Smart Health Model With A Linear Integer Programming Approach

A M H Pardede\textsuperscript{1,2}, H Mawengkang\textsuperscript{3}, M Zarlis\textsuperscript{2}, T Tulus\textsuperscript{2}, L A N Kadim\textsuperscript{1}, A Sihombing\textsuperscript{1}, S Ramadani\textsuperscript{1}, R Buaton\textsuperscript{1,2}, H Khair\textsuperscript{1}

\textsuperscript{1}STMIK Kaputama, Jl. Veteran No. 4A-9A,Binjai- Sumatera Utara, Indonesia
\textsuperscript{2}Fakultas Ilmu Komputer dan Informasi Teknologi, Universitas Sumatera Utara, Jl. Universitas No. 9A, Medan. Indonesia
akimmhp@live.com

Abstract. The concept of intelligent health is part of the realization of a smart city. Most hospitals experience shortages in the availability of resources, such as the lack of truly professional and qualified personnel in the health care field, limitations on hospital facilities and infrastructure. Capacity planning at the hospital is done by ensuring a balance between quality given to health care provided and the costs provided. The measuring instrument used in hospital capacity planning is to calculate the availability of resources at the hospital. In general, the capacity model is intended to calculate the amount of resources needed to be able to serve patients' needs quickly. The problem that is the main description of providing optimal health services based on the concept of “smart health” is how to provide services as early as possible with limited use of health resources. The main assumptions of modeling are only one type of health service can be met by each patient at a time, the number of medical staff is sufficient to fulfill each request, and the type of disease experienced by patients can be handled by available medical staff. The model produced in this study is expected to minimize travel costs, service costs and other costs arising from inaccuracies in providing services to patients.

1. Introduction

Generally, over time the demand for health services has increased. This happens because population growth continues to increase throughout the country, and internet network connections between countries have also accelerated [1]. The development of medical equipment is very incompetent and inappropriate, thus reducing the capacity of hospitals and clinics, services being less than optimal for patients, problems that arise are due to incompatibility with local resources [2].

In improving services, policy-making in scheduling and capacity schemes can be established in smart hospital environments through wireless sensor networks and intelligent health care systems [3]. Most hospitals experience shortages in the availability of resources, such as the lack of truly professional and qualified personnel in the health care field, limitations on hospital facilities and infrastructure [1]. Capacity planning at the hospital is done by ensuring a balance between quality given to health care provided and the costs provided. As a variable measuring instrument used in hospital capacity planning including the availability of the number of health nurses, the availability of the number of doctors and the availability of the number of inpatient beds. In general, the capacity model is intended to calculate the number of nurses needed [4]. The issue of decision is to coordinate multifold...
utilization to the maximum of resources within the hospital [5], to solve this problem, the most appropriate model to use is to solve using linear integer programming.

The problem that is the main description of the providing maximum health services based on the concept of "smart health" in this study is how to provide services as early as possible to patients with limited use of health resources.

The purpose of this study is to obtain a Smart Health model with a linear integer programming approach, so that the resulting model can solve problems to minimize travel costs, minimum service costs, and minimize costs due to inaccurate service delivery, and maximize service to patient demand.

2. State Of The Art
As a result of limited hospital resources that are not comparable to demand for care continues to increase, so traditional health services must be made smart, sustainable and efficient, so that dreams from various remote areas far from the middle of the city can be realized to get smart health. This is the beginning of smart health began to be applied. The concept of intelligent health care is a combination of several variables, namely intelligent sensors that are in patients, traditional health care, supporting devices that can be used, and intelligent ambulance systems, body sensors, intelligent emergency responses, smart hospitals, and information and communication technology (ICT). In hospitals that have become smart hospitals have implemented a smartphone application mechanism, cloud computing, and also includes ICT, as well as advanced data analysis techniques have also been used. In various hospitals that have implemented smart hospitals that are in one area or located in other regions have been able to obtain information and analysis of patient data in real-time. In each part of the smart hospital, either as a doctor, nurse or other medical personnel can transfer data / information and be able to directly test the data received. So real-time decisions about the patient's health conditions and treatments that occur now can be done quickly and precisely, because different doctors can analyze further information about patient data [6].

Effective Smart HealthCare requires collaboration from many people, including professionals in health care, doctors, facility management, and patients [7]. Collaboration is very important for home health management, where family members of patients may also be involved in providing first aid or providing faster information to the hospital. Communication and sharing of data or information from different people is the key to the success of intelligent health [8]. The main factor that causes the failure of smart hospitals is that communication between doctors and nurses is very bad, and the health monitoring of patients who are at home is also not good.

The Smart Heath system implemented can help the management of the public health department. Policy making and decisions can be made according to current needs in different regions / cities / provinces based on data obtained jointly, for example data on climate, environment, population hazards, health, and availability of facilities and infrastructure. Mining data is an opportunity that can optimize the making of unlimited public health decisions. [9].

Therefore, the submission of policy results and processes for data changes and data synchronization must first be analyzed so that the implementation can be carried out in real terms [10].

In health care is a model of queuing with different types of patients, in which one or more types of patients have priority over other types. It is more appropriate to consider the M / G / 1 queue model with the patient type. Patients with type 1 priority are patients who must be served as the highest priority, priority type 2 customers are the second highest priority customers and so on [11],[12].

Integer linear programming (integers) is used to solve problems into integers, and inputs from problems are also integers so that they can be called pure integer linear programs [13].

In a study conducted by GU et al., It introduced the Fog-Computing-Medical Cyber-Physical System system model (FC-MCPS). The notation used in the research is listed in figure 1 below. And presents
a mixed-integer-nonlinear-programming (MINLP) formulation on minimum cost issues with joint consideration of user associations, task distribution and VM deployments (virtual machines) [14]. Problems in the real world can be solved by mathematical modeling, problems can be modeled into mathematical forms that become equations [15], Mathematical principles are not only used for systematization, but also function to maximize results or minimize costs [16].

![Image]

Figure 2.1. The notations used in the model.

3. Problem Description
The problem that is the main description of providing optimal health services based on the concept of “Smart Health” is how to provide services as early as possible with limited use of health resources. The main assumptions of modeling are:
1. Only one type of health service can be met by each patient at a time
2. The number of medical staff is sufficient to fulfill each request
3. The type of disease experienced by patients can be handled by available medical staff

Following are the concrete notations used in the model:

SET

\( I \) = Presents a set of places where health services occur

\( J \) = Presenting the next set of health service destinations, \((i, j) \in N = (0, 1, ..., n)\)

\( O \) = Declares service center

\( H \) = Presenting a set of medical staff, \((h = 1, ..., H)\)

\( K \) = Presenting the type of service, \((k = 1, ..., K)\)
PARAMETER
\( \alpha_{ij} \) = Travel costs from place i to place j for providing health services to patients
\( \beta_{kh} \) = Medical staff costs to provide the type of service to k
\( t_{ij} \) = Travel time from my service center to the place of service request j
\( \tau_j \) = Time of service for patients j
\( W \) = Waiting time from medical staff who arrive at the patient's place before starting service
\( a_i \) = The earliest time the patient receives service
\( b_i \) = At the latest the patient receives service
\( S_{ih} \) = The time needed by medical staff to arrive at the place of patient i who needs service, and
\( D_i \) = The time needed by medical staff to leave the place of patient i who needs service. So there is a time interval \( S_i \in [a_i, b_i] \), \( D_i = \text{max}(w_i + \tau_i, a_i + \tau_i) \)
\( y_{khj} \) = Parameters that are 1 if the service type k can be provided by medical staff h in the patient's place j who needs, is worth 0 if not
\( z_{ij} \) = The parameter is worth 1 if the place of patient j has priority over the place of the patient i, worth 0 if not.

DECISION VARIABLE
In this model the decision variable is a binary variable.
\( x_{ij}^{hk} \) = 1, if medical staff h which gives the type of service k through the patient's place, and = 0, if not.

4. Modelling
The objective of this problem is to minimize travel costs, service fees and fees charged because it is not on time so that all requests for patients are served. The Optimization model can be written as follows:

\[
\text{Minimum } A = \sum_{i \in N} \sum_{j \in N} \sum_{h \in H} \sum_{k \in K} (\alpha_{ij} + \beta_{ij}) x_{ij}^{hk} + \sum_{i \in N} \sum_{h \in H} N_i (S_{ih})
\]

5. Formulate Model Constraints
Formulating model constraints is done by determining the actions or determining the initial value of the problem and emphasizing the limitations of the model to be built. The following describes the constraints on the model:
1. That every patient is only served once by medical staff
2. The medical staff departs immediately after completing the patient's service.
3. Medical staff can only go and return to the place where the patient needs it most.
4. Elimination of the sub-tour is given in Eq
5. Determine the waiting time needed.
6. Provide service delivery time that arrives at each patient's place.
7. Determine the value of punishment if medical staff arrives faster or slower in the place of patients who need services.
8. That medical staff can provide services only if the medical staff is qualified to carry out a type of health service.
9. The limited time, that medical staff must immediately go to the location of patients who need a higher priority to carry out services.
10. Range of variable value decisions.

6. Benefits Of Research
With the new Smart HealthCare model based on the Decision Support System model approach using linear integer programming it is expected to contribute:
1. Optimizing limited human resources for the better
2. Optimizing limited health facilities for the better
3. Empower patients to be more responsible for their health
4. Ensure that every Indonesian community benefits from global health research.

7. Future Research Plans
The next research plan will be testing the model to find out whether the model has been running well as desired. This is very important because it can provide information if there is an error in the model and of course a solution can be found immediately on the part where the model must be repaired. Model simulation using the Linear Interactive and Discrete Optimizer (LINDO) application.

8. Conclusion
The conclusions from the results of this study are as follows:
1. Smart Health Service Optimization Model is an optimization of health service delivery based on the Smart Health concept, by providing services as quickly as possible with limited utilization of health resources. The main assumption of this modeling is that only one type of health service can be fulfilled by each patient, the number of medical staff is sufficient to fulfill each request, and the type of disease experienced by the patient can be handled by available medical staff.
2. This model is a model that minimizes travel costs, service costs and other costs arising from inaccuracies in providing services to patients.

References
[1] S. Sitepu, H. Mawengkang, and Irvan, “Modeling an integrated hospital management planning problem using integer optimization approach,” in Journal of Physics: Conference Series, 2017.
[2] O. A. Fatunde and Timothy W Kotin, “Refinement of the Facility-Level Medical Technology Score to Reflect Key Disease Response Capacity and Personnel Availability,” vol. 1, no. July, 2013.
[3] X. Chen, L. Wang, J. Ding, and N. Thomas, “Patient Flow Scheduling and Capacity Planning in a Smart Hospital Environment,” IEEE Access, vol. 4, pp. 135–148, 2016.
[4] S. Sitepu and H. Mawengkang, “A Two-Stage Stochastic Optimization Model Of Hospital Nursing Staff Management Problem,” Int. J. Adv. Res. Comput. Eng. Technol., vol. 4, no. 1, pp. 44–47, 2015.
[5] S. Sitepu, H. Mawengkang, and I. Husein, “Optimization Model for Capacity Management and Bed Scheduling for Hospital,” in IOP Conference Series: Materials Science and Engineering, 2018.
[6] S. P. Mohanty, U. Choppari, and E. Kougianos, “Everything you wanted to know about smart cities,” IEEE Consum. Electron. Mag., vol. 5, no. 3, pp. 60–70, 2016.
[7] A. Alaiad and L. Zhou, “Patients’ adoption of WSN-Based smart home healthcare systems: An integrated model of facilitators and barriers,” IEEE Trans. Prof. Commun., vol. 60, no. 1, pp. 4–23, 2017.
[8] L. Lapointe, J. Ramaprasad, and I. Vedel, “Collaborating through social media to create health awareness,” in Proceedings of the Annual Hawaii International Conference on System Sciences, 2013, pp. 792–801.
[9] A. Solanas et al., “Smart health: A context-aware health paradigm within smart cities,” *IEEE Commun. Mag.*, vol. 52, no. 8, pp. 74–81, 2014.

[10] N. Ulltveit-Moe and V. Oleshchuk, “Decision-cache based XACML authorisation and anonymisation for XML documents,” in *Computer Standards and Interfaces*, 2012.

[11] I. Adan and J. Resing, “Queueing Theory,” *Technology*, vol. 15, no. x, p. 180, 2002.

[12] A. M. H. Pardede et al., “Framework For Patient Service Queue System For Decision Support System on Smart Health Care,” *Int. J. Eng. Technol.*, vol. 7, no. 2.13, pp. 337–340, 2018.

[13] R. Bosch and M. Trick, “Integer Programming,” in *Search Methodologies*, Boston, MA: Springer US, 2014, pp. 67–92.

[14] L. Gu, D. Zeng, S. Guo, A. Barnawi, and Y. Xiang, “Cost efficient resource management in fog computing supported medical cyber-physical system,” *IEEE Trans. Emerg. Top. Comput.*, 2017.

[15] Tulus, I. Z. Sefnides, Sawaluddin, Suriati, and M. Dwiastuti, “Modeling of Sedimentation Process in Water,” in *2nd International Conference on Computing and Applied Informatics 2017*, 2018, pp. 1–5.

[16] M. K. M. Nasution, “Modelling and Simulation of Search Engine,” in *International Conference on Computing and Applied Informatics 2016*, 2017, pp. 1–8.