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Pengembangan Sistem Pakar Berbasis Certainty Factor untuk Konsultasi Gizi dan Pencegahan Stunting di Daerah Pesisir: Studi Kasus Kabupaten Bengkalis

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ABSTRACT

This study developed a Certainty Factor (CF)–based expert system to support nutrition consultation and stunting prevention in coastal settings using Bengkalis Regency as a case study. A design science approach was employed to analyze local service constraints, acquire expert knowledge, formalize a rule base, implement an offline-first prototype (mobile client and admin dashboard), and evaluate its performance. Knowledge was elicited from nutritionists, midwives, and community health workers and encoded as IF–THEN rules with expert confidence weights; Evidence (anthropometry, infection history, infant and young child feeding, sanitation, and socioeconomic factors) was mapped to CF values and combined to yield risk scores and categories with explainable rule traces. Functional testing showed all user-story scenarios passed as expected, while initial expert validation and usability checks indicated the prototype provided rapid and standardized assessments suitable for first-line services. The results suggest the CF approach is feasible for coastal contexts with limited connectivity and can accelerate early screening and referrals. Future work will expand the local knowledge base, integrate electronic records, and conduct wider field trials to measure effectiveness at scale.

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1. Introduction

Stunting, defined as a height/age below -2 SD according to the WHO Child Growth Standards, is a form of chronic malnutrition that impacts physical growth, cognitive development, disease susceptibility, and long-term productivity [1], [4]. The challenge of preventing stunting is often more complex in coastal areas due to limited access to services, limited sanitation, and fluctuations in food availability. Globally, the UNICEF, WHO, and World Bank Joint Child Malnutrition Estimates (JME) report indicates that 23.2% of children under five will experience stunting in 2024, underscoring the need for accelerated intervention [2]. In Indonesia, the 2024 SSGI reported a stunting prevalence of 19.8%, indicating progress but remaining a public health priority [3].

Prompt and standardized nutrition consultations at the family/Posyandu level are crucial, especially when field data is incomplete or symptoms are ambiguous, such as a combination of anthropometric indicators (HAZ/WAZ/WHZ/BAZ), infection history, feeding practices, and sanitation conditions. Toddler nutritional status assessment refers to the WHO Child Growth Standards z-score, which provides growth

curves, documentation, and implementation tools for service practice [4]. In situations of partial/conflicting evidence, decision-making tools that can accommodate uncertainty are needed.

Expert systems offer a way to express expert knowledge into rules, thus providing primary decision support. Among uncertainty reasoning schemes, the Certainty Factor (CF), rooted in the MYCIN system, allows combining expert confidence and evidence strength to generate a certainty score for a hypothesis, while providing an explainable reasoning trail [5], [6]. Classic expert system literature also documents the practice of developing, representing, and implementing CF in rule-based systems [7], [8].

To address this need, this study proposes a Certainty Factor-based expert system for nutrition consultation and stunting prevention in a coastal context, using Bengkalis Regency as a case study. The system's objectives are: (i) to build a local knowledge base (anthropometric indicators, infections, feeding practices, sanitation, and socio-economic factors) with local nutrition professionals; (ii) designing a CF inference mechanism to combine multiple pieces of evidence into easily understood risk scores and categories; (iii) generating follow-up recommendations aligned with primary care guidelines; and (iv) designing an offline-first implementation to remain useful in areas with limited coastal connectivity. The paper's contributions include the design and implementation of a localized CF expert system, an application architecture that enables rule base updates, functional evaluation and initial usability testing, and documentation of rule trails for decision accountability.

2. Research Method

This research uses a Design Science Research (DSR) approach with a software Research and Development method. The focus is on designing, implementing, and evaluating a Certainty Factor (CF)-based expert system for nutrition consultation and stunting prevention in a coastal context. The main stages are: (1) context and needs analysis, (2) knowledge acquisition and rule base formulation, (3) CF model design and inference engine, (4) system design/implementation, (5) expert validation, (6) functional testing and usability testing, (7) results analysis and improvement. The main stages can be seen in Figure 1. [13], [18], [19], [21]

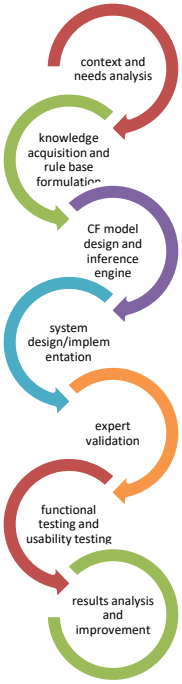

Figure 1. Main stages of the research

Bengkalis Regency is characterized by its coastal island character, with settlements far apart, inter-island mobility influenced by weather/tides, and uneven network connectivity. Primary nutrition services rely on integrated health posts (Posyandu) and community health centers (Puskesmas), supported by village midwives and community health workers. In practice, continuity of anthropometric measurements and consistency of nutrition consultations are often hampered by service times, variability in staff experience, and fragmented field data, such as infection history, breastfeeding/complementary feeding practices, and

sanitation conditions that are not always documented. This situation demands decision-making tools that remain reliable offline, are easy to operate on low-to-midrange devices, and produce output that is easily understood by community health workers and parents.

Key stakeholders include nutrition workers/community health center staff who require standardized and traceable assessments, community health workers/midwives who require step-by-step guidance during weighing and brief consultations, and parents/caregivers who require clear results and practical advice. The existing service flow, which consists of measurement/balance, brief consultation, and follow-up, reveals gaps in assessment variability, partial evidence, undifferentiated education, and connectivity constraints. Therefore, the system's functional requirements are: combining multiple pieces of evidence such as HAZ/WAZ/WHZ/BAZ, infections, dietary practices, sanitation, and socioeconomic factors into a Certainty Factor score and risk category, along with a rule trace; generating operational follow-up recommendations such as brief education and referral indications; providing a quick input form with range validation; storing history for follow-up; and providing an admin panel to update the rule base without rebuilding. Accompanying non-functional requirements include a usability target of SUS ≥ 68, an assessment response time of ≤1 second on low-end devices, privacy (minimizing personal data and local encryption), explainability through the display of rule traces, and portability for easy adaptation to non-coastal areas through rule reparametrization.

The processed input data includes age, gender, weight, length/height, history of infection in the last 2–4 weeks, breastfeeding/complementary feeding practices (frequency/variation), sanitation aspects (water, toilets, handwashing), and simple socio-economic indicators. The system outputs are CF scores per hypothesis, risk categories (normal/stunting/severe stunting), and action recommendations. These needs are collected through small focus groups (FGDs), semi-structured interviews with nutrition workers/nutrition volunteer, and priorities are determined using MoSCoW (must-haves: multi-evidence assessment, operational recommendations, input validation, usability, privacy). Acceptance criteria were formulated early on: risk category accuracy on expert-annotated case sets of ≥80% with Cohen's $\kappa \geq 0.6$, passing functional tests without critical defects, and a SUS score ≥ 68. Contextual risks—measurement quality, local rule bias, poor connectivity, and resistance to change—were addressed through brief training and range validation in the app, multi-expert consensus meetings, and light onboarding and job-aid for nutrition volunteer. Thus, the system design departed from the real service needs in Bengkalis and established measurable success benchmarks from the outset. Stunting status data can be seen in table 1

Table 1. Stunting status

category	description
normal	Z-Score greater than or equal to -2.00 SD (Standard Deviation), ">= -2 SD
stunting	Z-Score less than -2.00 SD (Standard Deviation), "< -2 SD to ≥ -3 SD
Several stunting	Z-Score less than -3.00 SD (Standard Deviation), "< -3 SD

The calculation of the certainty factor can be explained as follows. For example, suppose a toddler's parents choose the following characteristics and levels of confidence:

Table 2. Example of user data input

Characteristic code	CF User	information	Types of stunting level
S0001	0,8	Certain	
S0002	1,0	Very sure	
S0003	1,0	Very sure	
S0004	0,8	Certain	Normal
S0005	1,0	Very sure	
S0006	1,0	Very sure	
S0007	1,0	Very sure	

The CF value obtained from the user will then be multiplied by the previously determined Expert CF value. The result of this multiplication is as follows:

Table 3. The result of multiplying by the expert CF

code	Expert CF	CF User	Expert CF * CF User Or CF[H,E] = CF[H] * CF[E]
S0001	1,0	0,8	0,8
S0002	0,8	1,0	0,8
S0003	0,8	1,0	0,8

S0004	0,8	0,8	0,64
S0005	0,8	1,0	0,8
S0006	0,8	1,0	0,8
S0007	0,8	1,0	0,8

The next step is to determine the CF Combine value. To determine the CF Combine value, we use the data resulting from multiplying the Expert CF value and the User CF value. The following is the formula used to calculate the value.

$CF_{combine}$:

$$CF_{Combine}[H,E]_{1,2} = CF[H,E]_1 + CF[H,E]_2 * (1 - CF[H,E]_1) \quad (1)$$

$$CF_{Combine}[H,E]_{old1,3} = CF[H,E]_{old1} + CF[H,E]_3 * (1 - CF[H,E]_1) \quad (2)$$

Based on the formula above, a process of calculating the CFcombine value is carried out as below:

Table 4. $CF_{Combine}$ calculation result

CF Combine on normal		
	process	result
$CF_{Combine}[H,E]_{1,2}$	$CF[H,E]_1 + CF[H,E]_2 * (1 - CF[H,E]_1)$	0,96
	0,8 + 0,8 * (1 – 0,8)	$[H,E]_{old1}$
	0,8 + 0,8 * 0,2	
	0,8 + 0,16	
$CF_{Combine}[H,E]_{old1,3}$	$CF[H,E]_{old1} + CF[H,E]_3 * (1 - CF[H,E]_{old1})$	0,992
	0,96 + 0,8 * (1 – 0,96)	$[H,E]_{old2}$
	0,96 + 0,8 * 0,04	
	0,96 + 0,032	
$CF_{Combine}[H,E]_{old2,4}$	$CF[H,E]_{old2} + CF[H,E]_4 * (1 - CF[H,E]_{old2})$	0,99712
	0,992 + 0,64 * (1 – 0,992)	$[H,E]_{old3}$
	0,992 + 0,64 * 0,008	
	0,992 + 0,00512	
$CF_{Combine}[H,E]_{old3,5}$	$CF[H,E]_{old3} + CF[H,E]_5 * (1 - CF[H,E]_{old3})$	0,999424
	0,99712 + 0,8 * (1 – 0,99712)	$[H,E]_{old4}$
	0,99712 + 0,8 * 0,00288	
	0,99712 + 0,002304	
$CF_{Combine}[H,E]_{old4,6}$	$CF[H,E]_{old4} + CF[H,E]6 * (1 - CF[H,E]_{old4})$	0,9998848
	0,999424 + 0,8 * (1- 0,999424)	$[H,E]_{old5}$
	0,999424 + 0,8 * 0,000576	
	0,999424 + 0,0004608	
$CF_{Combine}[H,E]_{old5,7}$	$CF[H,E]_{old5} + CF[H,E]_7 * (1 - CF[H,E]_{old5})$	0,99997696
	0,9998848 + 0,8 * (1 – 0,9998848)	$[H,E]_{old6}$
	0,9998848 + 0,8 * 0,0001152	
	0,9998848 + 0,00009216	

Once the CF Combine value for each nutritional status type is determined, the next step is to calculate the confidence level. This percentage is obtained by multiplying the CF Combine value by 100%, resulting in a percentage value. The following are the results of this percentage calculation:

Table 4. The confidence percentage results

Stunting levels	Result value $CF_{Combine}$ * 100	Yield percentage (%)
Normal	0,99997696 * 100	99,998%

*The final CF combined value is 0.99997696 or 99.997696%. For ease of reading, this value is rounded to 99.998%.

3. Result and Discussion

The Certainty Factor approach used in this research resulted in a prototype nutrition consultation application capable of providing a rapid, structured, and understandable stunting risk assessment for health workers and nutrition volunteer in coastal areas. The knowledge base was compiled from nutrition expert principles (anthropometric indicators of weight for age, height for age, height for age, weight for height, disease history, parenting and diet, and environmental factors such as sanitation and clean water access). This was then transformed into IF–THEN rules with expert confidence weights, allowing the inference engine to calculate the certainty level of nutritional intervention recommendations for each child. A limited-scale field trial demonstrated that the application performed well under limited connectivity conditions, was relevant to the characteristics of coastal areas, and helped expedite initial screening, standardize the counseling process, and strengthen referrals of at-risk cases to service facilities.

Initial validation against expert assessments and WHO growth chart references indicated good decision suitability, along with positive feedback regarding ease of use, clarity of output (CF values and risk categories), and reporting support. These results confirm the initial feasibility of the application as an evidence-based stunting prevention tool at the primary level, while also opening up opportunities for further development in expanding the local knowledge base of coastal food, integrating digital health records, and evaluating effectiveness on a broader population scale.

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The system was designed to adapt to user needs for a stunting diagnosis system. The following illustrates the system design using a UML use case diagram.

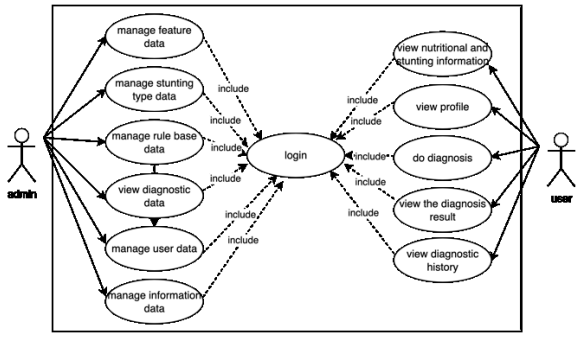

Figure 2. Usecase diagram

The following is a display of the application which can later be accessed by health workers, nutrition volunteer and the public.

Admin View

1. Login Page

The login page is used by officers/admins and contains credentials (email/username and password) and a "Login" button. Its purpose is to restrict access to the administration module.

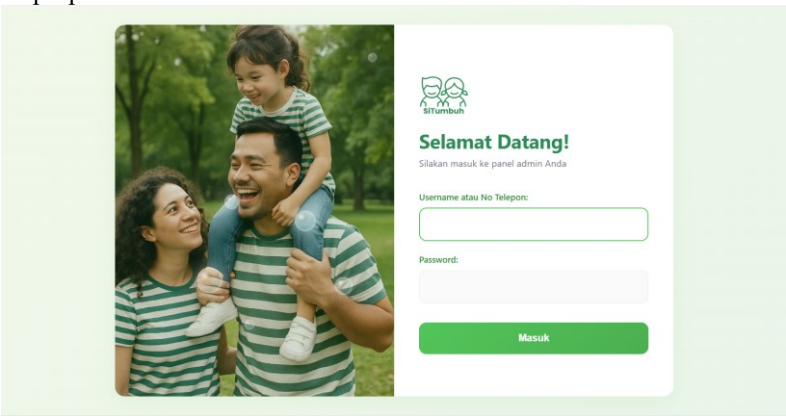

Figure 3. Login page for admin

2. Dashboard Page

The Dashboard page contains a summary of system statistics (e.g., number of users/parents, number of toddlers, total nutrition and stunting diagnoses, and recent activity). It also contains a navigation menu for data management and shortcuts to core functions (view data, download reports).

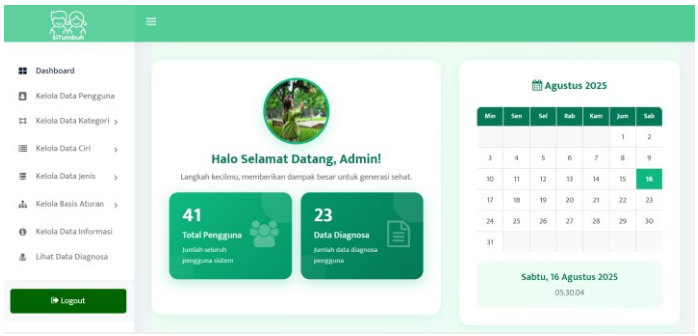

Figure 4. Dashboard page for admin

User Page (Parents)

1. Welcome Screen

The Welcome Screen is the opening screen with the Situmbuh logo and a start/continue button. It directs users to the Register or Login options.

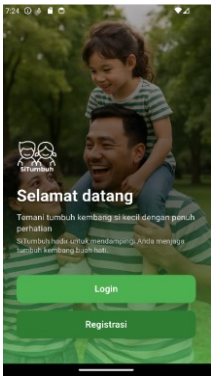

Figure 5. Welcome screen for user

2. Registration Page

The account creation form contains basic user information (name, email/phone number, password) and child information (name, date of birth, gender). This includes agreeing to the privacy policy. Click the "Register" button to save your account.

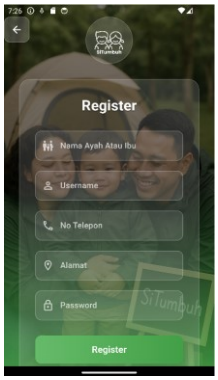

Figure 6. Registration page for user

3. Login Page

The login page is an authentication form for end users (parents/nutrition volunteer) to log into the application using their email/mobile number and password. There is a "Login" button and a help link if you forget your password.

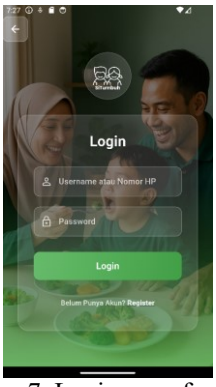

Figure 7. Login page for user

4. Home Page

The home page contains brief educational content related to nutrition and stunting (articles, tips, infographics) and navigation to key features. Purpose: Initial literacy prior to screening.

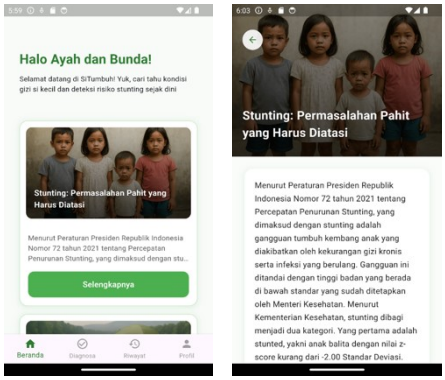

Figure 8. Home page for user

5. Diagnosis Type Selection Page

The Diagnosis Type Selection page displays two cards/options: Nutrition Diagnosis and Stunting Diagnosis. Users select one to access the screening form as needed.

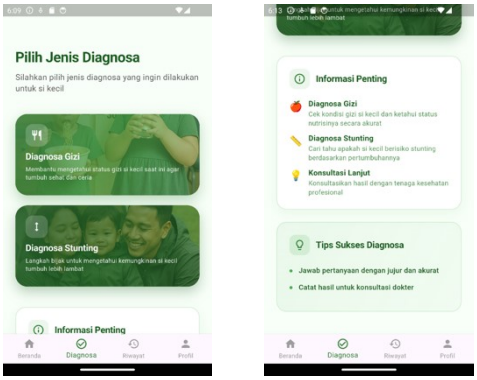

Figure 8. Diagnosis Type Selection for user

6. Nutrition Diagnosis Page

The nutrition diagnosis page is an input form for anthropometric data and supporting factors (e.g., weight, height/length, age in months, dietary history/symptoms). The "Process" button will run the Certainty Factor inference engine to assess nutritional status and display categories and follow-up recommendations.

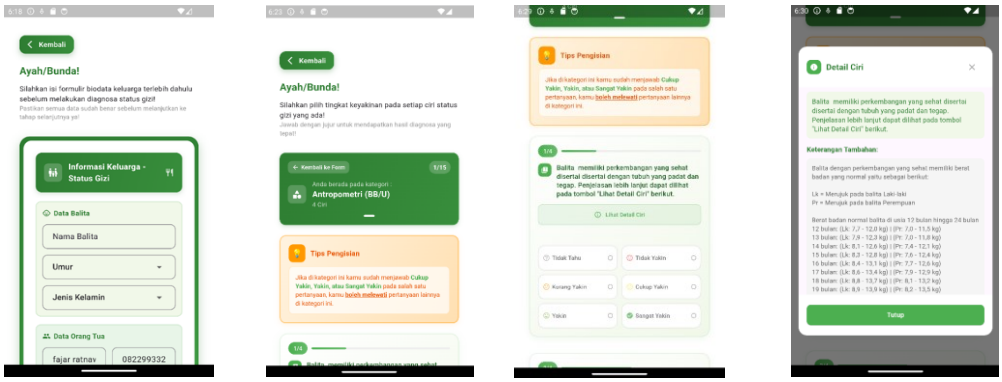

Figure 9. Nutrition Diagnosis page for user

7. Stunting Diagnosis Page

The stunting diagnosis page is a stunting risk screening form (e.g., age, height, birth history, diet/medical history). After being processed by the Certainty Factor module, the application displays the risk level/category and recommended interventions (monitoring, consultation, referral).

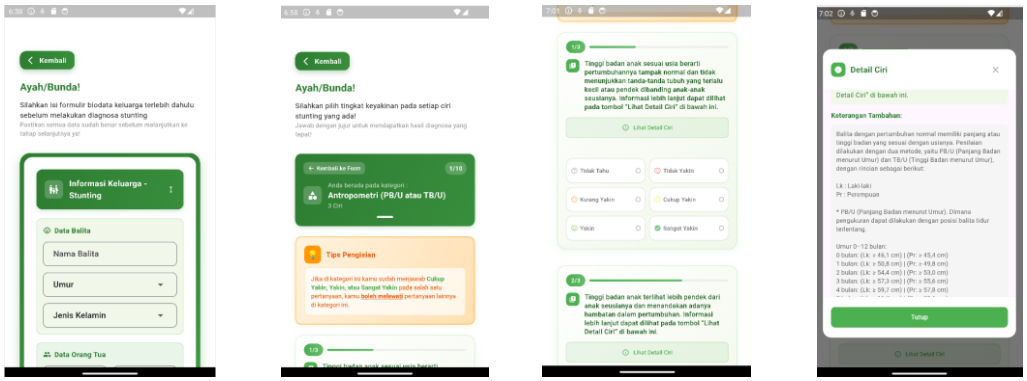

Figure 10. Stunting Diagnosis page for user

8. Diagnosis History Page

This page lists all screening results per child, along with the date and type of diagnosis. Users can review them, filter by period, and access details.

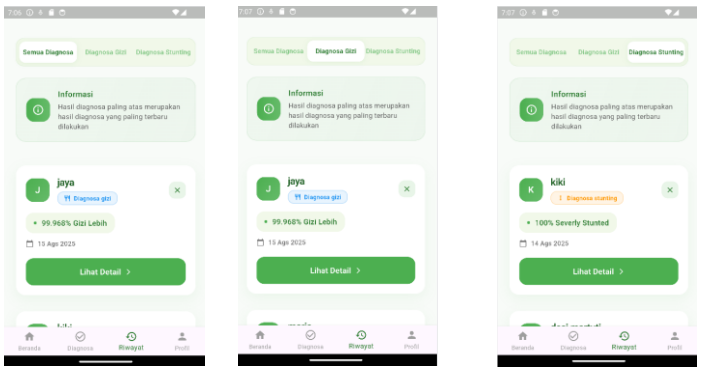

Figure 11. Diagnosis history page for user

9. Stunting Diagnosis History Details Page

This page contains details of stunting results, such as values/scores, categories (e.g., low–high), most influential factors, and specific recommendations. Save/download or share options are provided.

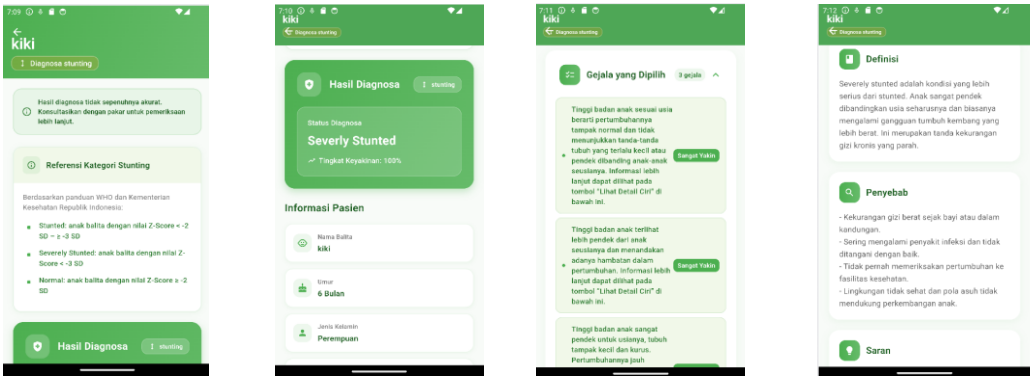

Figure 12. Stunting Diagnosis History Details Page for user

10. Nutrition Diagnosis History Details Page

This page contains detailed nutritional status results, including a summary of input, calculation results, interpretation, and suggestions for improving intake/monitoring. Share/save options are available.

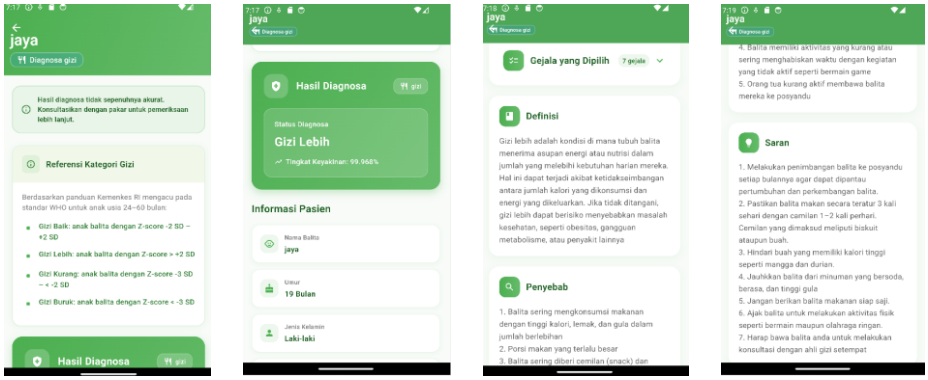

Figure 13. Nutrition Diagnosis History Details Page for user

11. Profile Page

This page contains user account information and child data, such as photo/name, contact information, and settings (change password, edit data, log out). It serves as a central hub for managing identity and preferences.

Figure 14. Profile Page for user

The next step is testing the functionality of the nutrition consultation application system. Functional testing of the nutrition consultation application employs black box testing techniques. The user level consists of two parts: the admin level and the user level (community). User level testing will assess the application's functionality according to the user level.

The test results using Black Box testing can be seen in Table 5

Table 4. Blackbox Testing

Admin Level of the "situbuh" nutrition consultation application				
NO	**User Stories**	**Acceptance test criteria**	**Expected Result**	**Status**
1	Situbuh admin can login to the System	Situbuh admin can access the login page	The system displays the login page.	Succeed
		Admin situbuh inputs valid username and password	The system displays the admin dashboard page	Succeed
		Admin situbuh entered the wrong username or password	The system rejects the login and displays an error message.	Succeed
		Admin leaves the username/password column blank then clicks login	The system displays the message "Username/Password is required"	Succeed
2	Situmbuh admin can manage user data	Admin can view user list	The system displays all stored user data.	Succeed
		Admin can access the add admin menu	The system displays a new admin data input form.	Succeed
		Admin can add new admin data	Admin data has been successfully saved into the system	Succeed
		Admin can access the add parent menu	The system displays the new parent data input form.	Succeed
		Admin can add new parent data	Parent data has been successfully saved into the system.	Succeed
3	Situbuh admin can manage stunting characteristics data	Admin can access the stunting characteristics data page	The system displays a list of data on stunting characteristics.	Succeed
		Admin can access the menu to add data on stunting characteristics	The system displays a new stunting characteristics data input form.	Succeed
		Admin can add new stunting characteristics data	Data is successfully saved and appears in the list.	Succeed
		Admin can access the stunting characteristics data edit menu	The system displays an edit form with the data already filled in.	Succeed
		Admin can change stunting characteristics data	Data successfully updated according to changes	Succeed
		Admin can delete stunting characteristics data	Data successfully deleted from the system	Succeed
4	Situbuh admin can manage nutritional status characteristics data	Admin can access the nutritional status characteristics data page	The system displays a list of data on stunting characteristics.	Succeed
		Admin can access the menu to add data on nutritional status characteristics	The system displays a form for inputting data on new nutritional status characteristics.	Succeed
		Admin can add new nutritional status characteristics data	Data is successfully saved and appears in the list.	Succeed
		Admin can access the menu to edit nutritional status characteristics data	The system displays an edit form with the data already filled in.	Succeed
		Admin can change nutritional status characteristics data	Data successfully updated according to changes	Succeed
		Admin can delete nutritional status characteristics data	Data successfully deleted from the system	Succeed
5	Situbuh admin can manage stunting characteristic category data to display characteristics based on category	Admin can view the list of nutritional characteristics categories	The system displays all stored nutritional trait categories.	Succeed
		Admin can access the menu to add nutritional characteristics category	The system displays a new nutritional characteristic category input form.	Succeed
		Admin can add new nutritional trait categories	Nutritional characteristic category data has been successfully saved into the system.	Succeed
		Admin can access the edit menu of nutritional characteristics category	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing nutritional characteristics category	Nutritional characteristics category data has been successfully updated according to changes.	Succeed
		Admin can delete nutritional characteristics category	Nutritional characteristics category data was successfully deleted from the system.	Succeed
6	Situbuh admin can manage stunting characteristic category data to display characteristics based on category	Admin can see the list of stunting characteristics categories	The system displays all saved stunting trait categories.	Succeed
		Admin can access the menu to add stunting characteristics category	The system displays a new stunting characteristic category input form.	Succeed
		Admin can add new stunting characteristics categories	Data on stunting characteristics categories has been successfully saved into the system.	Succeed
		Admin can access the edit menu for stunting characteristics categories	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing stunting characteristic categories	Data on stunting characteristics categories has been successfully	Succeed

			updated according to changes.	
		Admin can delete stunting characteristics category	Stunting characteristic category data was successfully deleted from the system	Succeed
7	Situmbuh admin can manage stunting type data	Admin can access the Manage stunting type data menu	The system displays a page listing stunting type data.	Succeed
		Admin can access the menu to add stunting type data	The system displays a new type of stunting data input form.	Succeed
		Admin can add data on new types of stunting	Stunting type data has been successfully saved into the system.	Succeed
		Admin can access the stunting type data edit menu	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing stunting type data	Stunting type data has been successfully updated according to changes	Succeed
		Admin can delete stunting type data	Stunting type data has been successfully deleted from the system.	Succeed
8	Situmbuh admin can manage nutritional status type data	Admin can access the nutritional status type data menu	The system displays a page listing nutritional status data types.	Succeed
		Admin can access the menu to add nutritional status type data	The system displays a new nutritional status type data input form.	Succeed
		Admin can add new nutritional status type data	Nutritional status type data has been successfully saved into the system.	Succeed
		Admin can access the edit menu for nutritional status type data	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing nutritional status type data	Nutritional status type data has been successfully updated according to changes.	Succeed
		Admin can delete nutritional status type data	Nutritional status type data was successfully deleted from the system.	Succeed
9	Situmbuh admin can manage stunting rule base data	Admin can view the list of stunting rule bases	The system displays all stored stunting rule base data.	Succeed
		Admin can access the menu to add stunting rule base data	The system displays a new stunting rule base data input form.	Succeed
		Admin can add new stunting rule base data	Stunting rule base data has been successfully saved into the system.	Succeed
		Admin can access the edit menu for stunting rule base data	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing stunting rule base data	Stunting rule base data successfully updated according to changes	Succeed
		Admin can delete stunting rule base data	Stunting rule base data successfully removed from the system	Succeed
10	Situmbuh admin can manage stunting rule base data	Admin can view the list of nutritional status rule bases	The system displays all stored nutritional status rule base data.	Succeed
		Admin can access the menu to add nutritional status rule base data.	The system displays a new nutritional status rule-based data input form.	Succeed
		Admin can add new nutritional status rule base data	Nutritional status rule base data has been successfully saved into the system.	Succeed
		Admin can access the edit menu for nutritional status rule base data.	The system displays an edit form with the data already filled in.	Succeed
		Admin can change the existing nutritional status rule base data	Nutritional status rule base data successfully updated according to changes	Succeed
		Admin can delete nutritional status rule base data	Nutritional status rule base data was successfully deleted from the system.	Succeed
11	Situbuh admin can view the diagnostic results data	Admin can see the list of diagnostic data results	The system displays a list of all stored diagnostic data results.	Succeed
		Admin can view details of specific diagnostic results	The system displays complete details of the selected diagnostic results.	Succeed
12	Situmbuh Admin can manage information data	Admin can view the list of information	The system displays all stored information data.	Succeed
		Admin can access the add information data menu	The system displays a new information data input form.	Succeed
		Admin can add new information data	Information data is successfully	Succeed

			saved into the system	
		Admin can access the information data edit menu	The system displays an edit form with the data already filled in.	Succeed
		Admin can change existing information data	Information data has been successfully updated according to changes	Succeed
		Admin can delete information data	Information data was successfully deleted from the system	Succeed
Toddler Parent Level				
NO	**User Stories**	**Acceptance test criteria**	**The results that expected**	**Status**
1	Parents of toddlers can register	Parents of toddlers can access the registration page	The system displays the registration form	Succeed
		Parents of toddlers can fill out the registration form with a username/cellphone number and password.	The system validates input and displays an error if any data is incorrect or empty.	Succeed
		Parents of toddlers can submit the registration form	The system saves the new account data and displays a success message.	Succeed
2	Parents of toddlers can log in	Parents of toddlers can access the login page	The system displays the login page.	Succeed
		Parents of toddlers enter a valid username/mobile number and password.	The system validates the account and allows entry to the main page of the application.	Succeed
		Toddler's parents entered the wrong username/cellphone number and password	The system displays a login failed error message.	Succeed
3	Parents of toddlers can view the information page	Parents of toddlers can view a list of available information.	The system displays all the information stored in the application.	Succeed
		Parents of toddlers can select one of the information to see the details.	The system displays the details of the selected information.	Succeed
4	Parents of toddlers can diagnose stunting	Parents of toddlers can access the stunting diagnosis menu	The system displays a list of diagnostic characteristics of stunting.	Succeed
		Parents of toddlers can fill in all the diagnostic characteristics of stunting with the answers provided.	The system receives input answers for each characteristic.	Succeed
		Parents of toddlers submit stunting diagnosis results	The system processes the answers and displays the results of the stunting diagnosis on the Diagnosis History page.	Succeed
5	Parents of toddlers can diagnose nutritional status	Parents of toddlers can access the nutritional diagnosis menu	The system displays a list of nutritional diagnostic characteristics.	Succeed
		Parents of toddlers can fill in all the nutritional diagnosis characteristics with the answers provided.	The system receives input answers for each characteristic.	Succeed
		Toddler's parents submit diagnosis results	The system processes the answers and displays the results of the toddler's nutritional status diagnosis on the Diagnosis History page.	Succeed
6	Parents of toddlers can view the diagnosis history	Parents of toddlers can access the diagnosis history page.	The system displays a diagnosis history page with three tabs: All Diagnoses, Stunting Diagnosis, and Nutrition Diagnosis. The default tab is 'All Diagnoses'.	Succeed
		Parents of toddlers can open the details of any of the diagnostic results in the “All Diagnoses” tab.	The system displays the details of the selected diagnosis.	Succeed
		Parents of toddlers can select the “Stunting Diagnosis” tab.	The system displays a list of stunting diagnosis results.	Succeed
		Parents of toddlers can open the details of one of the diagnostic results in the “Stunting Diagnosis” tab.	The system displays the details of the selected stunting diagnosis.	Succeed
		Parents of toddlers can select the “Nutritional Diagnosis” tab.	The system displays a list of nutritional diagnosis results.	Succeed
		Parents of toddlers can open the details of one of the diagnostic results in the “Nutritional Diagnosis” tab.	The system displays the details of the selected nutritional diagnosis.	Succeed
7	Parents of toddlers can	Parents of toddlers can access the profile	The system displays the account	Succeed

	view the profile page	page	information of the toddler's parents.	
		Parents of toddlers can press the logout button	The system logs the toddler's parent out of the account and returns to the login page.	Succeed
8	Participants can go to the home interface page	Participants can access the list of questions/questions page.	The system displays a home page containing questions.	Succeed
		Participants can see questions based on the question sequence number.	The system displays questions according to the question sequence number.	Succeed
		Participants can see the students' work time	The system displays the remaining processing time.	Succeed

Based on functional testing conducted on two main roles—Situmbuh Admin and Toddler Parent—all user story scenarios and acceptance test criteria were declared successful. On the admin side, the authentication feature (login true/false/blank), user management (admin and parent), domain data management (stunting and nutritional status characteristics, categories, stunting and nutritional status types), rule base management (CRUD rules for stunting and nutritional status), diagnostic result display, and information management all worked as expected, with appropriate validation messages and saved data changes. On the parent side, the registration and login flows functioned, information pages were accessible at a detailed level, the stunting and nutritional status diagnosis processes processed responses and saved results to the history (segmented into the All/Stunting/Nutrition tab), and the profile and logout pages functioned properly. These findings indicate the fulfillment of end-to-end functional requirements and the application's readiness for field/pilot testing; recommended next steps include non-functional testing (performance, security, offline-first), usability (SUS), and load testing and cross-device compatibility before operational release.

Usability testing using SUS scores can be seen in the figure 15

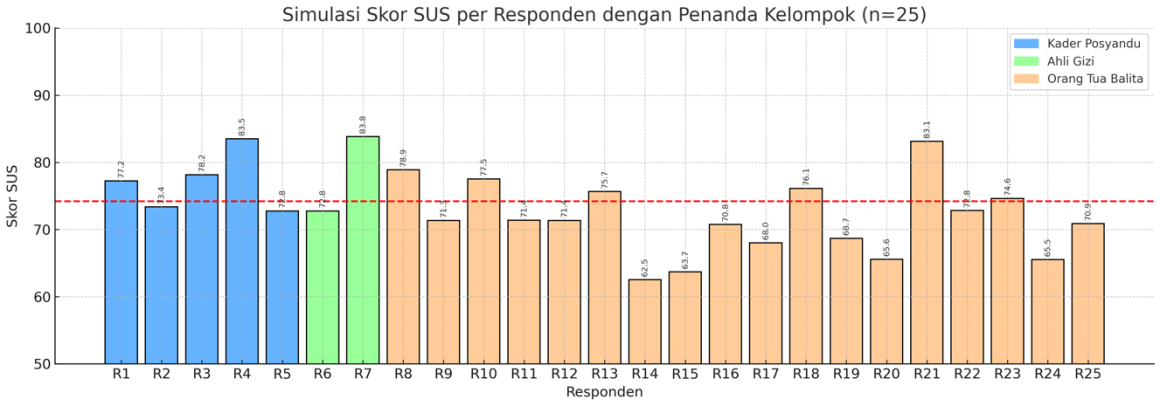

Figure 15. Usability testing using SUS

The results of usability testing using the System Usability Scale (SUS) on 25 respondents (5 Posyandu cadres, 2 nutritionists, and 18 parents of toddlers) showed an average score of 74.2, which is included in the good category. The distribution of individual scores was in the range of 60–90, with the majority of respondents rating the application as easy to use. Posyandu cadres and nutritionists gave relatively consistent scores in the good category, while parents of toddlers showed a wider variation in scores but remained predominantly in the good to very good categories. These findings confirm that the application is acceptable to various user groups and has strong implementation potential in the field.

4. Conclusion

The research yielded a localized CF-based expert system that transformed expert knowledge and primary-care guidelines into an explainable rule base for assessing stunting risk and nutritional status in coastal communities. The offline-first implementation ensured robustness under uneven connectivity, while end-to-end functional tests covering authentication, user and domain data management, rule-base CRUD, diagnostics, history, and information modules demonstrated that all acceptance criteria were met. Early validation against expert judgments and WHO growth-standard references indicated good decision suitability, and initial usability feedback from intended users (kaders/parents) confirmed that outputs—risk categories, CF scores, and follow-up recommendations—were clear and actionable. These findings support the feasibility of deploying the system as a standardized decision aid at the Posyandu/Puskesmas level to speed screening, harmonize counseling, and strengthen referrals for at-risk children. Limitations include a

still-limited set of local rules and a small-scale trial; future work should broaden expert participation, incorporate additional coastal dietary and environmental factors, integrate with electronic health records, and perform larger field studies to quantify impact on program outcomes and care pathways.[9][10]

For the system's implementation to be sustainable, integration with government policies is required, particularly Presidential Regulation No. 72 of 2021 concerning the Acceleration of Stunting Reduction. This system has the potential to become part of the digitization of Integrated Health Service Posts (Posyandu) as directed in the 2024/2025 SSGI, allowing screening results to be directly linked to official Ministry of Health records. This policy support will ensure the system's continued use in the field and expand its impact on national stunting reduction targets.

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