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Determinant factors that contribute to the increasing tuberculosis prevalence in Rokan Hilir, Indonesia

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ABSTRACT

Tuberculosis (TB) continues to be a severe public health problem at local, national, and global levels. At the local level, the trend of increasing the spread of TB cases in Rokan Hilir District, Indonesia requires the identification of the determinants, so that scenarios for prevention and control can be developed appropriately and effectively. Therefore, this study will identify factors contributing to increase TB incidence at the sub-district level in Rokan Hilir District. This study uses a mixed design (mixed method) consisting of observational studies, case control, and spatial approaches based on Geographic Information Systems (GIS). Observational studies were carried out on track record data of TB sufferers, demographics, and health infrastructure during the 2017-2020 period. The case-control approach was applied to socio-economic and physical environment variables in 53 case respondents and 61 control respondents. A GIS-based spatial method was used to acquire climate variability and perform interpolation, interpretation, and spatial presentation in thematic maps. The findings of TB incidents from 2017 through 2020 experienced an increasing trend of 19.58 % per year with an average number of cases (± SD) of 1,068 ± 60.97 cases/year. TB incidence increased with an expanding population ($R^2 = 0.675$), population density ($R^2 = 0.691$), number of health workers ($R^2 = 0.597$), and number of health facilities ($R^2 = 0.509$). The elevated risk of TB disease occurred in people of unproductive age [odds ratio (OR) 2.409, 95% confidence interval (CI) 1.130-5.134], low education (OR 4.027, 99% CI = 1.779-9.115), low income (OR 3.632), type of floor (OR 2.449, 95% CI = 1.144-5.239), wall type (OR 2.851, 99% CI =1.322-6.146), and occupancy density (OR 3.944, 99% CI = 1.799=8.647). Demographic, socio-economic conditions, physical environment, and the availability of health facilities and infrastructure were determinants influencing the incidence of TB. Scenario intervention on determinant factors is the key to successful TB disease control to meet the 2030 national TB disease incidence elimination target.

Keywords: Tuberculosis (TB), Determinants, Spatial Distribution, Indonesia.
Article type: Research Article.

INTRODUCTION

Tuberculosis (TB) as an infectious disease is included in the top ten causes of death worldwide. It is estimated that the number of TB sufferers globally in 2020 will reach 9.9 million people with 1.3 million deaths (WHO, 2021). There was an increase in the death rate from TB compared to 2019, which was 1.2 million (WHO 2020). The highest TB cases in 2019 were identified in Southeast Asia (44%), Africa (25%), Wand west Pacific (18%), and the rest were concentrated in the Eastern Mediterranean, America, and Europe (Puspita *et al*. 2021). Indonesia is ranked 3rd as a country with a high burden of TB (*high burden countries*), below India and China (WHO 2021). TB is the number one cause of death from infectious diseases among Indonesians of productive age (15-54 years) in 2021 (Ministry of Health RI 2022), and it is estimated that only 47.1 % of TB cases will be treated and reported.

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Based on the 2021 Indonesia Health Profile, the number of TB cases found was 397,377 cases, an increase of 12.91% from the number of TB case findings in 2020, with a prevalence of 301 per 100,000 population, and a mortality rate of 34 per 100,000 population (WHO 2021; RI Ministry of Health 2022). Riau Province is one of the provinces on the island of Sumatra with a relatively high TB caseload. The findings of all types of TB cases in Riau Province in 2021 were 9,244 cases (Ministry of Health RI 2021), an increase of 1,008 cases or 10.90% of the total number of TB cases in 2020, where Rokan Hilir Regency was ranked 3rd with the highest number of TB cases in Riau Province. Based on the Riau Province Health Profile, it is known that the number of TB cases in Rokan Hilir Regency is 856 cases, below Pekanbaru City (2,150 cases) and Kampar Regency (928 cases; Prov. Riau Health Office 2020). Based on the Riau Province Health Profile in 2018, the number of all TB cases registered and treated in Rokan Hilir Regency was 902 cases (Riau Prov. Health Office 2018), an increase of 44.35% to 1,302 cases, with a proportion of deaths of 4.3% in 2020 (Dinkes Prov. Riau 2020). The trend of increasing TB cases in Rokan Hilir Regency is inseparable from several risk factors related to the characteristics of *airborne diseases*. These characteristics lead to complexity in efforts to control TB disease in this district. Differences in demographic characteristics, climate variability, as well as socio-economic and physical environments are some of the determinants that need attention. In addition, it is undeniable that the issue of the availability of health workers (health workers) and the coverage of health service facilities (fasyankes) can also affect the prevalence of TB. The development trend of TB cases in Rokan Hilir District over the past few years has not shown any signs of decreasing. This indicates that adopting a national TB disease management strategy in this district through the *Directly Observed Treatment program Short course* (DOTS) has yet to give optimal results. The orientation and implementation of the DOTS program, which only focuses on partial aspects, namely short-term treatment with direct supervision of TB suspects, have not been able to prevent the spread and increase in TB cases with more complex determinants. Nonetheless, the most notable success in implementing the DOTS program was the computerized recording of TB case findings in the Rokan Hilir District, which had so far been recorded manually. The complex determinants of TB disease require a comprehensive scientific study involving variables that significantly influence the spread and increase of TB in this district. Several scientific studies on TB disease in this regency have been carried out, including research on the characteristics of TB sufferers in the regency by Gultom (2020), which resulted in factors such as age, gender, education, occupation, smoking habits, and drinking alcohol of TB sufferers at the Balai Jaya Health Centre, Rokan Hilir Regency. The condition of the house that does not meet health requirements is also a factor causing the decreased success rate of treatment for TB sufferers who seek treatment at RSUD Dr. RM. Pratomo Bagansiapiapi, Rokan Hilir Regency (Alini & Rosilawati 2017). The incidence and increase in TB cases in Rokan Hilir Regency can be prevented and managed if the determinants influencing it are known correctly. Several recent studies have shown that demographic factors (Kustanto 2020), climate variability (Pratiwi *et al*. 2021), physical environment (Lolan *et al*. 2022), socioeconomic (Pratiwi *et al*. 2020), availability of health workers and coverage of health care facilities (Kak *et al.* 2020; Jiang *et al.* 2022) correlate with TB cases in several regions of Indonesia. However, differences in an area's landscape will affect the characteristics of the determinants and variations in TB case groups (Zhou *et al.* 2021). Information about the determinants of increasing TB cases in Rokan Hilir District has never been explored and reported. So, this study will specifically identify and analyse the critical factors influencing increasing TB cases in this district. The information generated is a novelty that can be part of a formulating strategy, making sense and is practical for the comprehensive and sustainable management of TB cases in Rokan Hilir District.

Literature review

Tuberculosis (TB)

Tuberculosis (TB) is an infectious disease caused by the bacterium *Mycobacterium tuberculosis*, which can attack various organs, especially the lungs (WHO 2014; Infodatin Ministry of Health RI 2015). TB is an infectious disease that can develop rapidly due to airborne disease transmission or known as *airborne diseases* (Amanda 2018; Muslimah 2019). There are several species of *Mycobacterium,* including *M. tuberculosis, M. africanum, M. Bovis, and M. leprae*. Tuberculosis bacteria are also known as Acid Resistant Bacteria (BTA). The group of *Mycobacterium* bacteria other than *Mycobacterium tuberculosis* that can cause respiratory problems is MOTT (*Mycobacterium Other Than Tuberculosis*), which can sometimes interfere with the diagnosis and treatment of TB (Infodatin Ministry of Health RI 2018). *M. tuberculosis* is an aerobic and acid-resistant stem bacterium, a pathogenic or saprophytic organism. This tubercle bacillus measures 0.3×2 to 4 µm; this size is smaller than red blood cells (Price & Mary *in* Latifah *et al.* 2016). *M. tuberculosis* is transmitted through air droplets known as droplet nuclei produced by patients with pulmonary TB or laryngeal TB when coughing, sneezing, talking, or singing (Glaziou *et al.* 2015; Mertaniasih 2019). These droplets will remain in the air for several minutes to hours after the expectoration process (Mertaniasih 2019). This disease is contagious quickly, especially in people with weak power bodies. One TB sufferer is estimated to transmit the disease to 1 in 10 people around him/her (Sejati & Sofiana 2015). *M. tuberculosis* infection begins with the inhalation of droplets into the respiratory tract. Germs will be trapped in the upper respiratory tract through mucus produced by cells (Udin 2019). This condition will cause the main symptom, namely coughing up phlegm for two weeks or more. Cough can be followed by additional symptoms, namely lethargy mixed with blood, coughing up blood, shortness of breath, body weakness, decreased appetite, decreased body weight, malaise, night sweats without physical activity, chills for more than one month (Infodatin Ministry of Health RI 2018). TB disease not treated or incomplete treatment, can cause dangerous complications up to death. In 2016 the death rate due to TB disease in the world was 1.5 million (WHO 2017). Meanwhile, in Indonesia, at least 183 people died every day throughout 2017 due to contracting TB disease (RI Ministry of Health 2016). Several efforts to control TB disease have been carried out through various health programs. One of the TB prevention strategy programs that are still running today is DOTS (*directly observed treatment, short course*) or direct supervision of short-term drug ingestion. The DOTS program has been proven to reduce transmission rates and prevent the development of MDR (*Multi-drug resistance* = multiple immunities to TB drugs). However, because the program focuses on medical surveillance and treatment, the results of this program are felt to be different than expected.

Factors associated with the prevalence of TB disease

Demographics

Demography is the science that studies the dynamics of the human population. It is a sub-study of population geography, namely the study of population matters, so demography is often referred to as population (Suwito 2020). Demographic breakdowns are population analyses that include population size, structure, distribution, and how the population changes over time due to births, deaths, migration, and aging (Lee 2011). Population growth and density determine the speed at which disease can be transmitted. The larger the community, the greater the range of health problems. Infectious diseases can spread quickly in densely populated areas (Sumampouw 2017). Fitriana *et al.* (2013) found that the parameter of settlement density in a room affects TB disease with a Chi-Square significance value of 0.05. The dominant distribution and distribution of pulmonary TB cases are in areas with high population density, namely > 400 people km^{-2} (Hartanto *et al.* 2019). One of the risk factors for infectious diseases such as TB is the individual factor. In human-to-human infectious disorders, sex and age are often used to characterize individual sufferers. Various unique characteristics of TB disease are related to one another. So did the variables of gender and age.

Climate variability

Climate variability and disease incidence have a close relationship, especially with airborne diseases. Climate variability can predict various infectious diseases, which can be used as a guide for conducting health management, especially area-based disease management (Siamangunsong 2018). Climate is the average weather in a particular area over a long period (month, year). Climate variability includes all features related to temperature, wind patterns, rainfall, and humidity on the earth's surface (Purwantara 2015).

Socioeconomic

Socioeconomic determinants are important factors that influence the incidence of pulmonary TB. Either directly or indirectly, the risk factors will affect a person's health. Socioeconomic or ***social and economic determinants of health*** affect a person's health condition, starting from birth, growing up, working, and growing old, including the health system’s condition (Wardani 2014). Among the several factors that describe the socio-economic determinants of TB disease, include education, employment, income, knowledge, and behaviour (Nurhalina 2019). By knowing the socio-economic determinants, people will have better or worse risk factors that will make them more susceptible or immune to TB disease.

Home Physical Environment

The physical environment of the house dramatically influences the occurrence of disease because it is one of the transmission media for disease transmission, including TB. A place can be said to be healthy if it meets the criteria of a healthy house. A healthy home is a home that can meet physiological and psychological needs, can prevent infectious diseases, and can minimize accidents (Ramadhoni 2020). The physical environment of the house that does not meet health requirements is a risk factor for TB transmission. In contrast, the home's physical environment includes ventilation, lighting, humidity, type of floor, type of wall, and occupancy density (Andini 2018).

Availability of health and health human resources

The provision of human resources for health workers and health service facilities is an essential public health function (*EPHF*) which is the government's responsibility. At least there are ten types of crucial public health efforts, including: (i) Monitoring health status; (ii) Diagnosing and investigating health problems and health hazards; (iii) Informing, educating, and empowering people about health issues; (iv) Mobilizing partnerships and community action; (v) Developing individual and community health policies and plans; (vi) Enforcement of laws and regulations that protect health; (vii) Providing care for people who need health services; (viii) Ensuring the competence of public and individual health workers; (ix) Evaluating the effectiveness, accessibility, and quality of health services; (x) Researching new insights and innovative solutions to health problems (Wibisana 2019).

TB Control Program Achievements

Indonesia's national TB prevention program refers to the Indonesian Ministry of Health (2014) regarding the national strategy for managing pulmonary TB in Indonesia with the vision " *Towards a problem-free, healthy, independent and just society*." The missions carried out include: (i) Improving community empowerment, including the private sector and community and civil society in TB control; (ii) Ensuring the availability of complete, equitable, quality, and fair TB services; (iii) Ensuring the availability and equity of TB control resources; and (iv) Creating good TB program governance. The goal is to reduce morbidity and mortality due to TB and achieve health development goals to improve public health. The basic principle of TB services according to standards is that health services are provided to all people with TB carried out by health workers according to their authority at the FKTP (Puskesmas and their network) and both government and private FKTL. The services provided according to the applicable TB Control Guidelines include: (i) TB diagnosis is carried out bacteriologically and clinically and can be supported by other supporting examinations; (ii) Examination to monitor treatment progress is carried out at the end of intensive treatment, the 5th month and the end of treatment; (iii) Treatment using OAT with standard OAT guidelines (Tampubolon 2020). In line with the increasing cases of TB, in the 1990s, WHO and IUATLD (*International Union Against TB and Lung Diseases*) developed a TB control strategy known as the DOTS (*Directly Observed Treatment Short-course*) strategy. The DOTS strategy consists of 5 key components, including: (a) Political commitment, with increased and sustainable funding; (b) Case finding through microscopic examination of sputum with guaranteed quality; (c) Standard treatment, with supervision and support for the patient; (d) Effective OAT management and availability system; and (e) A monitoring, recording and reporting system capable of providing an assessment of patient treatment outcomes and program performance (Ministry of Health 2016). WHO has recommended the DOTS strategy for TB control since 1995. The World Bank has declared the DOTS strategy as one of the most *cost-effective health interventions*. The main focus of DOTS is finding and curing patients; priority is given to patients with infectious type TB. This strategy will break the transmission chain and reduce the incidence of TB in the community. Finding and curing patients is the best way to prevent TB transmission (Kemenkes 2014). Only now, the DOTS prevention program has reached all existing puskesmas. This is because there is no uniformity of treatment and a system for recording reports in all health service units, both government and private, so the cooperation of all parties involved in TB control is needed, especially at the sub-district level.

System modeling

Model

A model can be interpreted as a physical or mathematical system whose behaviour is used to analogously understand Phys, social, social, or biological systems and fulfil certain conditions (Arif 2017). Meanwhile, according to Napitupulu (2009), the model represents the natural system in a simple form involving only the most influential components. The model is used as a tool to analyse existing systems. The use of models in engineering relates to the natural world, while the engineering field relates to the human-created one. Models can convey knowledge about the system in an easy-to-use form, since the model represents essential system parts (Kurniawan 2018). So that the model that has been made is as expected, Haryono & Wardoyo (2012) formulated four essential characteristics of modelling, as follows:

1. The model must have a high level of generalization. The higher the conception of a model, the better the model will be. To be able to solve problems that are getting higher.
2. The model must have a transparent mechanism. A model that can explain the problem-solving tool that is carried out without hiding anything is good. If there is a formulation, then where it comes from must be explained
3. The model must have the potential to be developed. A model that can attract the interest of researchers to be able to continue research is promising, as well as being able to enable other researchers to develop models that are more complex and can help answer all the problems of the natural system;
4. The model must be sensitive to changes in assumptions. A model that consistently provides loopholes for other researchers to generate different beliefs is good. So this can indicate that the process of the model will not end.

System

The system is derived from the Greek word "systema," a set of subsets or elements regularly interconnected to achieve a common goal. Experts have views on defining a system, as follows:

1. L. James Havery revealed that the system is a logical and rational procedure for designing a series of components related to one another to function as a unit to achieve a predetermined goal.
2. John Mc. Manam argues that the system is a conceptual structure composed of interrelated functions that work as an organic unit to effectively and efficiently achieve a desired result.
3. Edgar F. Huse and James L. Bowditch said that the system is a series or series of parts that are interconnected and dependent in such a way that the interaction and mutual influence of one part will affect the whole.

Each other is interdependent and integrated (Wibowo 2015). According to its nature, the system is divided into: (i) a dynamic system and (ii) a static system (Ari 2017). The other categories are closed systems and open systems. Closed systems exist only in assumptions and analytical studies. By type, there are abstract systems and physical systems. Systems can also be components, boundaries, environments, interfaces, inputs, processes, outputs, goals, and objectives (Anggraeni 2017).

Dynamic system

System dynamics is a field to understand how things change according to time (Purnomo 2019). System dynamics is a method that can describe processes, behaviour, and complexity in the system (Umar & Dewata 2017). This dynamic system methodology has been and is being developed since Jay W. Forester first introduced it in the 1950s to solve complex problems that arise due to the causal dependence of various variables in the system.

Arif (2017) defines a dynamic system as the study of dynamic behaviour over time varying from a system which includes several components, including:

1. System definitions, system boundaries, input variables, and output variables
2. Formulation of a dynamic model of a physical system, usually in terms of mathematical or graphical relationships that are determined analytically or experimentally
3. Determination of the dynamic behaviour of the system model and the influence of system inputs on the system output variables of interest
4. Formulating recommendations or strategies to improve system performance by modifying system structure or parameter values.

The purpose of the system dynamic model is to study, recognize, and understand the structure, policies, and *delays* of a decision that affect the system's behaviour. In the framework of dynamic system thinking, problems within a system are not caused by external influences (*exogenous explanations*). Still, they are considered to be caused by the internal structure of the plan (*endogenous reasons*). The main focus of the system dynamics methodology is to understand a system so that the problem-solving steps provide feedback on the knowledge of the system.

Causal Loops

Causal loop diagrams are expressions of causal relationships in specific images. The elements of cause and effect, one of which refers to a qualitative (perceived) or quantitative (actual) measurable state. Process (rate) or information about conditions as a cause that produces conditions (levels) or influences operations as a result or preferably (Andhika 2019). A causal loop diagram is a tool to simplify system structuring. Detailed structuring for complexity simplification by the intent of systems thinking. Simplifications develop into dynamic structural patterns. Each system has different emotional behaviour patterns. Patterns can be used as initial guidelines in building a more detailed dynamic structure or for analysis (Indrawati 2012). After the elements of cause and effect have been sat down, then (which is connected with the causal arrow), it can be seen the type of effect caused by the cause, that is, the one-way effect, and the kind of effect that is caused by the reason is, in the same direction or the opposite direction. If the relationship is unidirectional, the arrow is positive (+); if it is in the opposite direction, it is negative (Prabowo *et al.* 2012).

Simulation

A simulation is a tool that is only used if there is an innate understanding of the problem to be solved. Simulation is designed to help solve a problem related to a system that operates naturally. Failure in a simulation experiment to produce a result is more often due to a lack of understanding of the system than knowledge of how to use simulation software (Arifin 2009). Simulation is an alternative solution to a problem, but the key remains in the entire system.

Verification and validation

Verification of the simulation model or virtual system operating model can be done by checking the suitability of the procedures used in processing the imitation system's operating data against the guidelines for operations on the natural system. Verification also needs to be done on computer programs and data processing worksheets compiled as an elaboration of methods. The primary purpose of verifying the system simulation model is to ensure that the compiled computer program and data processing worksheet are appropriate and correctly embody the conceptual simulation model that is used as the basis for preparing virtual system operating procedures. Checking the suitability of the operating model against the system simulation conceptual model needs to be done, since the form of the system operating model is not the same as the form of the conceptual simulation model. Checking is also necessary since inappropriate computer programs and simulation worksheets can provide virtual system operating results without experiencing execution errors even though the results obtained deviate far from the expected results. (Napitupulu 2009). Simulation model validation is done by checking the accuracy of the simulation program results and the simulation application worksheets that pass the verification. Model validation is not the same as model verification but is related based on the proof of models that have passed verification. If the guarantee concerns the preparation of the correct model, then validation involves the preparation of a suitable simulation model providing accurate results (Napitupulu 2009). Validation in dynamic system modelling can be done in several ways, including *direct structure tests* without processing the model, *structure-oriented behaviour tests* with model processes, and comparison of model behaviour with natural systems (*quantitative behaviour*). Pattern comparison, namely by testing the mean absolute percentage error (*mean fundamental percentage error*), is one of the relative measures involving percentage errors.

Model sensitivity and intervention

Model sensitivity is the model's response to the simulation, indicated by model behaviour and performance changes. Sensitivity test, namely intervention/treatment of input parameters and model structure, to see the level of sensitivity to changes in model output, so that the effect or impact of an intervention on overall performance can be observed. The intervention aims to explain the sensitivity of the parameters, variables, and the relationship between variables in the model. The sensitivity test results are in the form of changes (Muhammadi *et al.* in Rahman 2012). Model behaviour and performance to analyse the effects of interventions. Interventions are based on conditions that might occur in the real world, possible policy options, or feasible actions. The result of motion on changes in system performance is observed through changes in reference values, which can be patterns and trends that are desirable or undesirable. Sensitivity tests are carried out to find policy alternatives: accelerate the possibility of achieving positive results by research objectives or anticipate possible negative impacts, so that the overall performance of system elements does not fail/overshoot. There are two categories of sensitivity tests, namely functional interventions and structural interventions (Breierova *et al.* in Rahman 2012).

Previous studies

Riestina *et al.* (2015) conducted a study to see the relationship between knowledge, attitudes and actions of TB sufferers in preventing household contact at the Bagansiapiapi Health Center. The results showed that 67 respondents registered on form TB 06 (BTA+), the majority already had a good level of knowledge, attitude, and action with a percentage of >50%. There was a linear relationship with a positive direction between the level of knowledge, attitudes, and activities of respondents. Some of the respondents' actions in preventing household contact included conducting sputum examinations, covering their mouths when coughing, not throwing phlegm anywhere, and keeping their distance from suspected TB suspects Alini & Rosilawati (2017) identified a relationship between the condition of TB sufferers' homes and the success of TB treatment at Dr. RM. Pratomo Bagansiapiapi, Rokan Hilir Regency. The study was conducted using a *cross-sectional approach* using a sample of 50 populations who had received treatment for at least six months. As a result, of the 16 respondents whose homes met health requirements, 25.0 % failed TB treatment, while 34 respondents whose homes did not meet health requirements, 17.6 % were successful in treating TB. There is a relationship between home conditions and the success of TB treatment at a 95% confidence level ($P < 0.05$) with an OR (*Odd Ratio*) value of 14.0. This indicates that respondents whose housing conditions do not meet health requirements have a risk of 14 times experiencing failure in TB treatment compared to respondents whose housing conditions meet health requirements. Identification of TB disease in children by applying the perceptron method at the Bagan Batu health centre was carried out by Sihombing in 2016. The perceptron method uses an Artificial Neural Network (ANN) simulation approach using the Binary activation function (notation 0 and 1). Based on the 20 samples identified, the *output simulation results* of ANN were able to identify patterns of TB disease in children with an accuracy rate of 60%. Ariyanto *et al.* (2016) compiled a TB control model in plantation areas in Jember Regency. The study used a *mixed method* approach to solve the problem of treatment *dropout and diagnostic delay* caused by *patient delay*, which resulted in an increase in the incidence of MDR-TB in Jember District. The engineering model of prevention shows that religious leaders are a component that significantly influences the process of screening suspects and outreach to TB prevention. However, based on *social network analysis*, religious leaders are not central figures, so multiple parties have the same potential to contribute to TB control efforts. The model also shows that the effective intervention of religious leaders is at a different level than the sub-district level but at the village level. Cahyani carried out the area-based TB control planning model in Lumajang District in 2014. This descriptive study divides regions based on the average TB prevalence into high, medium, and low categories. Selection of alternative problem-solving in the model developed using a *fishbone diagram*, and CARL produces a planning model for each area category based on the type. In areas with a high prevalence category, the model shows that an alternative to increasing public knowledge about ACF and TB *screening campaigns* via radio is a practical scenario in increasing *active case finding*. Forming and fostering private practice doctor partnerships to send suspected TB patients to the Tekung Health Centre is the chosen alternative model in areas with moderate prevalence categories. Meanwhile, the scenario for planning TB control in low prevalence areas is by provoking TB patients to help detect the possibility of TB suspects around their environment. Herawati (2021) published the latest research on alternative TB treatments in Indonesian areas outside Sumatra and Java-Bali with a TB control model that is adjusted to the contribution of change. The changes referred to in the developed model are: (i) Increasing the screening of suspects in the form of notification of all types of TB cases based on CDR and CNR values at health facilities; (ii) Making changes to the organizational environment in health services; (iii) Fulfillment of basic facilities and infrastructure at each health facility; (iv) Increasing the recording of TB patients being treated to support an increase in the *cure rate* (v). There are changes to support the TB control implementation process, such as the organizational structure, referrals, and operational standards to increase the screening of suspects through CDR and CNR reporting.

Framework

The prevalence of TB disease in Rokan Hilir District has shown an increasing trend in recent years. This indicates that the implementation of TB control programs that have been carried out so far has yet to deliver maximum results. This is predicted due to the current prevention program focusing on monitoring and medical treatment for sufferers. The prevalence of TB, an airborne disease, is significantly influenced by several determinants. These determinants include demographic factors, climate variability, individual characteristics, socioeconomic conditions, physical environmental conditions, and the availability and quality of human resources and health facilities. Demographic factors consist of population and population density. Climate variability refers to climate variables consisting of air temperature, humidity, and rainfall. Individual characteristics are distinguished by two variables, namely gender, and age (productive and unproductive). Socioeconomic determinants are built on education, employment, income, knowledge, and behaviour. The determinants of the physical environment are the house's physical condition consisting of ventilation, lighting, humidity, floor type, wall type, and occupancy density which are measured based on the requirements of a healthy house. The determinants of Health and Health Human Resources are calculated based on the availability, adequacy, and distribution of Health and Health Human Resources, referring to the ideal ratio of several Healthcare professions and the coverage of Health Facilities compared to the population. The achievement of TB control program implementation refers to the value of the *Case Detection Rate* (CDR), *Case Notification Rate* (CNR), and *Success Rate* (SR) from each Health Facility. The relationship between the determinants of TB prevalence produces a close relationship (partial and extensive) which is illustrated by the *odds ratio* (affected risk), which is used as the basis for determining the critical variable determining the prevalence of TB disease. The crucial determinant variables are then translated into problem formulations based on system requirements. The problem formulation is classified based on the essential factors that form the basis for formulating TB disease management strategies. Identification of the built model system is an *input-output process*, and the formulation of a mental model (*causal loop*) refers to needs analysis, problem formulation, and essential factors of the critical variables associated with the prevalence of TB disease. Identification of the system will produce causality (cause and effect) and *feedback* from each subsystem formed from the critical variable plurality of TB disease, which is then formulated as a model formula to construct the structure of the model to be simulated. The model simulation was carried out to see the existing condition of TB prevalence in Rokan Hilir Regency and the projection based on the determined time unit without any intervention. The model simulation results in the form of an overview of existing conditions and forecasts of the prevalence of TB disease in the next few years are then validated using the MAPE (*Mean Absolute Percentage Error*) approach. The existing condition simulation model that has been validated is then intervened with several developed scenarios referring to the critical factors and variables to overcome TB disease's prevalence. Model scenario simulation will produce sensitivity values of the lever variables. Based on the sensitivity values of the lever variables, priority scenarios are then formulated and translated into a policy recommendation. The formulation of policy recommendations is then implemented in a TB disease management program in Rokan Hilir Regency on an ongoing basis.

MATERIALS AND METHODS

Research design

This study used a mixed design (*mixed method*) consisting of observational studies, case-control, and spatial approaches based on Geographic Information Systems (GIS). The determinant factors as research variables consist of demography, climate variability, socio-economic, physical environment, and health infrastructure. The study's dependent variable was the prevalence of TB cases in the Rokan Hilir District. An observational approach to the study was carried out on the variable prevalence of TB cases, demography, and health facilities and infrastructure. Observation is carried out by screening variable data originating from various reports and documents released by relevant institutions by the achievement of research objectives. The case-control approach was carried out on socio-economic and physical environment variables in patients with TB who were recorded as having received treatment at government-owned primary healthcare facilities as the case population and residents who were in the study sampling area based on the category of distribution of TB cases per district as the control population. The case sample refers to the average data of TB cases for the 2017-2020 period, which is divided into three categories, i.e., the low category (Rantau Kopar Health Centres), the medium category (Bangko Jaya and Bangko Kanan Health Centres), and the high category (Bagansiapiapi Health Centre, Bagan Punak and RSUD Dr. RM. Pratomo). Control samples were taken in administrative areas based on case sample health service facilities, namely Rantau Kopar District (low category), Bangko Pusako (medium category), Bangko (high-class). Calculate the number of case-control samples using the Lemesow equation: $n = N.Z^2_{1-\frac{\alpha}{2}}.p.\frac{q}{d^2(N-1)} + Z^2_{1-\frac{\alpha}{2}}.p.q$(p = estimated proportion

[0.2], q = 1-p, d = absolute precision [10%], $Z^2_{1-\alpha/2}$= Statistical [Z = 1.96 for α = 0.05], N = population size), which resulted in 53 samples of case respondents, and 61 samples of control respondents.
A GIS-based spatial approach is used to acquire climate variability data (temperature, humidity, rainfall). Spatial interpolation and interpretation of data are also used to describe the spatial distribution of climate variability and prevalence of TB cases in Rokan Hilir District. GIS analysis will produce a spatial visual presentation as a thematic map.

Data collection

The prevalence of TB is known based on observations of TB medical record data at all government health facilities and denominator data related to the findings of all TB cases recorded at the Rokan Hilir District Health Office in the 2017-2020 timeframe. Demographic variable data is obtained from observing population data contained in the *online portal https://rohilkab.bps.go.id/* belongs to the Central Bureau of Statistics of Rokan Hilir Regency. The scanned documents were from Rokan Hilir Regency in Figures in 2017-2020. *Online* portal sources by carrying out a series of processes to obtain the required data using *ArcGis Desktop 10.8 Ver. 10.7.0.10450*. Average air temperature data were obtained from a reanalysis of ERA-5 *European Centre for Medium-Range Forecast* (ECMWF) satellite imagery with a resolution of $0.25^0 \times 0.25^0$. Air humidity data were obtained from the assimilation of 1o × 1o resolution raster data released by The NASA *Prediction of Worldwide Energy Resource (POWER) project on the http://power.larc.nasa.gov* portal. Precipitation data was obtained from the interpretation of global *Climate Hazards Group InfraRed Precipitation with Station* (CHIRPS) data by *the US Geological Survey* (USGS) downloaded from the *IRI Data Library* on the portal *http://iridl.ldeo.columbia.edu/SOURCES/.UC SB/.CHIRPS/* resolution 0.05 º × 0.05 º. Climate variability data was acquired in the 2017-2020 timeframe. Recruitment data on socio-economic variables were obtained from an instrument in the form of a structured questionnaire which included information on gender, age, education, occupation, and income in the case and control samples. The sampling technique for obtaining data on socio-economic variables uses *non-probability sampling with the quota sampling method.* Physical environment variable data consists of ventilation area (cm), lighting (*lux*), humidity (%), floor type, wall type, and occupancy density. Ventilation area data were obtained from measurements using a meter, lighting with a *Luxmeter*, and humidity with a *Thermo Hygrometer*. The type of floor, wall and occupancy density are measured using an observation sheet. Determination of physical environment criteria refers to Kepmenkes RI/No.829/Menkes/SK/VII/1999 concerning Housing Health Requirements and Permenkes RI No. 1077/Menkes/PER/2011 concerning Guidelines for Indoor Air Sanitation. Health facilities and infrastructure data were obtained from observations of Rokan Hilir Regency BPS data on the *online portal*. The screening was carried out on data on the number of health workers consisting of doctors, nurses, midwives, pharmacists, and nutritionists, as well as the number of health facilities, including hospitals, polyclinics, health centres, auxiliary health centres (post), and pharmacies, which are contained in the Rokan Hilir Dalam Regency document. Figures range for 2017-2020. The proportion of availability of health workers and health facilities is known from the ratio of the number of health workers and health facilities to the population. Guidelines for determining the percentage of availability of health workers refer to the Decree of the Coordinating Minister for People's Welfare No. 54 in 2013. At the same time, the procedures for determining the availability ratio of health facilities refer to the Minister of Law and Human Rights Regulation Number 34 of 2016.

Data analysis

Statistical data processing using *software IBM SPSS Statistics Version 25* and *ArcGis Desktop 10.8 Ver. 10.7.0.10450* for GIS-based spatial analysis. The descriptive analysis method was carried out to get an overview of the data distribution of each research variable. Methods for analysing the relationship between demographic determinants, climate variability, availability of health workers, and health facilities with the prevalence of TB cases partially using the *Pearson correlation product moment test*. The method of analysing the relationship between socioeconomic determinants and physical environment with the majority of TB cases was carried out bivariate using the *chi-square test* on cases and controls ($p < 0.05$, odds ratio [OR], 95% confidence interval [CI]). The spatial distribution of climate variability (temperature, humidity, and rainfall) was interpolated using the

Inverse Distance Weighted (IDW) method (Azpurua & Ramos 2010). Meanwhile, the classification of spatial distribution uses the *Jenks Natural Breaks method* based on EHDP (Dent, 1999; Slocum 1999).

RESULTS

Prevalence and distribution of TB cases

It was found that all TB cases in Rokan Hilir Regency in the 2017-2020 period experienced an increasing trend of 19.58 % per year, with an average number of cases (± SD) of 1,068 ± 60.97 cases/year. TB cases are spread across all sub-districts, where the Bangko sub-district has the highest TB cases with an average (± SD) 266 ±34.2 cases/year. Meanwhile, the lowest TB cases were in the Bagan Sinembah Raya sub-district, with an average (± SD) of 15± 4.0 points/year. The highest prevalence of TB cases is also concentrated in Bangko District, with an average (± SD) of 32 ± 7.53 cases/10,000 population. Furthermore, the lowest majority of TB cases were in Tanjung Medan District, with a standard (± SD) of 6 ± 1.19 cases/10,000 population. Fig. 1 shows the district's spatial distribution of TB cases and prevalence per 10,000 population.

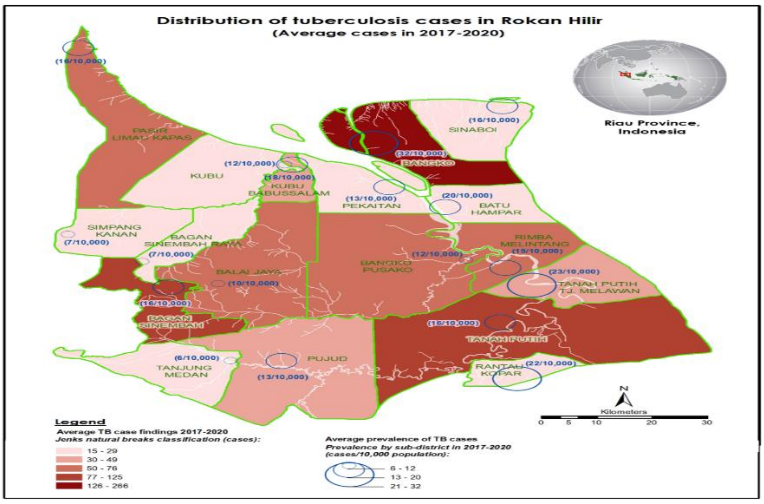

Fig. 1. Map of the average prevalence and distribution of TB cases in 2017-2020, Rokan Hilir, Indonesia.

TB case determinants

Demographic determinants are composed of the factors of population size and population density. The population of Rokan Hilir Regency in the 2017-2020 period has relatively increased, with an average growth rate of 2.53% per year. The average population (± SD) is 682,135 ± 16,592 people with an average density (SD) of 77 ± 1.8 people km^{-2}. The distribution of the high population (41,177-83,961 people) is concentrated in urban areas, such as in Bangko, Bagan Sinembah, Balai Jaya, Bangko Pusako, and Tanah Putih sub-districts. The low population distribution (6,952-9,083 people) is in Batu Hampar and Rantau Kopar Districts. High population densities (111-177 people km^{-2}) are concentrated in Bangko and Rimba Melintang districts. Meanwhile, sub-districts with low population density (30-32 people km^{-2}) are focused on Batu Hampar and Rantau Kopar sub-districts. The results of the *Pearson correlation product moment analysis* show that there is a solid relationship between demographic determinants (population and population density) and the increasing prevalence of TB cases in Rokan Hilir Regency during the 2017-2020 period ($R > 0.7$; $\alpha = 0.01$), with a positive relationship direction. These results indicate that there is a tendency for the prevalence of TB cases to increase as the number and population density increase. Fig. 2 shows the spatial distribution of demographic determinants (population and population density) and their relationship to the prevalence of TB cases in Rokan Hilir District.

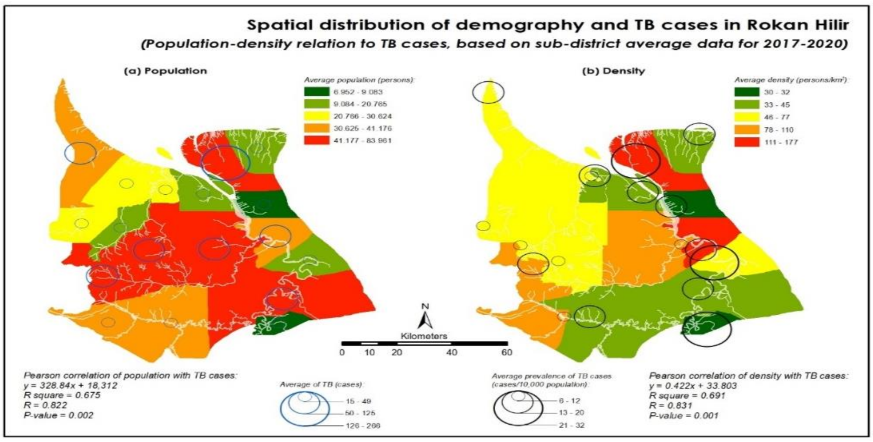

Fig. 2. Spatial distribution of population, population density, and their relationship with the prevalence distribution of TB cases during the 2017-2020 period.

Climate variability as a determinant of TB cases consists of temperature, humidity, and rainfall elements. The results of the reanalysis of ERA5 satellite imagery show an increase in air temperature in Rokan Hilir district with an average (± SD) of 0.30 ± 0.19 ºC during 2017-2020. The highest temperature is spread in Batu Hampar District with an average (± SD) of 27.87 ± 0.21 ºC, while the lowest temperature is distributed in Tanjung Medan District with an average (± SD) of 27.34 ± 0.18 ºC. The assimilation of POWER raster data results in an average (± SD) of air humidity value (± SD) of 87.33 ± 3.78% during 2017–2020. The highest average air humidity (± SD), 91.17 ± 0.34 %, was concentrated in the Districts of Pujud, Tanjung Medan, Bagan Sinembah, and Balai Jaya, while the lowest (± SD), 78.37 ± 0.75%, in Sinaboi District. The results of the interpretation of the CHIRPS -USGS data during 2017-2020 exhibited an average rainfall ± SD) of 2,792 ± 183.39 mm/year. The highest average rainfall (± SD) of 3,331 ± 340.95 mm/year is concentrated around the Tanjung Medan District, while the lowest, 2,600 ± 353.44 mm/year, concentrated in the Tanah Putih District, Tj. The results of the *Pearson correlation product moment analysis* exhibited that there is no significant relationship between climate variability (temperature, humidity, rainfall) and an increase in the prevalence of TB cases in Rokan Hilir Regency during 2017-2020 ($R< 0.25$; $\alpha = 0.05$). Fig. 3 illustrates the spatial distribution of climate variability (temperature, humidity and rainfall) and its relationship to TB cases in the Rokan Hilir District (Tables 1-2). Socioeconomic determinants consist of variables including gender, age, education, employment, and income. Case respondents were 53 people dominated by male (64.2%), unproductive age > 40 years (64.2%), low education (77.4%), not working (66.0%), and low income (83.0%). The distribution of control respondents by gender was more even, with respective percentages of 50.8 % (♂) and 49.2% (♀). The age of control respondents was dominated by productive period of 15-64 years (57.4 %), highly educated (54.1%), working both in the formal and informal sectors (50.8%), and the majority had low income <UMK (57.4%).

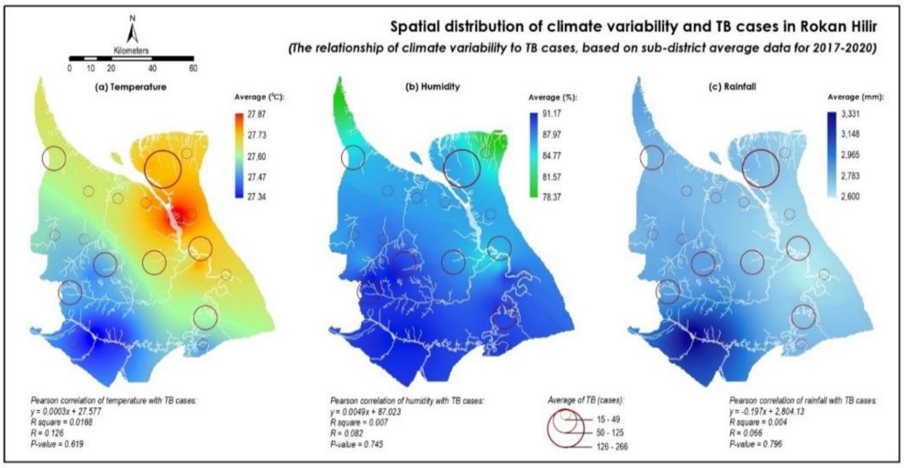

Fig. 3. Spatial distribution of temperature, humidity, rainfall, and their relationship with the distribution of TB cases during the 2017-2020 period.

Table 1. Research variables were collected and used in this study, along with their definitions and sources.

Variable	Definition	Source
TB case		
(1) Number of TB sufferers	The number of TB case findings for 2017-2020 was recorded in medical records at government health facilities and included in the Rokan Hilir District Health Office report.	(1,2) Observations by the author of TB medical record data at government health facilities and TB report data from the Rokan Hilir District Health Office (2017-2020).
(2) Prevalence of TB	The average number of TB cases per population by sub-district during 2017-2020.	
(3) TB prevalence distribution	Classification of the average spatial distribution of TB prevalence by sub-district.	(3) Interpretation by the author through GIS using the *Jenks Natural Breaks method* (Dent 1999; Slocum 1999).
Demographics		
(4) Total population	Total population (people) living by sub-district during 2017-2020.	(4,5,6) Observation of data by the author on *online documents for* Rokan Hilir Regency in Figures during 2017-2020 (https://rohilkab.bps.go.id/).
(5) Area	Administrative area by district (km^2).	
(6) Population density	The average number of residents per km^2 of the sub-district area (people/km^2) during 2017-2020.	
Climatology		
(7) Air temperature	The average air temperature (ºC) by sub-district was measured 2 m above the earth's surface during 2017-2020.	(7) Calculation by the author through re-analysis of *ERA-5 satellite imagery with a* resolution of 0.25º × 0.25º from ECMWF during 2017-2020 using GIS.
(8) Air humidity	Average air humidity (%) by the district during 2017-2020.	(8) Calculation by the author through assimilation of *POWER raster data* with a resolution of 1º × 1º during 2017-2020 (http://power.larc.nasa.gov) using GIS.
(9) Rainfall	The district's average total rainfall per year (mm/year) during 2017-2020.	(9) Calculation by the author through interpretation of *CHIRPS-USGS data* resolution 0.05º × 0.05º during 2017-2020 (http://iridl.ldeo.columbia.edu/ SOURCES /.UC SB /.CHIRPS/) using GIS.
(10) Distribution of climate variability	Classification of the spatial distribution of the average climate variability (temperature, humidity, rainfall).	(10) Interpolation of data by the author through GIS using the *Inverse Distance Weighted* (IDW) method (Azpurua & Ramos 2010).
Socioeconomic		
(11) Gender	Biologically and anatomically determined sexual division (Male [♂], Female [♀]).	(11, 12, 13, 14 and 15) Structured questionnaires by the author to case and control respondents using the *non-probability sampling technique* with the *quota sampling method*.
(12) Age	The length of life measured from birth with the classification of productive age is 20-40 years.	(12) Productive age range (Harmono *et al.* 2018).
(13) Education	Last formal education level completed (High [SMA/Diploma/Bachelor], Low [No School/SD/ junior high school]).	(13) Education level category (Hidayatunnisa *et al.* 2021).
(14) Jobs	Routine activities carried out to generate family income (Not Working/IRT, Working (formal/informal).	(14) Job classification (Suhardi *et al.* 2021). (15) Categories of income levels (Meitasari 2020).
(15) Income	Family income from main and additional work (High [≥ UMK], Low [≤ UMK]).	
Physical environment		
(16) Ventilation area	The area of the house's ventilation holes (cm) compared to the floor area of the house (Qualified [≥10% of floor area], Not eligible [<10% of floor area]).	(16) Measurements by the author using the meter (cm). (17) Measurement by the author using *Luxmeter* (*lux*).
(17) Room Lighting	The amount of natural or artificial light intensity in the house (Qualified [> 60 lux], Not eligible [< 60 lux]).	(18) Measurements by the author using a *Thermo Hygrometer* (%).
(18) Room humidity	Moisture content in the house (Qualified [40%-70%], Not eligible [<40% or >70%]).	(19, 20 and 21) Measurements by the author using observation sheets.
(19) Floor type	House floor material (Meets the requirements [Domination of waterproof materials], Does not meet the criteria [Dominance of non-waterproof materials]).	(16, 21) Criteria for housing health requirements according to Kepmenkes RI No. 829/Menkes/SK/VII/1999.
(20) Wall type	Material of the walls of the house (Meets the requirements [Domination of waterproof materials], Does not meet the criteria [Dominance of non-waterproof materials]).	(17, 18, 19 and 20) Guidelines for indoor air sanitation according to RI Minister of Health No. 1077/Menkes/PER/2011.
(21) Density of occupancy	Comparison between the area of the room and the number of occupants of the house (Not crowded [ratio >8m²/person with a room height of 2.8 m], Dense [ratio <8m²/person with a room height of 2.8 m]).	

Variable	Definition	Source
TB case		
Health infrastructure		
(22) Availability of health workers	The district has several health workers (doctors, nurses, midwives, pharmacists, and nutritionists).	(22 and 23) Observation of data by the author on *online documents for* Rokan Hilir Regency in Figures for 2017-2020 (*https://rohilkab.bps.go.id/*).
(23) Availability of health facilities	Number of health service facilities (hospital, polyclinic, puskesmas, pustu) by the district.	(22) The ideal ratio of health workers according to the Decree of the Coordinating Minister for Welfare No. 54 in 2013. (23) The ideal ratio of health facilities according to the Minister of Law and Human Rights Regulation Number 34 of 2016.

Table 2. Results of bivariate analysis of socio-economic determinants and physical environment with the prevalence of TB cases.

Variable	Case		Control		*p.s*	*OR*	*95% CI*
	n	%	n	%			
Socioeconomic Determinants							
Gender							
– Man	34	64.2	31	50.8	0.153	1.732	0.816-3.677
– Woman	19	35.8	30	49.2			
Age							
– Not Productive (>40 years)	34	64.2	26	42.6	0.023*	2.409	1.130-5.134
– Productive (20-40 years)	19	35.8	35	57.4			
Education							
– Low (No school/elementary/junior high school)	41	77.4	28	45.9	0.001**	4.027	1.779-9.115
– High (SMA/Diploma/S1)	12	22.6	33	54.1			
Profession							
– Not Working/IRT	35	66.0	30	49.2	0.071	2.009	0.941-4.289
– Employed (PNS, Private Employees, Entrepreneurs, Laborers, Farmers)	18	34.0	31	50.8			
Income							
– Low (If < UMK Rp. 2.5 million/month)	44	83.0	35	57.4	0.004**	3.632	1.509-8.742
– High (If ≥ UMK Rp. 2.5 million/month)	9	17.0	26	42.6			
Determinants of the Physical Environment							
Ventilation							
– Qualify	17	32.1	32	52.5	0.030*	2.337	1.087-5.021
– Not eligible	36	67.9	29	47.5			
Lighting							
– Qualify	13	24.5	38	62.3	0.000**	5.084	2.257-11.452
– Not eligible	40	75.5	23	37.7			
humidity							
– Qualify	14	26.4	36	59.0	0.001**	4.011	1,810-8,890
– Qualify	39	73.6	25	41.0			
Floor Type							
– Qualify	18	34.0	34	55.7	0.021*	2.449	1.144-5.239
– Not eligible	35	66.0	27	44.3			
Wall Type							
– Qualify	17	32.1	35	57.4	0.008**	2.851	1.322-6.146
– Not eligible	36	67.9	26	42.6			
Occupancy Density							
– Congested	21	39.6	44	72.1	0.001**	3.944	1.799-8.647
– Not solid	32	60.4	17	27.9			

Note: *Significant at the 95% confidence level; **Significant at the 99% confidence level.

The relationship between socioeconomic determinants and the prevalence of TB cases is known based on bivariate analysis using the *chi-square test*. According to the probability value (p - value), gender and occupation exhibited no significant relationship with the prevalence of TB cases ($p > 0.05$). Meanwhile, age, education level, and income were significantly related to most TB cases ($p < 0.05$). The *odds ratio* (OR) value of the age variable was 2.409, which means that old or unproductive age (>40 years) is 2.4 times more at risk of suffering from TB than productive age (20-40 years). People with low education (not attending school/elementary/junior high school) displayed a 4.02 times risk of suffering from TB disease compared to higher education (high school/diploma/bachelor degree). Low-income people (< 2.5 million/below the UMK) were 3.63 times more at risk of suffering from TB than those with high incomes (>2.5 million/above the UMK). The determinants of the physical environment consist of variables including ventilation, lighting, humidity, floor type, wall type, and occupancy density, with criteria referring to Kepmenkes RI/No.829/Menkes/SK/VII/1999 concerning housing health requirements. The results of bivariate analysis using *chi-square* showed that all independent variables of the physical environment had a significant relationship with the prevalence of TB cases ($p < 0.05$), with a measure of risk (OR) in the range of 2-5. The OR value of the ventilation variable was 2.337, which means that the condition of a house that does not meet the ventilation requirements <10% of the floor area is 2.3 times higher at risk of suffering from TB disease compared to places with ventilation ≥10% of the floor area. Houses with lighting < 60 lux exhibited a chance of 5.1 times suffering from TB disease compared to homes with lighting ≥60 lux. Room humidity <40% or >70% displayed four times the risk of suffering from TB disease compared to a house with 40-79% moisture. Homes with floors made of non-watertight materials displayed a 2.4 times risk of suffering from TB disease compared to houses with ground floors made of waterproof. As with the type of floor, a place dominated by walls made of non-watertight materials exhibited a 2.8 times risk of suffering from TB disease compared to houses with a predominance of walls made of impermeable materials. House occupancy density <8 m^2/person at a room height of 2.8 m revealed a risk of 3.9 times suffering from TB disease compared to a house occupancy density of > 8 m^2/person at the height of 2.8 m. Health facilities and infrastructure determinants consist of the variables including the availability of health workers (Nakes) and health service facilities (Fasyankes). The availability of health workers consists of physicians, nurses, midwives, pharmacists, and nutritionists. At the same time, the availability of health facilities consists of primary health facilities such as hospitals, polyclinics, health centres, and auxiliary health centres (pustu). Based on the provisions of the ideal ratio of health workers according to the Decree of the Coordinating Minister for People's Welfare (Kepmenko for People's Welfare) No. 54 of 2013 (health workers/1,000 population), it is known that health workers in Rokan Hilir Regency were not evenly distributed. Likewise, the ratio of availability of health facilities based on Minister of Law and Human Rights Regulation (Permen Hukum and HAM) No. 34 of 2016 (facility/16,000 population) also exhibited variable conditions. In general, the ratio of availability of health workers in Rokan Hilir Regency is 4-5 health workers/1,000 population. The situation is better for the availability of health workers, i.e., 6-9 health workers/1,000 residents spread across the sub-districts of Bangko, Batu Hampar, Kubu Babussalam, Tanah Putih Tj. Fight, and Rantau Kopar. Meanwhile, the Simpang Kanan, Balai Jaya, and Tanjung Medan sub-districts displayed a smaller ratio of availability of health workers, i.e., a 2-3 health workers/1,000 population. The rate (%) of availability of health facilities in Rokan Hilir Regency is generally still relatively low, with 2-3 health facilities/16,000 population. The sub-districts with a better ratio of health facilities (4-5 health facilities/16,000 people) are spread across the sub-districts of Kubu Babussalam, Kubu, Simpang Kanan Tanjung Medan, Pujud, and Rantau Kopar. A higher availability ratio of health facilities (6-8 health facilities/16,000 population) is spread across Batu Hampar, Pekaian, and Bagan Sinembah Raya sub-districts. The results of the *Pearson correlation product moment analysis* exhibited that there is a solid relationship between the determinants of health facilities and infrastructure (availability of health workers and health facilities) with an increase in TB cases in Rokan Hilir Regency during the 2017-2020 period ($R > 0.7$; $\alpha = 0.01$), with a positive relationship direction. These results indicated a relative increase in TB case findings based on the availability of health facilities and infrastructure. Fig. 4 illustrates the spatial distribution of the determinants of health infrastructure (availability of health workers and health facilities) and their relationship to TB case findings in Rokan Hilir District.

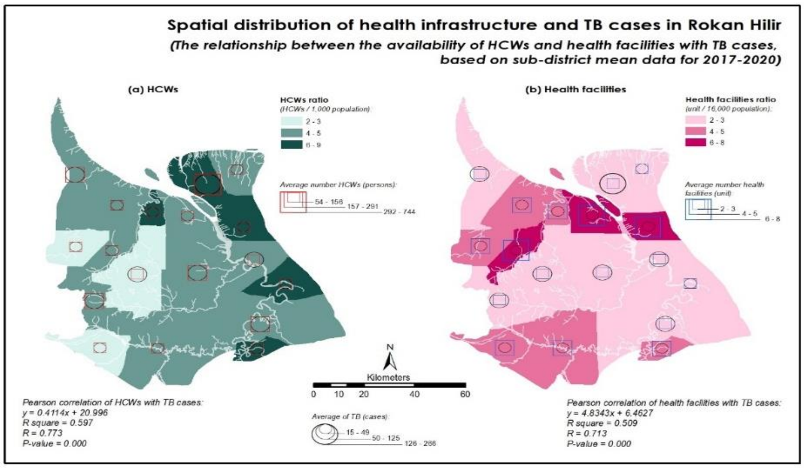

Fig. 4. Spatial distribution of the availability of health workers and health facilities and their relationship with TB case findings during the 2017-2020 period.

DISCUSSION

The number and density of the population in an area will determine the speed of transmission of TB disease. The results of the correlation analysis in Rokan Hilir District exhibited relatively the same conditions, where one TB case will increase every time there is an elevation in the population of 329 people. Likewise, the relationship between population density and the prevalence of TB cases showed that the relative risk of one TB case increases for every elevation in the population density of 0.4 people /km^2 which is significantly related to the incidence of TB in an area (Tanrikulu *et al.* 2008). Based on the analogue analysis, population density is a significant predictor of the occurrence of TB events (Shaweno *et al.* 2017). Similar to population distribution, TB cases in Rokan Hilir District are concentrated in urban areas, where exhibit a relatively high population density and tend to cause an increase in slums, poor hygiene, and nutrition, thereby accelerating the spread of TB disease (Aditama 2012). The area influences the difference in the value of the correlation coefficient of the population and population density variables with the prevalence distribution of TB cases (Jiang *et al.* 2020). In anticipating demographic determinants, it is necessary to distribute the population evenly from areas with high population density to areas with medium and low population density with a planned local transmigration program. So the population is concentrated in more than just a few sub-districts, which can cause population density to exceed sustainable limits. Batu Hampar, Pekaian, and Sinaboi sub-districts need to be prioritized as alternative transmigration areas to reduce population pressure in Bangko, Rimba Melintang, and Bangko Pusako sub-districts. No climate variability (temperature, humidity, and rainfall) is associated with increased TB cases in Rokan Hilir District. This shows that climate variability is not a directly determinant of TB disease in the Rokan Hilir District. Although several studies have examined the impact of climate change on TB patterns and burdens in several low- and middle-income countries (Maharjan *et al.* 2021), followed by a seasonal way of TB which tends to increase in spring and summer (Fares 2011; Koh *et al.* 2013). Based on an investigation using a meta-analysis of three databases: PubMed, Web of Science, and Embase regarding the relationship between TB cases and meteorological factors, it is known that TB risk is only positively correlated with rainfall, while temperature, humidity, air pressure, and sunshine duration do not have a significant correlation (statistically substantial; Qin *et al.* 2022). Climate variability (humidity, air pressure, and rainfall) does not directly impact the incidence of TB (Zhang & Zhang 2019). Socio-economic determinants influencing TB cases in Rokan Hilir Regency are age, education level, and income. People > 40 years are at risk of 2.4 times suffering from TB disease compared to the productive age range (20-40 years). This result is in line with the report of the Indonesian Ministry of Health (2020), which released data on findings of new TB cases in Indonesia, the highest being found in the age group 45-54 years, with a proportion of 17.3%. The high levels of exposure to *Mycobacterium tuberculosis* at the age of > 40 years are mainly caused by endogenous reactivity, namely, TB germs that are already present in the body become active again as the body's resistance decreases due to increasing age (Dotulong *et al.* 2015). At the age of over 40 years begin to fall in physical abilities for individuals (Priyono & Yasin 2016). Decreased immunity with age, increases the risk of contracting TB disease (Resende & Santos-Neto 2015). Residents with low education (not attending school/elementary/junior high school) are at risk of 4.02 times suffering from TB disease compared to residents with high levels (high school/diploma/bachelor degree). Nurjana (2015) stated that education level is a factor in predicting the risk of TB infection; the lower a person's education, the greater the risk of suffering from TB. The success of TB treatment has a higher percentage of highly educated people than those with low education (Chenciner *et al.* 2021). The level of income is an indicator of the economic condition of a family; with a high payment, a person will be able to meet Heiner's life needs, especially health (Wikurendra 2019). Low-income levels (< 2.5 million/below the UMK) are 3.63 times more at risk of contracting TB disease than high-income levels (>2.5 million/above the UMK). This condition is in line with the WHO report (2021), which states that over 95% of deaths from TB occur in low and middle-income countries, and it is among the top three causes of death for women at 15-44 years. TB morbidity is also higher among low/poor-income residents (Septia *et al.* 2013). Low education levels dominate low-income residents in Rokan Hilir Regency. Education level can determine decent work, higher income levels, and higher socioeconomic status, which can affect the risk of TB disease (Chenciner *et al.* 2021). Low-income people will reduce their ability to consume nutritious food, thereby increasing their vulnerability to TB transmission (Saunders & Evans 2020). Socioeconomic determinants are essential for developing TB control strategies in Rokan Hilir District. The high risk for educated and low-income residents is a critical variable in TB control apart from the age factor. Therefore, the efficiency and effectiveness of TB control programs in the future should be more directed at improving public health education with continuous preventive and promotive efforts, especially in the vulnerable age group (> 40 years). Improving the quality of service and the availability of free TB drugs will increase the rate (%) of TB treatment success, especially for the economically-vulnerable population. The assessment of the physical environment determinant criteria (ventilation area, lighting, humidity, floor type, wall type, and occupancy density) refers to housing health requirements based on Kepmenkes RI/No.829/Menkes/SK/VII/1999. The results of the correlation analyses exhibited that all physical environment variables were related to TB cases in Rokan Hilir District. Many studies support this result, such as the results of a recent literature review conducted by Nurany *et al*. (2022) via the Google Scholar search engine, journal.undip.ac.id, and the Garuda Portal, finding ten scientific journals indicating that ventilation area, occupancy density, lighting intensity, humidity, and room temperature are risk factors for TB incidence in Indonesia. Similar conditions are also found in Malaysia (Mohidem *et al.* 2021) and *high-burden countries* (Teo *et al.* 2021). The determinant of the physical environment on the incidence of TB does not stand alone by one factor, but many factors are interconnected and influence each other. Sufficient ventilation will cause minimal lighting and increase humidity in the room due to the evaporation process. A good ventilation area has an area of ≥10% of the floor area of the house (RI Ministry of Health 1999). Ventilation area <10% of the floor does not meet health requirements and can result in reduced oxygen concentrations, increased carbon dioxide, and humidity, hampering the process of air exchange and sunlight entering the house (Nurany *et al.* 2022). These conditions will result in the longer survival of *M. tuberculosis* secreted by TB sufferers when coughing and sneezing and infecting the occupants of the house due to inhalation through the respiratory process. A person who lives in a house with a ventilation area that does not meet health requirements (<10% of the floor area) experiences a 2.3 times risk of contracting TB disease compared to someone who lives in a house with a ventilation area that meets health requirements (≥10% of the floor area). Lighting, one of the determinant variables of the physical environment, consists of natural and artificial lighting. Natural lighting comes from sunlight that enters through ventilation or windows or glass tiles, while artificial lighting is produced by sources other than sunlight. The house is said to have ideal lighting if the measured light intensity is > 60 lux (Ministry of Health RI 2011). Lighting has a negative correlation with humidity. The lack of lighting in the room will cause an elevation in moisture, which can affect the growth of TB bacterial microorganisms (Nurany *et al.* 2022). Dark rooms tend to have high air humidity, so *M. tuberculosis* can survive for days or even months (Kenedyanti & Sulistyorini 2017). Someone who lives in a house with inadequate lighting (< 60 lux) has a risk of contracting TB by 5.0 times compared to someone who lives in a place that meets ideal lighting requirements (> 60 lux). Humidity is a variable that significantly influences the growth of bacteria and viruses. Indoor humidity is ideal and meets the requirements ranging from 40% to 60% (Ministry of Health RI 2011). Too high or too low air humidity can be an ideal breeding ground for *M. tuberculosis* (Mappau & Basri 2020). Room conditions with high humidity levels will reduce the ability of a person's immune system to fight microorganisms that enter through the respiratory tract (Purnama 2016). Living in a house with humidity that does not meet health requirements has the risk of contracting TB by 4.0 times compared to living in a house with humidity that meets health requirements. The determinants of TB incidence are also related to the quality of the building, such as the type of walls and floors. Types of walls and floors not made of waterproof materials are risk factors for TB disease (Dani & Suswani 2020; Mappau & Basri 2020). Several factors increase the humidity in the room caused by leaky roofs, floors, and walls that are not waterproof, which causes water infiltration through the pores of the construction (Zulaikhah *et al.* 2019). Someone who lives in a house with non-watertight floors and walls will be at risk of contracting TB disease 2.4 - 2.8 times compared to someone who lives in a house with waterproof floors and walls. Residential density is the floor area in the house divided by the number of occupants (Nurany *et al.* 2022). The size of the place that is not proportional to the number of occupants will make it crowded and create unhealthy conditions for the occupants. Occupancy density will be a risk factor for TB disease transmission if one occupant is infected with TB. A house is considered crowded and only meets health requirements if more than two people per 8 m^2 are filled, except for children under five (Ministry of Health RI 1999). The denser the occupants of the house will trigger a rise in room humidity due to sweat and the respiration process of the occupants (Kenedyanti & Sulistyorini 2017). Upraised humidity will facilitate *M. tuberculosis* to survive longer (Mappau & Basri 2020). Densely populated houses allow for more frequent contact between TB sufferers and other residents, so transmission of TB disease between occupants can occur more quickly. Someone who lives in a house with dense occupants experiences a 3.9 times risk of contracting TB disease compared to someone who lives in a place that is not crowded and meets the requirements. Building public awareness to apply the ideal requirements for the physical environment of the house plays a vital role in efforts to control TB disease. Optimizing the implementation of health campaigns and promotions regarding the prevention of TB disease transmission based on the characteristics of the physical environment by the government must be carried out on an ongoing basis. Socialization and counselling that recommend steps for planning and house architecture that meet health requirements will bring about improvements and can prevent an increase in TB cases in the future. The availability of health facilities and infrastructure (number of health workers and health facilities) dramatically affects the health status of the community. There is a significant correlation between the number of health workers ($R^2 = 0.597$) and the number of TB case findings. This means that the number of health workers influences 59.70% of the TB case results in Rokan Hilir. The number of health workers will significantly affect people's interest in utilizing and using health services (Delavari *et al.* 2016). The most dominant factor affecting the finding of TB cases at the age of >15 years is the TB diagnosis performed by health workers (Pangaribuan *et al.* 2020). An increase in the number of health workers is directly proportional to the elevation in the screening of suspected and *default rates* of TB disease (Nida 2014), which upraises the rate (%) of successful TB treatment (Datiko *et al.* 2017). The elevated population demands an increase in the number of health workers. The availability of health workers as implementers of health services still needs to meet the standard ratio per population, especially in remote areas (Saputra *et al.* 2015). The availability of health workers with an ideal balance will significantly affect health services, especially in the medical profession (Juwita *et al.* 2021). Facilities (50.90 %): The availability of health facilities, besides directly affecting a person's health status, will also affect the health services perceived by the community (Janis 2014). When the number of health facilities is small and the price spent to obtain health services is high, it reduces people's interest in using health services and vice versa (Calundu 2018). TB case findings tend to be more numerous in the sub-districts where the puskesmas is located; this indicates that the presence of health facilities in an area can increase TB case findings compared to other sites that do not have health facilities (Dhamayanti and Rahmaniati 2020). The correlation between the number of health facilities and TB case findings can be seen from the increase in TB case findings after the division of the puskesmas work area (Nida 2014). The ratio of health facilities to population is not yet ideal as an inhibiting factor in efforts to control TB disease, since it has a significant effect on *surveillance* and treatment of TB disease so far; it is still carried out passively (*passive case finding*). Not meeting the ideal ratio and limited access to health facilities will increase the vulnerability of TB disease transmission (Datiko *et al.* 2017; Saunders & Evans 2020). Fulfilling the ideal ratio of health workers and facilities is crucial in tackling TB. Recruitment of health workers in stages until it reaches a perfect balance based on population should be started, especially in priority areas with a high number of TB cases but with few health workers. Increasing skills and competencies through continuing health education and training in effective and efficient *surveillance* is also recommended. The TB case-finding program, which has been carried out passively (*passive case finding*), has been upgraded to an *active case-finding* and *active case monitoring program*. The involvement of community-based multi-stakeholder partnerships to participate in TB disease control needs to be considered. Procurement, development, development, and maintenance of health facilities in stages until an ideal ratio based on population is achieved can be a priority in the Regional Medium Term Development Plan (RPJMD), so that *screening* services and diagnostic tests for TB disease can be improved. The complexity of the determinants of TB described in this study requires multi-stakeholder coordination, strong political will, and significant budget support to produce comprehensive and sustainable TB control scenarios. Scenario intervention in tackling determinants is critical to meet the national TB incidence elimination target of 65 incidents per 100,000 population in 2030.

CONCLUSION

Defining determinant factors is very important in line with the increasing trend of TB incidence. The research findings show that demographic, socioeconomic conditions, physical environment, and the availability of health facilities and infrastructure are determinants that influence the incidence of TB. The incidence of TB increases with population, population density, number of health workers, and health facilities. At the same time, an increased risk of TB disease is known to occur in people of unproductive age, low education, low income, and the physical environment of the house (ventilation area, lighting, humidity, floor type, wall type, occupancy density) that does not meet health requirements. The recommended policy responses suggest that it is necessary to distribute the population evenly through planned local transmigration. The efficiency and effectiveness of TB control programs should be more directed at improving preventive and promotive health education, especially in the vulnerable age groups. Improving the quality of service and the availability of free TB drugs will increase the success of TB treatment, especially for the economically-vulnerable population. Building public awareness through campaigns and health promotion regarding the prevention of TB disease transmission based on the physical environment's characteristics should be carried out on an ongoing basis. Fulfilling the number of health workers and health facilities gradually to reach the ideal ratio in priority areas will improve *surveillance*, *screening*, diagnostics, and successful treatment of TB disease, so that the target of eliminating national TB incidence, namely 65 incidents per 100,000 population in 2030, can be achieved.

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