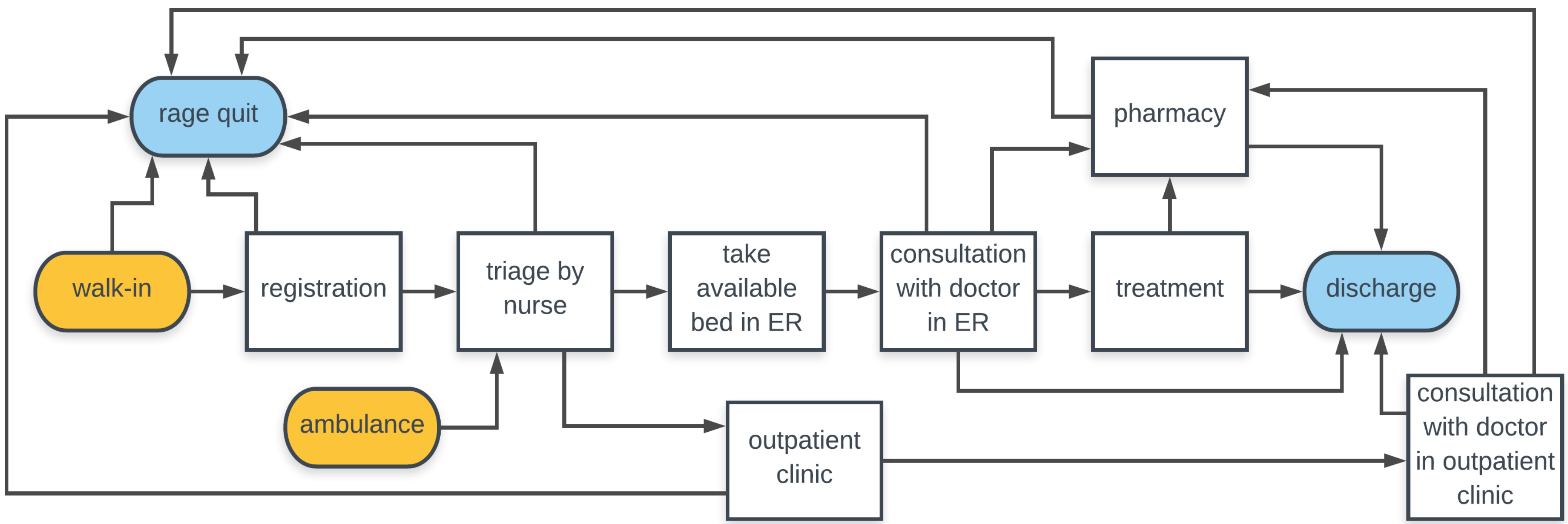
# Case Study: An Emergency Room

Monica Geller, the Medical Director of the Emergency Department of the Riverdale General Hospital (RGH) has been notified that the hospital in the nearby city of Bedrock must be completely shut down, for necessary repair and renovations after a recent fire.

Bedrock Teaching Hospital's (BTH) emergency room sees more patients than Riverdale's, and Ms. Geller is worried that the combined number of cases may overwhelm her current staff and available facilities. In the meantime, she has access to some of the doctors, nurses and other personnel, and all the medical supplies (including beds) previously assigned to the BTH.

In a board meeting, when she brought up this contingency, she was referred to the Computational Mathematics department of Quendelton State University, and your supervisor has instructed you to work with Ms. Geller. She's given you the following flowchart of a patient's path through the Emergency Room, from arrival to discharge.




This process is the same for all hospitals run by the Borduria National Health Service, so the model is general, and your solutions will be implemented in all national hospitals, should a similar situation ever arise.

1) Is the research question clear from the flowchart and the above paragraphs? What more information do you think you need (general information, rather than numbers)? Give is a partial list of possible solutions to explore.

2) One of Ms. Geller's main concerns is the time between triage and treatment for the worst patients in the emergency room. Your literature search has revealed four approaches used to model similar problems: Agent-Based Modelling, Queueing Theory, Discrete-Event Simulation, and System Dynamics. Except for ABM, all the other approaches focus on the events of the process, rather than the individual patients.

   Why would you choose the Agent-Based Modelling approach? What are the pros and cons?

3) Your PI has said that the current model is too complex, and will require more development time and computer time than the department can allot to the project. She has suggested the following simplified model:


Given the research question above, would you go ahead and use this model, or has it been over-simplified? What are your reasons? Can you fix it?

4) Here is a table of statistics, given to you by Ms. Geller. "-" represents "not applicable".

| Number | Patient Numbers (daily average) | ER | Outpatient Clinic |
|---|---|---|---|
| **1** | Walk-ins | 80 | - |
| **2** | Patients arriving by ambulance | 20 | - |
| **3** | Patients dying | ~ 1% | - |
| **4** | Patients leaving without being seen or treated | 6 | - |
| **5** | Patients referred to outpatient clinic | ~ 7% | - |
| | **Average Times** | | |
| **6** | Registration | 5 mins | - |
| **7** | Triage | 5 mins | - |
| **8** | Sanitise equipment and replace medical supplies used in the ER | 6 mins | ~ 30 sec |
| **9** | Pharmacy | 10 mins | - |
| | **Staff** | | |
| **10** | Number of doctors | 5 | 2 |
| **11** | Average number of doctors needed for a single patient | 1 | 1 |
| **12** | Doctor average time spent on one patient | 40 mins | 10 mins |
| | | | |
| **13** | Number of Nurses | 40 | 3 |
| **14** | Average number of nurses needed for a single patient | 2 | 1 |
| **15** | Nurse: average time spent by the first nurse on one patient in ER | 40 mins | 5 mins |
| **16** | Nurse: average time spent by the second nurse on one patient in ER | 55 mins | - |
| | | | |
| **17** | Break time allotted to doctors and nurses in the ER between patient interactions | 4 mins | - |
| | | | |
| **18** | Number of Pharmacists | 1 | - |
| | **Resources** | | |
| **19** | Number of doctors total | 23 | - |
| **20** | Number of nurses total | 40 | - |
| **21** | Number of Pharmacists total | 4 | - |
| **22** | Capacity of beds in the ER | 16 | - |
| **23** | Total number of beds available for use | 60 | - |
| **24** | Number of Ambulances | 10 | - |

Given the research question above, which pieces of information are important, and which are not? Cross those rows out.

5) You now have the final model, so you make plans to begin coding. In the simulation, would any of the following be agents? If so, what would their characteristics be?

a) Doctor (ER):

b) Nurse (ER):

c) Patient:

d) Pharmacist:

e) Doctor (clinic)

f) Nurse (clinic)

g) Receptionist

h) Nurse (triage)

6) The code for the correct version of the simplified model is almost complete. Only a few details remain.

   a. You must choose the time scale of the simulation. What would a time step represent, in your model? How many time steps do you think will be sufficient for the simulation to give meaningful results?

   b. How many runs should you do for each set of parameter values used for the simulation? Is there a reason?

   c. Based on your research question, the agents chosen in your model (and the characteristics of each agent), what findings would your data analysis emphasize?

# Case Study: Possible Responses

This is how **I** would answer the questions, based on experience with agent-based modelling. Your mileage may vary. They may also be sub-optimal. Everything here is subject to improvement, if I've missed anything.

1) No, certainly not. Specifically, there's no context given for the word "overwhelm". The paragraphs state that Ms. Geller has access to surplus resources, except for space. The ER bay has (right now) a finite capacity for beds. In exploring possible solutions, it's not been stated whether the ER bay can be extended to another nearby area in the hospital (very possible), or other considerations.

   In terms of the model, possible can be any combination of: more receptionists, more beds, more nurses, and more doctors. Some possible solutions (outside the scope of this project), and some regular policies can be found in *"Ten Solutions for Emergency Department Crowding"* [Derlet, Richards. West J. Emerg. Med, 2008 v.9(1)].

2) An ABM is best, since the problem given (wait time between triage and consultation) is specific to only one specific type of agent (the worst patients, with the highest triage priority). This makes agent-based modelling necessary for answering the question posed:

   *"In the current process of the ER, what can be done to minimize the wait time of the patient triaged as highest priority (P1), within the constraints given on available resources?"*

   Pros: perfect fit for the problem at hand
   Cons: model seems bloated, given the question to be answered

3) Your PI is almost correct: as it stands, the model is bloated.

   a. Since we are only concerned with the portion of the flow between "admission" and "consultation with ER doctor", we need not be concerned with any path after that, unless it results in readmission. Readmission is not represented in the flowchart.

The distinction between “walk-in” and “ambulance” patients should be kept, simply because

i. walk-in patients are likely assigned lower triage priority (on average) than those rushed in by emergency vehicle

ii. the walk-in patients will go through registration, while the ambulance patients will skip this step. This gives a very slight advantage to the ambulance patients, depending on the time taken for registration.

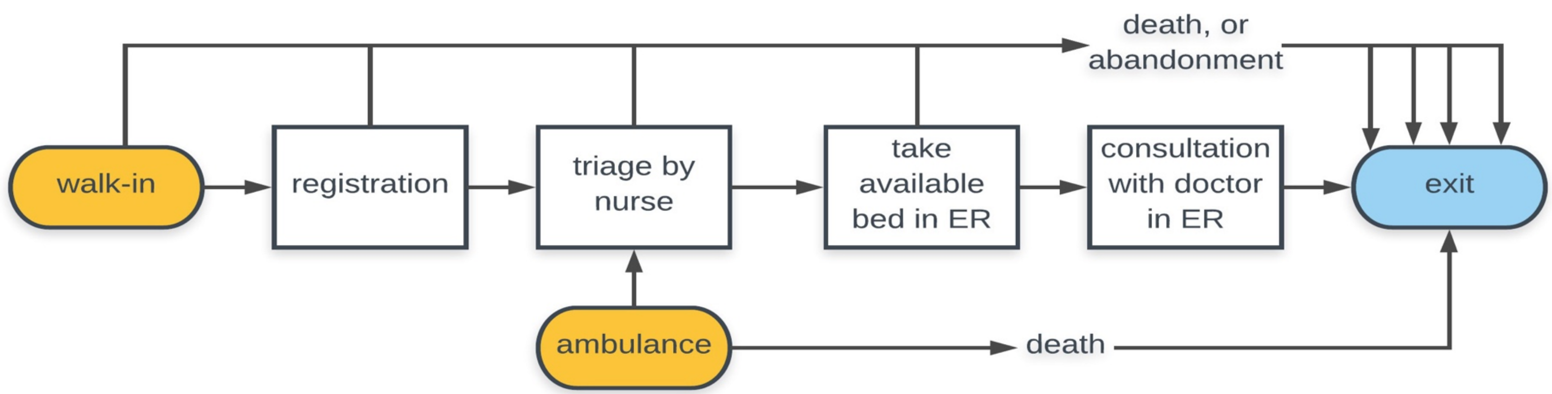
b. The “outpatient clinic” path can be erased, simply because it represents patients exiting the flow of the ER segment of the flowchart, and is equivalent to being immediately discharged. Since presumably the ER will be prioritised in resource allocation, this path is irrelevant to the research question. What’s important is that they occupy the time of the triage nurses.

c. The pharmacy flow can also be safely deleted, for reasons similar to the ones given above. The patients exit the flow at the end of the simulation, and we don’t care about the wait time here; they’ve already been treated. From a modelling standpoint, it’s also equivalent to being discharged.

d. All paths leading to the “treatment” and “rage quit” (exit due to frustration) portions of the flow are computationally equivalent to immediate discharge.

e. Death of a patient anywhere in the flow can also be modelled as immediate discharge, at any stage of the simulation.

Suggestion: **rename the “discharge” oval as “exit”, reinsert the “ambulance” and “walk-in” ovals, and delete the “treatment” box. The “pharmacy” and “clinic” sections of the flow will remain deleted. Death can be represented by paths to the “exit” oval from all stages of the flow. Bear in mind the distinction between the pools of nurses assigned to triage, and the ER self.**




4) Given the new flow chart and revamped model above, rows 9, 18, 21, and 24 are irrelevant; possible row 22 also, depending on whether adequate nearby space in the hospital can be made available to expand the ER bay (for patients assigned lower priorities during triage). All other statistics have a direct bearing on the research problem.

   Since the break time given in 16 is applied to all patient interactions, this buffer period can safely be added to all other doctor and nurse processing times in the flow, so just add 4 minutes to all consultation times in rows 12, 15 and 16. Row 17 can then be safely deleted.

   The same goes for row 8; since the sanitisation time applies to *all* patients, this can safely be deleted, since it's just a part of the wait for "take an available bed in the ER" portion of the flow. It's an overcomplication of the model, especially since it could result in the unnecessary creation of a "bed" agent with a characteristic state varying between "available", "occupied" and "being cleaned".

5) General principle: **anything in an agent-based simulation that is static, or common to all agents, can either be represented as a hub, data structure (most likely a queue), incorporated into given data, or just deleted (as was seen by the model reduction in Question 3).**

   The answers to parts a., b., and c. have been complicated by rows 15 and 16 of the table; since the two nurses assigned to each patient appear to have different roles, this introduced heterogeneity, and the creation of agents, so the answers for a. and b. are unusual.

a. From rows 12 and 15 of the table in Question 4, the doctor and the first nurse spend equal time on each patient. When the simulation is started, this first nurse and the doctor will each start their patient duties at the same instant, and this pair continues to work together (in time) for the rest of the simulation. Therefore, they can be modelled by the creation of a single agent for the doctor-nurse pair. Their characteristic would be a state varying between “busy” and “available”.

b. The second nurse also begins their duties on each patient at the same time as the above doctor-nurse pair, but separate during the treatment of the first patient, and only sync in intervals of 440 minutes. Therefore, this free nurse agent must be created with a single characteristic: either “busy” or “available”.

c. The research question deals with the average wait time between triage and doctor consultation for the most critical patients, so patient agents should be created with two characteristics: wait-time and priority. These two characteristics allow you to gather a breakdown of the average wait-times for each class of patient processed.

d. Deleted: since there is no pharmacy in the new model.

e. Deleted: there is no clinic in the new model.

f. Deleted: there is no clinic in the new model.

g. Since the receptionists just deal with patients for a constant time period (according to the table), they have no significant individual characteristics, and can be treated as homogenous entities. Therefore, the “receptionist” part of the flow can be computationally represented by a queue. The number of receptionists on duty can be changed by altering the length of the queue.

h. Since the triage nurses all just process patients in the same manner, they are also homogenous, and can also be implemented as a simple queue (similar to the receptionists). The number of triage nurses on duty can be changed by altering the length of the queue.

i. After triage, the “take bed available in the ER” is a queueing system that also considers numerical rank of the agents in the queue. This is called a “Priority Queue”, and can be implemented in this step. The number of beds available in the ER bay can be changed by altering the length of the priority queue.

Our simplified model now has **three** agents: **Patient, Doctor/First nurse, and Second nurse.**

6) Final details of the simulation:

a. Looking at the new model of the simulation in A3 (response 3 in the solutions above), the shortest process we are modelling is the registration, which takes **5 minutes**. Conveniently, all other times are “near” to multiples of 5, so this is a good time step to choose.

b. Same as the suggestion given during the workshop: **~ 20 runs**. More runs are great, if the simulation runs fast enough (depending on your implementation).

c. They should answer the research question implied in Question 2: the main result will be **the time waited between triage and doctor consultation/treatment for the most serious patients**. Based on the agents chosen in the simulation, this information can b given for patients of all priority levels, and a global average, for different numbers of triage nurses, receptionists, and beds (measured by the length of the queues used to represent them), and ER nurses and doctors.