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Hospital capacity management through simulation

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Abstract

This paper investigates different strategies that hospital managers can implement to use their resources more efficient. the resources in the hospital can be human resources, equipment and spaces that can be shared during extraordinary situations that hospitals have a surge in their arrivals for example earthquakes and pandemics. These different strategies are Internal Resource management, Patient transfer management between hospitals, Resource transfer between hospital and Temporary improvement of hospital resources. Required framework with simulation is provided. Then different outcomes are introduced which are Unmet demand, utility of the resources, served patients and queue length. Lastly expected outcome and the reasons for these expectations are described. These results provide insights for the managers who want to plan for improvement of their hospitals serving more patients.

Introduction

Hospitals are institutions that provide services to save people's lives, where different resources work together to provide the best service to patients. Therefore, proper planning and optimal use of hospital resources for providing services with the best stage of service has been the focus of planners and researchers. This planning becomes more important when the hospital is out of normal conditions. There are many examples of these special conditions. For example, Ghayoomi et.al showed that resource management plays a more important role during pandemics such as Covid-19, when people need to use hospitals more [1]. To the extent that some hospitals change all their resources to treat this group of special patients. Resource management can go beyond this and become inter-hospital resource management. Ghayoomi et.al showed sample of resource management in the situation that the hospital needs to investigate more resources for the management of the hospital when faced with a cyber-attack [2]. This article aims to investigate one of the most important methods of managing hospital resources in emergency situations, which is simulation.

Material and Method

There are many ways to manage hospital resources in non-normal situations. Some of the researchers have made these plans using deterministic methods [3]. These methods are usually complex mathematical models whose complexity has made them less practical. On the other hands, hospital simulation has been favored by researchers like Shahverdi et.al [4] due to the great flexibility it provides for problem analysis. To manage hospital resources, it is necessary to simulate each hospital separately. Then, according to the scope and type of the problem, they apply the existing solutions to improve the hospital's performance on the basic hospital and compare the results of using the scenarios [4]. Shahverdi et al illustrated that these kinds of simulation are implemented in estimating regional hospital capacity by simulating the hospitals in a region [5]. Figure 1 shows the regional map of the hospitals in Istanbul and the individual hospital.

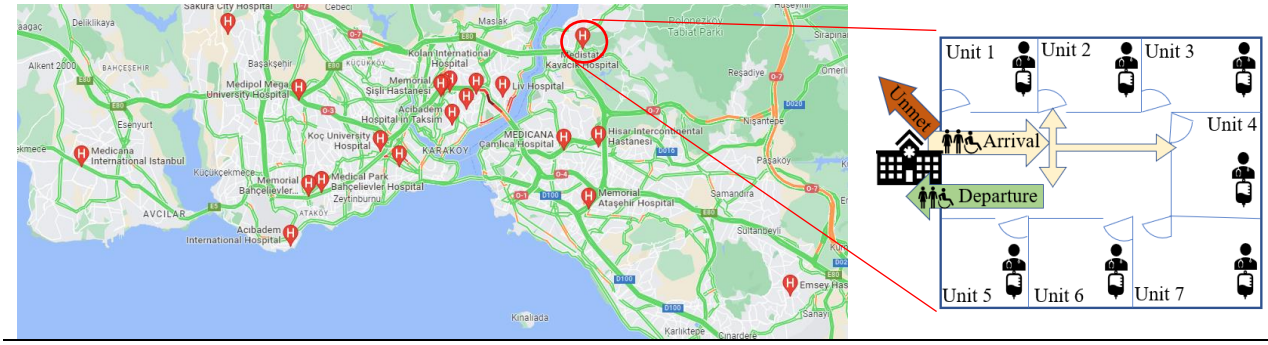
A summary of these solutions is presented as:

Internal Resource management: in this scenario the resources (human resources, spaces and equipment) in the units that can be used in other units can be assigned to them but not wise versa (for example ICU Dr can serve isolation room patients but not wise versa) [6]. This is implemented in the simulation by pooling the resources and running the model. In fact, it is some kind of relaxation in the constraints of the problem. When we let them to be assigned from a bigger pool of resources, the feasibility region increases and the optimal solution can be improved (Figure 2a).

Patient transfer management between hospitals: In this kind of management, the patients are transferred to a hospital having Idle resources and doing so the unmet demand is reduced [7]. In this strategy, a central planner sends the patients than can't be visited in a hospital to other hospitals. for example, in case of a cyber attack the patients can be transferred to other hospitals until recovery of the hospital (Figure 2c).

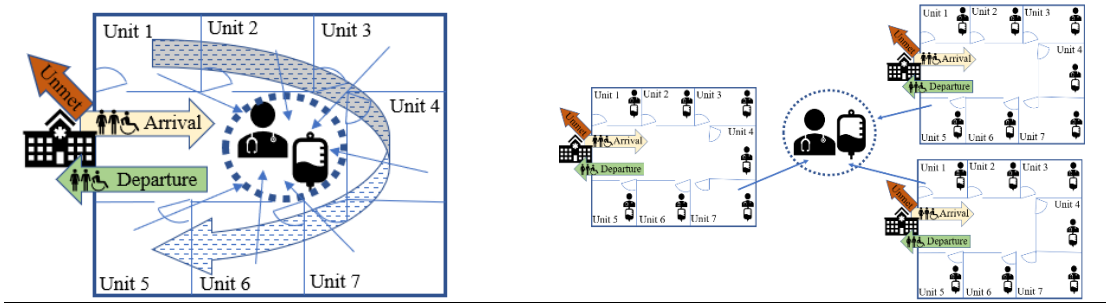
Resource transfer between hospital: In this strategy, the resources between hospitals are shared. For example, ICU nurses can work on other hospital with more patient arrival (Figure 2b).

Temporary improvement of hospital resources: There are a lot of examples in which the hospital needed to add extra and temporary units in tents or by repurposing space like parking to increase their capacity for serving patients and by hiring new human resources (Figure 2d).

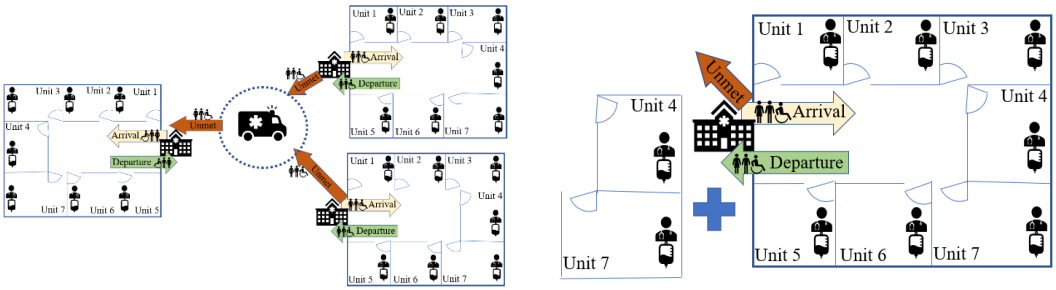


a): Hospitals in Istanbul b): Individual hospital

Figure 1. Regional map of hospitals in Istanbul and the system of one of the hospitals



a) *Internal Resource management* b) *Resource transfer between hospital*



c) Patient transfer management between hospitals d) Temporary improvement of hospital resources

Figure 2. Different strategies for managing hospital capacity efficiently during disasters

Experimental run design

In order to test different strategies a hospital can be simulated separately. The assumptions for the resources, flows and service times can be adopted from existing literature. Each of these four mentioned strategies can be tested with high surge of patients and can be compared to base hospitals without any policy. In order to simulate internal resource management a pool of resource with relevant units are defined in each hospital and is assigned to units with higher demands to remove the bottlenecks. That's while in the resource transfer between hospitals, these pools are bigger and the share of the resources are between hospitals and not the specific hospitals. in the temporary improvement of hospital resources, extra resources are added to each hospital to see how much resources are needed for the hospital to handle this surge of the patients. It can be used to provide an upper bound estimate for the required resources to make serve all the patients. Then by considering these bound hospital managers can provide plans to improve their performance during these extraordinary circumstances. In the patient transfer between hospital policy, a central triage sends unmet demand from busy hospitals to the Idle ones to use their resources.

Results

Different measures can show the performance of each strategy which is presented below that is summarized in Table1:

Unmet demand: the patients that can't be seen in the hospital due to unavailability of services or the patients who leave hospital because of long queue time are called unmet demand [8]. during the surge, expect to see a lot of unmet demand in the base case and those four strategies will reduce the unmet demands [9].

Utility of resources: Resource management during extraordinary conditions means that the Idle resources are used in the units and services that we need them [10]. Therefore, by implementing these strategies we can see increase in the utility of idle units and maybe a reduction in the utility of the busy units. notice that we cannot force our resources to work out of their capacity and doing so we can consider these regulations for human resources.

Queue length: In the surges the patients wait more on the queues and therefore longer queue length in the base scenario without improvement is seen [11]. But by implementing these strategies, in fact the ability of units for serving the patients are increased and therefore the queue length is reduced.

Served patients: managing resources lowers the unmet demand by providing service for the patients in the queues and the patients who leave the hospital in the base hospital. therefore, served patients are improved. We expect to have the most served patients in the Temporary improvement of hospital resources because it increases the capacity of the hospitals until they can see the all the patients. In fact, it provides an estimate for required resources to serve these patients.

Table 1. Expected outcomes by implemented strategies

Unmet demand	Utility of resources	Queue length	Served patients
Reduce	Increase in the Idle units and remaining constant or reduce in busy units	Reduce	Increase

Conclusion

Hospitals are one of the most important elements of society for treatment of the patients. When disaster happens, hospitals are needed more to serve the surge of the patients. Recent Covid-19 is an example of the situation in which many hospitals totally changed their resource role to handle these patients. During the surges the resources got more valuable to be able to save more lives. This study aims to briefly describe different solutions to handle this surge and provides a simulation framework to handle it within a hospital or in a region with multiple hospitals through simulation. Simulation of complex disasters is a well-known tool for analyzing them. For example, Ghayoomi and Partohaghighi [12] used this tool for investigating lake drought prevention using a DRL-based method combined with simulation [12].

The future works will try to simulate the hospital and test these different strategies with some scenarios to test the efficiency of the results and provide insights with numerical examples.

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