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THE INSURANCE PLAN DEPENDS ON THE COMPARTMENT MODEL TO THE RISK FACTORS FOR THE COST OF HEALTH CARE FOR INFECTIOUS DISEASES

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Abstract: Infectious diseases that occur in various countries, in addition to having a critical impact on the health sector and financial losses to the community, can also have an impact on health insurance companies because of extra claims. Insurance plays a role in preventing and transferring the risk of infectious diseases and seeks to model infectious diseases. The compartment model is a mathematical model most commonly used to describe susceptibility and infection in infectious diseases. In this systematic review of the literature, we provide an overview of the developmental capabilities of the compartmental model for insurance coverage. To report on the development of the compartmental model applied in planning insurance frameworks to provide health care benefits, we review the literature highlighting various compartmental models in infectious disease epidemics. The method used is to identify relevant publications using Dimensions, Science Direct, and Google scholar, with a focus on compartmental models of infectious disease dynamics. From the three databases, 45 articles were found in the initial search after removing duplicates. From 45 articles, reviewed in full text, finally resulted in 14 studies discussing the compartment model. We found that most of the reviewed journals used the SIR compartment model in planning the health care benefits insurance framework.

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1. INTRODUCTION

Various infectious disease outbreaks have critically impacted the health sector and financial losses to society. For decades, scientists have worked hard to understand the transmission characteristics of the disease so as to design control strategies to prevent the further spread of infection. The field of science that studies these epidemic diseases and, in particular, the factors that influence the incidence, distribution, and control of infectious diseases in human populations is called epidemiology. The dynamics associated with the spread of infectious diseases, for example, predicting the number of cases in a given time period and the probability that the disease will attack can be understood through mathematical models [1]. Epidemiological mathematicians and statisticians have made many contributions to the mathematical modeling of infectious diseases. This is because mathematical modeling has proven useful in analyzing, predicting, evaluating pandemic risk, detecting, and implementing efficient control programs [2]. In some works of literature, epidemic models have been able to express disease dynamics in different population structures, such as the compartment model in which a population is divided into several compartments by providing relatively simple assumptions on the rate of flow between different classes of population members through a system of differential equations [3,37]. The compartment model was first proposed by Kermack and McKendrick in 1927, namely the susceptible compartment model for infection and recovery (SIR). After how many decades, the SIR model was popularized by Anderson et al. in 1979. Then the compartment model was expanded in [4], discussing a time-delayed non-autonomous SIRS epidemic model. The SIR model and the SIS and SEIR compartmental models can be found in the classic monographs of [5] and [6]. Pongsumpun [7] described the transmission of respiratory diseases with the SIRI model, in which the population consisted of three compartments, assuming that recovered patients could become re-infected. Simon and Lefèvre [8] account for randomness in epidemiological dynamics with the formulation of the Markov chain through the expansion of the SIR deterministic compartment model.

The compartment model has its own advantages, among others, it does not require special knowledge for analysis and numerical methods for its calculations [9]. The infectious disease epidemiological compartment model has been widely used to evaluate public health policies, disease interventions, and is an element of public health decision-making to examine key risks from epidemics [10,38]. Apart from that, the infectious disease compartment model has also started to become part of decision-making in actuarial science. The insurance model is a process to develop a form of contract between two parties, namely insuring and the insured, in which the insurer exchanges a fixed premium to pay the insured fixed or variable benefits on the basis of financial losses due to the occurrence of a specified event. People facing financial loss due to some particular event want to establish a market that can contribute premiums to insurance funds to obtain compensation in the future. Some of the questions faced by the actuarial profession relate to the possibility of an epidemic occurring. This question, in addition to the number of individuals who will be infected as well as how many will need treatment at any given time. So the actuarial profession is very reasonable to add economic considerations based on compartmental models to design insurance coverage in order to provide financial means to protect the public from the adverse economic impact of the epidemic. For example, for the SIR compartment model, different identifications can be made from an insurance point of view, with the three compartments playing significantly different roles in the insurance model. Members in the susceptible compartment face the risk of being infected by a market that can contribute premiums to insurance funds in exchange for coverage for direct medical costs incurred if infected. During an epidemic outbreak, infected policyholders will benefit from claim payments provided by the insurance fund. The idea of developing an insurance model is to determine how much we need to allocate today (today) to cover future financial losses.

In the infectious disease model, policyholders are committed to paying premiums continuously as long as they are still vulnerable and medical expenses are continuously reimbursed for each infected policyholder. During the treatment period, some literature on compartmental models in various actuarial applications, Feng and Garrido [11] formulated financial arrangements between insurance companies and the insured with the SIR compartment model and applied it to the SARS epidemic occurred in 2003 in Hong Kong. Samaranayake et al. [12] present an actuarial model, namely determining the minimum premium level for infectious dengue fever in Sri Lanka based on the SIR model. The results showed that the infection rate was positively related to the premium level payment, while the recovery rate was negatively related to the premium level payment. Nkeki et al. [13] SIDRS compartment model applied to determine the present value of premiums paid by vulnerable groups and the present value of annuities and benefit payments to be received. Keeling and Rohani [14] different compartmental models have different trade-offs between complexity and accuracy, meaning that different compartmental models produce different insurance planning model results. A good model, of course, must be close to the actual conditions, in accordance with its objectives, and can be parameterized by the available data. To insurance that the susceptible populations are exposed to infectious diseases, obtain the present value of the premiums paid by vulnerable groups and the present value of the annuity and benefit payments received.

With this in mind, we review the development of the application of the infectious disease compartment model to actuarial concepts in the financial setting of the costs of medical care for infectious disease patients. We systematically reviewed the literature review by tracing articles published from 2015 to 2021 using Dimensions, Science Direct and Google Scholar, with a focus on compartmental models of infectious disease dynamics. From the three databases, 45 articles were found in the initial search after removing duplicates. From 45 articles, and reviewed in full text, finally resulted in 14 studies discussing the compartment model. In this review we highlight various communicable disease compartment models and perform a quantitative analysis of 14 articles modeling insurance coverage e.g. annuities, benefits, and reserve levels to compensate for the impact of an infectious disease epidemic.

2. MATERIALS AND METHODS

The material used to conduct this systematic literature review consists of two different materials. The first material is conceptual material in the form of theories, mathematical models, and other supporting concepts. While the second material is publication media that presents the conceptual study, such as conference papers, books, and scientific journals.

2.1. Materials

2.1.1. Compartment Model

The compartment structure, which was first introduced by Kermack and McKendrick [15] and is the basis of the dynamics model of infectious diseases, was later developed by several bio-mathematicians. The formulation of dynamic models for the transmission of infectious disease epidemics is divided into different compartments. A picture of the movement of the relationship between one compartment and another is called a compartment model [16]. The process of individual flow from one compartment to another is referred to as a compartment system. Pangestu et al. [17] the most common epidemic model is the SIR model where the population consists of three compartments, namely Vulnerable-Infection-Recovered, assuming that people who are susceptible to infectious diseases, can be infected through exposure to infectious people, and after a certain period of time recover. or die. Recovery is immunity to infection. This simplest version of the SIR model assumes homogeneous mixing and a fixed population size. Mahardika et al. [18] SEI1I2 HRD deterministic model, where the population size N consists of seven classes, namely susceptible (S), exposed but not infectious (E), infection class (I).

2.1.2. Insurance Plan

Insurance product planning goes through several important processes. There are several important coverages related to the planning process of an insurance product, namely determining the premium level, modeling premium reserves, and determining the number of claims protected based on these premiums. Planning insurance products, especially health insurance, is always related to the risk of disease that has the potential to make the insured sick. In addition, the health care financing factor of the sick insured also needs to be considered for determining the claims that will be covered in the insurance.

2.1.3. Infectious Diseases

Infectious diseases are diseases caused by bacteria, viruses, or parasites that can be transmitted through certain media. Infectious diseases are often also called infectious diseases because these diseases are suffered through viral, bacterial, or parasitic infections that are transmitted through various media such as air, syringes, blood transfusions, places to eat or drink, and so on. Infectious diseases are the result of a combination of various factors that influence each other. Non-communicable diseases are diseases that are not caused by germs but are due to physiological or metabolic problems in human body tissues. There are several types of infectious diseases, such as covid-19, dengue fever, malaria, seasonal flu, ARI, SARS, etc.

2.2. Methods

We identify studies that report on the compartmental model applied in planning an insurance framework that delivers health care benefits. To identify articles, the initial search searched the Dimensions, Science direct, and Google Scholar databases on October 16, 2021, namely scientific articles related to epidemiological models and actuarial applications published from 2015 to 2021. The review used a search strategy that would be tailored to each database by selecting the titles and abstracts consisting of the terms in Table 1 to mine the literature discussing the use of infectious disease models to determine insurance coverage.

Table 1. Database search term used for the literature review.

Search Number	Definition
(1)	Epidemiological Model
(2)	Epidemic Model
(3)	Mathematical Equation
(4)	Compartment
(5)	Deterministic Model
(6)	Diseases Model
(7)	Compartmental Model
(8)	Insurance
(9)	[1] OR [2] OR [3] OR [4] OR [5] OR [6] OR [7]
(10)	[9] AND [8]

The keywords in Table 1 were used to perform a study search on several databases. The search strategy based on the database used is divided into 3 types, namely: Dimensions, Science Direct, and Google Scholar.

2.2.1. Literature Result from Dimensions

Search using Dimensions with keywords: Search number (9) contained in Table 1 with the selection of "title and abstract" obtained as many as 246,470 publications. The search year limitation is articles published from 2015 to October 2021. 77,339 publications were obtained. Filtered through the original research articles by choosing the publication type, namely "article", there were 64,766 articles. Then the search was continued by adding the keyword AND “(8)”, obtaining 47 articles. The title and abstract records from the database were exported via bib tex. Of the 47 articles that can be accessed, as many as 40.

2.2.2. Literature Result from Science Direct

Searching using Science Direct with the same keywords as Dimensions by accessing "title and abstract" and the search limits from 2015 to 2021-2021 obtained 20,385 results by clicking "type article", and 13,841 articles were obtained. Then continued the search by adding the keyword "AND Insurance" and obtained 11 articles.

2.2.3. Literature Result from Google Scholar

The search stages using Google Scholar are in the title and abstract with the keywords [9] in table 1, and there is at least one word "(8)" in the title and abstract, and the search limits from 2015 to 2021 obtained 7 articles and which can be accessed as many as 4 articles. Overall search results from three databases were 55 articles. Duplicates were identified and deleted, Dimensions duplicates with Science Direct as many as 9. Dimensions and Google Scholar contained 1 article, while Science Direct with Google Scholar contained no duplicates, resulting in 10 duplicate articles. So the articles left for review are 45 articles.

2.2.4. PRISMA Selection

Articles that have been collected from searches in three databases are continued with article selection using the PRISMA flow. A detailed review is carried out on the article if the article meets the following criteria:

1. The article discusses the compartment model.
2. Articles that discuss the risk of health care costs.
3. Articles are written in English.

Based on the criteria for articles that are considered eligible for detailed review, only 14. The literature search process is presented in Figure 1.

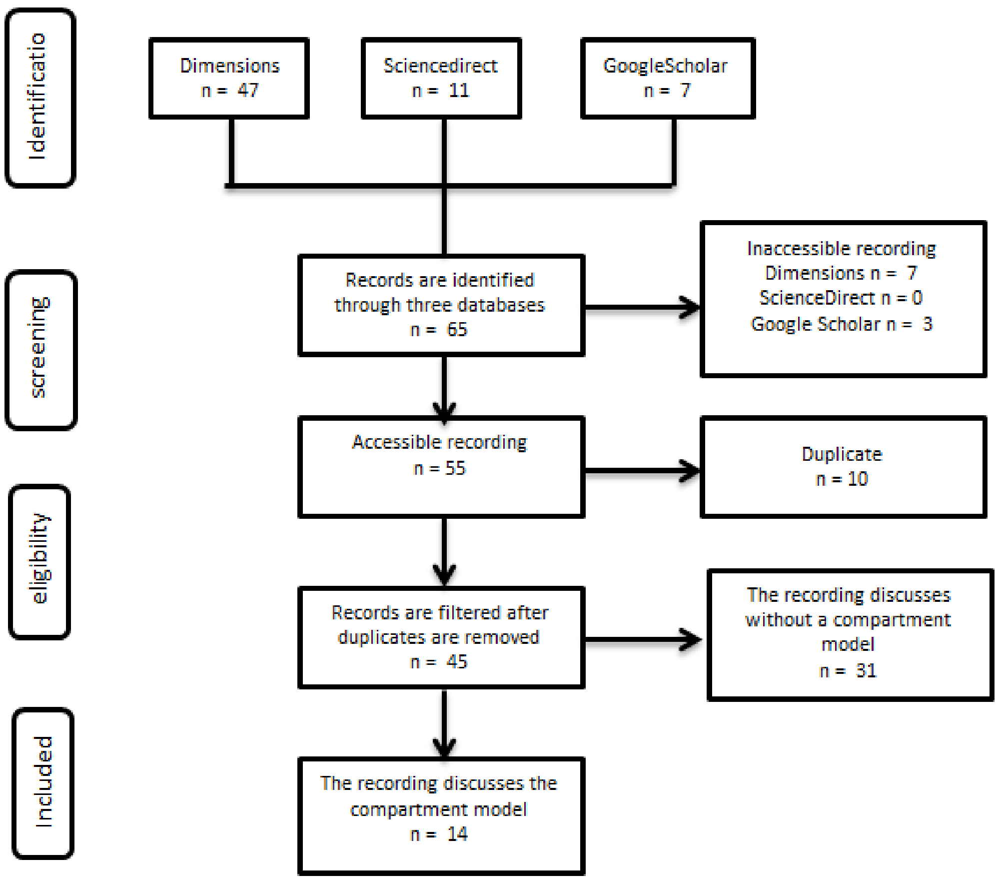

Figure 1. PRISMA Flow Chart of Article Selection

Based on Figure 1, it is found that the results of the PRISMA flow show 14 articles that are relevant to the main discussion topic. The selection process is based on the selection of articles that discuss the compartment model. The details of the literature generated from the PRISMA flow chart can be seen in Table 2.

Table 2. Results of article selection based on PRISMA

Ref.	Title (Year)	Model	Case Study	Method	Insurance Coverage the Exploratory	Results
[19]	An Insurance Based Model to Estimate the Direct Cost of General Epidemic Outbreaks (2017)	SIR	Dengue Fever	Numerical simulation, looking at the infected with the susceptible fraction as a probability density	Determine the expected value of future benefit payments and premium payments	The amount of premium as the average value of direct medical costs in the future
[20]	Analysis of Economic Burden of Seasonal Influenza: An Actuarial Based Conceptual Model (2017)	SIS	Seasonal Flu	Mathematical Analysis	Premiums (to cover units of future medical expenses)	Payment of premiums and claims for future medical care. depending on the degree of infection, and the rate of recovery
[21]	Epidemic Risk and Insurance Coverage (2017)	SIR	Dengue Fever	Recursive	To calculate the component of maintenance costs based on the premium level	Determination of premium based on the component of maintenance costs
[22]	Final out comes and disease insurance for a controlled epidemic model (2018)	SIR	Study Illustration	Study Illustration	Determine the expected value of the end state of the epidemic	The premium value is obtained from the state of the final population.
[23]	Fair Insurance Premium Level In Connected SIR Model Under Epidemic Outbreak (2019)	SIR	Dengue Fever	Premiums are calculated using the basic equality principle	Optimal insurance premium rates for population health care	Vaccination programs affect benefit savings

[24]	Insurance Model to Estimate the Financial Risk Due to Direct Medical Cost on Dengue Outbreaks. (2019)	SIR	Dengue Fever	Mathematical Analysis	Insurance plans to cover future financial burdens	The basic reproductive number is taken as a risk measurement index to reflect the risk of disease spread
[25]	Examining the Effects of Gradual Catastrophes on Capital Modelling and the Solvency of Insurers: The Case of COVID-19 (2020)	SIR	COVID-19	Markovian probabilistic approach, with Feynman path calculations and Dirac notation	Markovian probabilistic approach, with Feynman path calculations and Dirac notation	Consider the gradual long-term effects of catastrophic infectious diseases, by modifying the classical surplus model by applying a Markov chain with six states
[26]	Impact of inter-hospital transfers on the prevalence of resistant pathogens in a hospital–community system (2020)	SIVW	Study Illustration	Mathematical Analysis	To calculate the adjusted minimum premium rate for the inpatient plan	The premium rate for inpatient payments is determined based on the basic inter-hospital reproduction number
[27]	Fair Insurance Premium Rate In Connected Seir Model Under Epidemic Outbreak (2021	Deterministic and Stochastic SEIR with Migration Flux and	COVID-19	Mathematical Analysis	To determine the optimal level of insurance premiums for health care	Premiums depend on migration rate, disease severity and initial distribution of affected individuals

		Vaccination				
[28]	An Actuarial Approach for Modeling Pandemic Risk. (2021)	SIR	COVID-19	Mathematical Analysis	Determine the pure premium calculation	Obtaining reinsurance contract prices, such as excess of loss agreements
[29]	Labor market policies during an epidemic (2021)	SIRD	COVID-19	Mathematical Analysis	Insurance contract	The price of the insurance contract depends on the probability of infection
[30]	Modelling the impact of rapid diagnostic tests on Plasmodium vivax malaria in South Korea: a cost–benefit analysis (2021)	SEIT	Study Illustration	Differential Equation	Estimate the total medical costs through RDT microscopy scenario	Medical costs can be saved for 10 years after being given treatment
[31]	Propagation of cyber incidents in an insurance portfolio: counting processes combined with compartmental epidemiological models (2021)	SIR	Study Illustration	Gaussian Approximation Theory	Insurance portfolio	Insurance portfolio, depending on the intensity of the attack, infectious diseases against the policyholder
[32]	Ruin Problems for Epidemic Insurance (2021)	SIR	Study Illustration	Matrix-Analytic	The amount of premium received and the cost of care paid by the insurance	Reserve based on the probability of destruction

3. Results of Literature Review

The search stages generated in Figure 1 found 14 articles eligible for systematic review. We are interested in identifying Types of compartmental models and types of communicable diseases. Then, the insurance coverage was explored. Then, we identify many articles that use a particular compartment model. However, we do not critically evaluate each compartment model because the compartment model has many trade-offs and does not include a discussion of each article.

3.1. Literature Review Analysis based on Subtopics

The literature review analysis was carried out based on 3 subtopics of discussion, namely the type of compartment model, the type of infectious disease, and the insurance coverage being explored. Furthermore, the three subtopics were then analyzed further to see the distribution of the research. The results of the analysis can be used as an illustration of new opportunities for further research.

3.1.1. Compartmental Model Type

Literature analysis based on this subtopic was carried out by classifying articles using the compartment model. The compartment models used in these studies are SIR, SIS, SIVW, SEIR SIRD, and SEIT. Based on the analysis results, further classification of the literature based on the type of compartment model can be seen in Figure 2.

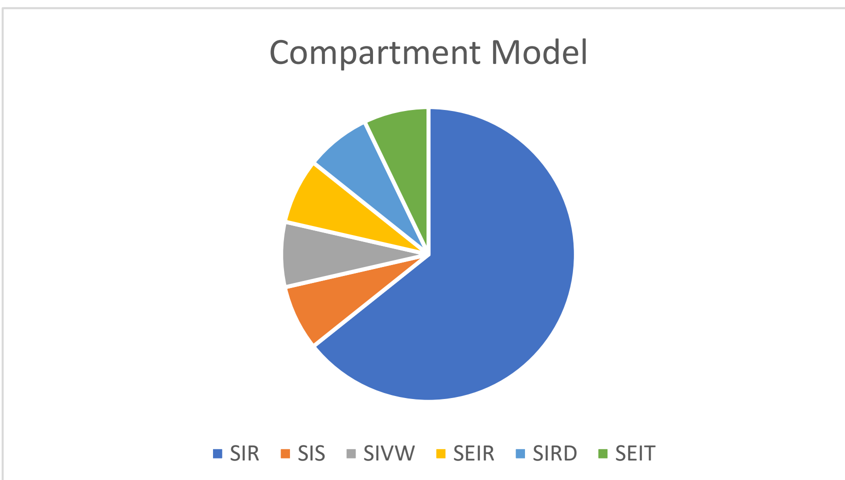

Figure 2. Venn Diagram of Literature based on Compartment Model

Based on Figure 2, the use of the SIR compartment model has the highest percentage of 64.28% or as many as nine articles [19, 21, 22, 23, 24, 25, 28, 31, 32], while those discussing the SIS compartment model, SIVW, SEIR, SIRD, and SEIT only have one article each. Therefore, the most common compartment model is the SIR. Research other than the SIR model can be said to be still rare.

In addition, when viewed based on the classification of compartment models, all models studied in the literature are homogeneous models. Therefore, there are new research opportunities in the exploration of non-homogeneous models. An example of the development of a non-homogeneous model is S1S2EIR. An illustration of the development of homogeneous to non-homogeneous models can be seen in Figure 3.

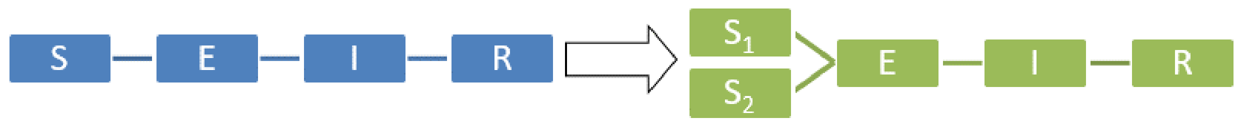

Figure 3. Compartment Development Model

Based on Figure 3, it can be formed to develop a homogeneous compartment model into a non-homogeneous one, namely S1S2EIR. Based on the results of the literature review obtained related to the topic of the compartment model used in insurance coverage, no one has examined the non-homogeneous model. Therefore, the development of the non-homogeneous model can be used as a reference for further research. The S1S2EIR compartment model has the advantage of providing a better description of the population. This is because the non-homogeneous form has population variations which are interpreted as population observations that are closer to reality.

3.1.2. Types of Infectious Diseases

Literature analysis based on infectious disease subtopics was carried out to classify articles based on the object of the studied disease. The infectious diseases used in these studies are Covid-19, Seasonal Flu, Malaria, and Dengue Fever, and some use simulation studies. Based on the analysis results, further classification of literature based on the type of infectious disease can be seen in Figure 4.

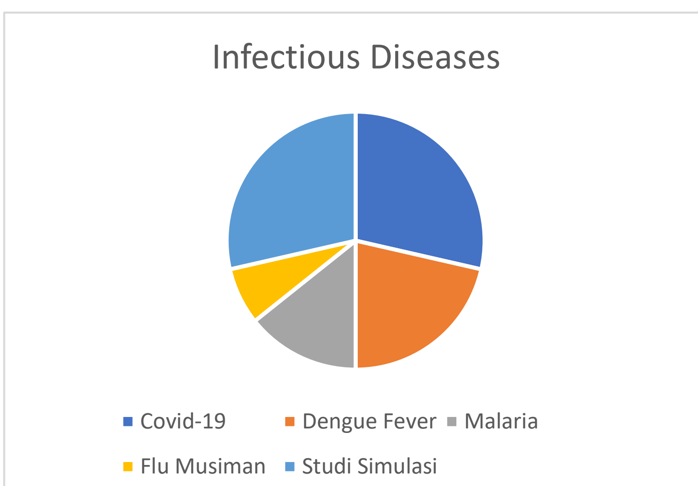

Figure 4. Venn Diagram of Literature based on Infectious Disease

Based on Figure 4, using research case studies on infectious diseases, and Covid-19 became the topic, namely 4 articles [25, 27, 128, 29]. In addition, studies that discuss cases of dengue fever, malaria, and seasonal flu each consist of 3 articles, 2 articles, and 1 article. Research other than cases of the disease can be said to be still rare. One of the cases that have not been discussed is ARI. ARI is a disease that attacks the lungs and is associated with shortness of breath. This ARI can be an interesting topic of discussion because it is known that many areas can be affected by this disease due to air pollution.

3.1.3. Exploration of Insurance Plan

Literature analysis based on insurance plan subtopics was conducted to classify articles based on the object of exploration of the insurance coverage under study. The insurance coverage used in these studies is the level of premiums, insurance products, premium reserves, medical expense claims, and insurance portfolios. Based on the results of the analysis, further classification of literature based on insurance coverage can be seen in Figure 5.

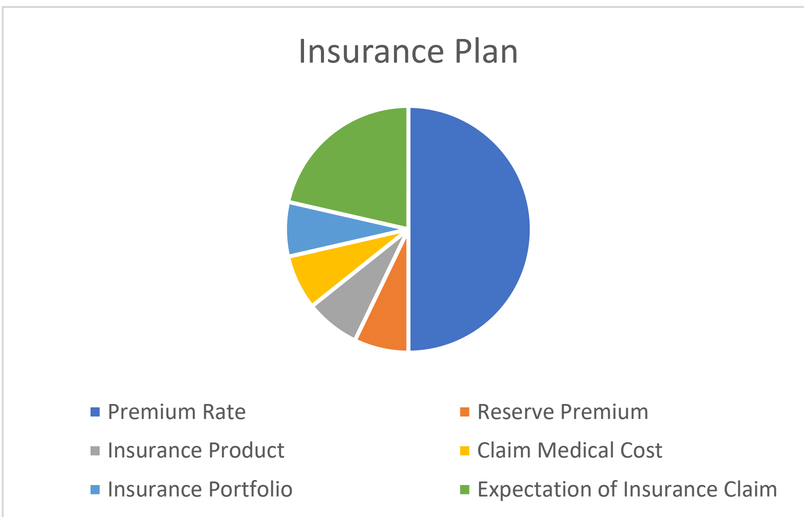

Figure 5. Venn Diagram of Literature based on Infectious Diseases

Based on Figure 5, the use of research topics on premium level insurance coverage is the topic, namely 7 articles. In addition, 2 articles discuss the expected value of claims in the future. While research related to insurance products, medical expense claims, portfolio insurance, and premium reserves each consists of 1 article. This rare topic can be used as a reference for new research on insurance coverage in infectious diseases and their compartmental models.

3.2. Literature Overviews

Feng and Garrido [11] calculated infection risk using the classical epidemiological compartment model and formulated financial arrangements between insurance companies and the insured, namely annuity, benefit, and reserve rate, using actuarial methodologies and applied their framework to the COVID-19 epidemic. Lefèvre et al. [21] apply a simple actuarial method to build insurance plans that protect against epidemic risk in a population. The model discussed is the extended SIR epidemic model in which the removal and infection rates depend on the number of removals registered. Then the cost of the epidemic is measured through estimates of the size of the epidemic and the time of infection.

Premiums received during an outbreak are measured by the average time of susceptibility. The recursion method is used to calculate the cost component and the appropriate premium level in the epidemic model. In their paper, they design insurance policies for vulnerable participants who face the risk of infection and formulate the financial obligations of the parties using actuarial techniques. Focuses on formulating epidemiological models for insuring susceptibility to infectious diseases and provides techniques for computing the present value of premiums paid by vulnerable groups, the present value of annuities and lump sum benefit payments received by infective deceased, as well as benefit reserves for insurance companies. A stochastic model containing standard Brownian motion was studied by Caraballo and Colucci [33].

Caraball and Keraani [34] explore the features of a stochastic SIR model with fractional Brownian motion. Lefèvre et al. [21] developed a recursive method to calculate cost components and premium rates according to the stochastic SIR insurance model and provided results on integral functions using the martingale argument.

Chernov et al. [27] proposed two different exponential models for infection rates before and after lockdown. The deterministic or stochastic SEIR compartment model with migration and vaccination fluxes is also a tool to measure the benefits gained through various reaction strategies and/or prevention, risk reduction of infection.

Lefèvre et al. [21] resolve financial risk with probability in the stochastic SIR insurance model. Lefèvre and Picard [22] generalize the SIR model to a controlled epidemic model, in which infections will be isolated by health organizations to alleviate disease severity and study the representation of epidemic outcomes and path integrals in terms of pseudo polynomials. Lefèvre and Simon [22] consider cross-infection between two populations to be related. This general approach to studying the Laplace transform of integral functions was developed by Lefèvre and Picard [22]. Lefèvre dan Simon [21] mengusulkan proses Markov terstruktur blok umum untuk pemodelan epidemi. Perera [19] considers control strategies in a simple SIR model and premium variations with respect to model parameters. Nkeki and Ekhaguere [13] built and studied the SIDRS model's insurance applications. Billard and Dayananda [35]developed a multi-stage

HIV/AIDS model considering non-disease deaths in each compartment, where the distribution of waiting times is used to measure the total amount of time an individual has in a country. Not only are the premiums determined by the different insurance functions, but the adjustment of health care costs is also included. Shemendyuk et al. [23] investigate a deterministic and stochastic SIR model with multiple centers and migration fluxes. The optimal health care premium is determined by considering different vaccine allocation strategies. Optimal resource allocation and contingency planning are also discussed by [36].

3.3. Visualization of Related Research Topics from Literature

Literature review analysis can be done by visualizing the topic mapping. Topic mapping is done by looking for keywords often appearing in related articles. This topic mapping was done using VOSviewer. The settings used regarding the minimum number of occurrences of words in the document are two times. In this case, the result of the VOSviewer mapping gives 32 words that cross the threshold. Words that appear at least twice in each document are divided into 3 clusters. The results showed that the most frequently occurring words were “model”, followed by “insurance”, “spread”, and “risk”. The visualization of the topic keyword mapping is shown in Figure 6.

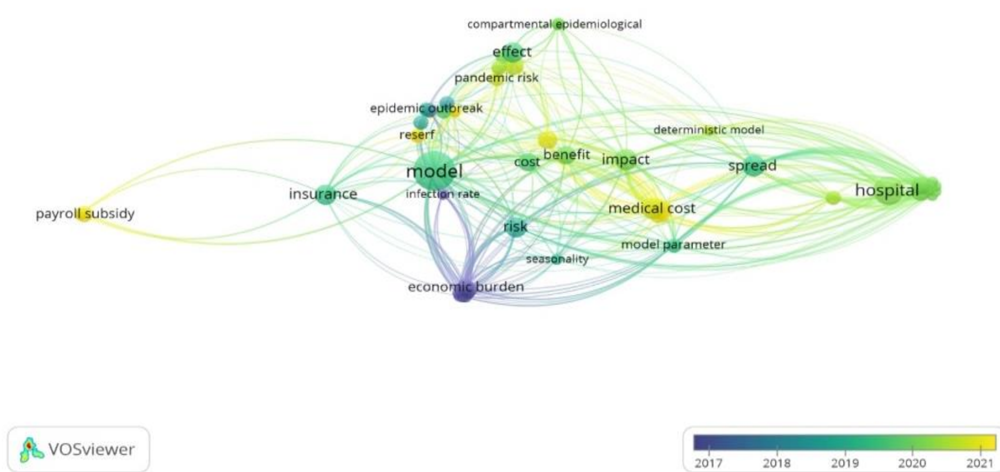

Figure 6. Network Visualization of Related Topics based on Keywords

3.3.1. Visualization of “Insurance” Topic Mapping as Main Node

Furthermore, topic mapping analysis can be carried out based on keywords that are used as the main node. This topic mapping is done by selecting “insurance” as the main node of the mapping network. The keyword “insurance” was chosen to explain the relevance of insurance coverage to other topics. Visualization of mapping the topic “insurance” as the main node, can be seen in Figure 7.

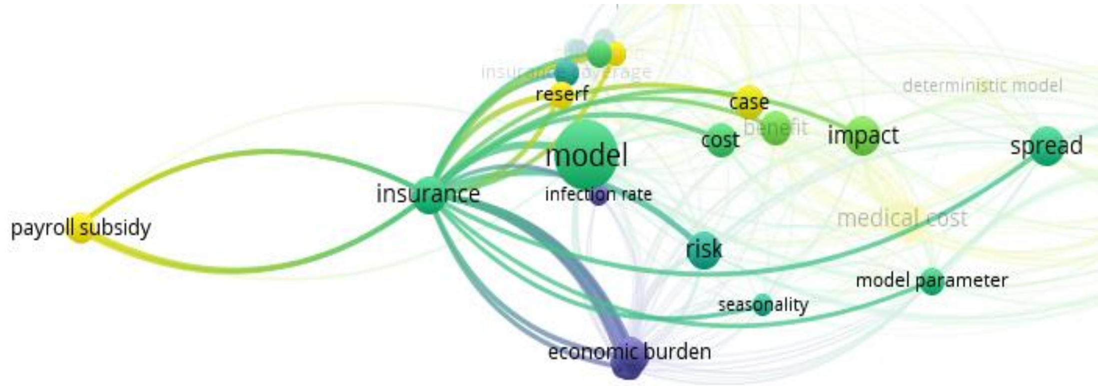

Figure 7. Network Visualization of Insurance as Main Node

Based on Figure 7, we get a form of topic mapping based on the keyword "insurance" as the main node, connected to several other keywords. The keywords that are directly related are risk, payroll subsidies, spread, economic burden, model, infection rate, cost, parameter model, case, impact, and spread. Based on this, it can be said that the opportunity for renewable topics related to insurance coverage is to relate the topic to the risk factors of health care financing. The health care cost factor can be used as an indicator to determine the size of the claim, as well as the premium reserve to cover the claim. Therefore, the topic of insurance research that uses the health care cost factor has not been carried out.

3.3.2. Visualization of “Disease Spread” Topic Mapping as Main Node

Furthermore, the topic mapping analysis is carried out based on other keywords that are used as the main node. This topic mapping is done by selecting “disease spread” as the main node of the mapping network. The keyword “disease spread” was chosen to explain the relevance of the topic of disease transmission to other topics. The visualization of mapping the “disease spread” topic as the main node can be seen in Figure 8.

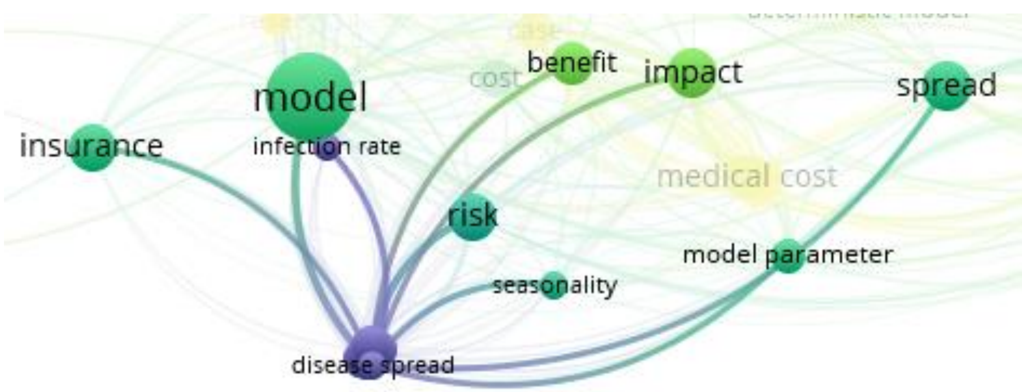

Figure 8. Network Visualization of Disease Spread as Main Node

Based on Figure 8, we get a topic mapping form based on the keyword "disease spread" as the main node, connected to several other keywords. The keywords that are directly related are insurance, model, infection rate, risk, benefit, impact, seasonality, risk, parameter model, and spread. Based on this, it can be said that the opportunity for the topic of novelty related to disease transmission is to relate the topic to the risk factors of health care financing. In addition, it can also be linked to other insurance coverage such as premium reserves or claims based on the risk of transmission of the disease.

3.3.3. Visualization of "Insurance Coverage" Topic Mapping as Main Node

Furthermore, the topic mapping analysis is carried out based on other keywords that are used as the main node. This topic mapping is done by selecting "insurance coverage" as the main node of the mapping network. The keyword "insurance coverage" was chosen to explain the relevance of the topic of the scope of insurance covered to other topics. Visualization of mapping the topic "insurance coverage" as the main node, can be seen in Figure 9.

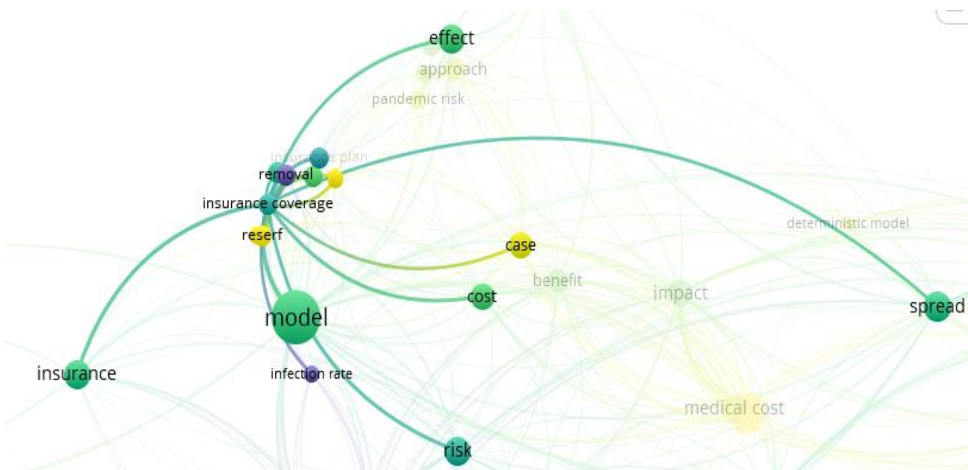

Figure 9. Network Visualization of Insurance Coverage as Main Node

Based on Figure 8, a topic mapping form is obtained based on the keyword "insurance coverage" as the main node, connected to several other keywords. The keywords that are directly related are infection rate, risk, spread, model, cost, case, impact, insurance, effect, removal, and insurance. Based on this, it can be said that the opportunity for renewable topics related to insurance coverage is to relate the topic to the risk of infectious diseases and the model of the spread of disease to create a model for the insurance product. The risk modeling factors for the spread of infectious diseases can be used as indicators for determining the size of claims, as well as premium reserves to cover these risk claims.

4. DISCUSSION

This study highlights the interaction between actuarial science and epidemiology and provides a literature review of the most recent results. The combination of modeling techniques from the two fields could revolutionize how we measure and model epidemic insurance. We hope to present a new source of inspiration for actuaries working in the dynamically evolving risk modeling and population assessment fields. We envision actuaries adding these epidemiological models and techniques to their growing risk modeling and analysis toolset.

From the results of this review, the compartmental model used in calculating the overall insurance coverage of the SIR model means that the population is homogeneous based on susceptibility, whereas, in reality, the level of susceptibility varies according to factors such as age or susceptibility to infection.

5. CONCLUSIONS

This study has reviewed the literature on compartmental models, infectious diseases, and their relation to insurance coverage. Furthermore, we have presented the results of a review of the compartment model that has been carried out by other researchers, namely SIS, SIVW, SEIR, SIRD, and SEIT. Based on the compartment model, no one has discussed a model with a non-homogeneous form, so the development of a non-homogeneous compartment model is an opportunity for new research. Non-homogeneous compartmental models, such as S1S2EIR, linked to coverage and insurance modeling, have not yet been implemented. In addition, regarding the types of infectious diseases, we found several cases that were discussed, namely covid-19, dengue fever, malaria, and seasonal flu, so that other cases could become research novelties. We provide advice regarding the discussion of ARI disease as the object of disease risk, which is a factor in the formation of the insurance model. In addition, insurance coverage that has been carried out in the related literature mostly discusses the level of premiums, while premium reserves are still rare. So that the combination of the discussion of premium reserves based on the non-homogeneous compartment model S1S2EIR which represents the spread of ARI disease, can be said as the latest research opportunity because no one has done it yet.

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CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

REFERENCES

[1] P. Bhattacharya, S. Paul, K.S. Choudhury, Different types of epidemic models and their characteristic behaviour by using Matlab, J. Interdiscip. Math. 18 (2015), 569–592. https://doi.org/10.1080/09720502.2014.914280.

[2] M. Pompella, N.A. Scordis, eds., The Palgrave handbook of unconventional risk transfer, Springer, Cham, 2017. https://doi.org/10.1007/978-3-319-59297-8.

[3] F. Brauer, Mathematical epidemiology: Past, present, and future, Infect. Dis. Model. 2 (2017), 113–127. https://doi.org/10.1016/j.idm.2017.02.001.

[4] L. Zhang, Z.-C. Wang, X.-Q. Zhao, Threshold dynamics of a time periodic reaction–diffusion epidemic model with latent period, J. Differ. Equ. 258 (2015), 3011–3036. https://doi.org/10.1016/j.jde.2014.12.032.

[5] F. Brauer, C. Castillo-Chavez, Mathematical models in population biology and epidemiology, Springer New York, 2012. https://doi.org/10.1007/978-1-4614-1686-9.

[6] O. Diekmann, H. Heesterbeek, T. Britton, Mathematical tools for understanding infectious diseases dynamics, Princeton University Press, Princeton, 2013.

[7] P. Pongsumpun, Simple model for respiratory diseases, Int. J. Biosci. Biochem. Bioinform. 7 (2017), 118–124. https://doi.org/10.17706/ijbbb.2017.7.2.118-124.

[8] C. Lefèvre, M. Simon, SIR-type epidemic models as block-structured Markov processes, Methodol. Comput. Appl. Probab. 22 (2019), 433–453. https://doi.org/10.1007/s11009-019-09710-y.

[9] M. Roberts, V. Andreasen, A. Lloyd, et al. Nine challenges for deterministic epidemic models, Epidemics. 10 (2015), 49–53. https://doi.org/10.1016/j.epidem.2014.09.006.

[10] S. Greenhalgh, C.V. Hobbs, S. Parikh, Brief report: Antimalarial benefit of HIV antiretroviral therapy in areas of low to moderate malaria transmission intensity, J. Acquir. Immune Defic. Syndr. 79 (2018), 249–254. https://doi.org/10.1097/qai.0000000000001783.

[11] R. Feng, J. Garrido, Actuarial applications of epidemiological models, North Amer. Actuarial J. 15 (2011), 112–136. https://doi.org/10.1080/10920277.2011.10597612.

[12] D.I.J. Samaranayake, D.L.M. Samaranayake, Insurance contract for epidemiological diseases spread, Sri Lanka J. Econ. Res. 5 (2018), 103-124. https://doi.org/10.4038/sljer.v5i2.51.

[13] C.I. Nkeki, G.O.S. Ekhaguere, Some actuarial mathematical models for insuring the susceptibles of a communicable disease, Int. J. Financial Eng. 07 (2020), 2050014. https://doi.org/10.1142/s2424786320500140.

[14] M.J. Keeling, P. Rohani, B. Pourbohloul, Modeling infectious diseases in humans and animals: modeling infectious diseases in humans and animals, Clin. Infect. Dis. 47 (2008), 864-865. https://doi.org/10.1086/591197.

[15] W.O. Kermack, A.G. McKendrick, A contribution to the mathematical theory of epidemics, Proc. R. Soc. Lond. A. 115 (1927), 700-721. https://doi.org/10.1098/rspa.1927.0118.

[16] J. Zhang, J. Lou, Z. Ma, et al. A compartmental model for the analysis of SARS transmission patterns and outbreak control measures in China, Appl. Math. Comput. 162 (2005), 909–924. https://doi.org/10.1016/j.amc.2003.12.131.

[17] D.S. Pangestu, S.T. Tresna, F. Inayaturohmat, et al. COVID-19 transmission model with discrete time approach, Commun. Math. Biol. Neurosci. 2022 (2022), 93. https://doi.org/10.28919/cmbn/7622.

[18] R. Mahardika, Widowati, Y. Sumanto, Routh-hurwitz criterion and bifurcation method for stability analysis of tuberculosis transmission model, J. Phys.: Conf. Ser. 1217 (2019), 012056. https://doi.org/10.1088/1742-6596/1217/1/012056.

[19] S.S.N. Perera, An insurance based model to estimate the direct cost of general epidemic outbreaks, Int. J. Pure Appl. Math. 117 (2017), 183-189.

[20] S.S.N. Perera, Analysis of economic burden of seasonal influenza: an actuarial based conceptual model, J. Appl. Math. 2017 (2017), 4264737. https://doi.org/10.1155/2017/4264737.

[21] C. Lefèvre, P. Picard, M. Simon, Epidemic risk and insurance coverage, J. Appl. Probab. 54 (2017), 286-303. https://doi.org/10.1017/jpr.2016.100.

[22] C. Lefèvre, P. Picard, Final outcomes and disease insurance for a controlled epidemic model, Appl. Stoch. Models Bus. Ind. 34 (2018), 803–815. https://doi.org/10.1002/asmb.2341.

[23] A.A. Shemendyuk, A.A. Chernov, M.Y. Kelbert, Fair insurance premium level in connected SIR model under epidemic outbreak, arXiv:1910.04839, (2019). https://doi.org/10.48550/ARXIV.1910.04839.

[24] S.S.N. Perera, Insurance model to estimate the financial risk due to direct medical cost on dengue outbreaks, in: F.T. Smith, H. Dutta, J.N. Mordeson (Eds.), Mathematics applied to engineering, modelling, and social issues, Springer, Cham, 2019: pp. 629–663. https://doi.org/10.1007/978-3-030-12232-4_20.

[25] M. Tamturk, D. Cortis, M. Farrell, Examining the effects of gradual catastrophes on capital modelling and the solvency of insurers: The case of COVID-19, Risks. 8 (2020), 132. https://doi.org/10.3390/risks8040132.

[26] M.J. Piotrowska, K. Sakowski, A. Lonc, et al. Impact of inter-hospital transfers on the prevalence of resistant pathogens in a hospital–community system, Epidemics. 33 (2020), 100408. https://doi.org/10.1016/j.epidem.2020.100408.

[27] A.A. Chernov, A.A. Shemendyuk, et al. Fair insurance premium rate in connected SEIR model under epidemic outbreak, Math. Model. Nat. Phenom. 16 (2021), 34. https://doi.org/10.1051/mmnp/2021028.

[28] D. Hainaut, An actuarial approach for modeling pandemic risk, Risks. 9 (2020) 3. https://doi.org/10.3390/risks9010003.

[29] S. Birinci, F. Karahan, Y. Mercan, et al. Labor market policies during an epidemic, J. Public Econ. 194 (2021),

104348. https://doi.org/10.1016/j.jpubeco.2020.104348.

[30] J.H. Kim, J. Suh, W.J. Lee, et al. Modelling the impact of rapid diagnostic tests on Plasmodium vivax malaria in South Korea: a cost–benefit analysis, BMJ Glob. Health. 6 (2021), e004292. https://doi.org/10.1136/bmjgh-2020-004292.

[31] C. Hillairet, O. Lopez, Propagation of cyber incidents in an insurance portfolio: counting processes combined with compartmental epidemiological models, Scandinavian Actuarial J. 2021 (2021), 671–694. https://doi.org/10.1080/03461238.2021.1872694.

[32] C. Lefèvre, M. Simon, Ruin problems for epidemic insurance, Adv. Appl. Probab. 53 (2021), 484-509. https://doi.org/10.1017/apr.2020.66.

[33] T. Caraballo, S. Keraani, Analysis of a stochastic SIR model with fractional Brownian motion, Stoch. Anal. Appl. 36 (2018), 895–908. https://doi.org/10.1080/07362994.2018.1490912.

[34] T. Caraballo, R. Colucci, X. Han, Predation with indirect effects in fluctuating environments, Nonlinear Dyn. 84 (2015), 115–126. https://doi.org/10.1007/s11071-015-2238-3.

[35] L. Billard, P.W.A. Dayananda, A multi-stage compartmental model for HIV-infected individuals: I – Waiting time approach, Math. Biosci. 249 (2014), 92–101. https://doi.org/10.1016/j.mbs.2013.08.011.

[36] X. Chen, W.F. Chong, R. Feng, et al. Pandemic risk management: Resources contingency planning and allocation, Insurance: Math. Econ. 101 (2021), 359–383. https://doi.org/10.1016/j.insmatheco.2021.08.001.

[37] N. Anggriani, M.Z. Ndii, R. Amelia, et al. A mathematical COVID-19 model considering asymptomatic and symptomatic classes with waning immunity, Alexandria Eng. J. 61 (2022), 113–124. https://doi.org/10.1016/j.aej.2021.04.104.

[38] S.T. Tresna, N. Anggriani, A.K. Supriatna, Mathematical model of HCV transmission with treatment and educational effort, Commun. Math. Biol. Neurosci. 2022 (2022), 46. https://doi.org/10.28919/cmbn/7319.