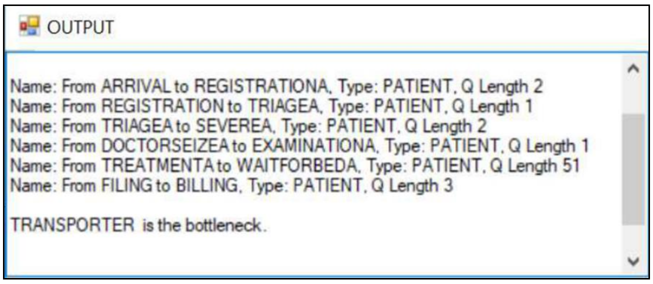

Figure 5: Number of waiting in queues.

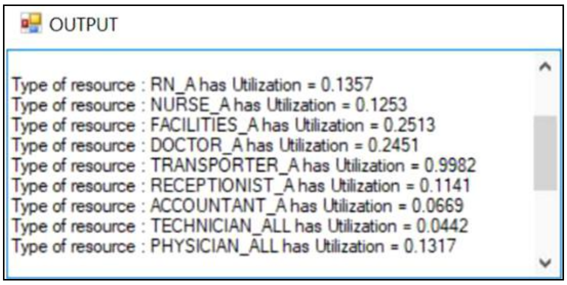

Figure 6: Resource utilization rates.

From Fig. 6, it is noticed that the highest utilization rate corresponds to the transporter resource (99 %). This is normal since the system possesses only one transporter to serve all incoming patients and therefore the bottleneck at this queue is justified.

The average patient *LoS* is equal to 395.09 minutes as per Fig. 7. It is higher than the expected *LoS* which must be 270 minutes as a threshold for a satisfied patient. Therefore, the system must be optimized in order to increase patient satisfaction. Moreover, the reward system which is represented by the optimization value is equal to 81. This value is higher than the optimization threshold and thus the new marking of resources is reliable for better performance of the overall system. The new resource allocation is depicted in Fig. 8.

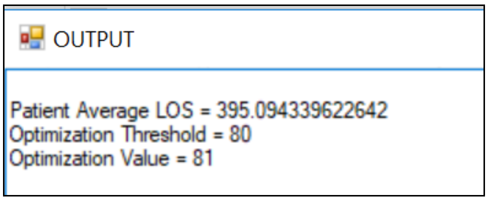

Figure 7: Patient *LoS* and optimization value.

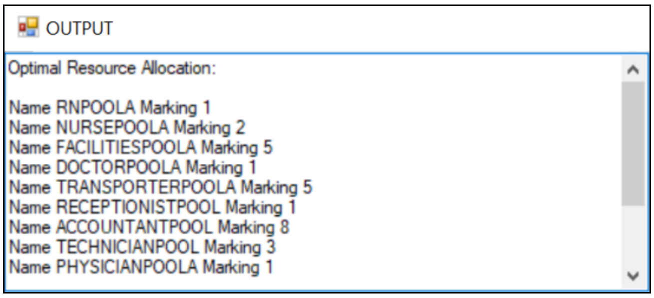

Figure 8: New resource allocation.

Fig. 9 shows the iteration number where the simulation is stopped after reaching an optimization value higher than the threshold along with the three satisfaction measures.

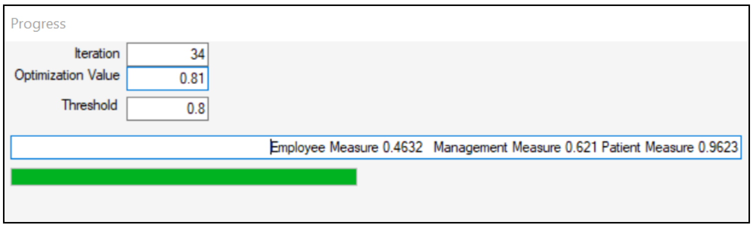

Figure 9: Best optimization iteration.

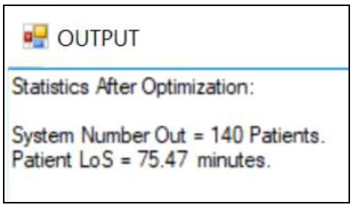

Figure 10: System Number Out and *LoS* after optimization.

The system number out is increased from 53 to 140 patients after optimization as per Fig. 10. This is a huge increase in the number of patients leaving the system which means higher hospital revenue. The *LoS* after optimization is decreased from 395.09 to 75.47 minutes as per Fig. 10 which means another attractive enhancement. Recall here that the optimization algorithm takes into consideration the revenue which reflects the owner satisfaction while suggesting the optimal resource allocation.

3.2 Output results and discussion

The output results collected from the simulation in Section 3.1 show that the bottleneck is the transporter. The statistics collected are illustrated in Table III. These values are compared to the values resulted from Arena simulation and are found very similar; thus, the reliability of the software in studying system flow of operation and defining bottleneck areas. After applying optimization using AMS, which is based on the MRA algorithm defined previously, the values collected for the system out, patient *LoS* and the reward system $\mathfrak{R}$ along with the three satisfaction factors: patient (F_1), owner (F_2) and employee (F_3) are found very similar to those calculated before. Moreover, the new resource allocation proposed by AMS software is almost similar to the one resulted from MRA algorithm. Thus, again the proof of reliability of this platform and that the engine works exactly as intended. This comparison is presented in Tables IV, V, VI.

Table III: AMS vs. Arena before optimization.

Performance measures		Arena outputs	AMS outputs
Number of System In		140	140
Number of System Out		60	53
Patient *LoS*		356.62	395.09
Resource utilization rates	Transporter	98.94	99.82
	Accountant	16.58	6.7
	Receptionist	14.99	11.41
	Technician	5.1	4.4
	Physician	12.66	13.17
	Doctor	33.05	24.5
	Nurse	28.97	12.5
	Facilities	20.27	25.13
	RN	19.37	13.57

Table IV: Comparison after optimization.

Performance measures	MRA outputs	AMS outputs
Reward System: $\Re$	77.2	81
Number of System Out	138	140
Patient *LoS*	112.96	75.47

Table V: Reward system using AMS.

Factors	Arena (%)	AMS (%)
F_1	94.75	96.23
F_2	53	62.1
F_3	44.755	46.32
$\Re$	77.2	81

Table VI: New resource allocations.

Resource type	MRA new resource allocation	AMS new resource allocation
Doctor	1	1
RN	1	1
Nurse	2	2
Transporter	9	5
Accountant	8	8
Receptionist	1	1
Physician	1	1
Technician	3	3
Facilities	5	5

4. AMS SOCIO-ECONOMIC BENEFITS

Economic and social benefits of the proposed platform AMS are presented in this section in order to highlight the advantage of using this software in emergency departments and why decision makers should consider it during potential system optimization phase. Xesfingi and Vozikis studied the relationship between patient satisfaction and a set of socio-economic healthcare indicators [17]. AMS proposes new resource allocations to better serve patients and eliminate wastes. When the ED is well managed and system flow is improved, the number of patients being served is increased. This is due to the advantage of this platform in decreasing the *LoS*. As an outcome, hospital's revenue is increased and thus the economic benefit of AMS. The most prominent benefits of AMS are efficiency and improved quality. Efficiency refer to improving productivity for serving patients such as lower waiting times, lower resources workload and an increase in system revenue. The major patient gain here is the improved timeliness and quality of care. Gain also includes a reduced risk of errors since medical resources workloads are decreased. As part of the socio-economic evaluation, a cost-benefit analysis is performed showing a significant net benefit margin that can be achieved by applying the optimization proposed by AMS. Studying the net benefit of the software includes a measure of financial returns along with the value of all positive and negative effects including hospital revenue, patient satisfaction and resource satisfaction. A well satisfied system attracts customers and opens the door for more customers to come in the future leading to a good reputation of the hospital. The cost of adding new resources is high which the platform is taking into account. Proposing additional medical resources for system improvement while taking into account the extra costs vs. the hospital revenue, guaranteed by the platform AMS, highlights the main economic benefit of this platform.

In general, the implementation of this platform needs some basic requirements such as medical and administrative IT applications: Patient Records Database and Departmental level Information System. These databases and the link between different units are strictly needed in order to facilitate the patient data retrieval and thus create the input data file that will be fed into the program. AMS is built in a modular structure, which allows smooth expansions in scope for the future. Through interviews with many decision makers and hospital managers, the numerous benefits and positive impacts of AMS are granted. The main benefit categories of AMS are summarized in Table VII.

Table VII: AMS socio-economic benefits.

Benefits	**Description**
Efficiency	Coping with increased demand
	Low operating costs
Quality of care	Patient safety
	Reduce medical errors risk
	Better effectiveness of care
	Reduce resource workloads
	Faster discharge
	Better prediction and pre-preparation in case of an occurring transfer between units
Faster access	Reduce waiting times during visits
Satisfaction	Balancing between three satisfaction factors: patient, owner, medical resource

The estimated price of the AMS framework is $20,000. It covers the software price including installation and manly hours for development. The fees are paid once. A CD is provided containing the software set up which any IT person can easily install. A study on yearly ED profit is presented in Table VIII. After purchasing and implementing AMS platform into the hospital's ED, decision makers can perform as many simulations as needed. It takes around one hour for one simulation to be completed depending on the complexity of the system under study. After simulation, recommendations are given in order to enhance the system performance. The system starts gaining more profit as soon as decision makers apply the recommendations resulted from the software. The cost increases or decreases based on these recommendations, by either adding or removing resources to better serve the case. However, profit always increases based on the weights decision makers specify in the software input data phase.

Table VIII: Yearly ED profit study after purchasing AMS.

	Year 1	**Year 2 and forward**
AMS purchasing fees	$20,000	NONE
Extra resources salaries expenses	$718,200	$718,200
Revenue from extra consultation fees after using AMS simulation	$970,200	$970,200
Net profit	$252,000	$252,000
Net profit after purchasing AMS	$232,000	$252,000

5. CONCLUSION

A new platform is developed, called AMS. This platform helps to organize and enhance any department in a hospital, specifically emergency departments (ED). The ED can have one or more units cooperating and sharing resources. The input data is fed into the software using an input file created by the user using a new language programming code based on English statements and simple keywords. The unit chosen as a case study for simulation using AMS is the ED of a hospital located in Lebanon. The platform is tested for several scenarios where the user based on the data entered receives the required solution either in normal flow or during catastrophic events. Scenarios can be highlighted such as allocating medical resources and calculating patient satisfaction rates. The reward system and optimization algorithm proposed in a previous work is also implemented in the platform where users can easily measure the level of satisfaction of their staff, patients, and owner. Improvements can be suggested accordingly by proposing new resource allocations. The main performance measures are resulted as collected statistics: *LoS*, utilization rates and queues markings. As part of future work, more features will be integrated with the platform such as implementing the Draw icon which allows visualization of the system under study. Also, developing a mobile application of AMS is under study and implementation. A study on the importance of mobile technology in healthcare is presented by Bhavnani et al. [18].

REFERENCES

[1] Oueida, S.; Char, P. A.; Kadry, S.; Ionescu, S. (2016). Simulation models for enhancing the health care systems, *FAIMA Business & Management Journal*, Vol. 4, No. 4, 5-20

[2] Weng, S.-J.; Cheng, B.-C.; Kwong, S. T.; Wang, L.-M.; Chang, C.-Y. (2011). Simulation optimization for emergency department resources allocation, *Proceedings of the 2011 Winter Simulation Conference*, 1231-1238

[3] Trzeciak, S.; Rivers, E. P. (2003). Emergency department overcrowding in the United States: an emerging threat to patient safety and public health, *Emergency Medicine Journal*, Vol. 20, No. 5, 402-405, doi:10.1136/emj.20.5.402

[4] Saghafian, S.; Hopp, W. J.; Van Oyen, M. P.; Desmond, J. S.; Kronick, S. L. (2012). Patient streaming as a mechanism for improving responsiveness in emergency departments, *Operations Research*, Vol. 60, No. 5, 1080-1097, doi:10.1287/opre.1120.1096

[5] Kuo, Y.-H.; Leung, J. M. Y.; Graham, C. A. (2012). Simulation with data scarcity: developing a simulation model of a hospital emergency department, *Proceedings of the 2012 Winter Simulation Conference*, 979-990

[6] Oueida, S.; Kadry, S.; Ionescu, S. (2017). Estimating key performance indicators of a new emergency department model, *International Journal of User-Driven Healthcare (IJUDH)*, Vol. 7, No. 2, 1-16, doi:10.4018/ijudh.2017070101

[7] Dragic, M.; Sorak, M. (2016). Simulation for improving the performance of small and medium sized enterprises, *International Journal of Simulation Modelling*, Vol. 15, No. 4, 597-610, doi:10.2507/IJSIMM15(4)2.343

[8] Oueida, S.; Ionescu, S. (2017). A resource aware extended workflow model for inconsumable resources: application to healthcare, *8th International Conference of Management and Industrial Engineering*, 377-389

[9] Simon, E.; Oyekan, J.; Hutabarat, W.; Tiwari, A.; Turner, C. J. (2018). Adapting Petri nets to DES: stochastic modelling of manufacturing systems, *International Journal of Simulation Modelling*, Vol. 17, No. 1, 5-17, doi:10.2507/IJSIMM17(1)403

[10] Zupancic, D.; Buchmeister, B.; Aljaz, T. (2017). Reducing the time of task execution with existing resources – comparison of approaches, *International Journal of Simulation Modelling*, Vol. 16, No. 3, 484-496, doi:10.2507/IJSIMM16(3)10.394

[11] Wang, Y. R.; Chen, A. N. (2016). Production logistics simulation and optimization of industrial enterprise based on Flexsim, *International Journal of Simulation Modelling*, Vol. 15, No. 4, 732-741, doi:10.2507/IJSIMM15(4)CO18

[12] Nie, X. D.; Chen, X. D.; Chen, X. (2016). Simulation study of flexible manufacturing cell based on token-oriented Petri net model, *International Journal of Simulation Modelling*, Vol. 15, No. 3, 566-576, doi:10.2507/IJSIMM15(3)CO14

[13] Sena, D. C.; Silva, E. M. M.; Costa, A. P. R.; Montevechi, J. A. B.; Pinho, A. F.; Miranda, R. C. (2017). Dynamic allocation of additional human resources using hybrid simulation, *International Journal of Simulation Modelling*, Vol. 16, No. 1, 84-95, doi:10.2507/IJSIMM16(1)7.371

[14] Oueida, S.; Aloqaily, M.; Ionescu, S. (2018). A smart healthcare reward model for resource allocation in smart city, *Multimedia Tools and Applications*, in press, 22 pages, doi:10.1007/s11042-018-6647-4

[15] Lee, M. L.; Park, I.; Park, D. U.; Park, C. (2017). Constrained ranking and selection for operations of an emergency department, *International Journal of Simulation Modelling*, Vol. 16, No. 4, 563-575, doi:10.2507/IJSIMM16(4)1.388

[16] Gul, M.; Guneri, A. F. (2015). A comprehensive review of emergency department simulation applications for normal and disaster conditions, *Computers & Industrial Engineering*, Vol. 83, 327-344, doi:10.1016/j.cie.2015.02.018

[17] Xesfingi, S.; Vozikis, A. (2016). Patient satisfaction with the healthcare system: Assessing the impact of socio-economic and healthcare provision factors, *BMC Health Services Research*, Vol. 16, Paper 94, 7 pages, doi:10.1186/s12913-016-1327-4

[18] Bhavnani, S. P.; Narula, J.; Sengupta, P. P. (2016). Mobile technology and the digitization of healthcare, *European Heart Journal*, Vol. 37, No. 18, 1428-1438, doi:10.1093/eurheartj/ehv770