Improving Service Delivery through Facility Layout Optimization: A Process Mapping Analysis in Teklehaimanot Health Center

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DECLARATION

I hereby declare that this thesis, entitled " Improving Service Delivery through Facility Layout Optimization: A Process Mapping Analysis in Tekelehaimanot Health Center" is the result of my own work and research, except where otherwise acknowledged. This work has not been submitted previously, in whole or in part, to qualify for any other academic award. All sources of information and data used have been duly acknowledged.

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Abstract

Teklehaimanot Health Center plays a crucial role in providing healthcare service to the community in Addis Ababa, Ethiopia. However, providing service with short waiting and service time to the community has been presented as a challenge in the healthcare facility. Teklehaimanot Health Center still struggles to deliver quality service to patients due to suboptimal layout design of the health center facility. This paper aims to optimize the facility layout of the outpatient department to improve the service delivery of Teklehaimanot Health Center. The objective is to develop a health center facility layout in Teklehaimanot Health Center that will improve service delivery by exchanging the department room by considering patient path. The research methodology consists of qualitative and quantitative data collection related to the time for every operation that takes place under the outpatient department. The proposed research integrates process mapping analysis, time study, facility layout techniques, multi-criteria decision making, and simulation to address the issue presented. Service time and waiting time are the key measuring variables. From the existing facility, a redesigned layout is developed, and simulation is used to validate the new optimized layout. By utilizing process mapping analysis integrated with time study and facility layout improvement, the research provides data-driven recommendations for the health center facility layout with minimum unnecessary movement of patients and minimum travel distance. The impact is evaluated by measuring the variables of service and waiting time the improvements in waiting time and service time achieved through the facility layout changes are likely very significant and impactful for the Teklehaimanot Health Center. Based on the result, the optimized proposed facility layout minimizes the average waiting time from 2.5 hours to 2.01 hours, which is a 19.60% reduction, and minimizes the service time from 0.79 hours to 0.64 hours, which is an 18.98% reduction. This shows a positive impact on improving service delivery and patient satisfaction in the health center.

Keywords: Service Delivery, Patient Satisfaction, Facility Layout, Service Improvement, Health Center

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Abbreviations

AHP - Analytical Hierarchy Process

ALDEP - Automated Layout Design Program

ANC - Antenatal Care

CAC - Compressive Abortion Care

CR - Consistency Ratio

CRAFT - Computerized Relative Allocation of Facilities Technique

DES - Discrete Event Simulation

KP - Key Population

KPIs- Key Performance Indicators

MCDM - Multi Criteria Decision Making

MOH - Ministry of Health

OPCS - Office of Population Censuses and Surveys

OPD - Outpatient Department

PMTCT - Prevention of HIV Mother to Child Transmission

SERVQUAL - Service Quality

SLP - Systematic Layout Planning

SNS - Social Network Strategy

THC - Teklehaimanot Health Center

VCT - Voluntary Counseling and Testing

Chapter One

1. Introduction

1.1. Introduction

Quality of service is an attitude and services are intangible, it is more acceptable to measure client attitudes using a performance-based method (Singh & Dixit, 2020). Now a days most service industries need to improve their quality-of-service through continuous assessment and evaluation (Nino et al., 2021). Most industry have unique customer so the measuring variables will vary based on the unique needs of their customer. So, companies should keep their eyes on their customer need in this fast-paced service industry (Xing et al., 2020). When this is applied to health services, every measuring dimension is sensitive since health is essential service that should be fulfilled and provided by the government.

In Ethiopia, most patients complain about service quality in health centers. To provide better healthcare service, dimensions of service quality need to be defined and then measured to increase patients' satisfaction. Improving service delivery in health centers in Ethiopia is pivotal for intensifying the overall healthcare system and fortifying better health outcomes for the population. To effectively tackle these challenges in a long-lasting manner, health centers must enhance their services by focusing on response time, cost efficiency, service time, and optimal utilization of resources (Tsinukal, 2019). By ensuring efficient and effective service, health centers can better meet the healthcare needs of patients. Numerous writers have maintained that ideas that were first created to increase the efficacy and efficiency of manufacturing processes can also be used to enhance the provision of services (Tarigan et al., 2020). Healthcare facilities should include creating settings that are suitable for the delivery of care to communities, boosting operational effectiveness, and enhancing patient flow and experiences (K. et al., 2021).

The study deals with how to improve the service delivery of Teklehaimanot Health Center by optimizing facility layout through process mapping analysis by integrating it with time study to track patient path and increase patient satisfaction by reducing service and waiting time since the current facility layout is not designed optimally as per closeness relationship of departments and minimum travel distance which contribute to unnecessary movement in the facility.

1.2. Background and justification

Due to the growing economic pressure, there is an increasing interest in improving service in health centers. The degree to which healthcare services meet or exceed the requirements and expectations of patients, caregivers, and other stakeholders is a typical definition of service quality in healthcare context and it includes several elements, such as patient-centeredness, timeliness, safety, efficacy, and equity of healthcare services (Bera et al., 2023).

The Health Sector Transformation Plan, created by the Ethiopian Ministry of Health, describes the strategic aims and objectives for the nation's healthcare sector. The significance of enhancing patient experience and service quality is emphasized in this plan. Furthermore, numerous research projects and publications in Ethiopia have examined various facets of the quality of healthcare services, frequently concentrating on certain dimensions including infrastructure quality, patient satisfaction, and healthcare staff competence (Tsinukal, 2019).

Teklehaimanot Health Center is a notable healthcare facility in Addis Ababa, Ethiopia. Named after the renowned Ethiopian physician, Dr. Yemane Teklehaimanot; the center is crucial in delivering primary healthcare services to the local community. The primary aim of Teklehaimanot Health Center is to provide accessible, comprehensive, and quality healthcare services to individuals, families, and communities within its catchment area. As a public health center, it serves as the first point of contact for individuals seeking healthcare services, emphasizing preventive care, health promotion, and basic treatment for common illnesses and injuries.

In Teklehaimanot Health Center, there is service quality assurance section but this department does assess the quality of healthcare service provided through questionnaires. According to the company report (Teklehaimanot Health Center's annual report, 2023, quality assurance department) shows that patients are 48% satisfied with the service, they get from Teklehaimanot Health Center. But the problem is the questionnaires used by the service quality assurance department don't measure which dimension to focus on and improve rather it measure service quality by the number of patients that get a chance to meet with healthcare providers which excludes response time (i.e. response time is the amount of time it takes for a patient to receive the necessary care or attention from the time they arrive at the health center facility), waiting time and service time. According to (Teklehaimanot Health Center monthly report, 2024, Quality Assurance Department) in January data from interviews with patients 50% of patients answered that the layout of the facility is bad and causing them to go here and there to get the service which shows a need for improvement is mandatory.

During observation, the facility layout is affecting the service delivery time of Teklehaimanot Health Center, areas of improvement can be assessed for every operation through process mapping analysis by taking time measures following patients' path. According to (Teklehaimanot Health Center's annual report, 2023, quality assurance department) company report, it shows that average the waiting time is 2.5hr which may cause death if the case is for seriously ill patient so it shows a pressing need for improvement. Therefore, redesigning the facility layout of the existing facility layout of the health center that will reduce waiting and service time is developed to enhance service delivery & patient satisfaction.

1.3. Problem statement

Most service providing companies in Ethiopia face challenges to meet or exceed customer satisfaction. When looking into healthcare sector the satisfaction level of patients is recorded as 50% with average length of stay 6-7 days which shows a gap to improve the service delivery of the health centers in general (Tsinukal, 2019).

The service quality at Teklehaimanot health center is suboptimal and there is a recognized need for improvement. The facility layout is one important area that has been recognized as a possible source of service inefficiency. The ground plus four building current layout is insufficient to allow for efficient patient flow and prompt service delivery. This causes a delay and has a detrimental effect on the general level of care that patients receive.

Insufficient facility layout in Teklehaimanot Health Center ground plus three building layout is inadequate to facilitate the provision of high-quality health service. Long waiting line before patients reach to health care providers (i.e. not sufficient space for the community to get health-related information during entrance during the service due to long waiting line). According to the company report (Teklehaimanot Health Center's annual report, 2023, quality assurance department), the average waiting time for outpatient service is 2.5hr & service time is 0.79hr. Inefficient departmental room and facility layouts cause problems with patient flow, all of which add to inefficient service delivery and dissatisfaction among patients.

Teklehaimanot Health Center's service quality is badly impacted by the constraints of the existing facility layout. The layout's inefficiencies result in delays, long waiting time, and lower patient satisfaction levels. These elements make it more difficult for the health center to deliver a seamless and fulfilling medical experience to patients. The current reason for the long waiting line is the wrong working procedure of reception room workers (reception room workers will wait for patients to be more than 15 to go to the doctors' room) because the reception room is far from multistory building and all OPD rooms are in the 2nd floor whereas laboratory and triage room is in the ground floor of multistory building. Therefore, departmental rooms are not designed as per closeness relationship which lack patient centered layout. It is best to perform process analysis in advance before proceeding to improve facility layout to further improve service delivery time (Ceylan et al., 2023).

Teklehaimanot Health Center's ground plus three buildings lack an optimal facility layout, which makes it more difficult for the facility to provide effective and high-quality healthcare services due to unnecessary movement associated in the facility. Solving this issue will lead to better patient satisfaction, higher-quality service delivery and more efficient use of the facility resources.

All of the above-listed problems in the service delivery of Teklehaimanot Health Center result in long waiting and service time that affect the service delivery. So, this long waiting time and service time shows a gap that needs improvement. Therefore, there is a pressing need to conduct a comprehensive process mapping analysis that focuses on patient path and explore facility layout optimization strategies to improve service delivery and address the identified challenges at Teklehaimanot Health Center.

1.4. Research Questions

The research questions of the study are;

- How the current facility layout can be modified by considering the closeness relationship between each department and minimizing unnecessary movement of patients to enhance service delivery of Teklehaimanot Health Center?
- What is the expected impact of the facility layout modification that will be proposed in terms of service time delivery, and enhances patient satisfaction at Teklehaimanot Health Center?
- What are the potential cost implications associated with redesigning the existing facility layout and reorganizing departmental rooms to improve service delivery at Teklehaimanot Health Center?

1.5. Objective of the Study

1.5.1. General objective

The general objective of the study is to improve service delivery of Teklehaimanot Health Center by optimizing existing facility layout through process mapping analysis.

1.5.2. Specific objective

The specific objectives of the study are;

- To identify opportunities to optimize the facility layout of Teklehaimanot Health Center by considering closeness relationship between departments that will improve service delivery.
- To propose evidence-based facility layout modifications to address challenges and inefficiencies related to service delivery such as; long waiting time and long service time.
- To estimate the potential cost implications associated with redesigning the existing facility layout and reorganizing departmental rooms to improve service delivery at Teklehaimanot Health Center.

1.6. Scope and limitations of the study

1.6.1. Scope of the study

The scope of this health center facility layout optimization study to improve service delivery focuses on a specific geographical area or health center facility, examining the aspects of service delivery such as patient flow, waiting time, service time, staff-patient interactions and patient experience by tracking patient path. The primary objective of the study is to improve service delivery by optimizing the existing layout of the health center facility considering factors such as physical arrangement of rooms based on closeness relation of different departments in outpatient department. Teklehaimanot health center was selected as the case study for this research due to its accessibility and cooperative nature in providing the necessary data, information, and access required for the study. This pragmatic consideration of accessibility and cooperation was a key factor in selecting the Teklehaimanot health center as the most suitable case study for this research. For this research Teklehaimanot health center is selected as a case company among 26 public health service providers in Addis Ababa, Ethiopia. Since the study focus on improving service delivery by optimizing the facility layout, it only focuses on operational process of outpatient department of Teklehaimanot Health Center using patient path record in each section from entrance to exist of every patient to understand the service gap presented from the root so that the research can deliver accurate information and result. The study is conducted within a specified timeframe, ensuring that resources and data collection efforts remain manageable and aligned with the defined boundaries.

1.6.2. Limitations of the study

The study contract data from Teklehaimanot Health Center and this data is collected from patients, healthcare providers, and company reports but getting clear and consistent data was difficult because most healthcare service providers give little attention to data related to time so this gap is cleared once the data collection started. In addition, to get more accurate data discussions is conducted to collect relevant data and information with service quality department, healthcare providers, and patients about the service since data are very important.

The facility layout that has been suggested is tested and validated using arena simulation software. The size and complexity of models that were built and simulated in the Arena student version were constrained and a greater variety of sophisticated capabilities were not accessible. So, simplification of the model is considered since the research focuses on key objective variables which are waiting time and service time that most significantly impact on improving service delivery. By reducing the complexity of the model, it is still possible to obtain meaningful results.

1.7. Significance of the study

By employing process mapping technique, this research aims to provide evidence-based insights into the potential improvements that can be achieved through optimizing the facility layout of Teklehaimanot health center. The layout that will be proposed will lead to reduce service delivery time, improve patient experiences and enhance overall service delivery & patient satisfaction. The findings of this research will contribute to the existing body of knowledge on healthcare facility layout optimization and will provide practical recommendations for healthcare administrators and facility managers to enhance service delivery & patient satisfaction in similar settings.

Also, university graduate students, undergraduate students, academicians, research institutions and individuals who are willing to conduct studies related to this topic in the future will get benefit from this research.

1.8. Organization of the paper

The research thesis consists of five sections. The first section introduces the general overview of the title, background and justification will be presented, main problems of the research will be discussed with research question that this research will answer, objective will be defined, scope and limitation will be presented. Section two comprises the literature review and the theoretical background. The third section deals with the methodology used to collect data for the research and will define analysis techniques with a framework. The fourth section contains the data analysis, results and discussion of the study. The fifth section gives a conclusion, recommendation and further research area.

Chapter Two

2. Literature Review

2.1. Introduction of service delivery

Service delivery is the output of service-providing company or organization that will determine customer satisfaction (Ponsignon et al., 2023). In many service-providing businesses customers are the main stakeholders and these organizations should work hard to meet and exceed their customer expectations (Swain & Kar, 2018). In general, understanding and determining what customers need is the crucial point to focus on improving service delivery (Lai & Chong, 2019). Continuous improvement in the provision of services, comprehension of customers' requirements, consideration of their opinions, and improvement of the customer-provider relationship are all necessary to promote customer satisfaction (Singh & Dixit, 2020). These days, small and medium-sized businesses face several issues and difficulties when implementing and reviving overall quality management into their service (AlOmari, 2021). Companies should create and put into practice suitable service delivery improvement plans that can be adapted to the changing needs and preferences of their clients (Bhat & Dar, 2018). In particular, the fact that meeting or surpassing client expectations is not always possible because doing so results in excessive use of resources and raises the cost of the service (Barrios et al., 2021). Stated differently, managers seek to enhance customer satisfaction, a goal that ought to stem from business strategy (Kitsios et al., 2019). Since providing services to consumers or users is the focus of service operations management, it also entails managing the processes that carry out those services, making sure goals are reached, and looking for ways to improve in the existing processes (Pena et al., 2013). Services are fundamentally distinct from physical items since they are interpersonal and intangible in nature, generated and consumed simultaneously, and co-produced with the client (Lai & Chong, 2019). The service concept entails designing and evaluating every component of service from the viewpoints of the customer and seller (Ponsignon et al, 2023). When customers can engage with the service provider in the service production process, it is more likely to infuse unpredictability into their demands (Swain & Kar, 2018). As services that will be provided in different organizations are different, knowing what customers need as per the service context of their organization is very important, and once the need of the customer is satisfied organizations need to strive to exceed their expectations in this rapidly changing environment to survive and stay competitive.

2.2. Service delivery in healthcare

All phases of the production process involve quality inspections for tangible output but due to the intangible nature of health services, patient-provider interactions and service delivery methods determine the quality of care received (Singh & Dixit, 2020). Improving the quality of healthcare services is one of the global healthcare industry's top priorities (Tsinukal, 2019). Technological advancements, societal awareness, functional and technical aspects all influence how patients view quality in healthcare service (Verma et al., 2020). Mastery of patient needs and expectations helps to enhance customer satisfaction by the service that will be delivered (Ali, 2018). Healthcare managers must evaluate each element to comprehend how patient perceptions are created (AlOmari, 2021). To deliver high-quality service to patients in the healthcare environment, healthcare providers should know better than their patients to increase their satisfaction level (Habidin et al., 2015). Like other service-providing companies or organizations health centers should also define, measure, and work for improvement to deliver quality service to patients and stay competitive in the market due to the multidimensionality of the attributes that these services possess.

Service quality measures in health centers are instruments that are used in science to quantify the quality of healthcare services (Shuv-Ami & Shalom, 2020). The Donabedian model is a fundamental framework for assessing the quality of healthcare that was created in the 1960s by well-known health services researcher Avedis Donabedian which the model suggests that three interconnected elements such as; structure, procedure, and outcomes—can be used to evaluate the quality of treatment and the environments, healthcare providers, and administrative frameworks under which healthcare is provided are referred to as the structural component which covers elements including a healthcare facility's architectural plan and architecture, the resources and equipment that are available, and the organizational traits that make service delivery possible (Naz et al., 2022). Another one well-known service quality model that has been used to measure service quality in the healthcare context is SERVQUAL lately has 10 dimensions which are reliability, access, responsiveness, competence, courtesy, communication, credibility, security, understanding the customer, and tangibles to measure the gap between customer expectations and experience and later on 1988 measuring dimensions has been reduced to responsiveness, assurance, tangibles, empathy, and responsiveness (Yucesan & Gul, 2020). The main importance of SERVQUAL for managers is that; it helps when organization resources are limited and shows a necessary area where service gaps are presented and the intention to close these gaps by managers is likely to increase the service quality perception and patient satisfaction (Pekkaya et al., 2019). Another listed importance of SERVQUAL model is that; it is known for its reliability; customers can easily and quickly fill the questionnaire, easy to analyze and interpret (Ali, 2018). Another model used to evaluate quality of service in health centers' is Kano model and it classifies customer preferences into must-be quality, one-dimensional quality, attractive quality, indifferent quality and reverse quality based on patient satisfaction, dissatisfaction, and delight (Barrios-Ipenza et al., 2021). It assists in determining which characteristics can raise or lower satisfaction, enabling healthcare managers to concentrate on the most important elements and deploy resources effectively (Barrios et al., 2021). The two main factors nowadays patients search for in high-quality medical treatment are cost and service quality (Habidin et al., 2015). Most researchers argue on the quality model that should be used to assess the quality in service sectors and SERVQUAL is listed as the best measuring model in healthcare settings because it assesses the gap between the expectations versus perceived quality since every service-providing company has its unique customer that the service will address (AlOmari, 2021). When it comes to healthcare service quality the satisfaction level is mainly affected by how many patients are cured by the service providers on time with low cost (Pekkaya et al., 2019). So, to satisfy patients it's vital to focus on different dimensions with a core to deliver error-free and on-time service.

After defining the right quality model, measuring quality dimensions is the next step that should be addressed to find gaps and areas of improvement in service delivery. Most researchers argue on dimensions of service quality because defining the right dimensions of quality service is a crucial stage to know area of improvement. It is observed that in private hospitals the building environment is the main factor that will facilitate the fast treatment and recovery process of patients by giving great attention to interior layout and architectural attributes (Lai & Chong, 2019). In most research the significant dimension that shows gap in the healthcare context is reliability (Pekkaya et al., 2019) in contrast in physiotherapy and rehabilitation hospital tangibility has shown a high negative score which means lower satisfaction that will lead to lower service delivery (Behdioğlu et al., 2019). In other study from SERVQUAL model, reliability was found to be the most determinant dimension for outpatients' department (Pekkaya et al., 2019). One factor that can be considered as a gap in many healthcare sectors is the long waiting time, and service locations, to minimize this gap E-service appointment system is presented as a solution (Kitsios et al., 2019). Furthermore, the length of waiting time affects the choice of returning to the service provider (Swain & Kar, 2018). On the other hand, dissatisfaction is associated with both high costs and limited access to care, long waiting time, shoddy department housekeeping and a strained doctor-patient bond are additional causes of dissatisfaction and low service delivery (Ali, 2018). Patient satisfaction was gauged by the health center's accessibility, waiting times, costs associated with insurance and treatment, atmosphere, and the caliber of services provided, patients placed the most value on accessibility to the health center and waiting time (Singh & Dixit, 2020). Even if there is no recorded data regarding waiting & service standard time in health centers as per MOH in Ethiopia, this research uses other literature finding from worldwide as benchmark. A study conducted in University of Nairobi, Kenya shows that the average waiting time in outpatient department is 55.3min which doubled in the case of THC (Wafula & Ayah, 2021). And again, study in UK primary care clinic shows that the average waiting time calculated to be 43min (McIntyre & Chow, 2020). As finding shows average waiting time in Addis Ababa, Ethiopia is 30 to 101min but THC waiting time are pass the higher end of the spectrum (Biya et al., 2022). So, healthcare service providers should pay attention on what is highly contributing to long waiting times and proceed to look for the root causes to reduce patient dissatisfaction and improve service delivery.

2.3. Facility layout for improving service delivery

Facility layout problem is an integral part of facility planning that aims to systematically arrange and locate all production units within a facility to improve the production operations of a company (C et al., 2018). It makes the case that healthcare service delivery and infrastructure design ought to be coordinated during planning and implementation and the goal of this integration is to assist value creation (Tzortzopoulos et al., 2008). In order to reduce wait times and congestion by applying queue theory, looks at how spaces are physically arranged, resources are distributed, and patient arrivals and throughput are managed so patient flow and the quality of care can be greatly impacted by the design of registration areas, exam rooms, diagnostic centers, and other important zones in a healthcare facility (Yaduvanshi & Sharma, 2019). By placing supplies closer to their intended use and utilizing ergonomic technologies to reduce heavy lifting, transporting, and turning of patients, facilities can be designed to reduce travel and walking times for caregivers, it will increase safety and promote a safety culture that benefits all facility occupants (Haryanto et al., 2021). In modern facilities, better designs, departmental proximity, effective clinical and business procedures, and improved information systems ought to all increase operational efficiency (Ali, 2018). To manage patient lines and lessen bottlenecks, for instance, major service locations should be placed strategically, entrances and exits should be made distinct, and waiting places should be designated (Amiens & Adedoyin, 2020). Design layout, staffing capacity, internal processes, and activities are the cornerstones of any health center facility planning (K.e.k et al., 2021). Health centers will offer different perspectives, in which hospital processes are organized around the emergency department for acute cases, outpatient department for patients that are referred for specialist consultation, diagnostic centers used for diagnostic & support services, inpatient wards for patients requiring overnight treatment (Shuv-Ami & Shalom, 2020). Process improvement for health centers' must occur within the existing context of financial realities, external regulation, and the shift from cost reduction to process improvement-driven competitive strategies, which are driving hospitals to strategically examine their facilities management and the design of such facilities gives the management interesting opportunities to influence performance and service delivery (K et al., 2021). Any function's well-considered position can speed up and enlighten service delivery, minimize time and expenditure, and minimize walking lines in the workflow and has a positive influence on customer satisfaction (Ceylan et al., 2023). Since facilities, customer behavior, satisfaction, queuing systems, and sales can have a noteworthy impact on service delivery (Kvillum et al., 2018). According to the Donabedian Bedell model, a health center's physical design and organization can have a direct impact on these care processes by influencing elements like patient privacy, provider accessibility, and multidisciplinary team coordination which also suggests that the best possible structural features and care processes will result in positive outcomes like enhanced patient satisfaction and health as well as increased overall healthcare system cost-effectiveness (Naz et al., 2022). So, it is crucial to consider facility layout as one factor that affects service delivery time and patient satisfaction level plus the rate of return.

Focusing on the service provider and hospital practices, through process innovation and redesign, healthcare is learning that doing things right the first time improves outcomes and can also cut off costs (Schouten et al., 2021). Redesigning the facility layout has a significant impact on reducing waiting time and total moment of displacement in health centers' (Tarigan et al., 2020). The best tool for enhancing material flow and the spacing between equipment (such as workstations and machines) that can be applied in service & manufacturing companies is systematic layout planning (Ceylan et al., 2023). One of the best futures of SLP is that; it gives freedom to redesign the layout from the existing layout by considering the relationship between rooms or processes with lower material handling cost (Haryanto et al., 2021) in the contrary no matter how methodical, the drawback of any manual approach is its rigidity and the reasons are that it requires a significant amount of time and labor to move templates and recalculate options, particularly when there are several facilities to be managed and such design reduces the costs of disruptions by providing a consistent context for varying process pieces to occur in varying and often unpredictable sequences and frequencies, service industries should also build their processes with flexibility (Peron et al., 2020). The architecture of hospitals and OPCS (Office of Population Censuses and Surveys) is to hold the maximum number of patients possible (Hoon & Rismanchian, 2018). Planning throughout layout design needs to be done effectively and efficiently to attain better performance.

The use of evidence-based practices reduces the amount of time that staff and patients must travel (Munavalli et al., 2022). Facility designer's attempts either to maximize the adjacency measure, minimize the total cost of material handling, or optimize a combination of two, can be formulated differently but it is usually considered an optimization problem

(Aguome et al., 2019). There are two traditional methodologies used in FLP; qualitative and quantitative methodologies (Maya et al., 2023). While the quantitative approach of FLP aims to minimize the total material handling costs between departments based on a distance function, the qualitative approach maximizes closeness rating scores between work centers or departments based on a closeness function derived from a relationship chart (Ceylan et al., 2023). The facility layout problem has a methodical, structured approach that uses the conventional engineering design procedure and it can be applied to create a brand-new layout or enhance an existing one (Peron et al., 2020). While enhancing an existing layout entails producing alternatives based on the present layout, developing a new layout entails creating one from "scratch" (Kokoç et al., 2016). Another objective of facility layout is to guarantee the physical environment's strategic functionality by integrating people, locations, processes, and technology (Teli et al., 2023). One of the problems that have been addressed in the case company of this research is that the rooms weren't designed as per the closeness relationship which contributed to long waiting time and service time so computerized layout optimization techniques will be used to improve service delivery of the health center. By applying techniques of redesigning the facility layout based on the existing facility layout, CRAFT (Computerized Relative Allocation of Facilities Technique) is selected for several benefits over conventional techniques like ALDEP and systematic layout planning (Deshpande et al., 2016). The ability to integrate multiple variables, expedite the process, reduce costs, and provide visual representations for improved analysis are some benefits of the CRAFT technique and it also combines the precision and flexibility of computer algorithms to allow for quick iterations and alternative design exploration (Maya et al., 2023). CRAFT offers a comprehensive and efficient approach to enhancing facility layout through data-driven decision-making and advanced layout handling (Kokoç et al., 2016). For design, CRAFT employs a heuristic optimization technique with ways of solving problems that find approximations to reach optimal solutions when finding the perfect answer is hard or takes a long time and frequently relies on experience, instinct, or general guidelines to direct their search for a solution (Najy, 2014). The lack of mathematical assurance that CRAFT will arrive at the intended optimal solution after a predetermined number of repetitions is one of its drawbacks (Maya et al., 2023). Manual modifications are usually needed because department shapes degenerate quickly with repeated iterations and produce output with erroneous placement, form, and alignment (Deshpande et al., 2016). It can't yield a negative X relationship, and other qualitative factors such as the impact of architecture are often overlooked and difficult to account for (Peron et al., 2020). CRAFT only featured one flow chart since it assumed that material movement is deterministic which the algorithm employed here perceives the material flow as uncertain and department rooms are limited to 40 only (Najy, 2014). So due to the listed limitations as a solution other researcher used CRAFT methodology in combination with other approaches to reach optimal results in previous studies. Because the results of the design facility layout using CRAFT only suggested a minimal total transfer cost across departments, simulation is included to show the overall time in the system, waiting time, and utilization (Teli et al., 2023). Even though most of the material currently in publication concentrates more on creating new layouts, there is still work to be done on making existing facilities better laid out, much research effort has been on the facility layout design process and there is still lack of solutions in the evaluation stage (Jamali et al., 2020). Although there are numerous ways to generate layout possibilities, reliable procedures are required to evaluate and compare these options impartially. This assessment phase, which aids in determining the optimal layout design based on particular standards like cost, throughput, safety, or ergonomics, is essential for decision-making. In this research selection of the final optimal layout option will be based on expertise opinion to close the gap of evaluation stage of improving layout selection methodology to land on the best patient-centered layout that enhance service delivery and patient satisfaction.

Since most health centers are built on multi story buildings considering only on horizontal movement won't make it optimal rather these layouts should consider the vertical movement as well. Multi-criteria decision making can be incorporate to select which appropriate floor arrangement is optimal for vertical movement of patient in health centers (Yucesan & Gul, 2020). For selecting the best technique of multi criteria decision making from alternatives research finding and complexity matters. Since AHP has proven to be helpful in ranking situations where multiple criteria are involved in decision-making and the selection between two options can be made just by applying the pairwise comparison concept, this technique presents a great advantage to be considered compared with other techniques of MCDM (Schaumann et al., 2020). AHP considers not only quantitative factors such as material handling cost and resource utilization but also qualitative factors for decision-making such as safety, environmental convenience and more realistic factors will be considered as per expertise opinion (Ahmadi et al., 2017). Ensuring effective and safe patient flow via the systems of healthcare facilities is a continuing concern because of growing patient complexity and rising demand, which can lead to minor errors and inefficiencies in healthcare delivery that cause hospital overcrowding and delays in services (Cubukcuoglu et al., 2021). Multi-floor layouts also focus on factors that need to be decided upon, like how departments are divided up among different floors, whether elevators are required, where it should be placed precisely, and where material handling should start and stop (K. et al., 2021). High-quality care delivery can be directly aided by the design and architecture of healthcare facilities that include queuing theory concepts (Yaduvanshi & Sharma, 2019). The new facility layout should be in line with the business objective rather than each unit functioning independently, and improving the facility layout should aim to improve the patients' overall hospital experience (Munavalli et al., 2022). The foundation of health center design was thought to be operational demand driven by patients (Vázquez-Serrano et al., 2021). In this research the selected techniques for vertical movement of patient between floors of the multi-story building of Teklehaimanot Health Center is AHP where both qualitative and quantitative factors will be evaluated for selection of floor placement that focus on patient path and other related factors. Based on the purpose of the studies the reviewed literatures are categorized in appendix A.

2.4. Discrete Event Simulation

Simulation is a copy of a system or procedure that might be found in the actual world (Asgary et al., 2020). The main advantage of simulation is by using simulation software we can see whether the model that will be developed will be valid or not and save time and cost of implementation (Erdemir et al., 2020). The process of creating a model of a real system and running experiments with it to either analyze how the system behaves or assess different approaches (within the constraints imposed by a criterion or set of criteria) for how the system should operate is known as simulation (Abideen & Mohamad, 2021). A representation that takes time and changes that happen over time into account is called a simulation model (Teli et al., 2023). A simulation model is a descriptive representation of a system or process that typically has parameters that enable configuration, or the representation of multiple slightly different system or process configurations including parameters that allow a user to vary the number of workers at a workstation, the speed of a machine or vehicle, the timing characteristics of a conveyor control system with a main goal of analysis, comparison, evaluation, prediction of system performance and issue detection of a system (Asgary et al., 2020). Simulation models are adaptable and may be adjusted to reflect shifting real-world conditions (Vázquez-Serrano et al., 2021). From different types of simulation, discrete event simulation can mimic future state lead time reduction which will help improve decision-making. Most improvements are associated with process time and lead time (Abideen & Mohamad, 2021) whereas continuous simulation is used when there is continuous behavior change in the system that will be tested; to suggest understanding the behavior of complex social and economic systems at the macro level (Erdemir et al., 2020). A discrete model is one in which the state changes only sometimes rather than constantly (Fun et al., 2022). These are contrasted with instance-based approaches, which generate new solutions based only on the current solution (Abideen & Mohamad, 2021). Approaches that look promising and that have just begun to be explored in the simulation optimization context are model-based methods and based on this context of simulation optimization, model-based techniques have emerged as promising and comparatively untapped alternatives, in contrast to instance-based techniques that produce solutions exclusively based on the existing solution (Brailsford et al., 2019). One benefit of DES is known as "individual heterogeneity" which refers to the fact that each modeled entity is randomly assigned a unique set of properties at the start of the simulation and argues that these individual characteristics, which are often overlooked by cohort models, may have a significant impact on the long-term outcomes that are predicted on the contrary one could see the absence of individuality as a glaring flaw in homogenous cohort models (Zhang, 2018). One limitation that has been listed in many simulation studies is that running the model needs immense amount of time-related data which is a challenge in many healthcare facilities to get well-recorded time-related data (DeRienzo et al., 2017). Therefore, users should balance the advantages and drawbacks of the simulation approach (Vázquez-Serrano et al., 2021). So, from the above-listed advantages in this research discrete event simulation will be applied to validate the new facility layout by considering waiting and service time as a measuring variable to improve the service delivery in the health center.

One popular stochastic modeling technique for dynamic, complex systems, including healthcare, is a discrete-event simulation (Vázquez-Serrano et al., 2021). The majority of healthcare systems are human-based, adaptive systems that require complicated interactions across various health center groups in addition to making use of scarce physical facilities and resources and most systems are difficult to comprehend, plan, and anticipate because of their high levels of variable and uncertainty (Schenk et al., 2023). Any hospital unit can use discrete event simulation modeling as a tool to help leadership make data-driven staffing decisions and to provide managers with improved operational awareness as the healthcare landscape changes frequently (DeRienzo et al., 2017). By applying discrete event simulation, health center managers deliver patients with fast service and manage resources in a better way in terms of cost and time (Improta et al., 2020). It facilitates the testing of ideal layout configurations, the detection of bottlenecks, and optimization of resource utilization in a controlled and dynamic virtual environment which will help to make data-driven, well-informed decisions that increase facility efficiency (Yemane et al., 2021). Because changes to the arrangement result in additional costs, simulation is essential to identify and analyze the best arrangement to adjust the layout based on the cost and quality of service, as well as the research and analysis of numerous scenarios (Munavalli et al., 2022). It can be difficult to predict and plan for workforce levels and physical space requirements, which can have an impact on employment practices, capital costs, and patient outcomes but any hospital unit can use discrete event simulation modeling as a tool to help leadership make data-driven staffing decisions and to provide managers with improved operational awareness as the healthcare landscape changes (DeRienzo et al., 2017). It provides a method to accurately describe any system by fusing simulation with animation. Notably, Arena automatically estimates the 95% confidence interval unless the user specifies otherwise and additionally ARENA input analyzer makes it easy to gather sufficient probability distributions for use in the models (Teli et al., 2023).

To start DES the first thing to consider is the process flow of the system as it is an input for Arena simulation software (DeRienzo et al., 2017). DES is a computer-based operation research technique that evaluates, forecasts, and optimizes proposed or current systems where change takes place at discrete epochs over time which represents various systems as networks of queues and activities (Schouten et al., 2021). Given its adaptability to scale changes, level of detail, individual patient focus, stochastic factors affecting the system, ease of changing the model's components, waiting for the time-related performance, the presence of queues, and the visual representation of patient flows, DES has been used in healthcare as a preferred modeling technique even big data analytics are now emerging it creates extra difficulties for procedures that are susceptible to unforeseen circumstances and changing situations (Vázquez-Serrano et al., 2021).

The main concept in DES revolves around on entity, resource and event. Anything that takes place in the surroundings at a specific moment is called an event (Bera et al., 2023). Within the realm of healthcare, entities refer to independent, self-contained items that possess characteristics and utilize resources throughout occurrences. For example, medical records, features or traits that are specific to an entity and are subject to change over time, such as age and medical history, are known as attributes (Vázquez-Serrano et al., 2021). These characteristics affect an entity's path through the simulation and the intervals between events. Resources, such as medical professionals, nurses, physicians, and so on, are items or facilities that offer a service to a dynamic entity (DeRienzo et al., 2017). Furthermore, queues are a key idea in DES since they arise when multiple entities compete for a single, limited resource and may need to wait for it to become accessible. Every queue follows its own set of rules and logic, which is known as "queue discipline"(Asgary et al., 2020). Although the use of DES in healthcare is generally on the rise to address operational problems, less than 10% of DES applications show real implementations after the modeling phase and future studies should therefore concentrate on putting the models into practice to evaluate how they affect patients, healthcare procedures, and perhaps even their clinical utility (Vázquez-Serrano et al., 2021). Combining simulation techniques alone is insufficient in the healthcare industry; hybrid DES models which combine mathematical models, statistics, improvement methodologies, and mapping techniques in recent years, no frameworks that can act as the basis for successful modeling and implementation are currently available to help the modeler create more reliable hybrid models, it is crucial to have this kind of framework facilitate the identification of the system (What), the goal

(Why), and the approach (how) (Vázquez-Serrano et al., 2021). In this research, DES will be applied to show the KPIs improvement that has been obtained by applying CRAFT & AHP techniques to optimize the horizontal and vertical movement of patient at THC.

2.5. Summary of literature findings and gap identified

Improving service delivery at Teklehaimanot Health Centre is the main goal of this research. In this study facility layout will be the target dimension to improve service delivery and enhance patient satisfaction of Teklehaimanot Health Center. The existing facility's layout and room arrangement, which cause needless patient mobility and longer wait and service time, have been identified as the main issue. The study uses a multifaceted strategy to address this problem. Initially, each stage of the patient journey is examined using process mapping analysis, and the time measurement study related to each service station are measured. The ideal layout is redesigned using the study as a basis. The study then uses a patient-centered approach and the relationships between other departments to optimize the room arrangement using the CRAFT (Computerized Relative Allocation of Facilities Technique) methodology. However, a focus group discussion with subject matter experts were held to overcome the limitation of CRAFT's when it came to taking qualitative elements into account which close the gap for evaluation stage of the optimal layout. This made it possible to include qualitative feedback and real-world events in their choice of final optimal layout of the health center. Additionally, the study employs the multi-criteria decision-making technique known as the Analytic Hierarchy Process (AHP) to assess the vertical movement of patients. This aids in figuring out the best vertical floor plans to improve patient path since THC facility is a multistory building all rooms can't be placed in one floor rather the vertical movement and floor arrangement should be taken to consideration to say the layout is optimized. Lastly, the new ideal arrangement of rooms simulated using Arena simulation program, utilizing real-time data from the time study which evaluate the improvement in key performance indicators, such as waiting and service time for outpatient department of THC.

This study fills a research gap by showing that conventional layout techniques are frequently used in hospitals instead of emphasizing a patient-centered approach. On the other hand, this research creates a health center design that complements the patient experience, guaranteeing improved service provision. This vacant research niche will be addressed by integrating CRAFT and AHP techniques to minimize waiting and service time that enhance service delivery in Teklehaimanot Health Center.

Chapter Three

3. Research Methodology

3.1. Introduction

This chapter discusses the methods by which data is being collected and analyzed. Both qualitative and quantitative data collection and analysis methods are being used in this research. Data has been collected through direct observation, unstructured interviews with patients, and time study. Healthcare professionals and patients are the main sources of data for this research study. This section explains how the research is organized starting from the preliminary assessment and observation to the extermination of the new facility layout by Arena simulation software. In data analysis, the existing process of the hospital is analyzed through process mapping analysis to track patient path in the facility, time study, and measurement of facility rooms with their relation one to another. Those tools clearly show where the long waiting & service time that affect the service delivery within the process and need major improvement will be identified. The solution will be given for long service delivery time by re layout the facility in a way that will minimize waiting time and service time of the service delivery by considering patient path. Arena simulation software will be used for analysis and improvement of the newly improved layout to measure the performance of the new system.

3.2. Research design

A preliminary assessment is done to have a general overview of the healthcare facility. Following the preliminary assessment, a problem statement is stated to investigate service improvement in Teklehaimanot Health Center through facility layout optimization. The research framework shows how this research went from preliminary assessment and observation to the last experimentation by arena simulation software and cost analysis. The framework shows how data has been collected and analyzed and what tools are deployed for improvement.

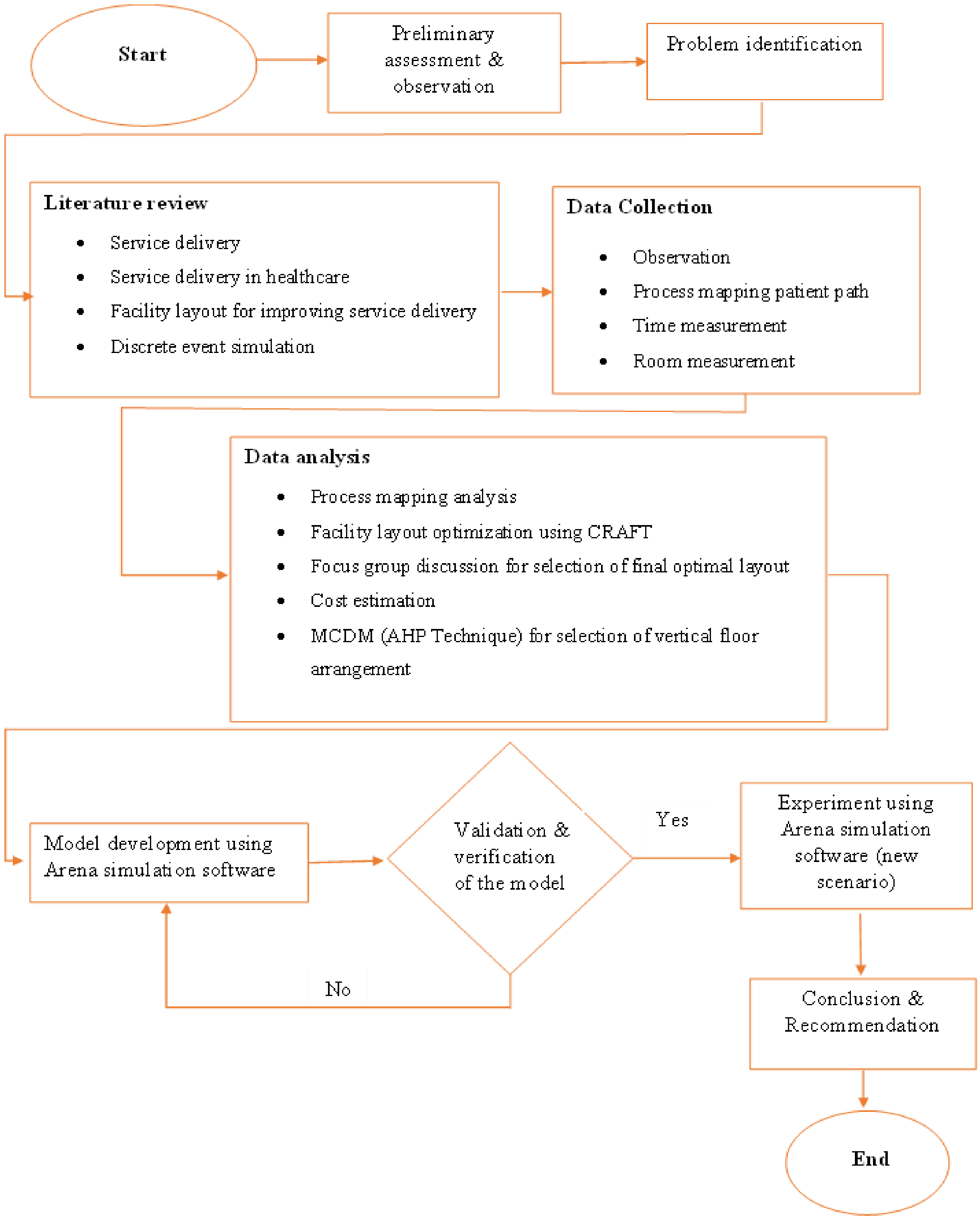


Figure 1 Methodology framework

3.3. Data collection

Both qualitative and quantitative data collection methods are employed for this research as well as both primary data sources and secondary data sources have been employed for this research.

- **Primary data**

As a primary source direct observation, unstructured interview, and time study is used. In addition, as a secondary data source different literature, journals, reviews, company reports are used. Literature review, different articles, reviews, journals, case studies and reports are reviewed in the literature review to get a thorough knowledge on the research area being studied. The literature reviews mainly focused on improving service delivery and the importance of facility layout to improve service delivery in healthcare sector. As a result, the literature gaps are being identified, areas that need further researching and the importance of this particular research is identified.

A. Observation

The observation method was one of the instruments used in this research to collect basic data and information about the primary services provided in the healthcare industry. It involved physically visiting each place selected for the study. This study thoroughly examines the work flow of the physical facility of the Teklehaimanot Health Center. Observation revealed that the current facility layout experiences inefficiencies in the service delivery. Delays and unnecessary movements were observed which impact the timely delivery of the service. The limited physical space within the health center poses a significant challenge for optimizing the facility layout. As per observation, the need to accommodate existing departments and services while improving the overall layout and the physical layout of the health center sometimes hinders effective collaboration and communication among staff members and minimize patient service time. This can lead to delays in patient care. From observation, it indicates that the current facility layout contributes to longer patient waiting times, inefficient routing, and inadequate waiting areas were identified as factors influencing patient flow to get the right service.

B. Time-motion study

The time that it takes to get served in Teklehaimanot Health Center facility is recorded using a stopwatch to calculate the service time and waiting time of patients. The goal of this time study is to have a thorough understanding of how patients currently receive care inside the health center. To do this, a time-motion study will be carried out to track and examine the flow of patients from the time they enter the facility until they get their services done. The study will involve direct observation of patients as they navigate through various stages of the service delivery process. Trained observers will record the start and end times of each task or activity performed by the patients, as well as any relevant observations or notes. Time-motion study will be conducted discretely and non-invasively, ensuring minimal disruption to both patients and healthcare providers.

Throughout the study, the observers will document various aspects of patients' experience, including check-in procedures, waiting times, interactions with staff, movement between different areas of the facility, and the overall duration of the service delivery process. The collected data will be meticulously analyzed to identify patterns, bottlenecks, and areas of improvement within the patient flow. Key metrics such as average waiting times, total service durations, and variations in process times will be calculated and compared against established benchmarks or standards.

By visualizing the current process through the time motion study, the research aims to provide a clear and detailed understanding of the patient journey within the health center facility. The findings will serve as a foundation for identifying potential inefficiencies, optimizing workflows, and enhancing the overall quality of the service delivery process.

- **Sampling strategy**

Monthly total no. of patients in the outpatient department within 24 working days is 35

Total no. of patients per month = 24*35

Total no. of patients per month = 840 patients/month

n = Sample size estimated of patients attending in the health center

Confidence interval = 95%

Marginal error (e) = 0.05

$n = N / 1 + N (e)^2$

$n = 840 / 1 + 840(0.05)^2$

$n = 270.967 \approx 271$ patients

C. Focus group discussion

In this research focus group discussion will be undertaken to do a relationship diagram between different service rooms in Teklehaimanot Health Center and understand the different perspectives of patients and healthcare professionals to create optimal patient-centered layout room configuration for the new layout that will be optimized. So, the selected individuals for focus group discussions are 2 healthcare providers, 2 patients, 1 person from the administration, and one person from the reception worker. This was perceived as an aid to the organization in monitoring best practices and design errors and overcoming the limitations of CRAFT methodology.

- **Secondary data**

Data from company reports of quality assurance records, documentation reviews, and case studies related to service delivery will be analyzed in detail to be used as input for the improvement of service delivery at Teklehaimanot Health Center. Also, other sources of secondary data collection will be used for the research such as the internet, literature review, and other related research, and practical applications.

3.4. Data Analysis Techniques & Model Development

Both qualitative and quantitative data analysis methods are employed for this research. The analysis methods which are employed for this research are listed below.

3.4.1. Process mapping analysis

In this study, service delivery at Teklehaimanot Health Center will be analyzed by focusing on measuring waiting time and service time. To achieve this, we will employ process mapping analysis in conjunction with time study. Process mapping analysis will allow us to visually represent the patient's journey from the moment patients enter the health center until their departure following each step of the process, including interactions with healthcare providers, waiting periods, and transitions between different areas within the facility. By capturing this information, we can gain a comprehensive understanding of the patient flow and identify potential bottlenecks or inefficiencies in the service delivery. Additionally, we will conduct a time study to measure the duration of each step in the patient service delivery process. This will involve systematically recording the start and end times of various activities, such as registration, consultation, laboratory tests, and medication dispensing. By collecting accurate time study data, we can quantitatively assess the duration of each activity and calculate average waiting and service times of the service delivery process. The data obtained from the process mapping analysis and time study will serve as valuable inputs for evaluating the service delivery at Teklehaimanot Health Center. By analyzing waiting time, and service time, it will be easy to identify areas of improvement in the facility layout and overall service delivery. This data-driven approach will provide insights that can inform decision-making and potentially enhance patient satisfaction at the health center.

3.4.2. Facility layout technique

It is a comprehensive analysis of the existing facility layout at Teklehaimanot Health Center to identify areas of improvement and optimize the service delivery. The analysis involved room measurements on the actual floor of the health center, followed by the application of layout planning technique, namely CRAFT. The objective is to select the best-optimized layout that minimizes waiting and service time of service delivery in Teklehaimanot Health Center for patients.

Step 1: Collect precise measurements of each room within Teklehaimanot Health Center's facility. This includes dimensions, room locations, and other relevant spatial information. These measurements serve as the basis for implementing and evaluating layout.

Step 2: CRAFT, a computer-based optimization method technique will be applied. Utilizing mathematical algorithms, CRAFT considered factors such as departmental relationships, space requirements, and material handling costs. By inputting the room measurements and from to chart, these parameters into the Excel, it will generate several alternative layout configurations with their cost. The objective is to minimize waiting and service time of patients that enhances overall service delivery and customer satisfaction by re-layout the existing layout of the health center.

The proposed layout configurations were then evaluated using appropriate evaluation criteria using focus group discussion. These criteria include factors such as process flow, and departmental interactions and shared resource among different department rooms. By assessing the proposed layouts against these criteria, the most suitable layout configuration will be identified. Following the application of these techniques, we evaluated each layout option based on its ability to minimize waiting and service time at Teklehaimanot Health Center. Key performance indicators such as travel distances, departmental proximity, and patient flow will be considered during the evaluation process. The layouts are compared based on their effectiveness in reducing waiting and service time by considering patients' path.

It is important to note that the selected layout option will serve as a recommendation for improving the facility layout at Teklehaimanot Health Center. Further validation of the proposed layout will be conducted through simulation to assess its impact on waiting and service time and improve service delivery.

By implementing a rigorous analysis that incorporates room measurements and the application of CRAFT, layout configuration will identify that has the potential to significantly improve service delivery at Teklehaimanot Health Center. The selected layout will serve as a foundation for future facility layout improvements, to minimize waiting time, service time, and optimizing the overall service delivery.

3.4.3. Multi-criteria decision making

A methodical and structured technique for assessing and contrasting solutions depending on several criteria or objectives is called multi-criteria decision analysis, or MCDA and the goal of MCDA is to give decision-makers a framework for transparently and objectively evaluating different options while taking into account a number of pertinent criteria (Singh & Dixit, 2020). Analytic Hierarchy Process is used to decompose complex decisions into a hierarchical structure of criteria and sub-criteria and the steps that will be implemented is listed below.

Step 1. Describe the decision-making main objective.

Step 2. Create the hierarchy of decisions

Step 3. Create the pairwise comparison matrices. Make a pairwise comparison matrix for every level of the hierarchy so that decision-makers (such as facility managers or healthcare specialists) can assess how important each criterion is in relation to the criterion at the level above it. Make use of a 9-point scale, where 1 denotes equal relevance and 9 denotes a component's exceptional importance over all others.

Step 4: Determine the local weights. Determine the normalized principal eigenvector for each pairwise comparison matrix. This eigenvector reflects the local weights or priorities of the compared items.

Step 5: Determine the global weights. Each element's local weights at a lower level are multiplied by the matching element's local weights at the next higher level.

Step 6: Sort the several floor plans according to their global weights; the option with the largest weight is the one that is most favored.

Step 7: Verify consistency. For each pairwise comparison matrix, determine the consistency ratio (CR) to make sure the comparisons are trustworthy and consistent. Reexamining and adjusting the comparisons is necessary if the CR is higher than 0.1.

Step 8: Interpret the results. Discuss the findings of the AHP analysis, including the ranking of the alternative floor arrangements and the reasoning behind the priorities.

3.4.4. Arena simulation software

Once the proposed layout is developed based on the findings from the layout planning techniques, it will be implemented in the Arena simulation software. The simulation model replicated the key aspects of the health center, including patient arrival patterns, appointment scheduling, resource utilization, and patient flow through various departments. Through the simulation, the performance of the proposed layout was evaluated by measuring key metrics such as waiting time and service time. Waiting time refers to the duration patients spend waiting for their turn or services, while service time represents the time it takes for patients to receive the necessary care or attention. Discrete event simulation is used for the proposed layout, capturing the waiting time and service time under the new configuration. This allowed for a direct comparison between the existing layout and the proposed layout in terms of their impact on patient waiting and service time. The results obtained from the simulation provided valuable insights into the effectiveness of the proposed layout improvements. The comparison of waiting time and service time between the existing and proposed layouts served as quantitative evidence of the potential benefits of the proposed changes. The use of Arena simulation software in the data analysis phase provided a dynamic and visual representation of the proposed layout improvements. It allowed for an accurate assessment of waiting time and service time, enabling the identification of bottlenecks, inefficiencies, and areas for further optimization. By incorporating simulation into the data analysis process, the proposed layout improvements were rigorously evaluated, providing quantitative evidence of the expected improvements in waiting time and service time. These insights contribute to the overall validation and effectiveness of the proposed layout changes in optimizing the service delivery at Teklehaimanot Health Center.

A. Model Verification

The process of confirming that the created simulation model is accurately and sufficiently implemented in relation to the conceptual model is known as "model verification" (Bera et al., 2023). In practice, verification is viewed as troubleshooting the simulation model, which can be accomplished using a variety of techniques, including animation through model execution. After grouping entities into a single entity picture, additional entity pictures are added to confirm that the entities are correctly matched. In order to verify the suitability of the model output results, trial runs of the simulation model were conducted for 30 replications using a range of input parameter settings.

B. Model Validation

Model validation is the process of proving that the model is a reasonable replica of the real system (Teli et al., 2023). While verification techniques are generally applicable, the approach taken to validate the model is likely to be much more specific to the model developed and the real system in question. Two methods of validating the model were employed: face validation, in which an individual looks at the model developed and declares that it is a replica of the real health center service flow; and statistical validation, which involves using statistical outputs such as the average waiting times and service times in the system validated the simulation model.

C. Number of Replications

The number of replications refers to the total number of simulations runs that need to be carried out in order to statistically assess the variations between the real system and the simulation model and improve output reliability (Vázquez-Serrano et al., 2021). More replication yields more accurate output results, making it possible to estimate the error introduced when modeling the real system and its integer value is either one or greater than one (Brailsford et al., 2019). Thirty simulations were run for 192 minutes in order to compile this research paper. Input distributions of simulation, processing time and others are probabilistic, the simulation outputs are also in variable number (Asgary et al., 2020). It is preferable to have an adequate number of replications in order to account for this variability in the output result and make the right decisions. Initial set of replications' summary statistics are used to determine whether more replications are needed at a given level of confidence. Sufficient number of replications to have reasonable statistical confidence given that additional replications can always be added later (Yemane et al., 2021). Assumptions during simulation model, observation recording, and critical factor identification were made. The number of replications analysis started with choosing ten primary number of simulations run.

Chapter Four

4. Data Analysis, Results and Discussion

4.1. Introduction

This section presents a comprehensive analysis of the findings obtained from the data collection process conducted for this thesis, which focuses on improving service delivery by optimizing the facility layout at Teklehaimanot Health Center. The paper aims to provide a detailed examination of the data gathered through observations, and focus group discussion, shedding light on the current state of the facility layout and its impact on service delivery.

A greater understanding of the elements influencing Teklehaimanot Health Center service delivery can be achieved using qualitative and quantitative approaches in conjunction with a systematic approach to data gathering. To determine the best and most effective layout that improves service delivery, the data collection procedure included direct observations of process mapping, time measurement, measurement of the current facility layout for optimization, and selection of floor that should be occupied based on patient path using MCDM technique. These provide valuable insights into perspectives regarding the facility layout and its implications for service delivery. The data collection process aims to identify the positive aspects of the current facility layout that contribute to efficient service delivery and the negative factors that hinder service flow, patient flow, and staff collaboration.

The findings derived from the data collection process will serve as the basis for the subsequent analysis, discussions, and recommendations in this research. By presenting the results in a clear and organized manner, it aims to provide evidence-based insights that can guide the optimization of the facility layout at Teklehaimanot Health Center, ultimately enhancing service delivery and improving the overall patient experience.

4.2. Data collection result

Observation revealed that the current facility layout experiences inefficiencies in the service flow. Bottlenecks, delays, and unnecessary movements were observed, impacting the timely delivery of services. The limited physical space within the health center poses a significant challenge for optimizing the facility layout. The observation highlighted the need to accommodate existing departments and services while improving the overall physical layout of the health center sometimes hinders effective collaboration and communication among staff members. This can lead to delays in patient care and coordination issues. The observation indicated that the current facility layout contributes to longer patient waiting times and service times.

4.2.1. Process mapping analysis

The current patient journey in the outpatient department of Teklehaimanot Health Center is displayed using a process mapping tool. The current service flow from the moment where the patient enters the system until departure which shows the movement in the health center and its many stations is shown in the process mapping analysis in detail.

A thorough understanding of the Outpatient department process flow is necessary for a comprehension of the OPD system. It includes actions undertaken at each service station, waiting period, and any other data that can be used to pinpoint the causes of process flow obstructions. This process mapping analysis uses draw.io to map the entire outpatient department workflow.

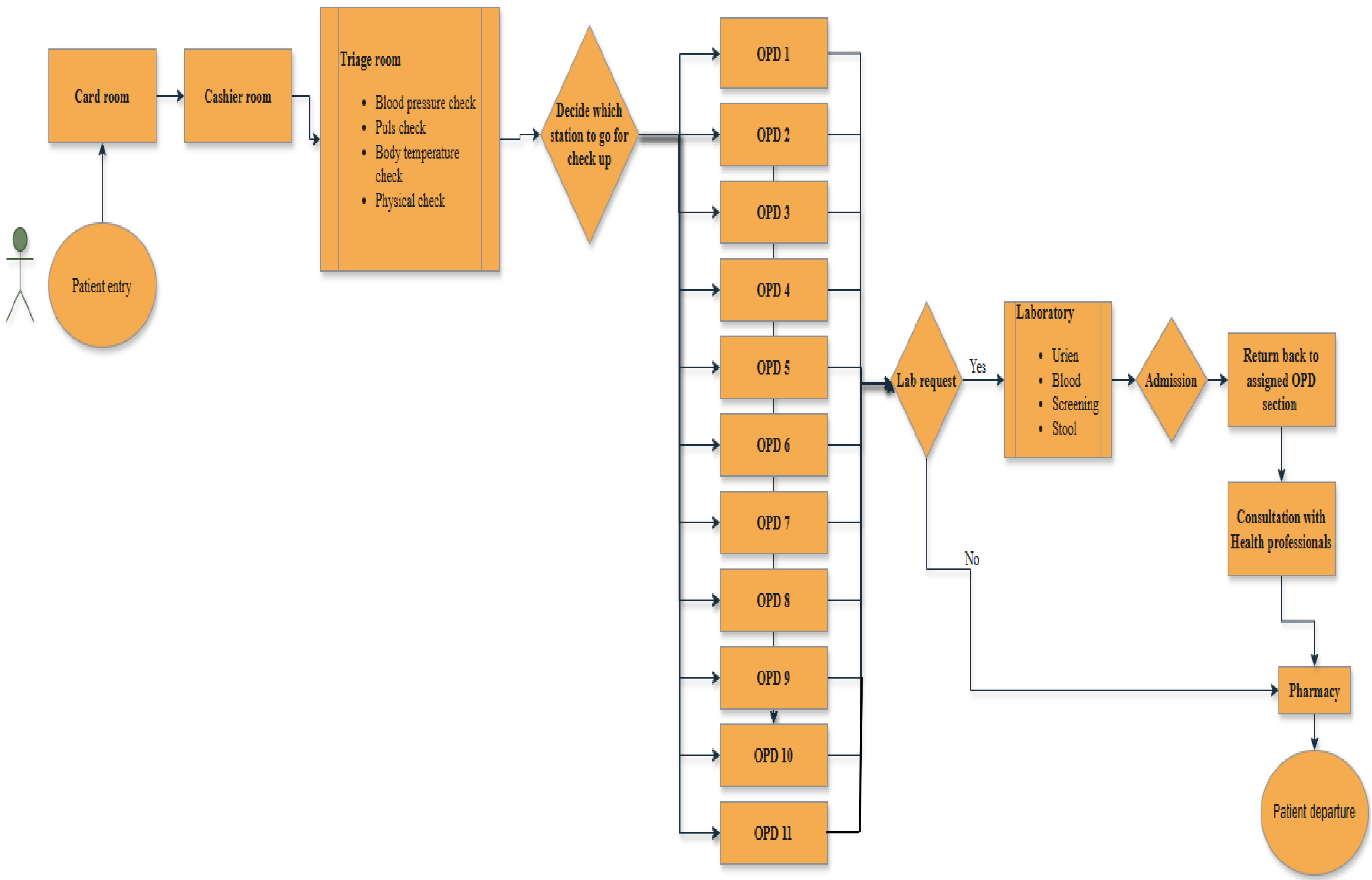


Figure 2 General Process map of the outpatient department at Teklehaimanot Health Center

As seen in the process map above, patients arrive at the health facility, go to reception, get a card, and join the triage line. In the triage room patients are grouped based on their illness, trauma, or case. Patients may enter further service stations, such as OPD 1, OPD 2, and so forth depending on their circumstances. After utilizing the OPD room, patients move to the laboratory station if there are any laboratory requests. And go back to the original service station after getting the lab report. Some patients may either go to the pharmacy to get their recommended drugs or leave the health center without going inside the pharmacy.

4.2.2. Time measurement

A time study tracking the patient's journey in Teklehaimanot Health Center's outpatient department was carried out as part of the data collection process. Time study analysis offers a quantitative foundation for assessing work practices, establishing reasonable performance expectations, and efficiently allocating resources. To find possibilities for process improvement, and promote operational excellence within the framework the study explores the field of time study analysis. Here under average time study of patient flow is listed in table below.

Table 1 Time study of patient path of OPD at Teklehaimanot Health Center

Department room	Waiting time	Service time
OPD 1	154.00 min	35.70 min
OPD 2	156.00 min	42.30 min
OPD 3	142.00 min	48.90 min
OPD 4	146.00 min	45.60 min
OPD 5	148.00 min	39.10 min
OPD 6	141.00 min	40.80 min
OPD 7	141.00 min	46.40 min
OPD 8	146.20 min	41.70 min
OPD 9	146.50 min	38.20 min
OPD 10	141.70 min	43.60 min
OPD 11	149.30 min	44.80 min

It is acknowledged that different OPD service stations provide varying types of services, the health center's internal reporting evaluates the OPD department as a whole, rather than examining each service station individually. To maintain consistency with the health center's own assessment and reporting methods, and to accurately reflect the true performance of the OPDs as a whole, the decision to use the average service time across all relevant OPD service stations is a reasonable approach. This allows for a comprehensive evaluation of the OPD department's efficiency and the potential impact on the overall patient flow and service delivery within the health center. By aligning the data analysis with the health center's internal reporting structure, the findings of this research will be meaningful and directly applicable to the real-world operations of Teklehaimanot Health Center. So, findings from time study shows that patients have to wait for an average of 147min. This is an estimated amount of time patients have to wait from the time patients arrive at the facility until departure. As finding shows health centers in Addis Ababa, Ethiopia average waiting time is 101min whereas finding from time study of 271 patients in THC is calculated as 147min which exceed by half an hour and shows pressing needs for improvement by finding out root causes (Biya et al., 2022). The average service time is observed as 42.6min. This is the amount of time patients should spend actively to get services from the health center including laboratory processes. And finding shown in UK primary care clinic, the average service time range between 15-22min which is lower than THC by half (McIntyre & Chow, 2020). From findings above THC shows long waiting and service time. So as a solution optimizing the existing facility layout of Teklehaimanot Health Center will enhance service delivery.

4.2.3. Existing facility layout

Teklehaimanot Health Center's current service flow shows an unnecessary patient flow that should be optimized. Patients frequently have to move back and forth between various service stations to receive a single comprehensive service due to the traditional arrangement of the facility department rooms. The lengthy average waiting time found in the time study file is the result of suboptimal facility layout of the health center. To receive the complete range of services patients, have to move between different floors and departments. Teklehaimanot Health Center consists of four primary departments: the delivery ward, outpatient ward, cancer ward, HIV & supporting facility ward. The health center facility is divided into ground plus three building. The existing health center facility layout is located at a dimension of 43 meters by 48 meters, as shown in figure below.

Figure 3 Existing facility layout of THC ground floor plan

4.2.4. Departmental area required & coding

Through analysis and interpretation of these measurements, researchers and planners can arrive at well-informed conclusions concerning the distribution of rooms, positioning, and general design of the facility. This analysis contributes to the development of a patient-centered, orderly atmosphere that supports efficient service delivery. Each ward has its own department rooms. To use in CRAFT Excel Add-in each department is coded in numbers including area requirements as shown in the table below.

Table 2 Room measurement of ground floor departments at Teklehaimanot Health Center

Ground floor department rooms			
Code in Excel Addin	**Department Name**	**Code**	**Area(m^2)**
1	Triage	TR	22.21m^2
2	Card room	CR	20.14m^2
3	Toilet 1	T1	39.93m^2
4	Cancer ward	CW	191.00m^2
5	Cashier room	CSR	10.03m^2
6	Archived room	DR	7.83m^2
7	Cleaner's room	CLR1	6.53m^2
8	Toilet 2	T2	7.83m^2
9	Sterilizing room	SR	8.70m^2
10	Laboratory technician's office	LTO	21.62m^2
11	Laboratory	LR	42.03m^2
12	Inpatient room	IBR	22.21m^2
13	Injection room	INR	20.14m^2
14	Emergency room	ER	37.49m^2
15	Pharmacy	P	37.49m^2

Table 3 Room measurement of delivery ward at Teklehaimanot Health Center

Delivery ward department room			
Code in Excel Addin	**Department Name**	**Code**	**Area(m^2)**
1	Cleaner's room 2	CLR2	10.42m^2
2	PMTCT room	PM	16.34m^2
3	ANC room	AR	16.34m^2
4	Delivery room 1	DR1	16.34m^2
5	Delivery room 2	DR2	17.21m^2
6	Delivery room 3	DR3	8.34m^2
7	Delivery procedure room	DPR	8.34m^2
8	Midwife rest room	MRR	10.88m^2
9	Toilet 3	T3	25.01m^2
10	Examination room	GE	16.53m^2

11	Ultrasound room 1	UR1	16.53m^2
12	Store 1	SR	10.41m^2
13	Empty room	ER	8.34m^2
14	Rest room	RR	8.34m^2

Table 4 Room measurement of OPD departments at Teklehaimanot Health Center

OPD department rooms			
Code in Excel Addin	**Department Name**	**Code**	**Area(m^2)**
1	OPD 1 (Geriatrics section)	OPD 1	10.42m^2
2	OPD 10 (Youth care section)	OPD 10	16.34m^2
3	OPD 9 (EPI room)	OPD 9	16.34m^2
4	OPD 8 (Infant care section)	OPD 8	16.34m^2
5	OPD 6 (Malnutrition care)	OPD 6	17.20m^2
6	OPD 7 (Psychiatry section)	OPD 7	8.34m^2
7	OPD 2 (Pediatrics)	OPD 2	8.34m^2
8	Quality Department	QR	10.88m^2
9	Toilet 4	T4	25.01m^2
10	OPD 3 (Adult care section)	OPD 3	16.53m^2
11	OPD 4 (Adult care section)	OPD 4	16.53m^2
12	OPD 5 (Adult care section)	OPD 5	10.42m^2
13	OPD 11 (HIV test section)	OPD 11	8.34m^2
14	Cleaner’s room 3	CLR 3	8.34m^2

4.2.5. Monthly patient flow between departments

Teklehaimanot Health Centre has a multi-story building, so it's critical to think carefully about where to put crucial departments to best use of available resources by considering patient flow. The facility's emergency room, card room, triage room, Cancer Ward, laboratory room, injection room and pharmacy are currently located on the ground floor of multi-story building. Patients from different units within the health center utilize these departments as shared resources. These ground floor service rooms must be positioned strategically to provide effective access and coordination, even if their positions don’t coincide with the main patient flow pathways. Recognizing the limitations of the multi-story building room layout and the necessity of co-locating some departments on the ground floor allows the facility management to concentrate on improving patient flow and resource use in this assigned area. This data will help Teklehaimanot Health Center to build an efficient facility layout plan that strikes a balance between patient experience and operational effectiveness. It will also complement the insights gathered from the monthly patient flow data analysis. From to matrix of the ground floor units is shown in the table below by tracking number of patient entered from one department to other, emphasizing how these vital service points are shared and interconnected by patient.

Table 5 From to matrix of ground floor department at THC

From/To	TR	CR	T1	CW	CSR	DR	CLR1	T2	SR	LTO	LR	IBR	INR	ER	P
TR	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0
CR	846	0	27	0	847	0	0	0	0	0	0	0	0	0	0
T1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CW	0	0	960	0	0	0	0	0	0	0	0	0	0	0	0
CSR	871	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLR1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T2	0	0	0	0	0	0	0	0	0	0	862	96	0	0	0
SR	0	0	0	0	0	0	0	0	0	98	102	0	0	0	0
LTO	0	0	0	0	0	0	0	0	0	0	880	0	0	0	0
LR	0	0	0	0	192	0	0	870	181	880	0	0	0	0	180
IBR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
INR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ER	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6 From to matrix of OPD room at THC

FROM-TO	OPD 1	OPD 10	OPD 9	OPD 8	OPD 6	OPD 7	OPD 2	QD	T3	OPD 3	OPD 4	OPD 5	OPD 11	CLR 2
D 1	0	0	0	0	0	0	72	0	0	0	0	0	120	0
D 2	0	0	0	0	0	0	0	0	0	0	0	0	144	0

D 3	0	0	0	96	0	0	0	0	0	0	0	0	0	0
D 4	0	0	0	0	120	0	120	0	0	0	0	0	24	0
D 5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D 6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D 7	0	0	0	0	0	0	0	0	0	0	0	0	24	0
D 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D 10	0	0	0	0	0	0	0	0	0	0	120	120	240	0
D 11	0	0	0	0	0	0	0	0	0	0	0	120	240	0
D 12	0	0	0	0	0	0	0	0	0	0	0	0	264	0
D 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0

4.2.6. Cost matrix for the existing facility layout

The unit cost matrix represents the money spent on patient transportation between departments to get the necessary service. For this reason, THC has designated personnel who transfer patients and their documentation from the reception area to the outpatient department and other service stations. Thus, THC uses receptionists to move patients and their documents and occasionally uses wheelchairs for transportation to those who are in serious condition of illness. As a result, when moving patients and documents between departments, the case company uses designated employees.

- The monthly salary of reception workers is 3,300 ETB with an average of 24 working days and 8 working hours per day. Therefore, the average working hour per month is 192 hours which is equal to 661,200 seconds per month.
- Average patient transportation time is calculated as:

Transportation cost = Monthly reception worker salary/ working time (in second)

Transportation cost = 3300 ETB per month/ 661,200 second

Transportation cost = 0.00499 ETB per second

➢ The average patient transportation time is 1.15 meters per second and the movement cost is calculated as:

Movement cost = Transportation cost / Average patient transportation time (in second)

Movement cost = 0.00499 second / 1.15 meter per second

Movement cost = 0.004515 ETB / second

To get the unit cost from one service station to another, rectilinear distance should be calculated and multiply with the movement cost. The ground floor of THC cost matrix is calculated as shown in the figure below.

From-To	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0.018	0.046	0.090	0.102	0.113	0.133	0.167	0.209	0.266	0.295	0.329	0.355	0.385	0.426
2	0.018	0	0.028	0.072	0.084	0.095	0.115	0.148	0.191	0.248	0.277	0.311	0.337	0.367	0.408
3	0.046	0.028	0	0.044	0.057	0.067	0.088	0.121	0.163	0.220	0.249	0.283	0.309	0.339	0.380
4	0.090	0.072	0.044	0	0.013	0.023	0.043	0.077	0.119	0.176	0.205	0.239	0.265	0.295	0.336
5	0.102	0.084	0.057	0.013	0	0.010	0.031	0.064	0.106	0.163	0.193	0.226	0.252	0.282	0.323
6	0.113	0.095	0.067	0.023	0.010	0	0.020	0.054	0.096	0.153	0.182	0.216	0.242	0.272	0.313
7	0.133	0.115	0.088	0.043	0.031	0.020	0	0.033	0.075	0.132	0.162	0.195	0.222	0.251	0.293
8	0.167	0.148	0.121	0.077	0.064	0.054	0.033	0	0.042	0.099	0.129	0.162	0.188	0.218	0.259
9	0.209	0.191	0.163	0.119	0.106	0.096	0.075	0.042	0	0.057	0.086	0.120	0.146	0.176	0.217
10	0.266	0.248	0.220	0.176	0.163	0.153	0.132	0.099	0.057	0	0.029	0.063	0.089	0.119	0.160
11	0.295	0.277	0.249	0.205	0.193	0.182	0.162	0.129	0.086	0.029	0	0.034	0.060	0.090	0.131
12	0.329	0.311	0.283	0.239	0.226	0.216	0.195	0.162	0.120	0.063	0.034	0	0.026	0.056	0.097
13	0.355	0.337	0.309	0.265	0.252	0.242	0.222	0.188	0.146	0.089	0.060	0.026	0	0.030	0.071
14	0.385	0.367	0.339	0.295	0.282	0.272	0.251	0.218	0.176	0.119	0.090	0.056	0.030	0	0.041
15	0.426	0.408	0.380	0.336	0.323	0.313	0.293	0.259	0.217	0.160	0.131	0.097	0.071	0.041	0

Figure 4 Existing ground floor Facility Layout Unit Cost

TO / FROM	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14
D 1	0	0.0386	0.0558	0.0729	0.0881	0.1004	0.1172	0.1308	0.1648	0.182	0.2082	0.2181	0.2304	0.2472
D 2	0.0386033	0	0.0172	0.0343	0.0495	0.0618	0.0786	0.0922	0.1262	0.1434	0.1696	0.1795	0.1918	0.2086
D 3	0.0557603	0.0172	0	0.0172	0.0323	0.0446	0.0614	0.075	0.1091	0.1262	0.1524	0.1624	0.1747	0.1915
D 4	0.0729173	0.0343	0.0172	0	0.0152	0.0275	0.0443	0.0578	0.0919	0.1091	0.1353	0.1452	0.1575	0.1743
D 5	0.0880877	0.0495	0.0323	0.0152	0	0.0123	0.0291	0.0427	0.0768	0.0939	0.1201	0.13	0.1423	0.1592
D 6	0.100391	0.0618	0.0446	0.0275	0.0123	0	0.0168	0.0304	0.0645	0.0816	0.1078	0.1177	0.13	0.1469
D 7	0.1172094	0.0786	0.0614	0.0443	0.0291	0.0168	0	0.0135	0.0476	0.0648	0.091	0.1009	0.1132	0.13
D 8	0.1307544	0.0922	0.075	0.0578	0.0427	0.0304	0.0135	0	0.0341	0.0512	0.0774	0.0874	0.0997	0.1165
D 9	0.1648427	0.1262	0.1091	0.0919	0.0768	0.0645	0.0476	0.0341	0	0.0172	0.0433	0.0533	0.0656	0.0824
D 10	0.1819997	0.1434	0.1262	0.1091	0.0939	0.0816	0.0648	0.0512	0.0172	0	0.0262	0.0361	0.0484	0.0652
D 11	0.2081867	0.1696	0.1524	0.1353	0.1201	0.1078	0.091	0.0774	0.0433	0.0262	0	0.0099	0.0222	0.0391
D 12	0.2181197	0.1795	0.1624	0.1452	0.13	0.1177	0.1009	0.0874	0.0533	0.0361	0.0099	0	0.0123	0.0291
D 13	0.230423	0.1918	0.1747	0.1575	0.1423	0.13	0.1132	0.0997	0.0656	0.0484	0.0222	0.0123	0	0.0168
D 14	0.2472414	0.2086	0.1915	0.1743	0.1592	0.1469	0.13	0.1165	0.0824	0.0652	0.0391	0.0291	0.0168	0

Figure 5 Existing OPD Facility Layout Unit Cost

4.3. Procedure of CRAFT

4.3.1. Analysis of existing facility of THC using CRAFT

The first step is entering the facility's name, total number of departments, number of fixed and variable points, and the distance in metric units first. The facility is known as "groundfloorh facility" as shown in figure below.

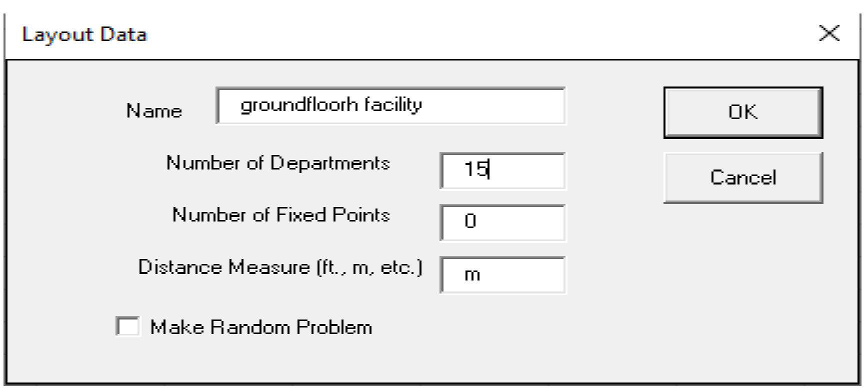


Figure 6 Facility Layout Data Entering Dialogue

Second, the facility information will be filled with dimensions such as total height, width, and area required in the dialogue box.

Facility Information

Scale-m/unit	1	Cells
Length-m	48	48
Width-m	43	43
Area-sq.m	2064	2064

Figure 7 Facility Information Entering Dialogue Box

Its measurements are 48 meters in width and 43 meters in height. The application automatically computes cells with the scale meter per unit that the user specifies the department area into the table. It is set to show that a one-unit cell corresponds to an area of one meter by one meter. The facility department information will be filled. The facility layout data is filled at the top of the spreadsheet to allow for further summary. The details include the department number, area and dimension of the facilities on exhibit, and the movement cost related to the original layout. On the other hand, the area, x, y centroid, and department color are displayed in table below.

Table 7 Existing facility ground floor department information of THC

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
D 1	1	23	23	1.54	3.84	1
D 2	2	21	21	4.50	3.50	2
D 3	3	40	40	11.5	4.00	3
D 4	4	191	200	31.45	8.50	4
D 5	5	7	7	22.07	22.78	5
D 6	6	11	11	21.95	27.22	6
D 7	7	7	7	26.07	22.78	7
D 8	8	7	7	32.50	24.50	8
D 9	9	9	9	39.38	25.61	9
D 10	10	22	22	41.86	26.36	10
D 11	11	43	44	33.72	22.59	11
D 12	12	23	23	41.54	34.84	12
D 13	13	21	21	36.35	36.92	13
D 14	14	38	38	28.18	45.50	14
D 15	15	38	38	29.00	37.07	15

Table 8 Existing OPD facility information of THC

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
D 1	1	18	18	1.16	5.50	1
D 2	2	17	17	2.20	14.08	2
D 3	3	17	17	19.55	3.14	3
D 4	4	17	17	11.38	1.79	4
D 5	5	18	18	15.77	1.94	5
D 6	6	9	9	19.50	7.50	6
D 7	7	9	9	2.16	2.50	7
D 8	8	11	11	19.86	14.31	8
D 9	9	26	26	13.73	15.07	9
D 10	10	17	17	5.14	15.55	10
D 11	11	17	17	7.14	2.08	11
D 12	12	11	11	9.13	14.68	12
D 13	13	9	9	1.50	10.50	13
D 14	14	9	9	19.50	10.50	14

Every department has been assigned a unique number and color to symbolize. The area necessary column also includes the area requirements for each department. The user must fill in the blank cell layout that the computer generates to fit the available area. The program will calculate the area defined for each department in the original layout in the next three columns. The x and y-centroid of each department are calculated. As a result, the numbers for each department on the blank layout accurately depict unoccupied space and the real facility layout. After completing the layout and placing the region within the department numbers, click the spreadsheet's top define facility button. Then, the application determines the appropriate coloring for every department and assesses the initial layout cost. The application makes use of the movement cost matrix and unit cost matrix to calculate the initial cost of the existing facility layout. The total initial cost of OPD and ground floor layout is calculated as 15,053.14 ETB. The location of the facility layout in Excel is shown figure below.

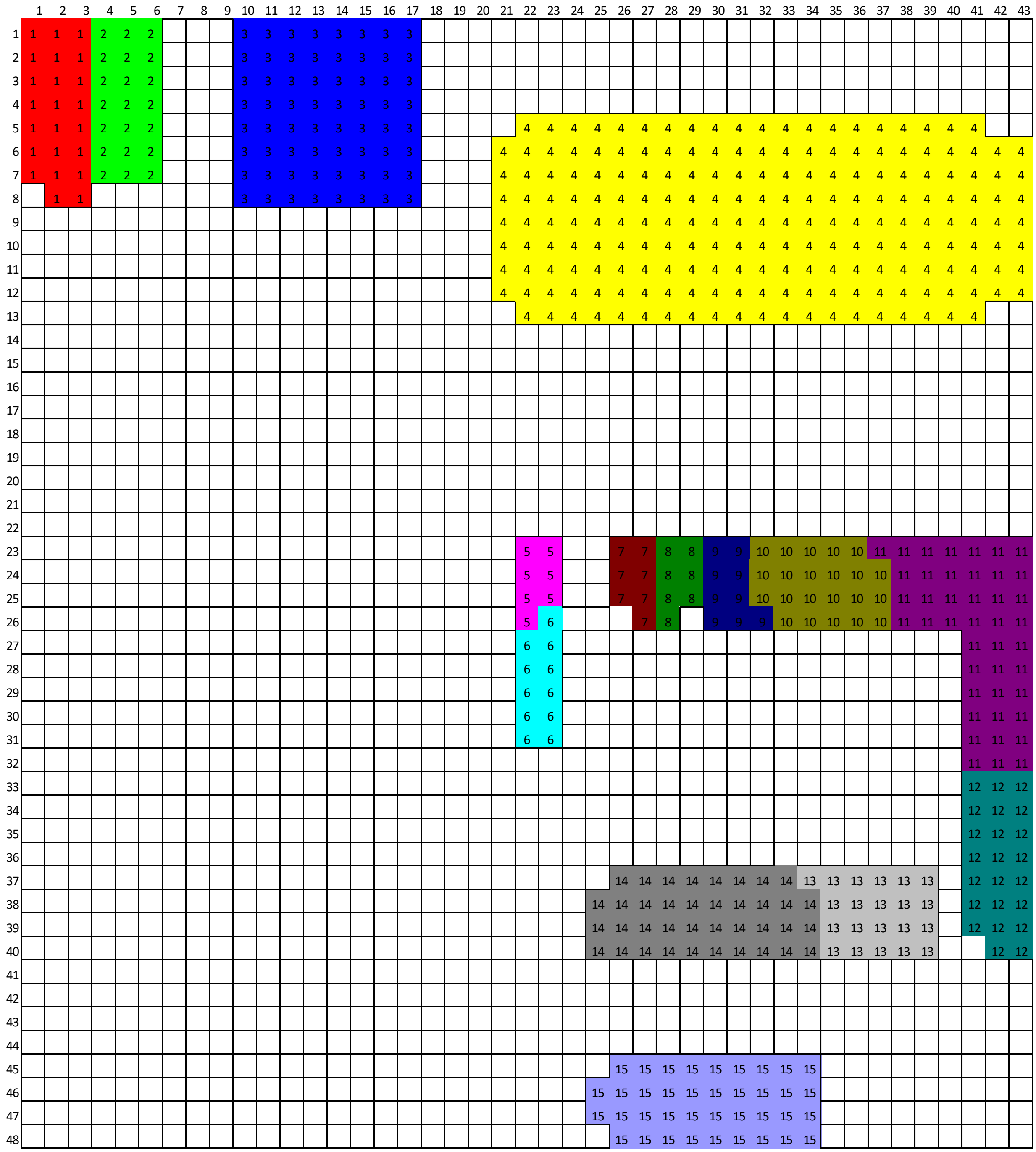


Figure 8 Existing ground floor facility layout

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	1	1			2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5
2	1	1	1			2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5
3	1	1	1			2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5
4	1	1	1			2	2	2	2	2	3	3	3	4	4	4	4		5	5	5
5	1	1	1																5	5	5
6	1	1	1																5	5	5
7	14	14	14																6	6	6
8	14	14	14																6	6	6
9	14	14	14																6	6	6
10	13	13	13																7	7	7
11	13	13	13																7	7	7
12	13	13	13																7	7	7
13	12	12	12																8	8	8
14	12	12	11	11	11	11	11	10	10	10	10	9	9	9	9	9	9			8	8
15	12	12	11	11	11	11	10	10	10	10	10	9	9	9	9	9	9			8	8
16	12	12	11	11	11	11	10	10	10	10	9	9	9	9	9	9	9			8	8
17	12	12	11	11	11	11	10	10	10	10	9	9	9	9	9	9	9			8	8

Figure 9 Existing OPD floor facility layout

4.3.2. Existing facility layout departmental flow

The flow between departmental centroids occurs when clicking the "show flows" button. The thin line in the figure illustrates a comparatively minor flow cost between the departments, while the thick line represents a substantial flow cost between different departments.

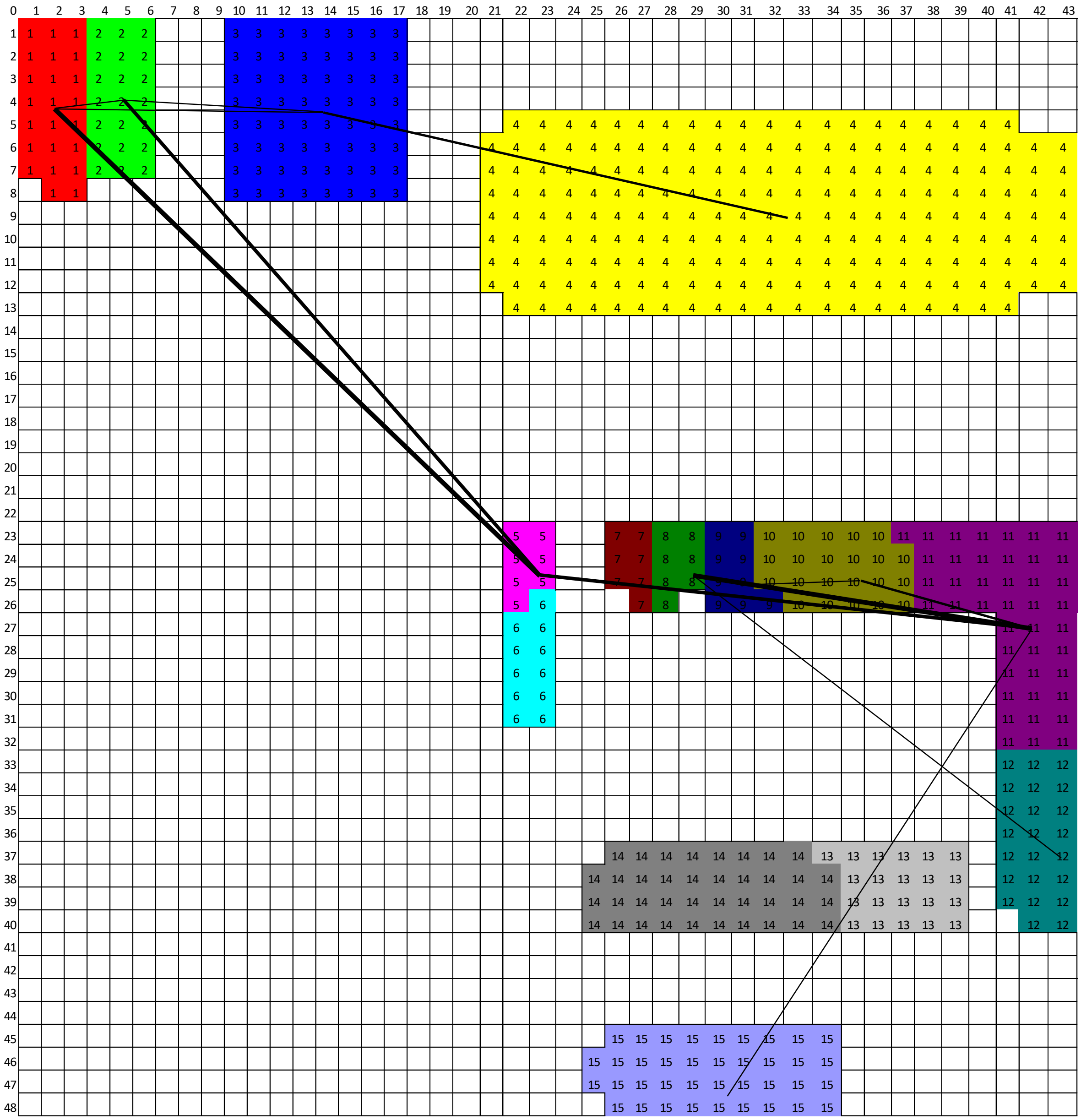


Figure 10 Ground floor departmental flow at THC

As shown in the above figure there is high flow rate of patient from triage and card room with cashier room and another flow that shows high flow rate is between reception room and laboratory. Other rooms also show less patient flow as compared with the other in the ground facility of multi-story building of THC. And this interdepartmental flow shows that departments that are connected with thick lines should be placed closer to minimize patient flow and enhance service delivery in the health center.

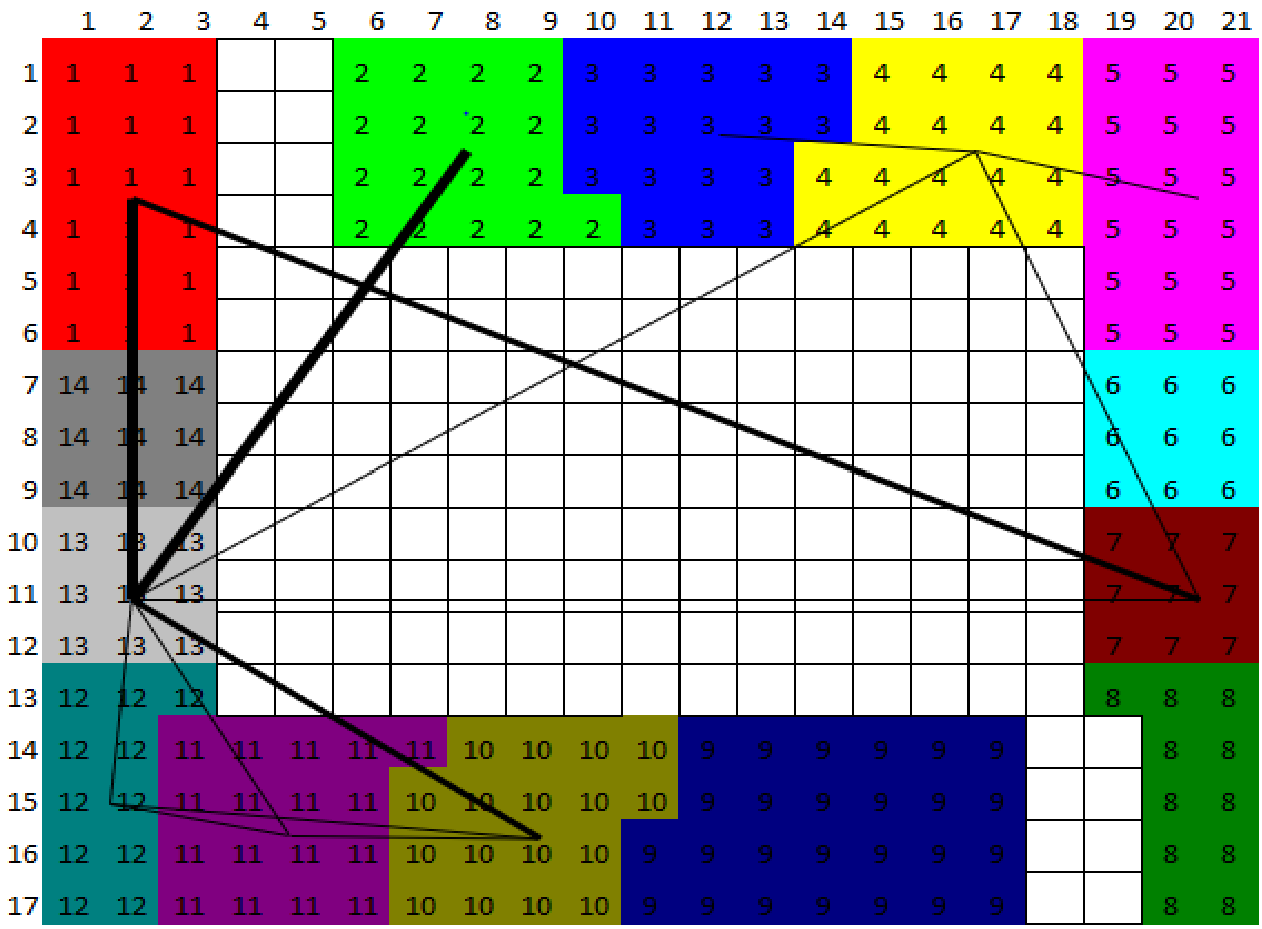


Figure 11 OPD floor departmental flow at THC

As shown the above figure departmental flow rate is seen between OPD 7, OPD 1, OPD 11 and OPD 10 but in the existing layout even this rooms are located in the same floor the location of each room isn't near which will cause high patient dissatisfaction. During optimization, it is a must to re-layout these rooms near since it shows high departmental flow.

4.4. Proposed health center layout

In the existing health center facility, the flow of patients hasn't been considered when designing the facility's layout between various departments. This results in long travel times for carrying out the necessary tasks, which lengthens the time it takes to provide the service. Therefore, it is better to plan a patient-centered layout that considers departmental relationships and operational procedures since the health center's ultimate focus is giving patients the best service. As mentioned in the methodology section, the CRAFT algorithm is the technique used but as a limitation, this technique has some limitations that require additional manual adjustments. In this study, the manual adjustment is undertaken based on expert opinion. As per the expertise, the main reason that contributes to long waiting time is triage and card room are located far from the main multi-story building where all service stations are placed so these two rooms should be located in place of the inpatient room and injection room since this rooms are interrelated to each other but independent of different rooms that building with the same area. Experts have raised the second point that some patients enter the system just for laboratory service, so the laboratory should be placed next to the cashier's room and cleaner's room is exchanged with cashier room since cleaner's room have no direct relation with the main service facility. After considering all the points listed above the final layout of the ground floor of THC is shown below.

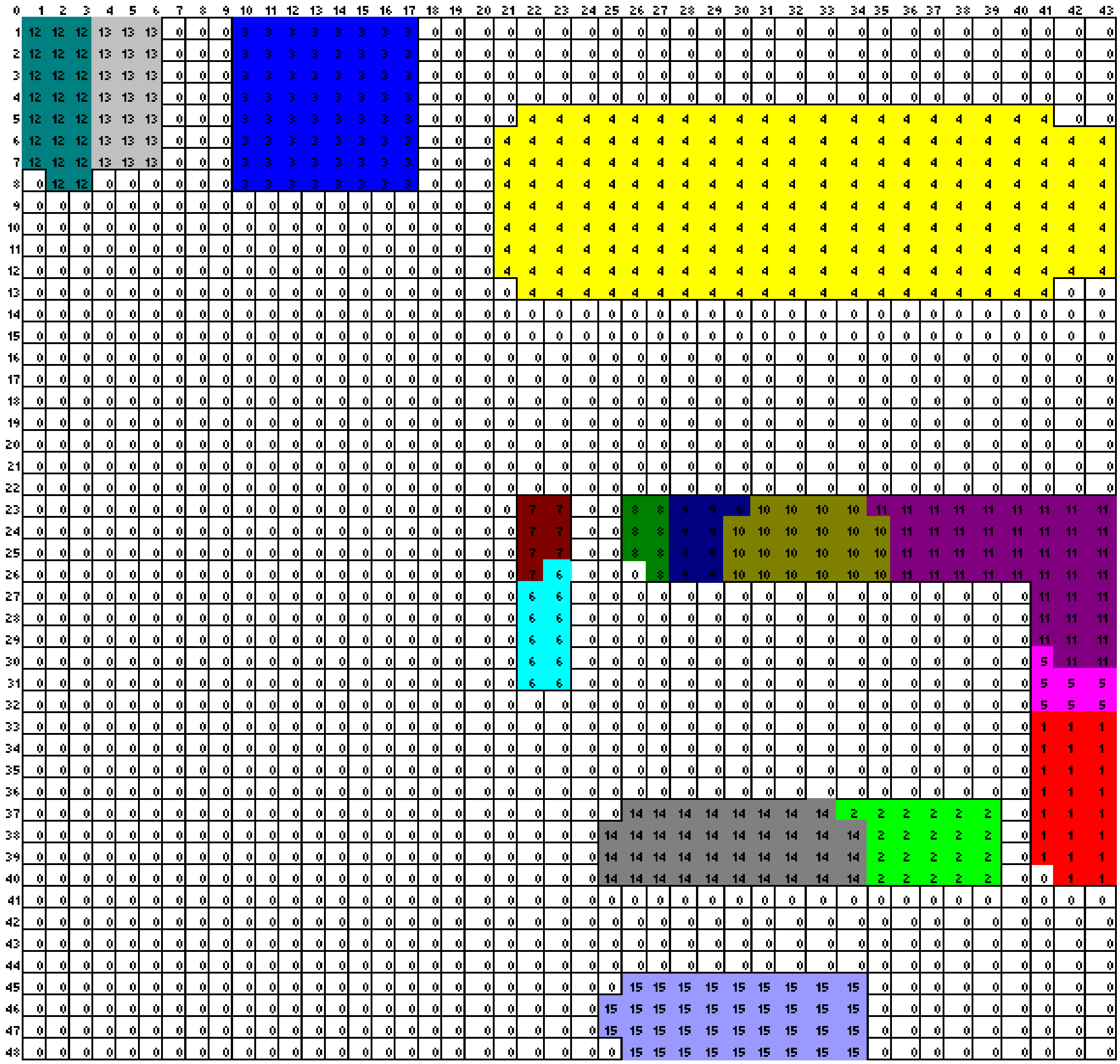


Figure 12 Proposed facility layout for ground floor departments at THC

The final revised floor plan of the ground floor of THC is shown the figure below.

Figure 13 Proposed facility floor plan of ground station of THC

Based on expertise opinion in the OPD department, there is a high number of patient flow from OPD 3, OPD 4, OPD 5, and OPD 10 to OPD 11 high patient flow so placing OPD 11 will minimize service time. In addition, OPD 1 is for patients over 65 years old so it is a must to put these room next to the stairs. Therefore, the final layout that has been selected by experts is shown in figure below.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	1	1	1			2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5
2	1	1	1			2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5
3	1	1	1			2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5
4	1	1	1			2	2	2	2	2	3	3	3	4	4	4	4	4	5	5	5
5	1	1	1																5	5	5
6	1	1	1																5	5	5
7	13	13	13																7	7	7
8	13	13	13																7	7	7
9	13	13	13																7	7	7
10	12	12	12																6	6	6
11	12	12	12																6	6	6
12	12	12	12																6	6	6
13	11	12	12																8	8	8
14	11	11	11	11	10	10	10	10	14	14	14	9	9	9	9	9	9			8	8
15	11	11	11	11	10	10	10	10	14	14	14	9	9	9	9	9	9			8	8
16	11	11	11	11	10	10	10	10	14	14	9	9	9	9	9	9	9			8	8
17	11	11	11	11	10	10	10	10	10	14	9	9	9	9	9	9	9			8	8

Figure 14 Proposed facility layout for OPD station at THC

The final floor plan of OPD station is shown in figure below.

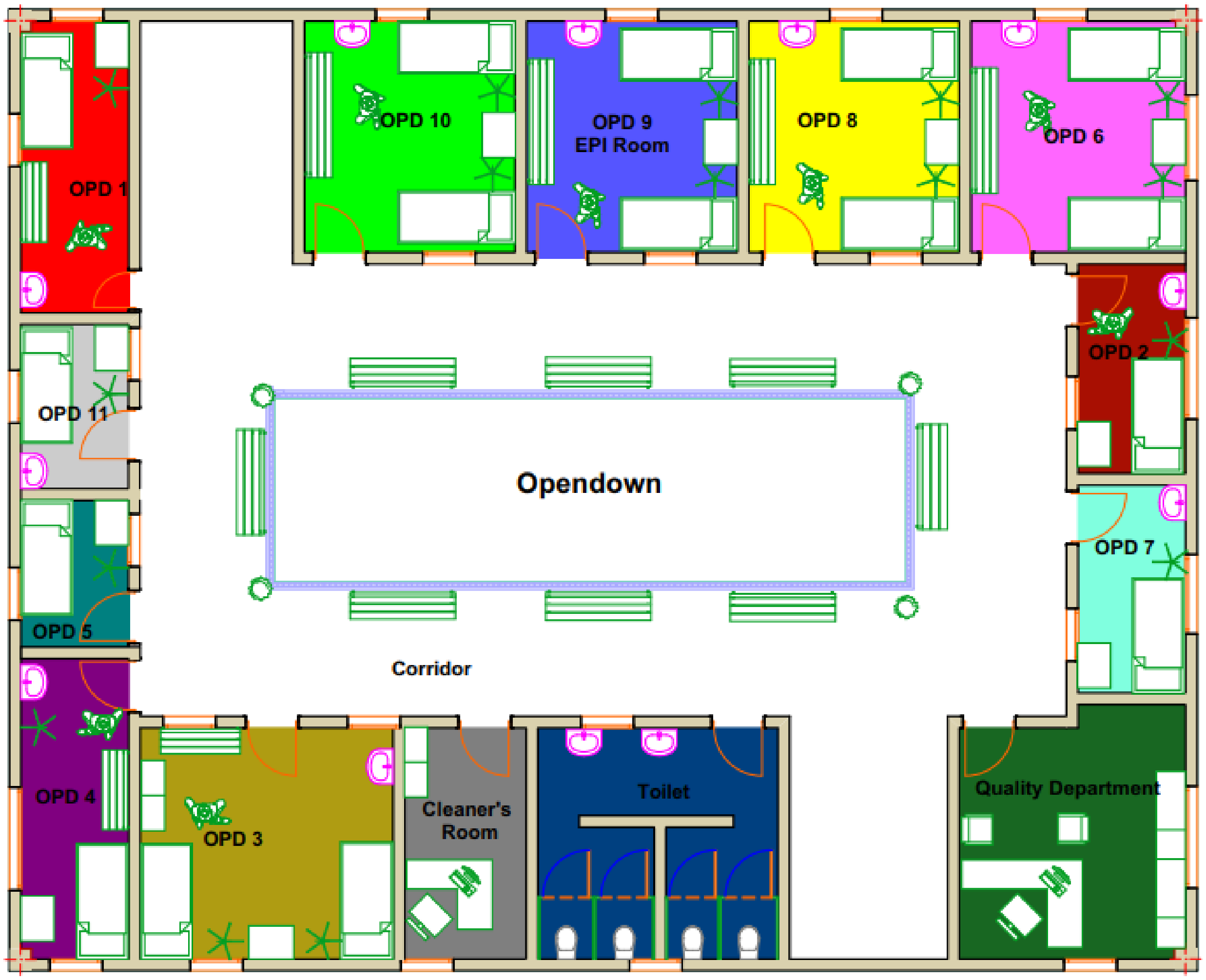


Figure 15 Floor plan of proposed layout of OPD at THC

4.4.1. Centroid of the Proposed Layout

In the new proposed layout X and Y centroid is different because departments are arranged based on patient flow into consideration but the area of each department and the colors assigned are similar to the existing health center facility layout.

Table 9 Centroid distance of ground floor departments proposed layout at THC

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
D 1	1	23	23	1.54	3.84	1
D 2	2	21	21	4.50	3.50	2
D 3	3	40	40	11.50	4.00	3

D 4	4	191	200	31.45	8.50	4
D 5	5	7	7	21.92	23.78	5
D 6	6	11	11	22.04	28.22	6
D 7	7	7	7	25.92	23.78	7
D 8	8	7	7	32.50	25.50	8
D 9	9	9	9	39.38	26.61	9
D 10	10	22	22	41.86	27.36	10
D 11	11	43	43	33.87	23.54	11
D 12	12	23	23	41.54	35.84	12
D 13	13	21	21	36.35	37.92	13
D 14	14	38	38	29.23	46.00	14
D 15	15	38	38	29.00	38.07	15

Table 10 Centroid distance of proposed OPD departments layout at THC

Department	Color	Area-required	Area-defined	x-centroid	y-centroid	Sequence
D 1	1	18	18	1.16	5.50	1
D 2	2	17	17	2.20	14.08	2
D 3	3	17	17	19.55	3.14	3
D 4	4	17	17	11.38	1.97	4
D 5	5	18	18	15.77	1.94	5
D 6	6	9	9	19.50	7.50	6
D 7	7	9	9	2.16	2.50	7
D 8	8	11	11	19.86	14.31	8
D 9	9	26	26	13.73	15.07	9
D 10	10	17	17	5.14	15.55	10
D 11	11	17	17	7.14	1.91	11
D 12	12	11	11	9.13	14.68	12
D 13	13	9	9	1.50	10.50	13
D 14	14	9	9	19.50	10.50	14

Monthly patient flow between departments for the newly proposed layout is similar to the existing health center facility layout.

4.4.2. Cost estimation of the final proposed layout

In this research, the facility layout of Teklehaimanot Health Center was redesigned and analyzed by considering the areas of expertise that have been raised and conducting a data analysis of the monthly patient flow matrix to reach at the final facility layout that is patient centered. The final cost of this proposed layout for ground floor and OPD departments were calculated as 10,008 ETB, which shows a decrement of 5,045.14 ETB compared to the previous ground floor facility and outpatient (OPD) ward configuration. This data-driven optimization demonstrates the potential to deliver more cost-effective care through strategic facility planning informed by insights into service expertise and patient utilization patterns.

4.5. Multi-Criteria decision making

Currently, Teklehaimanot Health Center occupies a multi-story building, with different departments and services dispersed over the first, second, third, and fourth floors. Relocating one of the current departments to the neighboring building formerly used for cancer patient care is something the management team is thinking about doing to improve service delivery and optimize the facility's layout.

The criteria to be considered in this MCDM analysis include:

1. Accessibility for Patients and Staff
2. Accident-free facility for patient (safety)
3. Available Space and Capacity
4. Noise and Privacy Levels

Pairwise comparisons with key stakeholders, including facility administrators, patient representatives, and healthcare professionals will determine the relative value of each criterion. This will guarantee that the priorities and concerns of all pertinent stakeholders are reflected in the decision-making process. Subsequently, the MCDM analysis will assess every floor alternative in light of the predetermined criteria, resulting in the computation of weighted scores for every choice. It will be suggested that the floor with the greatest total score be moved to the nearby building. To improve the decision-making process's resilience, a sensitivity analysis will be carried out to evaluate the suggested solution's stability in various weighing scenarios. This action will give the management of Teklehaimanot Health Center additional evidence that the final suggestion is reliable and will enable the management team to make an informed, data-driven decision.

4.5.1. Analytic Hierarchy Process (AHP)

The AHP analysis was conducted to evaluate which floor to move to the former building of the cancer care building. Each floor contains different departments as shown table below.

Table 11 Floor departmental room information

Floor	**Departments**
Ground floor (Shared department)	Cashier room, Document room, cleaner's room, Toilet, Sterilization room, Laboratory technician room, Laboratory room, Inpatient room, Injection room, Emergency room.
First floor (Delivery department)	PMIC room, ANC room, three Delivery rooms, Midwife rest room, Toilet, General examination room, Ultrasound room, Store, rest room and cleaner's room.
Second floor (OPD department)	OPD 1, OPD 2, OPD 3, OPD 4, OPD 5, OPD 6, OPD 7, OPD 8, OPD 9, OPD 10, OPD 11, toilet and quality department.
Third floor (HIV Care unit & Supporting facility)	Cervical procedure, Ultrasound room, 2 supporting room for HIV related cases, ART 1, ART 2, ART Pharmacy, Toilet, store, Family planning, KP & SNS, Cervical screening room, VCT room, CAC room

To select which floor to relocate to the former cancer care building, the selection criteria are as follow:

1. Accessibility for Patients and Staff
2. Accident-free facility for the patient (safety)
3. Available Space and Capacity
4. Noise and Privacy Levels

Step 1: Pairwise comparison of Criteria

A panel of experts, including healthcare professionals, facility managers, and patient representatives, was engaged to perform pairwise comparisons of the criteria. The relative importance of each criterion was assessed using a 9-point scale, where 1 represents equal importance and 9 represents extreme importance of one criterion over another. The resulting pairwise comparison matrix is as follows:

Table 12 Pairwise comparison for floor selection

Criteria	Accessibility for patients and staff	Accident-free facility for patient(safety)	Available space and capacity	Noise and privacy level
Accessibility for patients and staff	1.00	3.00	9.00	5.00
Accident-free facility for patient(safety)	0.33	1.00	9.00	3.00
Available space and capacity	0.11	0.11	1.00	3.00
Noise and privacy level	0.20	0.33	0.33	1.00

Step 2: Criteria weight calculations

Based on the pairwise comparison matrix, the criteria weights were calculated using the eigenvalue method. The resulting weights are:

- Accessibility for patients and staff: 0.57
- Accident-free facility for patients (Safety): 0.29
- Available space and capacity: 0.07
- Noise and Privacy Level: 0.06

Step 3: Evaluation of floor alternatives

Each of the five floors (ground, first, second, and third floor) was assessed against the four criteria using a 9-point scale, where 9 represents the best performance and 1 represents the worst performance. The performance scores for each floor alternative are as follows:

Table 13 Evaluation of floor alternatives

Floor/Criteria	Accessibility for patient	Accident-free facility	Available space and capacity	Noise/Privacy

Ground Floor	1	3	5	1
First Floor	9	9	8	8
Second Floor	8	6	8	2
Third Floor	8	6	7	5

Step 4: Weighted score calculations

The weighted scores for each floor alternative were calculated by multiplying the performance scores with the corresponding criteria weights and then summing the weighted scores across all criteria. The final weighted scores are:

- Ground Floor: 0.57 × 1 + 0.29 × 3 + 0.07 × 5 + 0.06 × 1 = 1.87
- First Floor: 0.57× 9 + 0.29 × 9 + 0.07 × 8 + 0.06 × 8 = 8.86
- Second Floor: 0.57 × 8 + 0.29 × 6 + 0.07 × 7 + 0.06 × 5 = 7.15
- Third Floor: 0.57 × 8 + 0.29 × 6 + 0.07 × 8 + 0.06 × 2 = 7.03

Step 5: Ranking and recommendation

Based on the calculated weighted scores, the ranking of the floor alternatives from highest to lowest is:

1. First Floor (delivery department) = 8.86
2. Second Floor (OPD department) = 7.15
3. Third Floor (HIV care unit & supporting facility) = 7.03
4. Ground Floor (Shared departments) = 1.87

Therefore, the recommendation is to relocate the first floor (delivery ward) of multi-story building of THC to the former cancer care building, as it has the highest overall weighted score and high performance across the evaluated criteria. Then after the vertical floor arrangement will be changed since the first floor will be placed on the former cancer ward building. First floor will be occupied with OPD department and the second floor will be occupied by HIV care unit & supporting facility which have an impact on reducing walking distance and alter service time as well.

4.6. Simulation model

The use of Arena simulation software will be a crucial component of the analysis, results, and discussion sections of this research. The primary objective is to leverage this simulation tool to quantify and demonstrate the improvements in key performance indicators (KPIs) achieved through the application of the CRAFT methodology & AHP technique for optimizing patient path and improve service delivery time at THC. The CRAFT methodology focuses on optimizing the horizontal movement whereas AHP technique to decide on convenient floor arrangement to optimize vertical movements of patients within the healthcare facility. The idea is to minimize the amount of walking time and avoid unnecessary movement taken by patient by reorganizing the floor layout and placing key service stations closer based on patient flow. Because of the existing facility layout lack proximity between key service rooms that should be placed nearby, patients take longer time by walking in the health center facility. The ultimate service delivery time is one of the key KPIs that could be greatly impacted by this patient flow improvement.

A model of the healthcare facility is made using Arena simulation software, which will capture the current design and patient flow procedures. After then, this simulation model will be used as a reference point. Rearranging the floor design and placing the service stations optimally are two modifications recommended that is included to simulate the improved patient flow and quantify its influence on the KPIs. Arena simulation allows for the collection of data on various performance metrics, including patient waiting time and service time. By comparing the baseline scenario to the improved layout scenario, the quantifiable benefits of the patient centered layout optimization by implementation can be clearly demonstrated.

This data-driven analysis will be a valuable contribution to empirical evidence supporting the effectiveness of the proposed improvements regarding optimization of facility layout. The use of Arena simulation software will be a crucial tool in this research, enabling the objective assessment of the impact of the redesigned facility layout on the key performance indicators of the healthcare center, ultimately strengthening the service delivery at THC.

4.6.1. Simulation model for existing health center facility

The primary purpose for using Arena simulation software in this research is to first build and validate a simulation model of the existing facility layout and processes at Teklehaimanot Health Center. By integrating the findings from the earlier process mapping analysis regrading patient path with time study data collected for each service station, Arena model allows to accurately replicate the actual patient flow and operations within the health center. This step is crucial to ensure the simulation accurately mirrored the real-world system. By comparing the key performance indicators, such as patient waiting time and service time, between the actual health center data and the initial Arena simulation to validate the model's ability to capture the existing conditions.

Only after establishing this baseline model, it is possible to confidently proceed with testing the impact of the proposed facility layout optimizations result that has been proposed using CRAFT methodology to identify opportunities to reduce the walking distances between critical service stations, such as triage room, card room, and cashier room that will have great impact in reducing key performance indicators such as waiting time and service time. By incorporating these layout changes into the Arena simulation, it is possible to quantify the resulting improvements in the key performance indicators.

Ultimately, the Arena software provided a robust platform to first validate the existing health center operations through process modeling and time study integration. This gives a reliable baseline to then assess the anticipated benefits of the proposed layout changes that enables to generate data-driven evidence to support facility optimization recommendations.

The existing facility layout model has been developed and run using Arena simulation software. As an input for building the model process map of the existing facility layout has been used and the time study file used as an input to get best theoretical distribution of each service station that the patient follows to get service in Teklehaimanot Health Center. The model developed to show the existing service flow is shown in figure below.

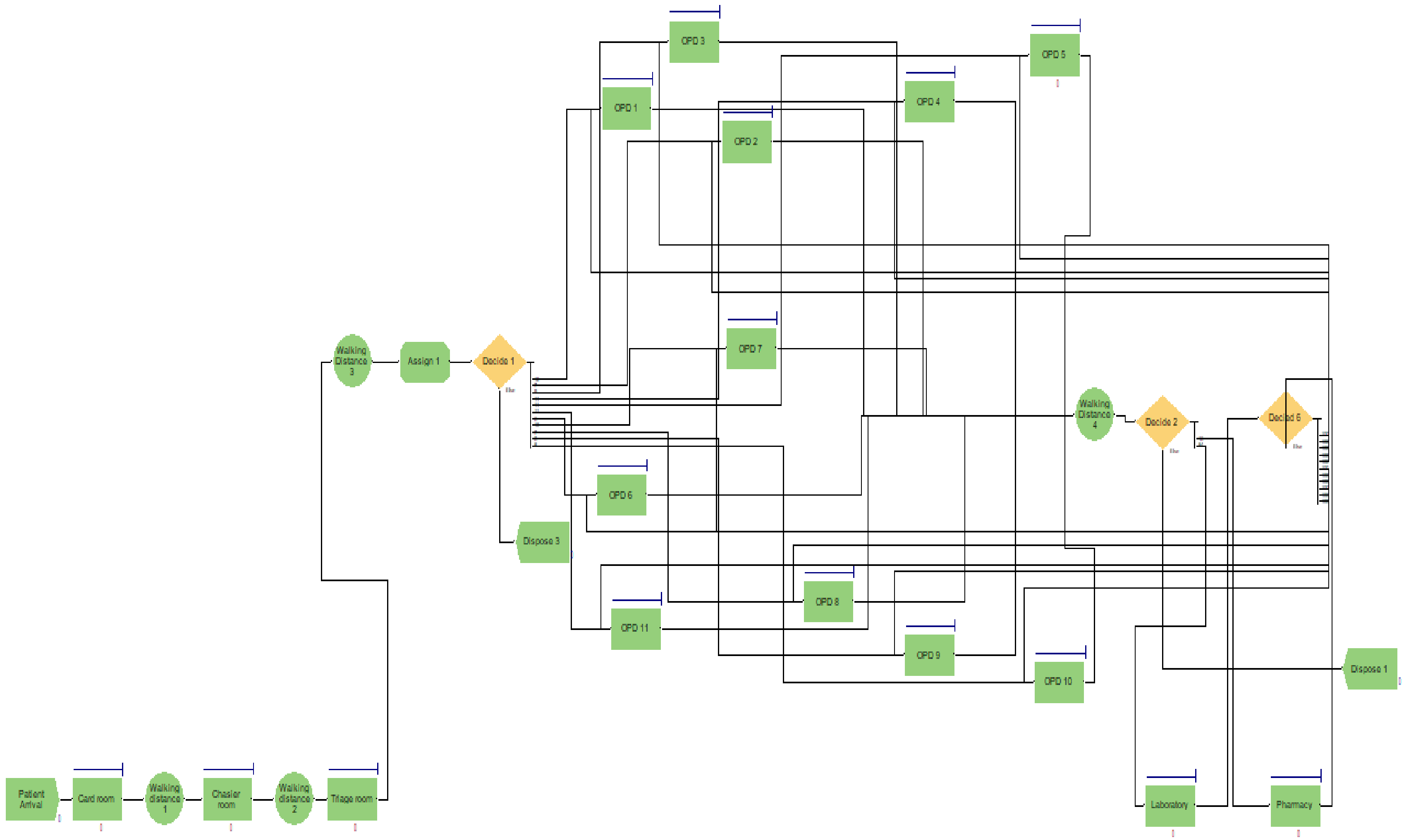
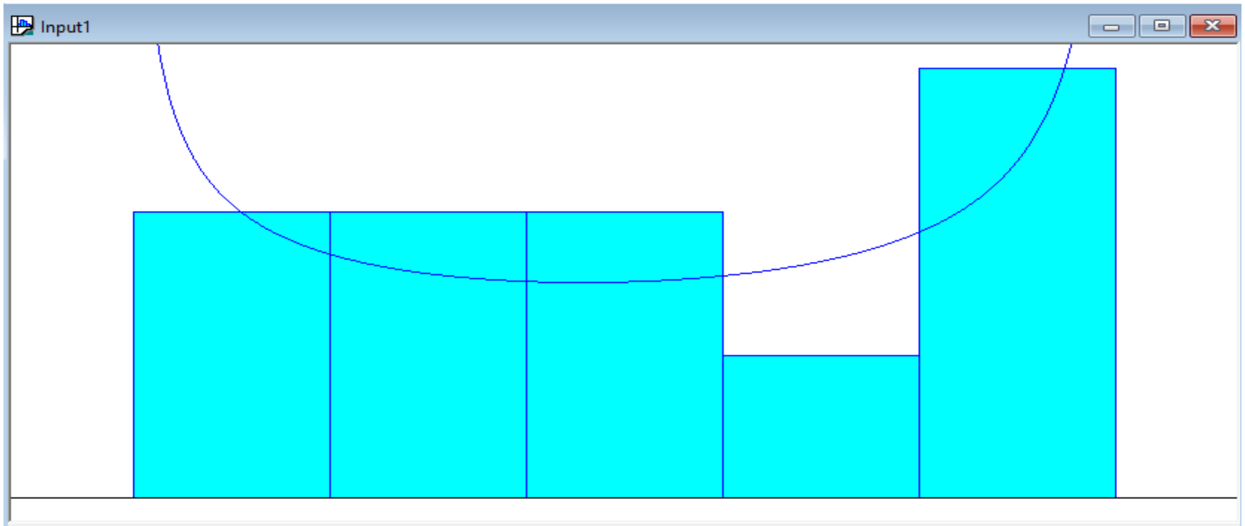


Figure 16 Existing facility of THC patient flow simulation mode

4.6.2. Input analyzer for determining best theoretical distribution of each service station

In order to optimize a healthcare facility's layout and operations, a full grasp of the underlying processes and their features is necessary. Accurately modeling the service processing times for different facility activities, like patient registration, triage, and laboratory, is a crucial step in this research. It systematically investigates the most appropriate theoretical probability distributions to describe the empirical data gathered from the healthcare context by utilizing the Arena Input Analyzer. In addition to improving the simulation model's accuracy, the distribution fitting procedure offers important insights into the patterns and inherent variability seen in service delivery operations. The results of this research can then guide, layout optimization tactics, and process improvement projects to improve service delivery of THC. The distribution for each station is decided using fit all button. The figure below shows input analyzer used for card room station. And the distribution of each service station will be listed in table from input analyzer data.




```
          Distribution Summary

Distribution:    Beta
Expression:      2 + 2 * BETA(0.665, 0.602)
Square Error:    0.012869

Kolmogorov-Smirnov Test
  Test Statistic          = 0.121
  Corresponding p-value   > 0.15

          Data Summary

Number of Data Points     = 10
Min Data Value            = 2.1
Max Data Value            = 4
Sample Mean               = 3.05
Sample Std Dev            = 0.664

          Histogram Summary

Histogram Range           = 2 to 4
Number of Intervals       = 5
```

Figure 17 Distribution for card room service station summary using arena input analyzer

Table 14 Theoretical distribution of each service station of THC using input analyzer

Sr. no.	Service description	Distribution	Expression	Square Error
1	Card room	Beta	2 + 2 * BETA (0.665, 0.602)	0.013
2	Cashier room	Beta	5.12 + 3.36 * BETA (0.855, 0.657)	0.061
3	Triage room	Beta	18 + 6 * BETA (0.827, 0.795)	0.056

4	OPD 1	Beta	22 + 13 * BETA (1.38, 0.965)	0.042
5	OPD 2	Beta	12.5 + 58 * BETA (0.449, 0.386)	0.071
6	OPD 3	Triangular	TRIA (0.001, 3.16, 5)	0.133
7	OPD 4	Beta	31 + 7.78 * BETA (0.649, 0.623)	0.008
8	OPD 5	Normal	NORM (16.6, 3.09)	0.011
9	OPD 6	Beta	21.1 + 6.84 * BETA (0.98, 0.924)	0.019
10	OPD 7	Weibull	22 + WEIB (3.13, 1.31)	0.024
11	OPD 8	Triangular	TRIA (34, 43.7, 45)	0.059
12	OPD 9	Beta	43 + 12 * BETA (1.52, 0.951)	0.035
13	OPD 10	Beta	32 + 12 * BETA (0.824, 0.781)	0.098
14	OPD 11	Uniform	UNIF (32, 44)	0.100
15	Laboratory	Beta	21 + 24 * BETA (0.708, 0.569)	0.047
16	Pharmacy	Beta	32 + 12 * BETA (0.824, 0.781)	0.098

For each service station to develop the simulation model input analyzer has been used to get the best theoretical distribution. Overall, general simulation reports of the existing layout of health center on KPIs are shown figure below.

Existing layout	Waiting time	Service time
OPD 1	2.62	0.74
OPD 2	2.62	0.77
OPD 3	2.62	0.65
OPD 4	2.62	0.70
OPD 5	2.62	0.71
OPD 6	2.62	0.72
OPD 7	2.62	0.82
OPD 8	2.62	0.54
OPD 9	2.62	0.80
OPD 10	2.62	0.77
OPD 11	2.62	0.73
Average	**2.62**	**0.72**

Figure 18 Existing average waiting and service time of simulation output

4.6.3. Simulation of proposed health center layout

The research aims to improve service delivery at Teklehaimanot Health Center in Addis Ababa, Ethiopia, through facility layout optimization. The study begins with a process mapping analysis to thoroughly understand the patient flow and key service stations within the health center of outpatient department. This is followed by measuring the dimensions of each service room to enable the use of the CRAFT (Computerized Relative Allocation of Facilities Technique) methodology for optimizing the existing facility layout considering horizontal movement of patients. Additionally, the Analytical Hierarchy Process (AHP) technique is employed to arrange the placement of various departments and floors. To quantify the expected improvements, Arena simulation software is used. The Arena model allowed for comprehensive process modeling based on the earlier time study data, enabling the evaluation of key performance indicators such as patient waiting time and service time. By simulating the proposed layout changes, including the relocation of the outpatient department to the first floor to minimize vertical movement, the research could validate the anticipated reductions in walking distances between critical service areas. The Arena simulation also facilitated scenario analysis and sensitivity testing to ensure the robustness of the findings. Ultimately, the use of Arena simulation software provided a powerful platform to justify the proposed facility layout optimization and its positive impact on improving service delivery at the Teklehaimanot Health Center.

A new plan that attempted to reduce the walking distances between various service areas is recommended as a solution to the lengthy wait times that patients at Teklehaimanot Health Center were facing. It is predicted that this new arrangement will directly affect patient waiting and service times. Using the Arena simulation, a new simulation model is created in order to assess the efficacy of the suggested arrangement. The main modifications to the facility's layout, such as the rearranged patient flow routes and adjusting the walking distance between stations, were included in this simulation model. The new model for the proposed health center facility is shown below.

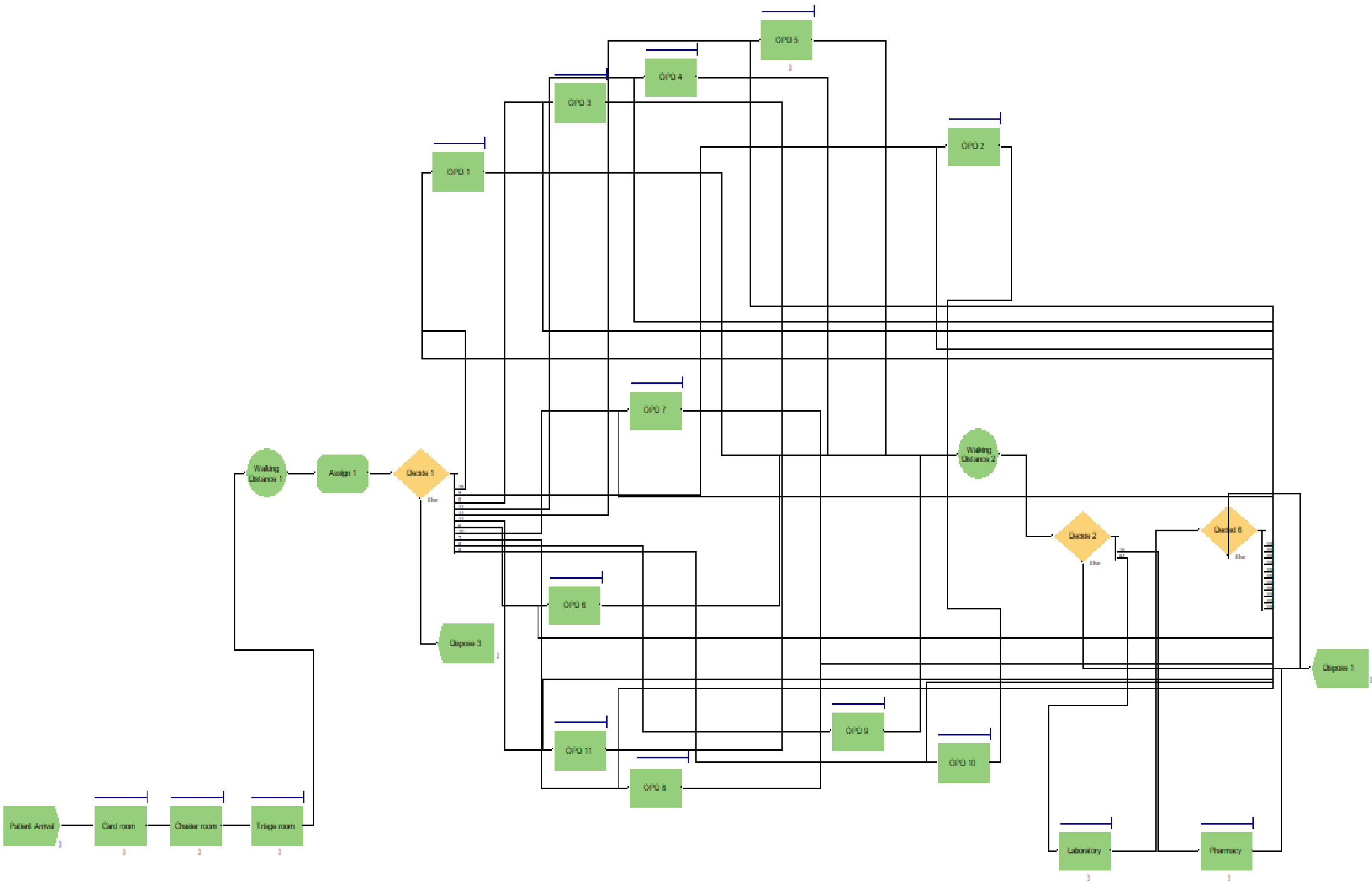


Figure 19 New simulation model of the proposed health center layout

The new proposed layout has shown an improvement in terms of waiting time ad service time for each service station of the health center. Overall, simulation reports of the new health center layout are shown in figure below.

Optimal layout	Waiting time	Service time
OPD 1	2.01	0.66
OPD 2	2.01	0.69
OPD 3	2.01	0.58
OPD 4	2.01	0.63
OPD 5	2.01	0.63
OPD 6	2.01	0.64
OPD 7	2.01	0.73
OPD 8	2.01	0.48
OPD 9	2.01	0.71
OPD 10	2.01	0.68
OPD 11	2.01	0.65
Average	**2.01**	**0.64**

Figure 20 Proposed average waiting and service time of new simulation output

4.7. Discussion

While the time study conducted as part of this research project found the current waiting time to be 2.45 hours and the service time to be 0.71 hours, the researchers opted to use the data reported by the THC in the conclusion. The decision to use the THC annual report data was made due to the relatively small sample size of the time study, which only included 271 patients. In contrast, the THC report is based on the facility's yearly operational data, providing a more comprehensive and representative picture of the actual waiting and service times experienced by patients at the health center. While the time study data provided useful insights, the researchers acknowledge that the yearly data from THC report is likely more reflective of the true operational conditions at the health center.

The suggested layout modifications at the Teklehaimanot Health Center are amply illustrated by the simulation results. The lengthy walks that were previously noted to occur between vital departments such the card room and the cashier room—as well as between the triage room and the OPD floor were found to be important factors in the total amount of time that patients had to wait. In addition, the vertical movement of patient has been reduced by half since the OPD station come to the first floor. The simulation model indicated a noteworthy reduction in the average waiting time from 2.5 hours to 2.01 hours by strategically moving the injection room and the inpatient room, to card room and the triage room within the multi-story building. This 19.6% reduction in wait time could significantly enhance the delivery of the service as a whole. In addition, a notable 18.98% improvement in service time is seen, going from 0.79 hours to 0.64 hours. This improvement can be attributed to shorter walking distances and more effective patient flow. The aforementioned results underscore the need of meticulously evaluating the spatial associations and closeness of crucial departments in a healthcare establishment. By optimizing the arrangement, noteworthy operational advantages are achieved, including decreased wait times, service time that enhance service delivery and patient satisfaction.

Table 15 Comparison of current and proposed layout on service delivery time at THC

Comparison	**Average service delivery time before layout improvement (THC annual report)**	**Average service delivery time after layout improvement (simulation)**	**Improvement in percentage (%)**
Average waiting time for OPD service	2.5hr	2.01hr	19.60%
Average service time of OPD service	0.79hr	0.64hr	18.98%

The suggested layout modifications lead to major savings in terms of wait and service time. The final layout, which moved the inpatient room, injection room, triage room, card room, and placement of each floor, was predicted to cost only 10,008 ETB, a decrease of nearly 33.5% from the initial estimate of 15,053.14 ETB. The reason for this significant cost reductions is that the multi-story building's available space was used more effectively, and there was less need for major construction or restoration work. Through layout optimization and departmental re location, the health facility is able to obtain a more economical solution that aligned with the available budget and resources.

The total effectiveness of the health center as well as patient satisfaction may directly and favorably benefit from these operational improvements. The suggested layout's cost-effectiveness a 33.5% decrease in implementation costs also emphasizes how thoughtful facility design may lead to better service delivery and increased financial sustainability. These findings highlight how crucial it is to include thorough simulation-based analyses in the planning and optimization process for healthcare facilities because doing so empowers administrators to make data-driven choices that improve patient satisfaction and care quality overall.

Chapter Five

5. Conclusion & Recommendation

5.1. Conclusion

The study aims to optimize the existing health center facility layout using improvement algorithm to enhance service delivery. After careful analysis of the service delivery time, the following conclusions are drawn.

- Findings amply illustrate the critical significance that department proximity and strategic space planning can play in improving service delivery and operational efficiency. The initial design flows, notably the considerable separation between vital areas like triage room, cashier, and card room, led to long walking times that hampered overall service effectiveness. The suggested layout modifications, which includes the deliberate displacement and co-location of important station, produced outstanding outcomes. The final streamlined layout yielded real operational benefits in addition to a 33.5% reduction in the initial implementation cost. The most notable improvement is in the average service time, which dropped from 0.79 hours to 0.64 hours by 18.98%, while the average patient waiting time decreased by 19.60% from 2.5 hours to 2.01 hours. The significance of using a patient-centered approach in healthcare facility design, where the spatial linkages and proximities of services are carefully examined to streamline the user experience, is highlighted by these compelling findings.

Therefore, optimizing existing health center facility layout have significant impact on service delivery time and patient satisfaction.

5.2. Recommendation

The analysis conducted, the findings, and the conclusions reached set recommendations that are put out to Teklehaimanot Health Center.

- The research findings have clearly demonstrated that the current facility layout at Teklehaimanot Health Center is suboptimal, resulting in long service delivery time to patients. To address this, the health center should prioritize a patient-centered layout when redesigning the facility layout. This involves strategically positioning key departments and services, such as the card room, cashier, and triage room, in close proximity to one another to minimize patient walking distances and streamline the care journey which at the end highly affect the service delivery time.

- The research findings have demonstrated the significant impact that facility layout can have on key operational metrics, such as patient waiting time and service time. By prioritizing operational efficiency in the facility redesign process, Teklehaimanot Health Center can unlock substantial gains in service delivery, ultimately enhancing the overall quality of care provided to patients.
- To redesign the existing facility of multi-story building of THC, the facility of health center that has been optimized and proposed in this research can be used as input to enhance service delivery time and patient satisfaction.

5.2. Future research areas

After conducting research and analyzing the different aspects of service delivery parameters, the following research areas are recommended to be undertaken in the future.

- Forecasting Patient Demand and Service Utilization Patterns in Health Centers using Time Series Analysis
- Optimizing Resource Allocation and Appointment Scheduling in Health Centers through Queuing Theory

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Appendix

Appendix A: Summary of Literature Review

Author	Objective of the study	Facility type	Tools used in the study	Measuring variable	Impact on service delivery	Limitations of the study
(Hoon & Rismanchian, 2018)	Propose a method to help healthcare organizations analyze complex hospital processes and find the optimal patient-centered layout based on real characteristics of the system in order to increase the efficiency of care services.	Hospital	Process mining techniques were applied to extract process-related information, such as process model and pathway patterns, from the event log of an Emergency Department (ED) in Seoul, South Korea.	Total walking distance of patients	Improve the overall service efficiency in healthcare settings resulting in an optimal layout that showed a 37.95% improvement in the total walking distance of patients	The study does not address all possible factors that may impact hospital facility layout planning such as patient and personnel's safety and security that must be taken into account when designing a hospital building.
(Tarigan et al., 2020)	Minimize waste and improve the layout of facilities to speed up the service process and reduce patient waiting time	Clinic	Lean service , value stream mapping, systematic Layout Planning method	Service processing time and total transfer moment	Total transfer moment of 64.49% reduces the proposed layout 1,935 meters/week to 687 meters/week. The processing time was reduced by 22.62% from 4271.8	The proposed layout is the only one due to limited land and minimizes changes to the actual layout

					seconds to 3304.67 seconds	
(Cubukcuoglu et al., 2021)	Renovation of existing hospital	Hospital	Quadratic Assignment Problem (heuristic optimization algorithm)	Flows between facilities and distances between locations	Minimizes the internal transportation processes between interrelated facilities where each facility is assigned to a location in an existing building	Consider all facilities to be accommodated in all available locations, while in reality there might be facilities that can only be accommodated in certain locations due to particular technical requirements.
(Turgay, 2018)	Aimed to find the most proper design with minimum cost by considering alternative facility layout plans and determining the highest system performance design of the facility layout.	Cellular manufacturing	Multi-objective simulated annealing algorithm	As material handling cost, normalized cost value, remoteness function value, and cost coefficients.	Proposed a three-stage heuristic approach for solving MOFLP, which included normalizing the data matrix of each objective, using an entropy-based approach to compute the objective weights, and solving MOFLP with linear programming and a multi-objective simulated annealing approach for n=9.	No limitation has been listed.

(Deshpande et al., 2016)	Reduce WIP, optimum space utilization and improve the flow process of production system	RMG alloy steel industry in Bharuch	CRAFT & ALDEP	Material handling cost through facility layout optimization	Using CRAFT MHC has been reduced by 0.1% & using ALDEP MHC has been reduced by 23%	Reduce the effort made by production worker.
(Munavalli et al., 2022)	To minimize the waiting times by obtaining optimal and sub-optimal layout designs.	Clinic (applicable only in outpatient department)	Meta heuristic algorithm	Waiting time and cycle time	Waiting time of the new redesigned layout has been reduced by 21.6 minute and cycle time has been reduced by 16.06 minute	No limitation has been listed.
(Tongur et al., 2020)	To minimize the transportation time of patients and hospital staff	Hospital	Meta-heuristics algorithms	Transportation time of patients and hospital staff	Efficiency is 58% better when compared with the existing layout	No limitation has been listed.

Appendix B: Focal Group Discussion

Discussion Points	Participants	Date	Place
Selection of optimal layout, interdepartmental relation that centered on patient path and staff flow as well	Ms. Yamlak B (HO) ,Nurse Bira Shiferawu, Nurse Meaza Girma, Mrs. Meseret Misasewu (HO), Mr. Zeray Kassahun, Mrs. Getana Gurmu	1-June-2024	Teklehaimanot Health Center, Addis Ababa, Ethiopia