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Design of Tuberculosis Diagnostic Clinical Pathway Information System at Hospital X Bandung

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Abstract: Tuberculosis (TB) remains a significant public health challenge in Indonesia, including at Hospital X Bandung, where the diagnosis process still relies on paper-based clinical pathways that are prone to errors and inefficiencies. This research aims to design a web-based information system to digitize the clinical pathway of TB diagnosis to improve the accuracy, consistency, and speed of patient treatment. The system development method uses the Waterfall approach with the stages of needs analysis, design, implementation, and testing. The system was developed using the Flask framework with the Python programming language, utilizing SQLAlchemy for SQLite database management. The implementation results include key features such as patient data input, structured clinical pathway forms, medical record management, and treatment evaluation tracking. Black box testing shows that all system functionality is running as expected, including data validation and patient information storage. This system is expected to reduce the variation in clinical practice, improve medical documentation, and facilitate real-time patient monitoring. Future development suggestions include integration with other hospital systems, the addition of artificial intelligence-based prediction features, and optimization of the interface for mobile access.

Keyword: Clinical Pathway, Tuberculosis, Information System, Flask, Python

INTRODUCTION

Tuberculosis (TB) is a major public health challenge in Indonesia, as hospitals such as Hospital X Bandung still rely on paper-based manual clinical pathways that are prone to errors and inefficiencies. The high rate of illness and death from TB not only impacts individual health but also puts a strain on the health system as a whole. In this context, the implementation of standardized *clinical pathways* is an important solution to improve the consistency and quality of TB diagnosis (Namira Fatimah Azahra & Sugiarti, 2023).

Hospital X Bandung currently faces significant obstacles in diagnosing TB due to a fragmented recording system and reliance on manual procedures. The diagnosis process involving several stages, such as symptom collection, sputum examination, and interpretation

of radiology results, is often recorded inconsistently between doctors. This has the potential to lead to variations in clinical practice and delays in diagnosis. A web-based information system that integrates *a clinical pathway* for TB diagnosis can simplify workflows, ensure adherence to protocols, and facilitate structured documentation (Madiah et al., 2024). This approach also allows for *real-time* tracking of patient histories, which is critical for diseases such as TB that require continuous monitoring.

However, the implementation *of the clinical pathway* in many hospitals, including Hospital X Bandung, still relies on paper-based manual systems that are prone to errors and inefficiencies. The digitization of *the clinical pathway* for TB diagnosis is considered a strategic step to address this problem while improving the accuracy and speed of patient treatment (Yunengsih, Suryani, & Syahidin, 2024).

The clinical pathway itself is an important tool in standardizing TB diagnosis and treatment, which has been proven to improve the efficiency and consistency of services (Namira Fatimah Azahra & Sugiarti, 2023). However, the success of the pathway is highly dependent on the implementation of an integrated and easily accessible information system. A study by Fajriani, (2021) shows that web-based information systems designed with a modular approach are able to simplify workflows, reduce clinical variation, and support real-time patient documentation.

On the technical side, the development of Flask and SQLite-based health information systems has gained attention due to their flexibility and efficiency. Flask, as a *lightweight yet* powerful Python *framework*, facilitates integration with data analysis libraries such as Pandas and NumPy, and supports structured and continuous system development (Chauhan, Singh, Verma, Parasher, & Budhiraja, 2019). Meanwhile, using SQLAlchemy as an ORM makes it easier to manipulate data while still allowing flexibility in executing SQL queries for advanced analytics needs.

The integrated system allows aggregate data analysis for the identification of TB epidemiological patterns in the hospital's work area. However, challenges such as resistance to change and limitations of technological infrastructure need to be anticipated through gradual training and modular approaches in system development (Wicaksono, Romadhony, & Sulistiyo, 2014). Collaboration with stakeholders, including local health authorities, is also important to ensure the system's alignment with local policies.

In the article, Solomon et al., (2023) emphasized the importance of a phased approach in the implementation of digital systems in the hospital environment, given challenges such as infrastructure limitations and resistance to change. Intensive training, stakeholder engagement, and compliance with local policies are key factors for successful system adoption. Therefore, the development of a modular *clinical pathway* information system focused on a single clinical phase such as TB diagnosis is considered a strategic step that allows for gradual and sustainable improvement of service quality (Dewi et al., 2024).

The study designed a web-based information system to digitize *the* TB diagnostic clinical pathway *with the aim of improving accuracy, and improving real-time patient monitoring*. The system is designed using *the waterfall* method, while the scope of designing this system is limited only to the stage of designing an information system to support TB diagnosis. This focus was chosen to ensure that the designed system can be truly optimized at one clinical phase first before being developed further into the treatment or monitoring phase.

METHOD

This study uses *a qualitative* descriptive method with a *software engineering* approach to design a web-based information system that supports the diagnosis *of the clinical pathway* diagnosis of TB. The system development method chosen is the *Waterfall model* because of its structured nature, allowing the stages of analysis, design, implementation, testing, and maintenance to be carried out systematically (Madiah et al., 2024).

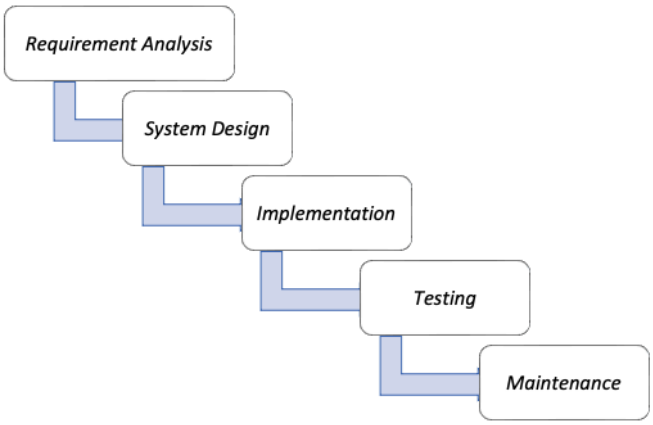


Figure 1. Stages of the *Waterfall Method*

The stages of *the waterfall* method include:

1. *Requirement Analysis*

At this stage, the collection of system needs is carried out based on interviews, observations, and literature studies. The goal is to understand the process of releasing medical results that are underway and identify the functional as well as non-functional needs of the system to be developed.

2. *System Design*

Based on the needs that have been analyzed, a system design is carried out which includes the creation of a context diagram, *Data Flow Diagram* (DFD), *Entity Relationship Diagram* (ERD), and user interface (UI) design. This design is the basis for the implementation of the system.

3. *Implementation*

The system was developed using the Flask framework with SQLite/MySQL databases. This implementation follows the design that has been made, starting from the folder structure, to *the generated* results of reports in the form of excel.

4. *Testing*

The test is carried out using *the black-box testing* method to ensure that every feature on the system works according to the needs. In addition, direct trials were also carried out with users (medical officers) to get initial feedback.

5. *Maintenance*

This stage includes evaluating the system based on the results of testing and user feedback, as well as further improvement or development if problems are found in the use of the system.

1. Data Collection Techniques

In this study, the researcher used several data collection techniques that aimed to obtain comprehensive information about the needs and design of *a clinical pathway* information system for tuberculosis diagnosis. This approach includes qualitative and secondary methods that rely on actual conditions in the field and applicable regulations. The details of the data collection techniques used can be seen in Table 1 below:

Table 1. Data Collection Techniques

Data Collection Techniques	Data Source	Purpose
Structured Interviews	Medical Officer, Coder, Head of Medical Records	Exploring the flow of the implementation *of the TB clinical pathway*, manual system constraints, and user needs for an integrated information system.
Field Observation	The process of administration and assessment of TB patients	Identify the actual process of implementing the TB pathway and user interaction with the current system.
Documentation	SOP, *Clinical Pathway Form*, TB Medical Record	Collect written evidence and archives used in the implementation of the TB pathway, as the basis for system design.
Literature Study	Academic literature, Ministry of Health regulations	Study academic literature and official regulations from the Ministry of Health to understand *clinical pathway standards*, basic concepts of medical information systems, and government regulations related to the management of BPJS patients, especially in referral services. This study is important to ensure that the system designed is in accordance with the principles of data interoperability, service efficiency, and the applicable minimum service standards (SPM). Understanding clinical *pathways* and referral flows can increase the effectiveness of hospital information systems, highlighting the importance of integrating medical information systems with national policies such as the Minister of Health Regulation No. 30 of 2022 concerning the Implementation of Health Information Systems. (Indonesia, 2022; Junaedi, Suryani, & Fadly, 2024).

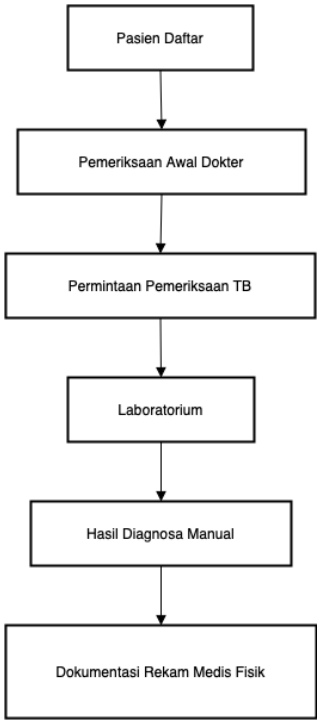
2. Tools Used

The tools used for the system development use the python programming language with Flask as the *back-end framework* with SQLAlchemy support for *database management*. *The database* used is SQLite, while the interface is built with HTML/CSS and Bootstrap to make it responsive and easily accessible through various devices (Ghimire, 2020). The test was conducted using *a black box testing* software testing method that only evaluates the functionality of the system from the outside (*end-user perspective*) without looking at the code structure or internal logic (Verma, Khatana, & Chaudhary, 2017).

RESULT AND DISCUSSION

1. Analysis of Existing Systems

Treatment of TB at Hospital X is currently still carried out manually. The process starts from recording the patient's identity at the registration counter, followed by an initial examination by a general practitioner, to referral to the laboratory for further examination. The results of the examination are then recorded on paper medical records and physically stored by the medical record unit. There is no system that facilitates a standardized TB clinical management pathway, so the flow of diagnosis and follow-up is highly dependent on individual medical personnel. Some of the problems faced include duplication of data recording, delays in handling due to data not available in *real-time*, and lack of control over the stages of TB diagnosis that should be in accordance with clinical standards. Based on initial observations and interviews, users (doctors, nurses, and medical record staff) need an integrated system that facilitates TB diagnosis tracking and pathway-based clinical decision-making.



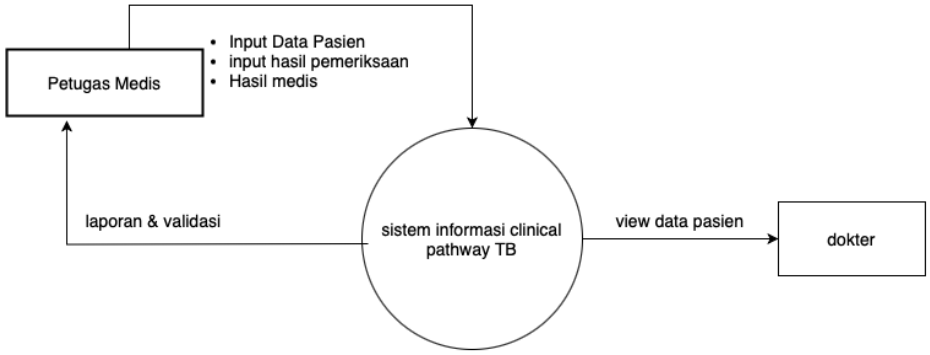
Source: Research data

Figure 2. The flow of direct observation results at RS X

2. System Design

a. System context diagram

Context diagrams are used to illustrate the relationship between the developed information system and the external actors that interact directly with the system. In this *clinical pathway* information system for tuberculosis diagnosis, a context diagram describes the flow of data exchange between users and systems in the macro (upper-level) scope.



Source: Research data

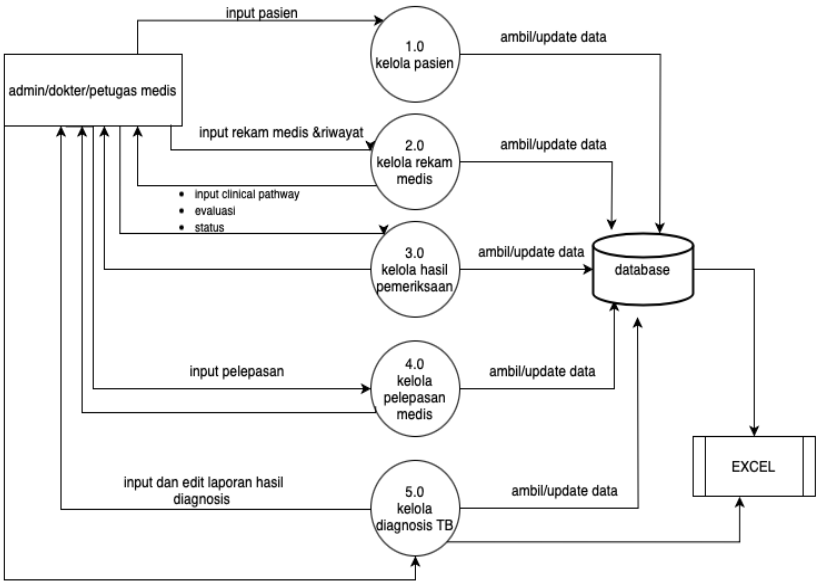
Figure 3. System context diagram

With this system, it is hoped that the entire process of documenting and reporting the *tuberculosis clinical pathway* can be carried out in a more structured, fast, and error-free manner, and in accordance with hospital accreditation standards and Ministry of Health regulations.

b. *Data Flow Diagram* (DFD) Level 0

In the early stages of system design, DFD Level 0 is used to describe the general flow of data between user entities, systems, and databases. The system then processes the data and

communicates with the *database* to store or retrieve the information needed (Abdussalaam & Oktaviani, 2020).

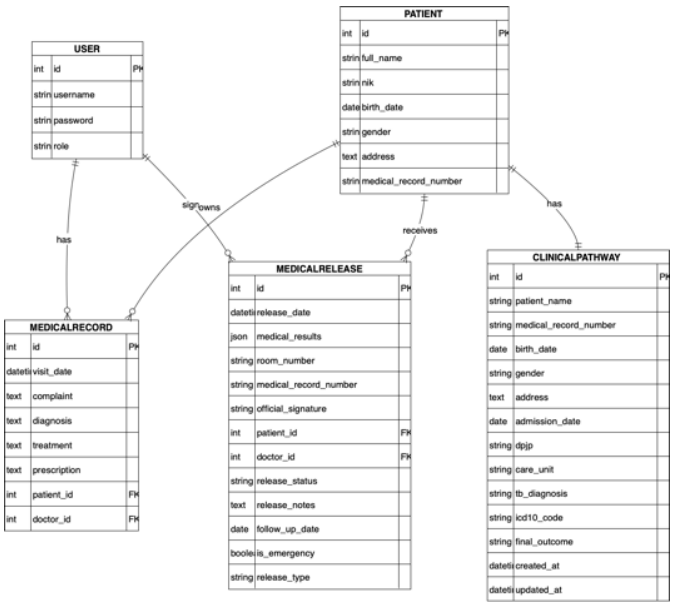


Source: Research data

Figure 4. DFD level 0 *TB clinical pathway* system

c. *Entity Relationship Diagram* (ERD)

To describe the structure of the database, an Entity Relationship Diagram (ERD) is used which shows the main entities and the relationships between tables. A verified diagnosis will result in a suitable *clinical pathway*. Any activity in the system, such as data input or validation (Abdussalaam & Ramdani, 2023).



Source: Research data

Figure 5. ERD TB *clinical pathway* system

This database design supports data integrity and ease in the process of tracking clinical activities. These processes take place cyclically and continuously, reflecting the reciprocal relationship between users and systems in supporting the clinical flow of TB diagnosis.

d. SQLAlchemy Model Structure (ORM)

In this system, data management is carried out using *Object Relational Mapping* (ORM) provided by SQLAlchemy (Luong, 2019). For example, the Patient entity is implemented in the form of a Python model as follows:

```
class Pasien(db. Model):
   id = db. Column(db. Integer, primary_key=True)
   nama = db. Column(db. String(100))
   tanggal_lahir = db. Column(db. Date)
   diagnosis=db.relationship('Diagnosis', backref='patient', lazy=True)
```

This model defines the patient's basic attributes, such as id, name, and tanggal_lahir. In addition, there is a one-to-many relationship with the Diagnosa entity, where a single patient can have multiple diagnostic data. With this approach, the table structure in the *database* can be managed declaratively, consistently, and directly integrated with the application's logic (Ghimire, 2020).

e. Flask Project Folder Structure

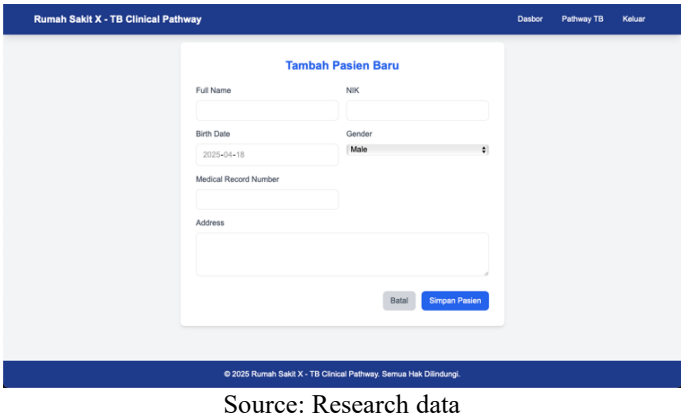
This information system was developed using the Flask framework, with a modular directory structure to maintain the regularity of the project (Whitham & Cruickshank, 2017). The system folder structure is as follows:

/App
/templates → contains HTML files with Jinja2 template engine
/static → store assets such as CSS, JavaScript, and image files
/models → contains definitions of all *database models* (ORMs)
/routes → handle endpoints and data processing logic
__init__.py → Flask app initialization file and *database connection*
config.py → store the main configuration of the application (*database* URI, secret key, etc)
run.py → as the main *entry-point* for running the Flask server

This structure facilitates system maintenance, continuous development, and the separation of logic between components to be more organized (Evan & Saian, 2023).

f. User Interface Design (UI/UX)

The user interface is designed with a simple yet functional approach, with the main goal of providing easy access for medical personnel using this system. There are several main pages in the interface design: Patient Input Form: This page is used to add new patient data to the system.



Source: Research data

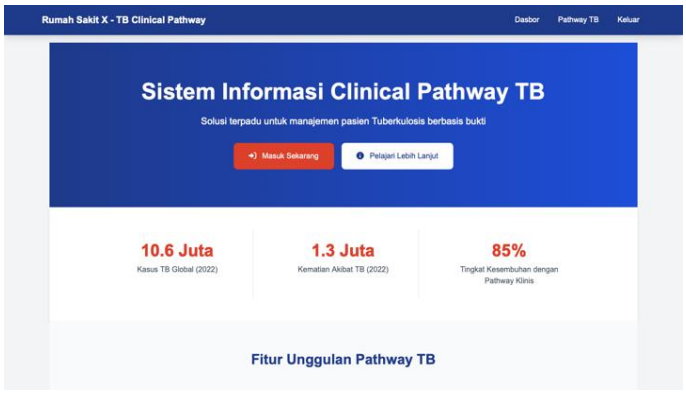
Figure 6. Patient Add Page

3. System Implementation

The implementation of the *Clinical Pathway information system* for the diagnosis of TB has been successfully realized using the Flask framework and the SQLite database with SQLAlchemy ORM. This system is designed to assist in the systematic and protocol-based recording, monitoring, and evaluation of TB patients. The following are the implementation results of each of the main features of the system.

1. Home Page and User Authentication

The system displays a landing page that contains an overview of the purpose and benefits of using *the clinical pathway* in Tuberculosis cases. Users are directed to log in or register first. In this process, a simple login interface with an account validation feature is found.

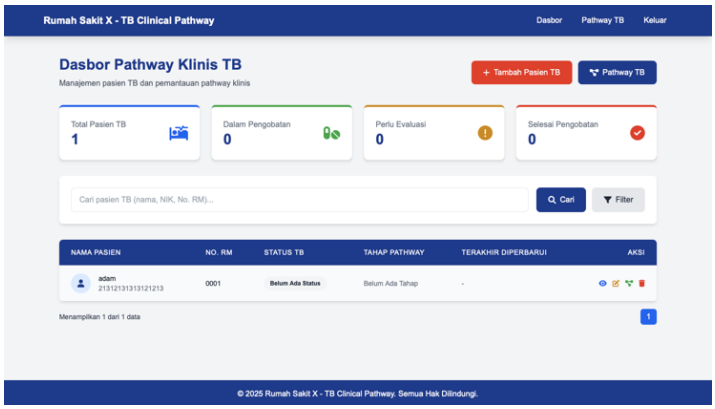


Source: Research data

Figure 7. Home Page

2. Patient Monitoring Dashboard

After logging in, users are redirected to a dashboard page that presents a summary of TB patient statistics, including the total number of patients, patients under treatment, patients who need evaluation, and patients who have completed treatment. The dashboard also provides a search and filter feature by name, NIK, or medical record number. This feature makes it easier for medical personnel to navigate patient data efficiently. Clinical *Pathway View*: The system will display clinical flows based on diagnostic data that has been validated by the physician.

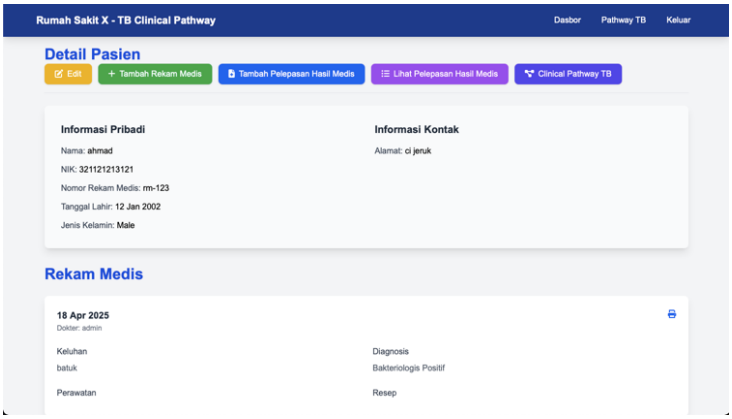


Source: Research data

Figure 8. Dashboard page

3. Details and patient data management page

The Add New Patient feature allows users to input basic patient data such as full name, NIK, date of birth, gender, medical record number, and address. This data is then displayed in the patient's details page, which also includes several action buttons such as "Add Medical Record", "Add Pathway", as well as the option to view the release of medical results.



Source: Research data

Figure 9. Details and patient data management page

4. Formulir Pathway TB

The *Pulmonary TB Clinical Pathway* form is divided into six sections:

1) Part 1 - Patient and Hospitalization Information and -Main Complaints and Anamnesis

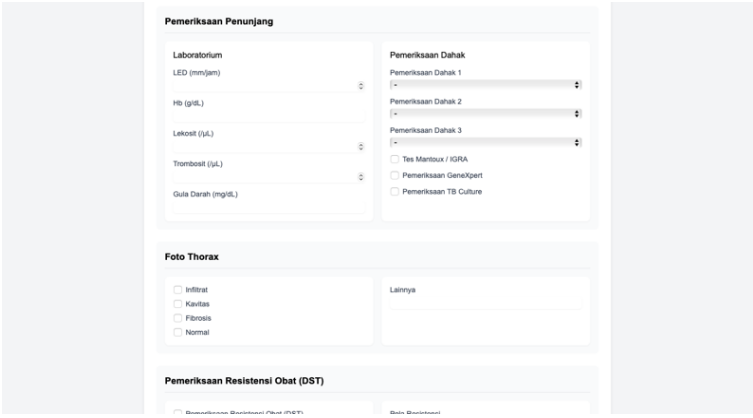
Displays the patient's identity information and date of treatment. Some columns such as "DPJP" and "Maintenance Unit". Part 2 Contains data on major complaints and disease history. This column supports the input of typical TB symptoms such as chronic cough, fever, and weight loss. Diagnosis and Lab Examination Form: Doctors and laboratory staff can fill in the results of the patient's tuberculosis examination, including clinical symptoms, laboratory results, and other supporting data.

Source: Research data

Figure 10. Form part 1&2 *clinical pathway* TB

2) Sections 3 & 4 Physical and Supporting Examinations and Diagnosis and Therapy

This section includes the results of blood pressure, body temperature, and thoracic assessments. Supporting examination columns such as LED, Hb, Leukocytes to sputum tests and there are placeholder symbols. Part 4 Contains the diagnosis of "Bacteriological Pulmonary TB" with the ICD-10 code (A15.0), as well as category 1 TB therapy, including intensive and advanced phase OAT. Fill in the fields for what vitamins are given in the form of a text box.



Source: Research data

Figure 11. Part 3&4 form *clinical pathway* TB

3) Sections 5 & 6 - Evaluation and Final Results

The feature to evaluate the patient's condition on days 3, 7, 14, and the end of the intensive phase is available, although some of it has not been filled. The system supports input for the treatment end result (e.g. "Cured") as well as OAT consumption compliance status.

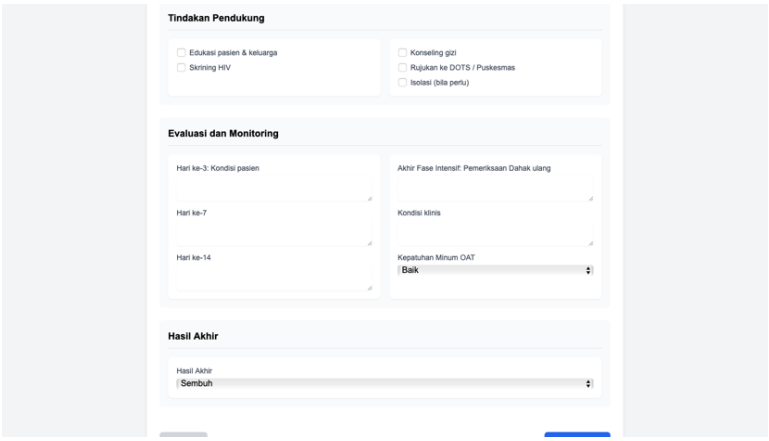


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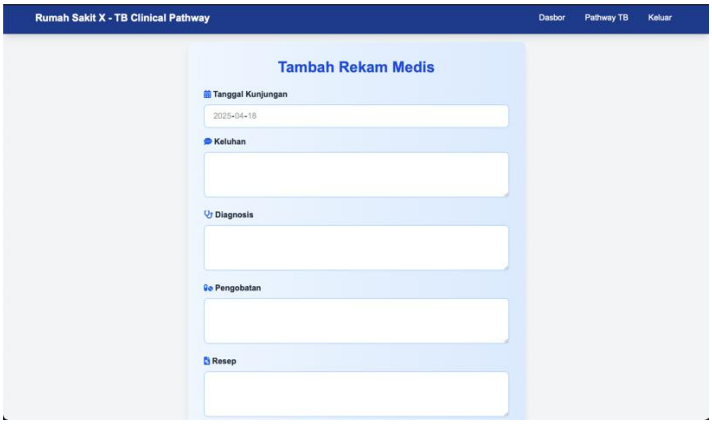
Figure 12. Sections 5&6 Evaluation and Final Results

4) Features of Add Medical Records

This form allows the addition of patient visit data such as visit dates, complaints, diagnoses, medical procedures, and prescriptions.

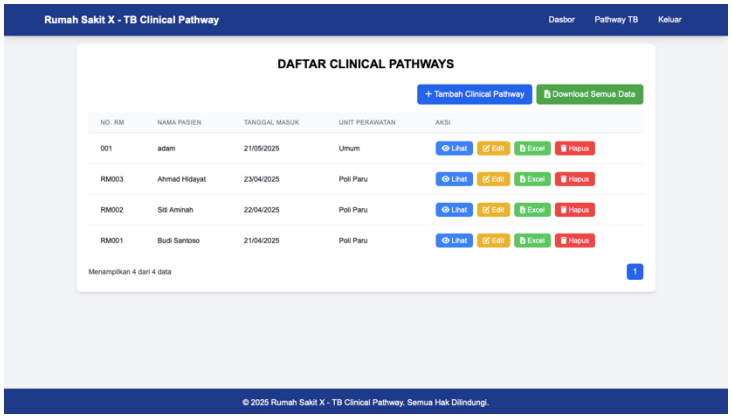


Source: Research data

Figure 13. Features of Add Medical Records

5) List of *Clinical Pathways* and Data Action

Users can view a list of patient *clinical pathways* that have been input through a table that displays key data such as patient name, medical record number, admission date, and advanced actions such as "View", "Edit", "*Download* Excel", and "Delete". Some action icons still use placeholder symbols.



Source: Research data

Figure 14. List of *Clinical Pathways*

Specification table of form data for *the Clinical Pathway* Diagnosis of Pulmonary TB information system. This table details the field name, data type, validation, and description for each part of the form.

Table 2. Specification of TB *clinical pathway* data form

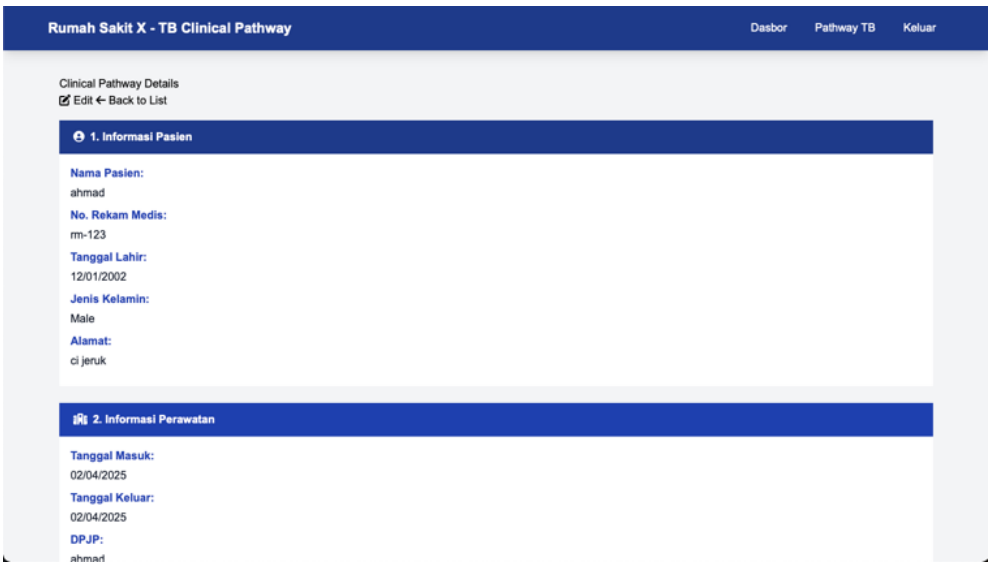
Section	Field Name	Data Type	Validation	Description
A. Patient Data	Full Name	String	Required, 3–100 characters	Patient's full name
	NIK (National ID Number)	String (16)	Required, 16 digits	National Identification Number
	Medical Record Number	String	Required, unique	Patient ID number in hospital
	Date of Birth	Date	Required, format YYYY-MM-DD, not later than today	Validates patient's age
	Gender	Enum	Required, options: Male, Female	Gender option
	Address	Text	Optional	Patient's residential address
B. Treatment Information	Admission Date	Date	Required, ≤ today	Date when patient was admitted
	Discharge Date	Date	Optional, ≥ Admission Date	Filled when treatment ends
	Attending Physician	String	Optional	Responsible doctor
	Care Unit	String	Optional	Example: Inpatient, Outpatient
C. Complaints & Anamnesis	Chief Complaint	Text	Optional	Main complaint at admission
	Clinical Symptoms	Checkbox List	Optional	Checklist of TB-specific symptoms
	Previous TB History	Boolean	Optional	Whether patient had TB before
	TB Close Contact	Boolean	Optional	Contact with active TB patient

	Other Medical History	Text	Optional	Comorbidities such as DM, HIV, etc.
D. Physical and Supporting Examinations	Blood Pressure	String	Format XXX/YY	Example: 120/80
	Pulse	Integer	Optional, range 40–180	Heart rate per minute
	Respiratory Rate	Integer	Optional, range 10–40	Breaths per minute
	Body Temperature	Float	Optional, range 34.0–42.0	In Celsius
	BMI	Float	Optional, range 10.0–40.0	Body Mass Index
	Nutritional Status	Enum	Optional, based on BMI	Example: Thin, Normal, Overweight
	Thoracic Examination	Enum	Optional, options: Rales, Wheezing, Normal	Lung auscultation results
E. TB Supporting Screening	Hemoglobin	Float	Optional, 4.0–20.0	Hemoglobin level
	Leukocytes	Integer	Optional	White blood cell count
	Platelets	Integer	Optional	Platelet count
	Random Blood Glucose	Float	Optional	In mg/dL
	Sputum Examination (1,2,3)	Text	Optional	Result of AFB smear or GeneXpert
	Mantoux / IGRA	Text	Optional	Tuberculin test
	GeneXpert / TB Culture	Text	Optional	Molecular or culture TB test
	Chest X-ray	Text	Optional	Radiology findings
F. Diagnosis and Therapy	Clinical Diagnosis	Text	Required	Clinical TB diagnosis
	ICD-10 Code	String	Optional	Standard disease code, e.g., A15.0
	TB Category	Enum	Required, options: Category 1, 2, etc.	Based on treatment history/status
	Intensive Phase TB Therapy	Text	Required	Example: RHZE 2 months
	Continuation Phase TB Therapy	Text	Required	Example: RH 4 months
	Additional Drugs / Vitamins	Text	Optional	Supplements such as B6
G. Supporting Actions & Evaluation	Education	Boolean	Optional	Patient and family education
	HIV Screening	Boolean	Optional	Whether HIV screening was done
	Nutrition Counseling	Boolean	Optional	Whether counseling was provided
	Referred to DOTS	Boolean	Optional	Referral for treatment monitoring
	Day-3 Evaluation	Text	Optional	Early response to therapy
	Day-7 Evaluation	Text	Optional	Clinical improvement
	Day-14 Evaluation	Text	Optional	Change in clinical status

	End of Intensive Phase Evaluation	Text	Optional	Follow-up examination results
	TB Drug Compliance	Enum	Optional, options: Good, Moderate, Poor	Adherence assessment
	Final Outcome	Enum	Required, options: Cured, Died, Default, Failed	Final TB treatment outcome

Source: Research data

The Recapitulation view or evaluation page can access patient pathway recap reports in a format that can be printed or exported as a document.



Source: Research data

Figure 15. Page view of form input results

Nama Pasie	Tanggal Ma	Tanggal Kel	ICD 10	Diagnosis	Penjamin	Pemeriksaan DST	Hasil DST	Tanggal DS	Pola Resistensi	Ada Kompl	Jenis Komplikasi	Penanganan Komplikasi	Efek Samping OAT	Penangana	ALT	AST	Bilirubin Total	Bilirubin Di	Kreatinin
Budi Santo	21/04/202	16/05/202	A15.0		dr. Ahmad	Ya	Sensitif	26/04/202	Tidak ada resistensi	Ya	Hepatitis	Monitoring fungsi hati	Mual, muntah	Pemberian	45	40	1,2	0,4	1
Siti Aminah	22/04/202	17/05/202	A15.0		dr. Budi	Tidak				Tidak					30	28	0,8	0,2	0,9
Ahmad Hid	23/04/202	18/05/202	A15.0		dr. Siti	Ya	Sensitif	28/04/202	Tidak ada resistensi	Ya	Gangguan penglih	Konsultasi oftalmologi	Penglihatan kabur	Pemberian	50	45	1,5	0,5	1,1
adam	21/05/202	21/05/202	A15.0		dr. ahmad	Ya	Resisten	21/05/202	RIF	Ya	Hepatitis	mmm	mmm	mm	90	90	90	90	90

Source: Research data

Figure 16. Patient *report* output results

a. System Testing

System testing is carried out using *the black box testing* method to ensure that all key functions in the application are performing as expected. The focus of the test was on features related to the patient data input process, filling out the Pulmonary TB *clinical pathway* form, to medical record management.

Table 3. Results of *the black box* testing of the *TB* clinical pathway system

Form	Testing Scenarios	Tested Inputs	*Expected Output*	Result	Information
Add Patient	Submit complete data	Name, NIK, TTL, Gender, Address	Data saved successfully	Valid	Form successfully saves new patient data
Add Patient	Submit blank data	(Blank)	Validation error	Valid	Mandatory field notification appears

TB Pathway Form – Early Education	Submit complete education	Educational data, dates	Data saved successfully	Valid	Data coming into DB
Form Pathway TB – Physical Examination	Invalid date	Blank or misformatted dates	Validation error	Valid	Date format error notification appears
Form Pathway TB – Diagnostik	Negative and positive data input	BTA examination, thoracic photo	Appropriate data stored	Valid	Validation of the results of the examination runs
Form Pathway TB – Terapi	Not choosing a regimen	Empty	Validation error	Valid	Must choose one of the therapy options
Form Pathway TB – Evaluasi	Add evaluation notes	Text of the note	Records saved	Valid	Text area functions normally
Add Medical Records	Submit data valid	Diagnose, ICDX, Actions	Data saved successfully	Valid	Connecting to patients properly
Access the Patient Details Page	Click on the patient's name	N/A	Patient details appear	Valid	The page opens without errors

Source: Research data

Overall, the entire test scenario passed according to expectations, showing that the developed system has a good level of stability and accuracy at the data input, validation, and storage stages.

CONCLUSION

This research has successfully designed and implemented a *web-based* Tuberculosis Diagnosis Clinical Pathway Information System using *the Flask* framework and the SQLite database. This system is present as a solution to the main problem at Hospital X Bandung, namely the dependence on paper-based manual processes that are prone to errors and delays. The main achievements of the system include:

1) Standardization of TB Diagnosis
   The system provides a structured form that covers all stages of TB treatment, from anamnesis, physical examination, laboratory results, to the administration of OAT therapy, in accordance with national protocols. The integration *of this clinical pathway has* been proven to be able to reduce variations in clinical practice between doctors.
2) Document Management Efficiency
   Digitization of medical records and pathways allows for faster and *real-time* tracking of patient history. In addition, the report export feature (in Excel format) is very helpful in the reporting process, both for internal and external needs.
3) Data Validation and Accuracy
   Based on *black box* testing, the system is able to validate inputs precisely, such as filling in dates, NIKs, and laboratory results. All data is stored accurately according to the designed test scenario.

Development Suggestions

In order for the system to be more optimally used and support the sustainability of health services at Hospital X Bandung, some of the recommended development suggestions include:

A. System Integration
   1) Connect the system with the Hospital Information System (SIRS) and/or the National Medical e-Record to enable automatic synchronization of patient data.

2) Development of APIs for laboratory data integration, so that BTA or GeneXpert results can be entered into the system automatically without manual input.

B. Smart Feature Addition

1) TB Risk Prediction: Added a simple *machine learning module* that is able to analyze symptom patterns and laboratory results to predict the likelihood of patients suffering from TB.
2) Notifications & Reminders: A reminder feature of the patient's control or evaluation schedule (e.g. 3rd or 7th day of therapy) via WhatsApp or email.

C. User Interface Development

1) Create *a mobile-friendly version* so that healthcare workers can access the system flexibly in the field.
2) Added an analytics dashboard to present data visualizations, such as TB case trends, medication adherence rates, and other statistics.

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