Journal of Theoretical and Applied Information Technology
30th June 2019. Vol.97. No 12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

LIMITED RESOURCES OPTIMIZATION OF HEALTH CARE SERVICES WITH A LINEAR INTEGER PROGRAMMING APPROACH

[1]A M H PARDEDE, [2]M ZARLIS, [3]H MAWENGKANG, [4]T TULUS
[1]Graduate Program Of Computer Science, Departement Of Computer Science, Universitas Sumatera Utara, Medan, Indonesia
[2]Departement Of Computer Science, Universitas Sumatera Utara, Medan, Indonesia,
[3,4]Department Of Mathematics, Universitas Sumatera Utara, Medan, Indonesia,
E mail: [1]akimmhp@live.com, [2]m.zarlis@yahoo.com, [3]hmawengkang@yahoo.com, [4]tulus_jp@yahoo.com

ABSTRACT

If the availability of resources in the service center is very adequate, services can be carried out optimally, but we cannot be sure in this situation and even if excessive resources can also result in wasteful costs. If the number of requests more than the number of resources available at the service center can result in non-fulfillment of service requests, this can lead to a long queue of service requests, and if the demand for health care comes from an emergency patient (prioritized patient) can definitely cause this problem to die need to be handled better so as not to cause harm to service providers and patients as service recipients. Health service requests by patients that provide information about the location and type of service desired will be received by the service provider / server connected to the internet service, so that health care request information can be scheduled by the server (hospital health). Communication between the resources available on the server allocates time for each health service that maximizes the limited use of resources to meet the patient's health service needs. The purpose of this study is to simulate the Smart Health model on health services using linear integer programming, so that the resulting model can solve the problem of limited available resources that can serve all requests so that services and services can be done quickly, so as to reduce the risk of losing lives or risks that can endanger the patient. From the new models produced, this maximizes health services and minimizes the time of arrival of medical personnel at the place of request, where when patients request treatment for medical care from the hospital, health care will be provided according to the patient's request.

Keywords: *Health Care, Hospitals, Optimization, Patients, Services.*

1. INTRODUCTION

Optimal first come first serve method can be done if the required resources are still sufficient, but this will be a new problem if the demand for services is more than the availability of resources, finally a long queue will occur. Service requests can come from various sources or devices owned by patients connected to internet services which are then used by healthcare providers to enter services and obtain schedules from servers [1]. Optimization can be done by reducing operational costs and maximizing the use of resources.

Overcoming the growing problem of the elderly population, it needs to be improved in providing better services to people who need health care, this reflects the hope that humans want to have a longer life. [2].

In providing maximal health services to patients, smart health services are needed, namely the need to provide quality care to patients by reducing health care costs and, solving limited resource problems [3]. From the eighties, the majority of research has focused on optimization methods, and now it has discussed green computing, so that the use of resources can be carried out effectively and efficiently and environmentally friendly [4].

Most hospitals spend resources, such as requiring quality professional care, limited hospital equipment and facilities, and adding to their operational costs [5], hhospital capacity planning, closely related to ensuring a balance between the quality of health services received and the costs incurred [6].

In the hospital, capacity planning relates to ensuring a balance between the quality of health

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

care provided and the costs provided. In a plan it involves predicting the specific quantity and attributes of the resources that will be needed to provide health care services at a certain level of quality and cost [7]. The most basic measure of hospital capacity planning is the number of inpatient beds that are in accordance with the number of doctors and the number of nurses. In general, the capacity model is intended to calculate the number of nurses needed, while the capacity of the management model should ideally also provide insight into opportunities to increase capacity use [8].

Smart environments include devices and the use of intelligent support system techniques [9], as well as dynamic scheduling policies and capacity planning schemes. However, to design an efficient design that satisfies the user requires a technique at the start of the design to model and evaluate the design effect [10]. The purpose of the initial evaluation is to predict the impact of the system before use. These new features bring a new perspective on usage techniques [9].

The use of telecommunications technology by health care providers and patients to exchange information and health services for patient care and monitoring is increasing. Smart HealthCare is developing in solving health care problems such as the increasing demand for services to increase accessibility for out-of-hospital care, increasing demand for health services due to the increasing number of elderly people and increasing demand for services for chronic diseases, and the need to increase the efficiency of available resources [11].

All medical care is given to patients, and for the benefit of patients, and is done ethically in accordance with the law, but in the end all of these are under the control or desires of the patients themselves, most patients do not have a thorough understanding of health status, do not respect diagnostic decisions , and not fully understand most of the decisions made by doctors, nurses, and other health care practitioners, even though this is basically for the benefit of patients. And there are even patients who appreciate the clinic to consult a doctor, but use the same medicine as other patients just by studying the symptoms of almost the same disease, even though that is consistent with the fact that these patients have never received medical training [12], because the wrong use of this drug will definitely have a negative impact on patients.

Smart HealthCare is a hospital service system for requesting patients who need health care that can be served by a hospital (resource provider server) quickly by performing services in a place where patients need health care, providing medical personnel services according to disease, providing necessary equipment in accordance with the disease, providing services by minimizing all costs incurred for health care, and maximizing the use of all limited resources.

Modeling and simulation are important tools in resolving epidemic epidemics (outbreaks of disease in certain communities / regions that exceed normal or normal numbers) that occur suddenly, to understand the spread of epidemics in connected networks, some models are proposed and studied. In a study conducted by Younsi, it discussed the problem of spreading epidemics on social networks by building and analyzing the nature of small world networks [13]. Social networking, family groups, neighbors, circle of friends, and health care systems are classic examples as key roles in human activities and life, modeling pariative care networks as a special type of health care system using an agent-based approach, this model provides a framework for studying various aspects of the system from both perspectives that focus on improving the quality of life of patients with life-threatening or near-death diseases, addressing this problem is done by providing various support services to help patients be more active and comfortable in living the rest of their lives [14].

To provide health services to patients who need health care on demand or the occurrence of sudden health problems, it must be ascertained the actions that must be taken or the actions of the doctor as the management of the decision maker, so that the need to provide quality health care can be maximized against patients, and it is possible to reduce health care costs and overcome the problem of lack of limited nursing staff resources.

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

2. STATE OF THE ART

Many questions about smart cities, are they smart cities and why so many people discuss them? In recent years there has been a growth in ICT information and communication technology that has exploded due to technological advances and the design of hardware and software. The use of ICTs in cities in various forms for various urban activities has led to an increase in the operating effectiveness of cities named using many different terms such as “cyber ville”, “digital city”, “city electronics” ", “flexibility”, “city information“, "city cable", and "smart city". Smart City or Smart City is the biggest abstraction among the names used, which although some cities only use city monitoring systems. Smart cities are a concept and there is still no clear and consistent concept definition between academics and practitioners.

In a simple explanation, smart cities are places where traditional networks and services are made more flexible, efficient, smart, and sustainable with the use of information, digital, and telecommunications technology, to improve their operations in the interests of their population. In other words, in a smart city, digital technology translates into better public services for the population, and for better use of resources even if it affects the environment that is less supportive [15].

Smart City strives to improve performance through the application of flexible and efficient networks [16], sustainable networks and traditional services using information, digital and telecommunications technology, and is expected to create greener, safer, faster and more friendly cities [17]. Safe City as part of the Smart City [18], covers all aspects of safety in the city. On the other hand, Smart Technology has many uses in the field of safety to build the Safe City system [19].

Sustainability of smart cities is related to infrastructure and city governance, energy and climate change, pollution and waste, and social, economic and health problems. Quality of life can be measured in terms of the emotional and financial well-being of citizens. The smart aspect of urbanization includes many aspects and indicators, such as technology, infrastructure, government, and the economy. The uniqueness of smart cities is conceptualized as ambitions to improve the economic, social and environmental standards of the city and its inhabitants. Various frequently cited aspects of city intelligence include smart economics, smart people, intelligent governance, intelligent mobility, and intelligent life [15].

In smart hospitals, various mechanisms including ICTs, cloud computing, smartphone applications, and sophisticated data analysis techniques are used in the operation of their systems. Patient data can be done in real-time in various offices in smart hospitals or even various smart hospitals in the same city or city. Medical technicians, nurses, and doctors can have access to test data without losing time in transferring the same information physically from one office to another. Similarly, different doctors can see information to assess the patient's condition. And in dealing with drug needs, the inventory control model can be used to determine drug supplies at any time [20].

To test the efficiency and accuracy of the Integrated Mobile Community Health Care System (IMCHCS), a prototype has been built that is capable of performing different physiological tests, namely: body temperature, blood pressure, heart rate, weight, eye strength, hearing and height tests [21], so that real-time decisions regarding the patient's health conditions and appropriate care can be done [15], conclusions in the proposed research IoT that can monitor the condition of patients online, monitoring systems for patients at risk for heart attack and body temperature that are not normal. If the condition is in a bad condition, there will be a warning notification that will be sent to the hospital server website as a condition monitor, and also applies a travel traffic monitoring system directly using Google maps, so that the ambulance will arrive on time at the patient's location [22].

The need to provide health services is focused on areas such as inadequate resources, limited access to health services and technology, increasing access to data/information systems to health care, improving technology more efficiently and overcoming shortcomings in the availability of experienced professionals in the field of health care in rural areas [23].

Effective Smart HealthCare requires collaboration among many people, including patients, doctors, and health care professionals, and management of facilities in hospitals [24]. Collaboration is very important for home health management, where patient family members may also be involved. The effectiveness of collaboration, in turn, depends on communication and various information among different people in this arrangement [24]. Poor efficiency in the communication of doctors and nurses to patients and the inability to monitor the health of patients at home is the main contributing factor.

The determinants of success in the process of providing health services to the community are the availability of health care workers [25], availability of trained staff, solving problems of geographical barriers in rural/remote areas [17], [26], and includes health provider privacy, cost constraints, data security issues and other technical barriers [23].

The Smart Health concept is a complement to cellular health in the context of smart cities. ICT progress is used by the health sector to create cellular fireplaces, and the central government encourages local governments to be called smart cities. Agusti Solanas, et al. Claims that smart city infrastructure and technology can be utilized and combined with the concept of m-health and

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

telemedicine to create new and ubiquitous concepts (new technologies that make it easier for users and can do everything the user wants), are richer in smart health [27].

Decision Support Systems (DSS) represent the concept of the role of computers in the decision-making process. This term has become an attraction for researchers, practitioners and managers to argue that the field of Information Systems Management and Management is a focus that does not need to be narrowed. Like many titles or terms this is not well defined. For some authors, DSS implies an interactive system for use by managers. For others, the main problem is support, not the system (Keen, 1980), which in general can be concluded that the decision support system (DSS) extracts raw data into information that supports decision-making activities in a business or organization.

The design of a decision support system model for intelligent health care describes a decision support system model for smart health care starting with entering patient data or data received from a patient-installed device or a smart device installed in the patient. the data will be received by the server that handles the distribution of patient services, if priority 1 / the main patient, in this case has been deleted in the previous section, the patient must be served and prioritized at the nearest hospital that is connected. to the server system, and in this condition it is also proposed to immediately bring the patient [28], and maybe the patient can be escorted by the patient's family or the closest person who is encouraged because in this case the first priority is to bring first aid to patience. Furthermore, the priority distribution of patient care 2 will be provided by hospital services depending on the decisions that will be given by the system, where consideration in the assessment is the availability of resources in the hospital, the availability of specialists who handle this disease. or the availability of polyclinics, the availability of supporting equipment needed and the availability of inpatient rooms that provide information about room types/classes. The following is presented in the framework of the Design decision support system model for smart health care.

Problems that occur in the real world can all be solved by mathematical modeling, problems can be modeled into mathematical forms that become equations [29], Mathematical principles are not only used for systematization but also function to maximize results or minimize costs [30]. Models that emphasize cost-effectiveness focus on the physical accuracy that will be used [31], and violating capacity limits can be done by giving a penalty value [32]. In the GU et al. Study, it introduced the Fog-Computing-Medical Cyber-Physical System (FC-MCPS) model, which presents mixed-integer-nonlinear-programming (MINLP) formulations on minimum cost issues with joint consideration of user associations, task distribution and VM deployment (virtual machine) [33].

In solving problems minimizing costs based on consideration together through user associations, task distribution, and the deployment of Virtual Machines can be completed with the formulation of MINLP (mixed-integer nonlinear programming), and by providing restrictions on: User limits, Task Distribution limits, Limitations Virtual Machine Placement, and QoS (quality-of-service) Limitation. The study concludes: To overcome the problem proposed by phase-based heuristic algorithm Linear Programming, so the algorithm has the advantage [33].

This study discusses problems in decision making in maximizing health care services for patients in hospitals, using linear integer programming. The difference with previous studies is explained that what is discussed in this study are the resource variables available at the hospital (doctors, nursing medical staff and other technicians), considering the location of health services, health service destinations, service centers, the number of medical staff, the types of services, the cost of travel from the place to provide health services to patients, the cost of medical staff to provide the type of service, the length of travel time from the service center to the place of request for service, the length of time the patient medical staff who arrive at the patient's place before starting the service, the earliest time the patient receives service, the time at the latest the patient receives service, the length of time required by the medical staff to arrive at the patient's place, and the length of time required by the medical staff to leave the patient need service. So that in solving the problem of this research, a model that can solve problems to minimize travel costs, minimum service costs, and minimize costs due to inaccurate time of service delivery, and maximize service to patient demand.

3. DATA COLLECTION

Data sources for benchmarking (a process commonly used in management or generally strategic management) in this study are medical data on health in hospitals and health services, so that numerical data obtained in the form of matrices can support the modeling process and provide

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

clarity objective function of the model mathematically. Data is taken from the set of minimum function matrices, and explained in detail as in the table below:

Table 1 : The function states the cost of h medical staff travel from place i to the j place to provide health services to patients

α	j = 1	j = 2	j = 3	j = 4	j = 5
i = 1	3	4	9	7	10
i = 2	6	5	6	7	6
i = 3	2	1	6	5	4
i = 4	5	8	1	10	7
i = 5	4	6	6	6	7

Description: Costs for *h* medical staff travel in units of 10,000 rupiah. The table above explains the travel costs of medical staff *h* from α_{ij} (i = 1, j = 1) worth = 100.000, travel costs of *h* medical staff from α_{ij} (i = 1, j = 2) worth = 50.000, travel costs of *h* medical staff from α_{ij} (i = 1, j = 3) worth = 40.000, travel costs of *h* medical staff from α_{ij} (i = 1, j = 4) worth = 40.000, and so on.

Table 2: The function states the travel cost of the type of medical service k from place i to place j for the provision of health services to patients

α	j = 1	j = 2	j = 3	j = 4	j = 5
i = 1	2	2	7	8	9
i = 2	10	1	7	1	4
i = 3	8	2	2	10	7
i = 4	8	9	10	10	3
i = 5	6	10	2	1	6

Description: The cost of travel for the type of medical service *k* in units of 10,000 rupiah. The table above explains the cost of travel based on the type of medical service *k* from α_{ij} (i = 1, j = 1) worth = 20.000, travel costs based on the type of medical service *k* from α_{ij} (i = 1, j = 2) worth = 20.000, travel costs based on the type of medical service *k* from α_{ij} (i = 1, j = 3) worth = 70.000, travel costs based on the type of medical service *k* from α_{ij} (i = 1, j = 4) worth = 80.000, and so on.

Table 3: The function states the honorarium of medical staff h from place i to place j for providing health services to patients

β	j = 1	j = 2	j = 3	j = 4	j = 5
i = 1	10	7	8	3	5
i = 2	8	8	4	1	2
i = 3	4	6	4	3	9
i = 4	8	3	5	8	1
i = 5	8	9	4	8	4

Description: The cost of paying medical staff *h* in units of 10,000 rupiah. The table above explains the *h* medical staff honorarium fees from β_{ij} (i = 1, j = 1) worth = 100.000, medical staff honorarium *h* from β_{ij} (i = 1, j = 2) worth = 70.000, medical staff honorarium *h* from β_{ij} (i = 1, j = 3) worth = 80.000, medical staff honorarium *h* from β_{ij} (i = 1, j = 4) worth = 30.000, and so on.

Table 4: The function states the fee for the type of service to k from place i to place j for the provision of health services to patients

β	j = 1	j = 2	j = 3	j = 4	j = 5
i = 1	8	8	10	2	4
i = 2	8	1	7	6	1
i = 3	4	2	6	7	1
i = 4	8	2	4	5	3
i = 5	5	9	5	2	5

Description: Service type honorarium fee *k* in units of 10,000 rupiah. In the table above, it explains the honorarium fee based on the type of service *k* from β_{ij} (i = 1, j = 1) worth = 80.000, honorarium fee based on type of service *k* from β_{ij} (i = 1, j = 2) worth = 80.000, honorarium fee based on type of service *k* from β_{ij} (i = 1, j = 3) worth = 100.000, honorarium fee based on type of service k from β_{ij} (i = 1, j = 4) worth = 20.000, and so on.

Table 5: The function states the cost of the time needed by medical staff h to arrive at the place of the i patient who needs service

t	j = 1	j = 2	j = 3	j = 4	j = 5
i = 1	1	10	5	10	1
i = 2	9	6	8	4	3
i = 3	4	3	5	5	7
i = 4	10	1	9	5	6
i = 5	8	8	10	8	6

Description: conversion of 1 minute of time needed by medical staff *h* in units of minutes to units costing 10,000 rupiah (time span 10 minutes to 100 minutes to costs 10,000 to 100,000). The table above explains the costs of the time needed by *h* staff from t_{ij} (i = 1, j = 1) worth = 10.000, costs for the time needed by staff h from t_{ij} (i = 1, j = 2) worth = 100.000, costs for the time needed by staff *h* from t_{ij} (i = 1, j = 3) worth = 10.000, costs for the time needed by staff *h* from t_{ij} (i = 1, j = 4) worth = 100.000, and so on.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

4. PROBLEM DESCRIPTION

The main problem described in the provision of 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, which when conducting health care services, medical staff *h* depart from place *i* to place *j* for provide health care services so that the results of modeling that are made can solve these problems, while the results of modeling smart health services are as follows [34]:

1. Minimize the cost of *h* medical staff travel from place *i* to place *j* at the time of providing health services to patients.
2. Minimize the cost of travel for medical services type *k* from place *i* to place *j* at the time of providing health services to patients.
3. Minimize the cost of medical staff *h* from place i to place *j* for providing health services to patients.
4. Minimize service type costs to *k* from place *i* to place *j* at the time of providing health services to patients.
5. Minimize the time needed for medical staff *h* to arrive at the place of *i* patients who need services.
6. Maximizing service to patient requests.

And the main assumptions of this modeling are:

1. Each type of health service can fulfill health care for each patient according to the type of request for the type of care service *k*.
2. The number of medical staff is limited.
3. The types of diseases experienced by patients can be handled by available medical staff.

Thefollowing is explained the notation used in the model:

Set

i = Presents a set of places where health services occur

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

o = Declares service center

h =Presenting a set of medical staff $h \in H = (1,\ldots,n)$

k = Presenting the type of service $k \in K = (1,\ldots,n)$

Parameter

α_{ij} = Travel costs from place *i* to place *j* for providing health services to patients

β_{kh} = Medical staff costs h to provide the type of service to *k*

t_{ij} = Time of travel from the service center *i* to the place of service request *j*

τ_j = Time of service to 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 *i* receives service

b_i = At the latest the patient *i* receives service

S_{ih} = The time needed for medical staff *h* to arrive at the place of *i* patients who need services, and $S_i = a_i$

D_i = The time needed by medical staff to leave the place of *i* patients who need services. So there is a time interval $S_i \in [a_i, b_i]$, $D_i = maks\{w_i + \tau_i, a_i + \tau_i\}$

y_{khj} = Parameters that are worth 1 if the type of service *k* can be provided by medical staff *h* in the place of patient *j* who need it is worth 0 if not

z_{ij} = The parameter is worth 1 if the place of patient *j* has priority than where the patient *i*, is 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.

5. DISCUSSION OF THE MODEL

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 [34]:

$$\textbf{Minimum } A = \sum_{i\in N}\sum_{j\in N}\alpha_{ij}\sum_{h\in H}x_{ij}^{h} + \sum_{i\in N}\sum_{j\in N}\alpha_{ij}\sum_{k\in K}x_{ij}^{k} + \sum_{i\in N}\sum_{j\in N}\beta_{ij}\sum_{h\in H}x_{ij}^{h} + \sum_{i\in N}\sum_{j\in N}\beta_{ij}\sum_{k\in K}x_{ij}^{k} + \sum_{i\in N}\sum_{j\in N}t_{ij}\sum S_{ij}^{h} \quad (1)$$

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Equation (1) states the travel costs of h medical staff from place i to place j for the provision of health services to patients, stating the cost of travel for the type of medical service k from place i to the provision of health services to patients, stating medical staff honorarium costs h from place i to place j for the provision of health services to patients, the function states the type of service fee to k from place i to place j for the provision of health services to patients, stating the cost of the time needed by medical staff h to arrive at the patient i service.

There are several limitations or constraints that need to be fulfilled.

$$\sum_{j\in N}\sum_{h\in H}\sum_{k\in K} x_{ij}^{hk} = 1 \quad \forall \boldsymbol{i} \in N \setminus \{0\} \tag{2}$$

Equation (2) states that each patient is only served once by medical staff

$$\sum_{i\in N} x_{ij}^{hk} - \sum_{i\in N} x_{ji}^{hk} = 0 \quad \forall \boldsymbol{j} \in N \setminus \{0\}, \quad \forall \boldsymbol{h} \in H, \forall \boldsymbol{k} \in K \tag{3}$$

Equation (3) is proposed to ensure that medical staff depart immediately after completion of the patient's service.

$$\sum_{j\in N}\sum_{k\in K} x_{0j}^{hk} = 1 \quad \forall \boldsymbol{h} \in H \setminus \{0\} \tag{4}$$

$$\sum_{j\in N}\sum_{k\in K} x_{j0}^{hk} = 1 \quad \forall \boldsymbol{h} \in H \tag{5}$$

Equations (4) and (5) to ensure that medical staff can only go and return to the place of the patient who is in dire need.

$$\sum_{i\in R}\sum_{j\in R}\sum_{h\in H}\sum_{k\in K} x_{ij}^{hk} \le |\boldsymbol{R}| - 1 \quad \forall \boldsymbol{R} \subseteq \boldsymbol{N} \setminus \{0\} \tag{6}$$

The sub-tour elimination is given in Equation (6)

$$w_j = maks\left(a_i - s_i - t_{ij}, 0\right) \quad \forall \boldsymbol{j} \in \boldsymbol{N} \setminus \{0, i\} \tag{7}$$

Equation (7) determines the waiting time needed.

$$\sum_{i\in N}\sum_{h\in H}\sum_{k\in K} x_{ij}^{hk}\left(s_i - t_i - t_{ij} + w_j\right) = s_i \quad \forall \boldsymbol{j} \in \boldsymbol{N} \; \{0, i\} \tag{8}$$

Equation (8) gives the time of service that arrives at each patient's place.

$$N_i\left(s_i\right) = y.w_i + \lambda.max\left(s_i - b_i, 0\right) \tag{9}$$

Equations (9) determine the value of penalties if medical staff arrive faster or slower in the place of patients who need service.

$$x_{ij}^{hk} \le y_{jhk} \quad \forall \boldsymbol{i} \in \boldsymbol{N}, \; j \in N \setminus \{0\}, \boldsymbol{k} \in K, h \in H \tag{10}$$

Equation (10) provides that medical staff can provide services only if the medical staff is qualified to carry out a type of health service.

$$D_i + t_{ij} + t_j \le r_{ij} D_j \quad \forall \boldsymbol{i} \in \boldsymbol{N}, \; j \in N \setminus \{0\} \tag{11}$$

Equation (11) presents time limitations. Priority r states that medical staff must immediately go to the location of patients who need higher priority to carry out services.

$$s_i \in [a_i, b_i] \; \forall \boldsymbol{i} \in \boldsymbol{N} \tag{12}$$

$$x_{ij}^{hk} \in \{0,1\} \quad \forall \boldsymbol{i}, j \in N, h \in H, \boldsymbol{k} \in K \tag{13}$$

Equations (12) and (13) state the range of variable decision values.

6. MATHEMATICAL MODELING CALCULATIONS

To carry out mathematical modeling calculations this research is used the Linear Interactive and Discrete Optimizer (LINDO) modeling application. The following is a model to minimize medical staff travel costs h from place i to place j at the time of providing health services to patients, minimizing the cost of travel of medical services type k from place i to place j when providing health services to patients, minimizing medical staff costs h from place i to place j for providing health services to patients, minimize the type of service costs to k from place i to place j at the time of providing health services to patients, minimizing the time needed for medical staff h to arrive at the patient i who need services is as follows :

Min 10 A11 + 5 A12 + 4 A13 + 4 A14 + 3 A15
+ 9 A21 + 5 A22 + 9 A23 + 5 A24 + 1 A25
+ 3 A31 + 10 A32 + 9 A33 + 4 A34 + 10 A35
+ 4 A41 + 8 A42 + 9 A43 + 1 A44 + 1 A45
+ 1 A51 + 4 A52 + 3 A53 + 10 A54 + 7 A55
+ 2 A11 + 2 A12 + 7 A13 + 8 A14 + 9 A15
+ 10 A21 + 1 A22 + 7 A23 + 1 A24 + 4 A25
+ 8 A31 + 2 A32 + 2 A33 + 10 A34 + 7 A35
+ 8 A41 + 9 A42 + 10 A43 + 10 A44 + 3 A45

+ 6 A51 + 10 A52 + 2 A53 + 1 A54 + 6 A55
+ 10 B11 + 7 B12 + 8 B13 + 3 B14 + 5 B15
+ 8 B21 + 8 B22 + 4 B23 + 1 B24 + 2 B25
+ 4 B31 + 6 B32 + 4 B33 + 3 B34 + 9 B35
+ 8 B41 + 3 B42 + 5 B43 + 8 B44 + 1 B45
+ 8 B51 + 9 B52 + 4 B53 + 8 B54 + 4 B55
+ 8 B11 + 8 B12 + 10 B13 + 2 B14 + 4 B15
+ 8 B21 + 1 B22 + 7 B23 + 6 B24 + 1 B25
+ 4 B31 + 2 B32 + 6 B33 + 7 B34 + 1 B35
+ 8 B41 + 2 B42 + 4 B43 + 5 B44 + 3 B45
+ 5 B51 + 9 B52 + 5 B53 + 2 B54 + 5 B55
+ 1 T11 + 10 T12 + 5 T13 + 10 T14 + 1 T15
+ 9 T21 + 6 T22 + 8 T23 + 4 T24 + 3 T25
+ 4 T31 + 3 T32 + 5 T33 + 5 T34 + 7 T35
+ 10 T41 + 1 T42 + 9 T43 + 5 T44 + 6 T45
+ 8 T51 + 8 T52 + 10 T53 + 8 T54 + 6 T55

Information obtained that the maximum value of the objective function is 75 and the optimal decision variable value is:

Table 6: Variable Value of Optimal Decisions

VARIABLE	VALUE	REDUCED COST
A11	0,00	3,00
A12	0,00	4,00
A13	0,00	7,00
A14	0,00	0,00
A15	1,00	0,00
A21	0,00	2,00
A22	0,00	4,00
A23	0,00	8,00
A24	0,00	2,00
A25	1,00	0,00
A31	0,00	5,00
A32	0,00	12,00
A33	0,00	2,00
A34	1,00	0,00
A35	0,00	0,00
A41	0,00	7,00
A42	0,00	5,00
A43	0,00	3,00
A44	1,00	0,00
A45	0,00	2,00
A51	0,00	7,00
A52	1,00	0,00
A53	0,00	14,00
A54	0,00	7,00
A55	0,00	12,00
B11	0,00	5,00
B12	0,00	6,00
B13	1,00	0,00
B14	0,00	4,00
B15	0,00	10,00
B21	0,00	8,00
B22	0,00	7,00
B23	0,00	4,00
B24	0,00	4,00
B25	1,00	0,00
B31	0,00	6,00
B32	0,00	6,00
B33	0,00	8,00
B34	0,00	13,00
B35	1,00	0,00
B41	0,00	0,00
B42	1,00	0,00
B43	0,00	1,00
B44	0,00	5,00
B45	0,00	0,00
B51	0,00	7,00
B52	1,00	0,00
B53	0,00	3,00
B54	0,00	6,00
B55	0,00	4,00
T11	0,00	0,00
T12	0,00	0,00
T13	0,00	0,00
T14	1,00	0,00
T15	0,00	0,00
T21	0,00	0,00
T22	1,00	0,00
T23	0,00	0,00
T24	0,00	0,00
T25	0,00	0,00
T31	0,00	0,00
T32	1,00	0,00
T33	0,00	0,00
T34	0,00	0,00

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

T35	0,00	0,00
T41	0,00	0,00
T42	0,00	0,00
T43	0,00	0,00
T44	1,00	0,00
T45	0,00	0,00
T51	0,00	0,00
T52	0,00	0,00
T53	0,00	0,00
T54	0,00	0,00
T55	1,00	0,00

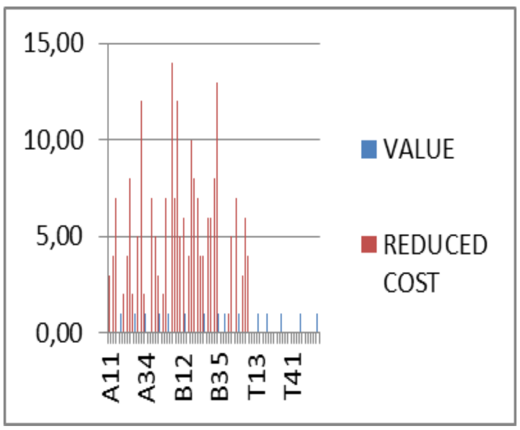

Figure 1: Variable Value of Optimal Decisions

Table 7: Slack or Surplus

ROW	SLACK OR SURPLUS	DUAL PRICES
2)	0,00	-8,00
3)	0,00	-9,00
4)	0,00	-7,00
5)	0,00	-10,00
6)	0,00	-4,00
7)	0,00	0,00
8)	0,00	0,00
9)	0,00	0,00
10)	0,00	0,00
11)	0,00	0,00
12)	0,00	0,00
13)	0,00	0,00
14)	0,00	0,00
15)	0,00	0,00
16)	0,00	0,00
17)	0,00	0,00
18)	0,00	0,00
19)	0,00	0,00
20)	0,00	0,00
21)	0,00	0,00
22)	0,00	0,00
23)	0,00	0,00
24)	0,00	0,00
25)	0,00	0,00
26)	0,00	0,00
27)	0,00	0,00
28)	0,00	0,00
29)	0,00	0,00
30)	0,00	0,00
31)	0,00	0,00
32)	0,00	-5,00
33)	0,00	-11,00
34)	0,00	-2,00
35)	0,00	-8,00
36)	0,00	-8,00
37)	0,00	0,00
38)	0,00	0,00
39)	0,00	0,00
40)	0,00	0,00
41)	0,00	0,00
42)	0,00	0,00
43)	0,00	0,00
44)	0,00	0,00
45)	0,00	0,00
46)	0,00	0,00
47)	21,00	0,00
48)	35,00	0,00
49)	21,00	0,00
50)	27,00	0,00
51)	37,00	0,00

Journal of Theoretical and Applied Information Technology
30th June 2019. Vol.97. No 12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

52)	0,00	-1,00
53)	0,00	-1,00
54)	0,00	-1,00
55)	0,00	-1,00
56)	0,00	-1,00

Slack or surplus provides information on whether the constraints are active or not. If the slack or surplus is zero, then the constraints include active constraints. But if it is not zero, then the constraints do not include active constraints. For example, at line 5, this obstacle is the active resistance with a negative double price, which is 10.00. This value indicates that the addition of each unit value of the right segment in an obstacle will cause the objective function value to decrease by 10.00.

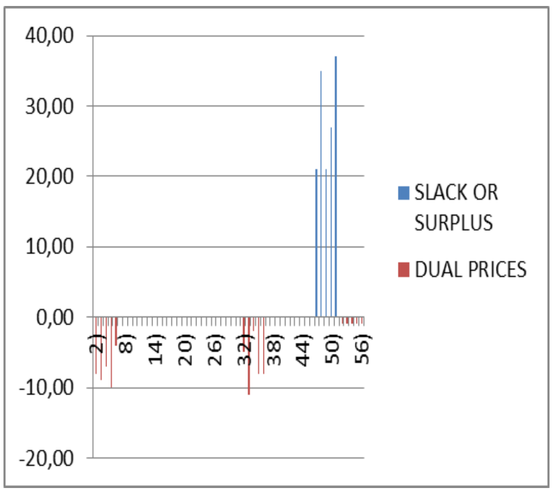

Figure 2: Graph of slack or surplus

The output of the sensitivity analysis is as follows:

Table 8: Sensitivity Analysis

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
A11	11,00	INFINITY	3,00
A12	12,00	INFINITY	4,00
A13	15,00	INFINITY	7,00
A14	8,00	INFINITY	0,00
A15	8,00	0,00	INFINITY
A21	11,00	INFINITY	2,00
A22	13,00	INFINITY	4,00
A23	17,00	INFINITY	8,00
A24	11,00	INFINITY	2,00
A25	9,00	2,00	INFINITY
A31	12,00	INFINITY	5,00
A32	19,00	INFINITY	12,00
A33	9,00	INFINITY	2,00
A34	7,00	0,00	INFINITY
A35	7,00	INFINITY	0,00
A41	17,00	INFINITY	7,00
A42	15,00	INFINITY	5,00
A43	13,00	INFINITY	3,00
A44	10,00	2,00	INFINITY
A45	12,00	INFINITY	2,00
A51	11,00	INFINITY	7,00
A52	4,00	7,00	INFINITY
A53	18,00	INFINITY	14,00
A54	11,00	INFINITY	7,00
A55	16,00	INFINITY	12,00
B11	10,00	INFINITY	5,00
B12	11,00	INFINITY	6,00
B13	5,00	4,00	INFINITY
B14	9,00	INFINITY	4,00
B15	15,00	INFINITY	10,00
B21	19,00	INFINITY	8,00
B22	18,00	INFINITY	7,00
B23	15,00	INFINITY	4,00
B24	15,00	INFINITY	4,00
B25	11,00	4,00	INFINITY
B31	8,00	INFINITY	6,00
B32	8,00	INFINITY	6,00
B33	10,00	INFINITY	8,00
B34	15,00	INFINITY	13,00
B35	2,00	6,00	INFINITY
B41	8,00	INFINITY	0,00
B42	8,00	0,00	INFINITY
B43	9,00	INFINITY	1,00
B44	13,00	INFINITY	5,00
B45	8,00	INFINITY	0,00
B51	15,00	INFINITY	7,00
B52	8,00	3,00	INFINITY

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

B53	11,00	INFINITY	3,00
B54	14,00	INFINITY	6,00
B55	12,00	INFINITY	4,00
T11	1,00	INFINITY	0,00
T12	5,00	INFINITY	0,00
T13	9,00	INFINITY	0,00
T14	1,00	0,00	1,00
T15	6,00	INFINITY	0,00
T21	10,00	INFINITY	0,00
T22	7,00	0,00	7,00
T23	10,00	INFINITY	0,00
T24	7,00	INFINITY	0,00
T25	8,00	INFINITY	0,00
T31	8,00	INFINITY	0,00
T32	2,00	0,00	2,00
T33	9,00	INFINITY	0,00
T34	4,00	INFINITY	0,00
T35	10,00	INFINITY	0,00
T41	7,00	INFINITY	0,00
T42	4,00	INFINITY	0,00
T43	7,00	INFINITY	0,00
T44	3,00	0,00	3,00
T45	9,00	INFINITY	0,00
T51	10,00	INFINITY	0,00
T52	8,00	INFINITY	0,00
T53	9,00	INFINITY	0,00
T54	10,00	INFINITY	0,00
T55	3,00	0,00	3,00

There is information about sensitivity analysis. The variable column shows the decision variable, and the current column coefficient shows the objective function coefficient. While the allowable increase in variable A11 is the value increase limit so as not to change the optimal value of the decision variable. Whereas the allowable decreases and the limit decreases so as not to change the optimal value of the decision variable.

7. CONCLUSIONS

The conclusions from the results of this study are as follows:

1. Obtained information that the maximum value of the objective function is 75.00000 at the 28th iteration step
2. The Smart health service optimization model is the optimization of health service delivery based on the Smart Health concept, by providing quality care services as quickly as possible to patients by reducing health care costs and, overcoming the problem of lack of limited nursing staff resources with maximum use of resources.
3. This model is a model that minimizes travel costs, service costs and other costs that arise due to inaccuracies in providing services to patients.

REFRENCES:

[1] D. Niyigena, C. Habineza, and T. S. Ustun, “Computer-based smart energy management system for rural health centers,” in *Proceedings of 2015 IEEE International Renewable and Sustainable Energy Conference, IRSEC 2015*, 2016.

[2] H. Demirkan, “A smart healthcare systems framework,” *IT Prof.*, vol. 15, no. 5, pp. 38–45, 2013.

[3] L. Catarinucci *et al.*, “An IoT-Aware Architecture for Smart Healthcare Systems,” *IEEE Internet Things J.*, vol. 2, no. 6, pp. 515–526, 2015.

[4] E. B. Nababan, A. R. Hamdan, S. Abdullah, and M. S. Zakaria, “A branch and bound algorithm in optimizing job shop scheduling problems,” in *Proceedings - International Symposium on Information Technology 2008, ITSim*, 2008.

[5] M. Y. Lin, K. S. Chin, and K. L. Tsui, “A weighted multi-objective therapist assignment problem in Hong Kong,” in *IEEE International Conference on Industrial Engineering and Engineering Management*, 2016.

[6] S. Sitepu, H. Mawengkang, and Irvan, “Modeling an integrated hospital management planning problem using integer optimization approach,” in *Journal of Physics: Conference Series*, 2017.

[7] A. M. H. Pardede *et al.*, “A Framework For Sharing Patient Data And Service Facilities Using Ipv6 Technology To Support The Advancement Of Smart Health Care Technologies A,” in *Journal of Physics: Conference Series*, 2019.

[8] S. Sitepu and H. Mawengkang, “A Two-Stage Stochastic Optimization Model Of

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Hospital Nursing Staff Management Problem," *Int. J. Adv. Res. Comput. Eng. Technol.*, vol. 4, no. 1, pp. 44–47, 2015.

[9] 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.

[10] A. M. H. Pardede, Y. Maulita, and R. Buaton, "Application modeling ipv6 (internet protocol version 6) on e-id card for identification number for effectiveness and efficiency of registration process identification of population," in *Journal of Physics: Conference Series*, 2018, vol. 978, no. 1.

[11] S. S. Al-Majeed, I. S. Al-Mejibli, and J. Karam, "Home telehealth by Internet of Things (IoT)," in *Canadian Conference on Electrical and Computer Engineering*, 2015.

[12] P. Szolovits, J. Doyle, W. J. Long, I. Kohane, and S. G. Pauker, "Guardian Angel : Patient-Centered Health Information Systems," no. May, pp. 1–43, 1994.

[13] F.-Z. Younsi, A. Bounnekar, D. Hamdadou, and O. Boussaid, "SEIR-SW, Simulation Model of Influenza Spread Based on the Small World Network," *Tsinghua Sci. Technol.*, vol. 20, no. 5, pp. 460–473, 2015.

[14] N. Moradianzadeh, P. M. Zadeh, Z. Kobti, and K. Pfaff, "An agent model to support social network-based palliative care," in *2017 IEEE Symposium on Computers and Communications (ISCC)*, 2017.

[15] S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything you wanted to know about smart cities," *IEEE Consum. Electron. Mag.*, vol. 5, no. 3, pp. 60–70, 2016.

[16] A. M. H. Pardede, Y. Maulita, R. Buaton, H. Mawengkang, and M. Zarlis, "IPv6 Modeling in E-ID Cards as Efficiency Efforts in the Population Registration Process," *Jour Adv Res. Dyn. Control Syst.*, vol. 10, no. 07–Special Issue, pp. 1874–1878, 2018.

[17] M. Musoke, "Simple ICTs reduce maternal mortality in rural Uganda: a telemedicine case study," *Bull. von Med. Mundi Schweiz*, 2002.

[18] D. Hartama, H. Mawengkang, M. Zarlis, and R. W. Sembiring, "Smart City: Utilization of IT resources to encounter natural disaster," in *Journal of Physics: Conference Series*, 2017.

[19] D. Hartama *et al.*, "A research framework of disaster traffic management to Smart City," in *2017 Second International Conference on Informatics and Computing (ICIC)*, 2017, pp. 1–5.

[20] F. Ghassami and M. Ghandehary, "An investigation on the effect of electronic management information system on inventory control of hospital pharmaceutical," in *8th International Conference on e-Commerce in Developing Countries: With Focus on e-Trust*, 2014, pp. 1–5.

[21] S. Sakib, R. Haq, and T. Wazed, "Unified mobile public health care system (UMPHCS) for underdeveloped countries," in *2014 International Conference on Informatics, Electronics and Vision, ICIEV 2014*, 2014.

[22] H. N. Saha, N. F. Raun, and M. Saha, "Monitoring patient's health with smart ambulance system using Internet of Things (IOTs)," in *2017 8th Industrial Automation and Electromechanical Engineering Conference, IEMECON 2017*, 2017.

[23] P. M. Cunningham *et al.*, "Implications of baseline study findings from rural and deep rural clinics in Ethiopia, Kenya, Malawi and South Africa for the co-design of mHealth4Afrika," in *GHTC 2016 - IEEE Global Humanitarian Technology Conference: Technology for the Benefit of Humanity, Conference Proceedings*, 2016.

[24] 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.

[25] A. Thompson, E. Castle, P. Lubeck, and P. S. Makarfi, "Experience implementing OpenMRS to support maternal and reproductive health in Northern Nigeria," in *Studies in Health Technology and Informatics*, 2010, vol. 160, no. PART 1, pp. 332–336.

[26] F. Ngabo *et al.*, "Designing and implementing an innovative SMS-based alert system (RapidSMS-MCH) to monitor pregnancy and reduce maternal and child deaths in Rwanda," *Pan Afr. Med. J.*, 2012.

[27] A. Solanas *et al.*, "Smart health: A context-aware health paradigm within smart cities," *IEEE Commun. Mag.*, vol. 52, no. 8, pp.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

74–81, 2014.

[28] 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.

[29] 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.

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

[31] A. Alsalemi *et al.*, "Developing cost-effective simulators for patient management: A modular approach," in *2017 Fourth International Conference on Advances in Biomedical Engineering (ICABME)*, 2017, pp. 1–4.

[32] K. Dorling, J. Heinrichs, G. G. Messier, and S. Magierowski, "Vehicle Routing Problems for Drone Delivery," *IEEE Trans. Syst. Man, Cybern. Syst.*, 2017.

[33] 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.

[34] A. M. H. Pardede *et al.*, "Smart Health Model With A Linear Integer Programming Approach," in *Journal of Physics: Conference Series*, 2019.