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Dynamic Model of Urban Public Cemeteries Development Strategy: Case Study of Manado City, Indonesia

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Abstract: The development of a policy strategy for public cemeteries through System Dynamics (SD) modeling is crucial in addressing the pressing issue of limited urban land. This research aims to formulate long-term solutions for the future cemeteries needs. Data was collected through field observations, surveys, and focus group discussions. The analysis employed a system dynamics approach, formulating two different scenarios. Two policy scenarios were developed to evaluate cemetery land sustainability. Scenario 1 represents a baseline condition with existing burial practices and no additional policy intervention. Scenario 2 incorporates integrated interventions, including land expansion, vertical burial implementation, and mortality reduction through public health improvements. The results confirm that SD provides a robust framework for conceptualizing cemetery provision as a dynamic urban policy issue rather than a static spatial allocation. Scenario Two emerges as the optimal strategy up to 2045, reducing annual deaths by 313 individuals (from 5,275 to 4,961), lowering the Crude Death Rate from a high to a moderate category, and significantly easing pressure on cemetery land. This scenario decreases the required cemetery land from 42.99 hectares to approximately 11.86 hectares and increases land carrying capacity by 16.62 hectares relative to the projected deficit. These findings demonstrate that health-oriented policies can function as indirect spatial planning instruments, extending conventional approaches to urban land management under conditions of scarcity.

Keywords: Policy Strategies, Scenario, System Dynamics, Urban Public Cemeteries

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Introduction

The rapid expansion of Asian cities and rising living standards have intensified competition for urban land, placing cemeteries under growing pressure and rendering them vulnerable within contemporary development agendas. Although death and burial practices are integral to Asian urban culture, cemeteries are frequently framed as unwanted or unprotected heritage, resulting in excavation, relocation, or complete removal to accommodate infrastructure and real estate development (Dlábiková et al., 2017; Ocón & Young, 2024). In Indonesia, this pressure has manifested acutely as widespread shortages of cemetery land, a condition exacerbated by the COVID-19 pandemic, which significantly increased urban mortality rates and demand for burial space. These shortages are further complicated by social resistance to interring bodies from outside local communities and by the limited provision of public cemeteries, despite their recognized role as urban green spaces (Ellise et al., 2022; Fahrul et al., 2021; Merdekawati, 2024; Pujiono et al., 2021). Cemetery land distribution remains poorly documented, and available public burial space is disproportionate to average mortality rates, reflecting inefficient land use and weak management practices (Amoah et al., 2024). While these conditions have been widely acknowledged, most discussions remain descriptive, emphasizing spatial scarcity or normative planning failures without offering operational tools to anticipate future demand or guide policy interventions in land-limited urban contexts.

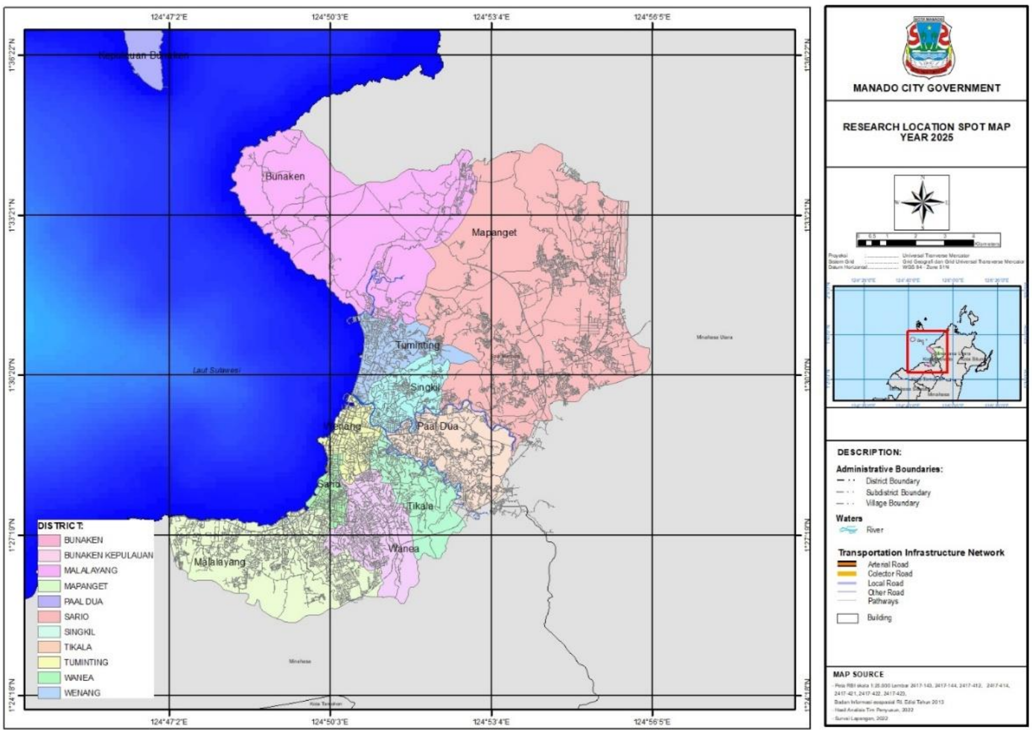
Existing scholarship on urban cemeteries has largely focused on spatial suitability, environmental impacts, typological characteristics, or normative planning frameworks. GIS-based multi-criteria analyses have been used to assess cemetery suitability from legal, technical, socio-economic, and ecological perspectives (Pujiono et al., 2021), while environmental law studies have examined pollution risks and conservation status (Fernandes, 2021). Other works frame cemeteries as multifunctional public spaces, highlighting their cultural, social, and ecological potential (Grabalov & Nordh, 2022; Maddrell et al., 2023). Innovative design-oriented studies have proposed garden cemeteries, smart cemeteries, urn cemeteries, and vertical cemeteries as spatially efficient alternatives (Agostini & Pereira, 2024; Iezzi et al., 2024; Klingemann, 2024; Santos, 2023). However, these studies predominantly assess spatial form, environmental performance, or conceptual design, rather than quantitatively modeling how such approaches respond to long-term population growth, mortality trends, and land constraints. Similarly, policy-oriented analyses often reveal that cemeteries are treated merely as disposal sites, excluded from strategic urban public space planning, and rarely integrated into forward-looking land-use policies (Giguere, 2018; Grabalov, 2022; Silva-Bessa et al., 2022). Consequently, the literature remains fragmented, offering valuable insights yet lacking a measurable, dynamic framework to support decision-making for future cemetery provision.

In Manado City, historical mortality data from 2015 to 2023 shows that the average annual demand for burials exceeds existing burial capacity, resulting in a cumulative shortage that will intensify after 2035. Furthermore, the provision of public burials increasingly competes with residential, infrastructure, and commercial land uses. Based on population growth and mortality trends, the projected cemetery land deficit will reach 46.37 hectares by 2045 if no interventions are implemented. This study addresses that gap by shifting the analytical focus from static spatial or normative assessments toward a dynamic, policy-oriented modeling approach. Unlike previous studies that describe cemetery distribution patterns (He, 2024) or propose innovative but conceptually bounded design models (Agostini & Pereira, 2024; Santos, 2023), this research explicitly seeks to quantify future cemetery land demand and evaluate management strategies under conditions of limited urban land. The novelty of this study lies in its application of a SD model to formulate an implementable policy strategy for public cemetery development. This study frames public cemetery provision as a dynamic urban system influenced by demographic change, health conditions, and land-use policy interactions. The main problems addressed include land scarcity, unmanaged mortality impacts, and fragmented cemetery planning policies. By integrating population growth, mortality rates, land availability, and management scenarios, the SD approach enables simulation of long-term outcomes and identification of intervention leverage points. This moves beyond descriptive mapping or normative critique toward a measurable, anticipatory framework capable of informing urban policy. In doing so, the study contributes a distinct methodological advancement to the literature on urban cemeteries, positioning public burial grounds not only as cultural or spatial entities, but as dynamically managed urban systems essential to sustainable city planning under land scarcity.

Research Method

Area of Study

The study was conducted in the city of Manado, the capital of North Sulawesi Province, Indonesia. Geographically located at 124°40' - 124°50' East Longitude and 1°30' - 1°40' North Latitude, Manado is situated at the northern tip of the Sulawesi Island. As of 2023, the city comprises 11 districts and 87 sub-districts with a population of 454,606. The location map is presented in Figure 1 below.



Source: Geospastial data Manado, 2024

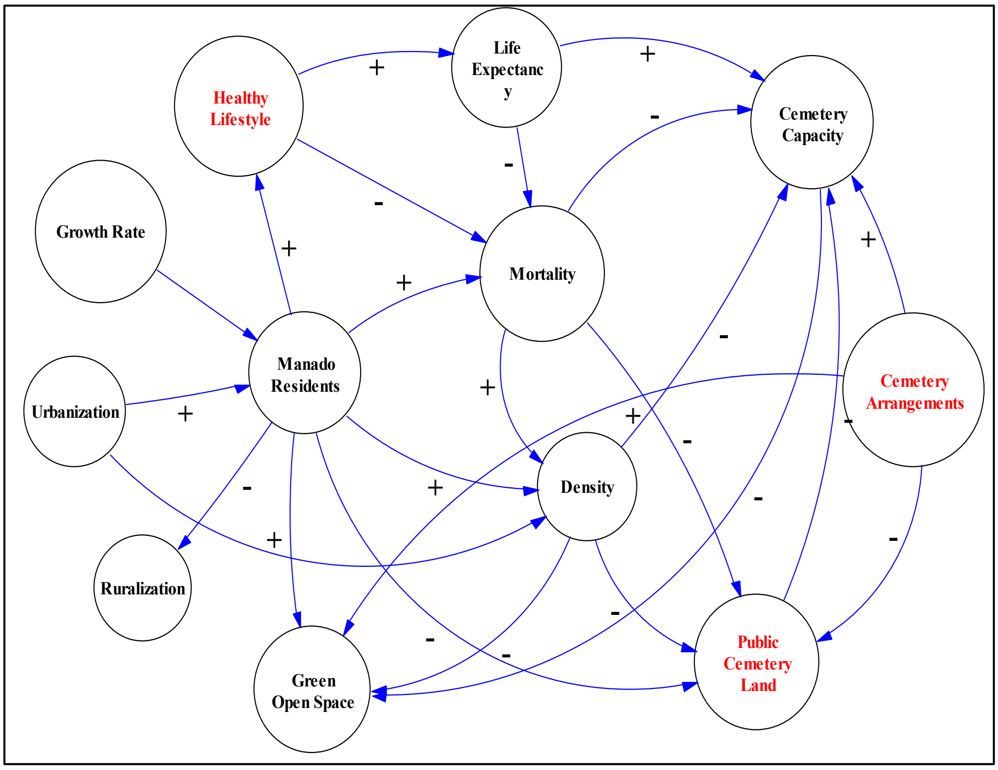
Figure 1. Area of Study

Data Collection

Primary data were obtained through field surveys and focus group discussions with cemetery managers and local government officials, while secondary data were sourced from statistical agencies and planning documents.

Parameters

The FGD identified three key parameters highlighted in red on the Causal Loop Diagram (CLD): healthy lifestyle, public cemeteries land, and cemetery arrangements (see Figure 2). These parameters will serve as leverage points in the systems dynamics model to develop effective strategies for sustainable cemetery management. The CLD illustrates reinforcing loops between population growth and burial demand, as well as balancing loops introduced through health policy interventions.



Source: FGD, 2024

Figure 2. Causal Loop Diagram (CLD) Public Cemetery Land

Basis for Quantifying Relationships between Variables

This study quantifies relationships between variables based on demographic transition theory and population health frameworks, which view mortality as a dynamic outcome influenced by socioeconomic development and public health interventions rather than a fixed parameter. In line with these perspectives, mortality is modeled as a time-dependent variable within a System Dynamics framework, where health-related policies act as levers that modify mortality trends over time. Changes in mortality directly affect burial demand and cumulative cemetery land requirements, allowing the model to represent how population health improvements indirectly function as land-use management mechanisms in urban cemetery planning.

Strengths the proposed model serves as a policy-oriented simulation tool, allowing for comparative evaluation of long-term cemetery management strategies. In the System Dynamics model, these relationships are operationalized by adjusting mortality flows using calibrated elasticity parameters derived from historical mortality trends and expert judgments obtained through focus group discussions. This approach allows mortality reductions to emerge endogenously from policy intensity, while maintaining consistency with observed demographic patterns in Manado. Cemetery land demand is then calculated as a downstream effect of mortality outcomes, based on applicable burial land standards, ensuring that spatial implications are causally related and not exogenously imposed

Model Validation and Limitations

Model validation was performed through historical behavior reproduction, comparing simulated mortality and land demand trends against observed data from 2015–2023. The model successfully replicated both pre pandemic and post-pandemic mortality dynamics, indicating adequate structural validity. Conceptual validation was further strengthened through expert elicitation, ensuring alignment between model structure and real world policy mechanisms.

The validation process employs two testing methods according to Barlas (1989): Absolute Mean Error (AME) with an acceptable threshold of <5% and Absolute Variation Error (AVE) with an acceptable threshold of <30%. The results of which are presented in Table 1, which the primary data used for model validation consists of historical population data from Manado City, shows an AME of 1.08% and an AVE of 2.03%

Table 1. SFD Model Data Validation

No	Year	Population History	Population Simulation	AME (%)	AVE (%)
1	2015	423,257	425,634	0.56%	1.13%
2	2016	425,634	428,145	0.59%	1.18%
3	2017	427,906	432,769	1.14%	2.29%
4	2018	430,133	435,755	1.31%	2.63%
5	2019	431,880	438,108	1.44%	2.91%
6	2020	433,635	439,817	1.43%	2.87%
7	2021	451,916	441,005	2.41%	4.78%
8	2022	456,580	459,130	0.56%	1.12%
9	2023	458,580	459,864	0.28%	0.56%
			Average	1.08%	2.03%

Source : Analysis Results, 2024

However, this study acknowledges several limitations. The healthy lifestyle variable represents an aggregated policy construct and does not distinguish between specific health interventions. Moreover, migration, changing burial preferences, and institutional performance variability are not explicitly modeled. Consequently, the model is intended as a strategic planning instrument rather than a predictive epidemiological tool.

Analysis Data

Analysis data using a SD approach as a conceptual and methodological tool. Unlike static land-use calculations, a System Dynamics approach captures feedback loops, time delays, and non-linear interactions between mortality rates, burial demand, and land availability.

The research design consists of four stages: problem identification, data collection, system dynamics modeling, and scenario evaluation. The systems dynamics analysis began by defining the system's objectives, selecting system requirements to achieve those objectives, and formulating problems derived from the FGD results. The next step was to identify the system by creating a causal loop diagram to facilitate the visualization of relationships between variables, both input and output. Technical analysis was conducted by constructing a Stock Flow Diagram (SFD) to enable simulations and model scenarios, aiding policymakers in developing the best policy strategies.

Uncertainty in Projections through 2045

Long-term projections to 2045 are subject to uncertainty arising from demographic volatility, policy implementation consistency, and socio-cultural adaptation. To address this, the study adopts a scenario-based approach that captures a range of plausible futures under varying policy intensities. Long-term projections are subject to uncertainty; therefore, scenario-based analysis is used to test policy robustness. These scenarios do not represent forecasts but conditional outcomes contingent upon sustained governance commitment. Periodic recalibration is therefore essential to maintain policy relevance.

Periodic recalibration in this study is applied by updating key model parameters particularly mortality and population growth rates using the latest observed data at predefined intervals. This procedure minimizes cumulative simulation error, maintains parameter validity under changing conditions, and improves the robustness of long-term scenario outputs, thereby ensuring that policy evaluations of cemetery land demand remain empirically grounded.

Results and Discussions

Mortality Rate and Crude Death Rate

In 2015, the annual death toll reached 1,651 people, accounting for 0.4% of Manado's population at that time. A significant increase occurred in 2017, reaching 3,509 deaths per year or 0.8% of the city's population. Subsequently, a surge in deaths was observed during the COVID-19 pandemic in 2019 and 2020, reaching 4,312 (1% of the population) and 4,839 (1.1% of the population), respectively. After that, the death rate continued to increase by 1.1% per year. For a more detailed view, please refer to Table 2.

Table 2. Mortality Rate in Manado City from 2015 to 2023

No	Year	Amount	%
1	2015	1,651	0.4%
2	2016	1,948	0.5%
3	2017	3,509	0.8%
4	2018	4,109	1.0%
5	2019	4,312	1.0%
6	2020	4,839	1.1%
7	2021	4,912	1.1%
8	2022	4,990	1.1%
9	2023	5,080	1.1%

Source: Manado Central Statistics Agency, 2024

The data above can be used to calculate the Crude Death Rate (CDR). The CDR is a measure of the number of deaths per 1.000 people per year. Calculation of CDR using the formula (Weeks 2005):

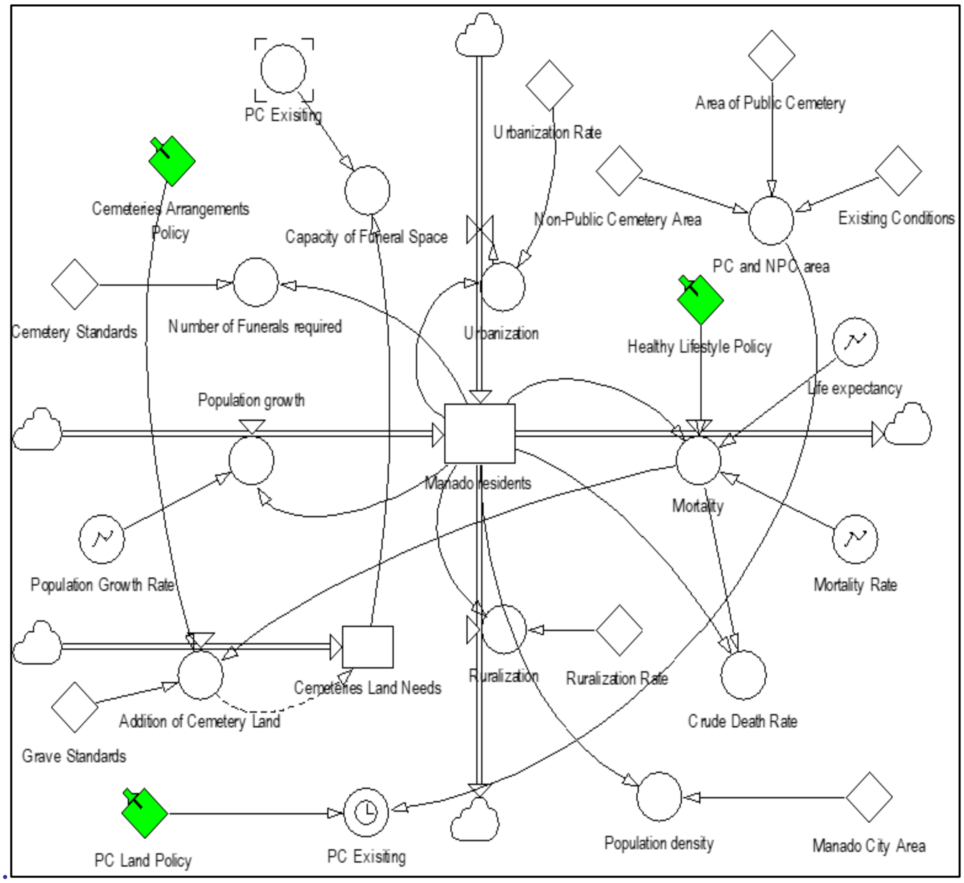
$$\left(\frac{D}{P}\right) x1000 \quad (1)$$

With,
D = number of deaths in a given year
P = total population in the middle of the year
1000 = constant number

If the CDR is less than 10, it is categorized as low; between 10 and 20 is considered moderate; and more than 20 is classified as high. The calculated CDR for Manado City in 2023 was 22.20, indicating a high CDR category.

System Dynamics model

The Stock Flow Diagram (SFD) scenario is constructed in Figure 3, presents a simulation based on controlled inputs and interventions on three key parameters identified from the FGD: (1) healthy lifestyle, (2) public cemetery land, and (3) cemetery arrangements, as depicted by the green stocks.



Source: Analysis, 2024

Figure 3. SFD Public Cemeteries Developmnet of Manado City

The Figure 3, represents the structural configuration of the SD model used in this study. Circular elements indicate state variables (stocks) that accumulate over time, such as population size, mortality-related outcomes, and cumulative burial demand. Rectangular elements denote rate variables (flows) that regulate changes in the stocks, including birth, death, and burial processes. Diamond-shaped elements represent auxiliary variables that mediate relationships between stocks and flows, such as policy parameters or adjustment factors. Arrows illustrate causal linkages and information flows between variables, indicating the direction of influence within the system. The highlighted components emphasize key intervention points where policy actions particularly health related or land management measures are introduced into the model. Overall, the diagram visualizes the feedback-driven structure through which demographic and health dynamics influence long-term cemetery land demand.

The analysis using SD demonstrates that without any intervention efforts on the model's critical parameters, several parameters such as the death rate will continue to increase starting from 2024 at a rate of 5.112 individuals per year, further increasing to 5.275 individuals per year. The CDR will also increase to 22,20, categorizing it as high. The demand for cemeteries land will continue to rise, reaching an area of 54,85 hectares, while the carrying capacity of cemeteries land will continue to decrease by 46,37 hectares (see Tabel 3 below).

Table 3. Result Analysis SFD Cemeteries of Manado City

Year	Manado Residents	Mortality	CDR	Land requirements	Carrying capacity
2015	425,634	1,660	7.8	0.62	7.86
2016	428,145	1,969	9.2	1.24	7.24
2017	432,769	3,549	16.4	1.98	6.50
2018	435,755	4,183	19.2	3.31	5.17
2019	438,108	4,381	20	4.88	3.60
2020	439,817	4,926	22.4	6.53	1.96
2021	441,005	4,807	21.8	8.37	0.11
2022	459,130	5,050	22.0	10.18	-1.69
2023	459,864	5,104	22.2	12.07	-3.59
2024	460,554	5,112	22.2	13.98	-5.50
2025	461,245	5,120	22.2	15.90	-7.42
2026	461,937	5,127	22.2	17.82	-9.34
2027	462,630	5,135	22.2	19.74	-11.26
2028	463,324	5,143	22.2	21.67	-13.19
2029	464,019	5,151	22.2	23.60	-15.12
2030	464,715	5,158	22.2	25.53	-17.05
2031	465,412	5,166	22.2	27.46	-18.98
2032	466,110	5,174	22.2	29.40	-20.92
2033	466,809	5,182	22.2	31.34	-22.86
2034	467,509	5,189	22.2	33.28	-24.80
2035	468,211	5,197	22.2	35.23	-26.75
2036	468,913	5,205	22.2	37.18	-28.70
2037	469,616	5,213	22.2	39.13	-30.65
2038	470,321	5,221	22.2	41.09	-32.60
2039	471,026	5,228	22.2	43.04	-34.56
2040	471,733	5,236	22.2	45.00	-36.52
2041	472,440	5,244	22.2	46.97	-38.49
2042	473,149	5,252	22.2	48.93	-40.45
2043	473,859	5,260	22.2	50.90	-42.42
2044	474,570	5,268	22.2	52.88	-44.40
2045	475,281	5,276	22.2	54.85	-46.37

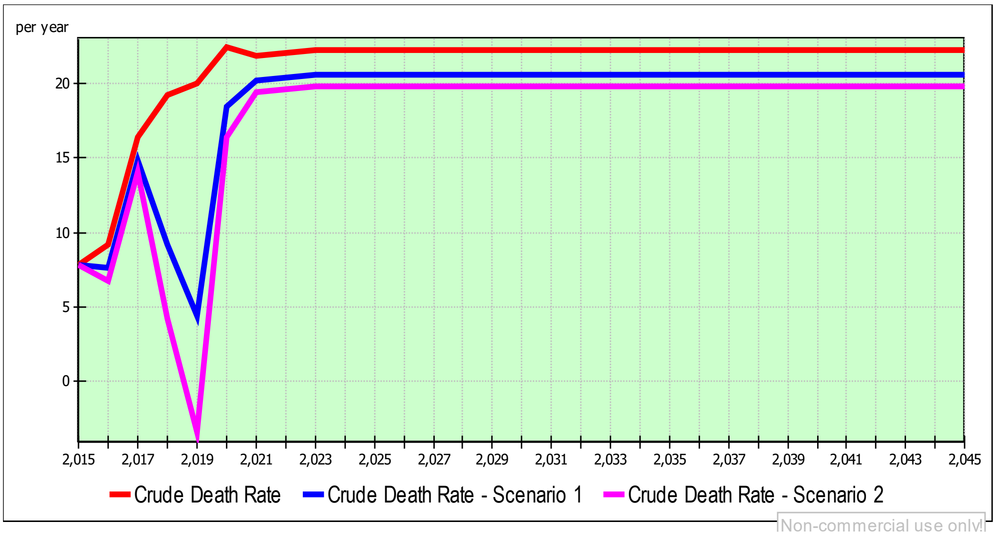
Source: Analysis, 2024

Two simulation scenarios were developed, each involving policy interventions targeting three critical parameters: (1) healthy lifestyle, (2) public cemeteries land, and (3) cemeteries arrangement. In the first scenario, the healthy lifestyle policy aimed to double the current level of healthy lifestyle practices, representing 50% increase in policy effort. The public cemeteries land policy involved acquiring an additional 10 hectares of cemeteries land, while the cemeteries arrangement policy adopted a two tier stacking cemeteries model. The second scenario followed a similar approach, tripling the current level of healthy lifestyle practices (75% increase) and acquiring 20 hectares of additional cemeteries land, with the adoption of a three-tier stacking cemeteries model. The analysis outcomes are visually depicted in Table 4, Figures 4, 5, and 6.

Table 4. Scenario Public Cemeteries Of Manado City

Year	CDR		Mortality		Cemeteries Land requirements	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
2015	7.8	7.8	1,660	1,660	0.31	0.16
2016	7.6	6.8	1,627	1,456	0.62	0.31
2017	14.8	14	3,205	3,033	0.93	0.45
2018	9.2	4.2	2,008	917	1.53	0.73
2019	4.4	-3.4	970	-752	1.90	0.82
2020	18.4	16.4	4,105	3,684	2.09	0.75
2021	20.2	19.4	4,527	4,383	2.86	1.09
2022	20.4	19.6	4,764	4,616	3.71	1.50
2023	20.6	19.8	4,822	4,676	4.60	1.94
2024	20.6	19.8	4,833	4,689	5.50	2.38
2025	20.6	19.8	4,844	4,701	6.41	2.81
2026	20.6	19.8	4,855	4,714	7.32	3.26
2027	20.6	19.8	4,866	4,727	8.23	3.70
2028	20.6	19.8	4,878	4,739	9.14	4.14
2029	20.6	19.8	4,889	4,752	10.05	4.58
2030	20.6	19.8	4,900	4,765	10.97	5.03
2031	20.6	19.8	4,911	4,778	11.89	5.48
2032	20.6	19.8	4,923	4,791	12.81	5.92
2033	20.6	19.8	4,934	4,804	13.73	6.37
2034	20.6	19.8	4,945	4,817	14.66	6.82
2035	20.6	19.8	4,957	4,830	15.59	7.28
2036	20.6	19.8	4,968	4,843	16.52	7.73
2037	20.6	19.8	4,979	4,856	17.45	8.18
2038	20.6	19.8	4,991	4,869	18.38	8.64
2039	20.6	19.8	5,002	4,882	19.32	9.09
2040	20.6	19.8	5,014	4,895	20.25	9.55
2041	20.6	19.8	5,025	4,909	21.19	10.01
2042	20.6	19.8	5,037	4,922	22.14	10.47
2043	20.6	19.8	5,049	4,935	23.08	10.93
2044	20.6	19.8	5,060	4,948	24.03	11.40
2045	20.6	19.8	5,072	4,962	24.98	11.86

Source: Analysis, 2024

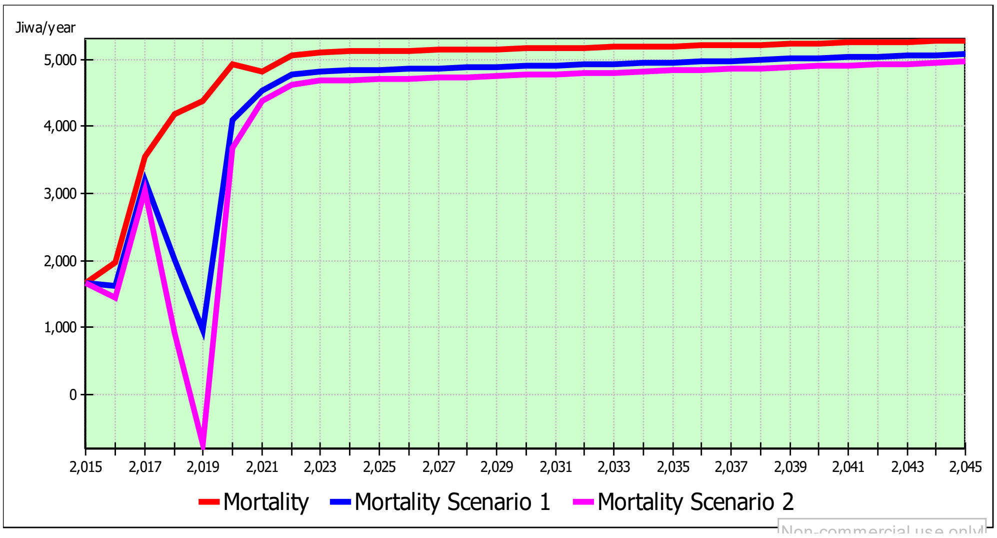


Source: Analysis, 2024

Figure 4. Result Scenario for CDR

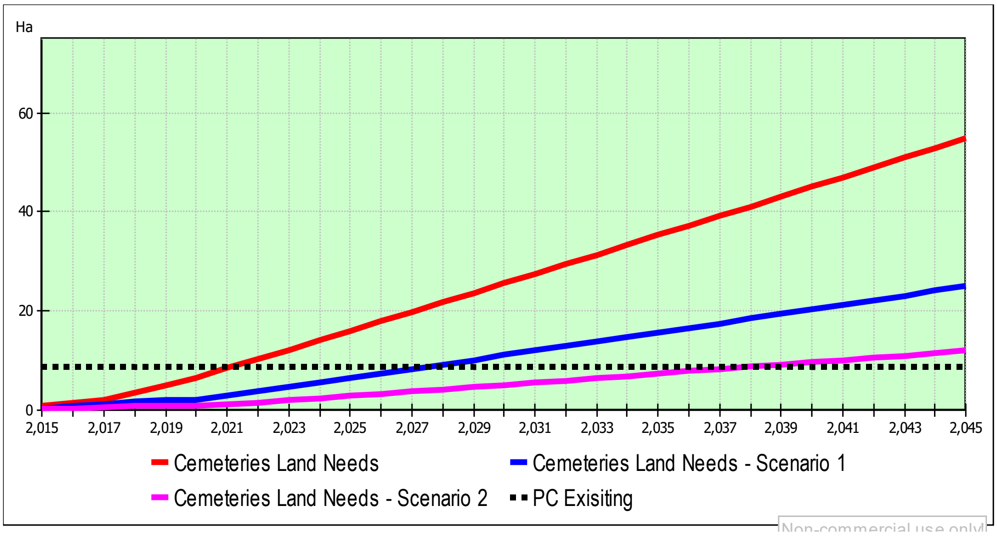
The analysis results in Figure 4 reveal that implementing the policies in scenario one decreased the CDR to 20.60 from the initial value of 22.2, although it still remains in the high category. The analysis results indicate that implementing the policies in scenario two is optimal, as the CDR decreased to 19.80, falling within the moderate category. Considering the difficulty of achieving a low category, this result is commendable. In scenario two, the number of deaths also decreased by 313 individuals, from the existing 5,275 individuals per year to 4,961 individuals per year. Under these conditions, scenario two policies performed better than scenario one policies.

Similarly, the number of deaths decreased by 203 individuals, from the existing 5,275 individuals per year to 5,071 individuals per year (see Figure 5).



Source: Analysis, 2024

Figure 5. Result Scenario for Mortality



Source: Analysis, 2024

Figure 6. Result Scenario for Cemeteries Land Needs

Similarly, regarding the need for cemeteries land, when applying scenario one policies, the analysis results show a reduction in cemeteries land requirements by 29.87 hectares, resulting in a need for only 24.98 hectares, compared to the initial requirement of 54.85 hectares. Furthermore, when implementing scenario two policies, the analysis results demonstrate a significant decrease in cemeteries land requirements by 42.99 hectares (more than double the reduction in scenario one), resulting in a need for only 11.86 hectares, compared to the initial requirement of 54.85 hectares until 2045. This implies that scenario two policies still perform betterz than scenario one policies. This can be seen in Figure 6 above.

The best policy formulation after interventions were carried out on the three main parameters as leverage points was in scenario two. The comparison between scenario one and scenario two, can be seen in Table 5 below.

Table 5. Comparison between Scenario One and Scenario Two for Optimal Cemetery Policy Strategies

Scenario	Policy strategies	Impact
Scenario 1	• The adoption of a healthier lifestyle has doubled compared to current conditions.	• The Crude Death Rate has decreased to 20.60 from an initial rate of 22.2. However, it remains within the high category. • The number of deaths has declined by approximately 203 individuals per year, from the current figure of 5,275 deaths/year to 5,071 deaths/year.
	• An additional 10 hectares of burial land has been provided to meet the total projected need of 18.48 hectares.	• The land carrying capacity for cemetery has increased by 39.87 hectares, leaving a remaining shortfall of only -6.50 hectares, compared to the previous deficit of -46.37 hectares.
	• A double-layer (tiered) burial model has been implemented.	• This model reduces burial land demand by 29.87 hectares, resulting in a total requirement of only 24.98 hectares, down from the original projection of 54.85 hectares by the year 2045.

Scenario	Policy strategies	Impact
Scenario 2	• Improving a healthy lifestyle (three-fold increase in healthy lifestyle practices compared to the current state).	• There has been a reduction in the Crude Death Rate from 22,2 to 19,80, which now places it in the moderate category. • Reduction of 313 deaths per annum has been observed, decreasing the death rate from 5.275 to 4.961.
	• Additional cemeteries land (20 hectare expansion of the cemetery is required to fulfill the total land requirement of 28,48 hectares).	• The cemetery land capacity has increased by 62,99 hectares.
	• Implementing vertical cemeteries (three-tier cemeteries system).	• Reduction of 42,99 hectares in cemetery land requirements has been achieved, leaving a projected need of only 11.86 hectares by 2045, down from the original estimate of 54,85 hectares.

Source: Analysis, 2024

Policies require the involvement of civil society in local innovation, and as awareness of the importance of health and quality of life increases, various studies have been conducted to evaluate the effectiveness of different types of policy interventions. Furthermore, there is a need for broader collaborative promotion among key stakeholders to facilitate healthy lifestyle behaviors, supported by government funding (Valentino et al., 2023; Wargers et al., 2024). This means that the findings of this research on the strategy of promoting healthy lifestyles are in line with the findings of the aforementioned studies, where an increase in healthy lifestyles can reduce the risk of death and decrease the need for cemetery land. However, land expansion alone does not automatically increase burial demand; rather, it serves as a temporary buffer when combined with mortality reduction and alternative burial practices.

This research finding, through the policy of adding cemetery land, is part of cemetery planning and management. This finding is in line with Demirli (2015) finding that long-standing cemetery policies adapt to and reflect changes in cultural trends, cemetery management, planning, regeneration, other pressures on land, and changes in the natural environment where the cemetery is located. It is crucial that cemetery planning consistently articulates its role as green infrastructure from the outset, as part of sustainable urban cemetery planning and management (Amoah et al., 2024; McClymont & Sinnett, 2021).

The relevance of this research lies in its connection to policies for implementing the latest cemeteries models with a stacked or vertical concept, aligned with research findings (Długozima & Nejman, 2022; Iezzi et al., 2024; Neckel et al., 2017). These studies suggest that vertical cemeteries present itself as a highly viable alternative to reduce the space allocated for graves, in addition to solving cemetery overcrowding issues, promoting green spaces in urban areas, and minimizing the risk of environmental and population contamination.

Revisiting the Causal Link between Healthy Lifestyle Policies and Cemetery Land Demand

The reduction in cemetery land demand observed in Scenario 2 should be interpreted as an emergent systemic outcome rather than a simplistic cause effect relationship. Healthy lifestyle policies operate upstream by moderating mortality trajectories, which cumulatively reduces burial demand over time. The System Dynamics framework explicitly captures this delayed causality, reinforcing the conceptual robustness of the policy argument.

The empirical finding that a reduction of 313 deaths per year translates into a substantial decrease in land demand by 2045 underscores the strategic importance of health oriented policies within spatial planning discourse. This reinforces the notion that public health interventions can function as indirect yet powerful land-use management instruments.

Socio-Cultural Constraints and Institutional Preconditions for Vertical Cemeteries

While vertical cemeteries demonstrate clear spatial efficiency, their implementation is contingent upon social acceptance and institutional readiness. Burial practices in Manado are deeply embedded within religious and cultural norms, potentially generating resistance toward multi-tier burial systems. Therefore, technical feasibility alone is insufficient.

Institutionally, local governments must possess regulatory clarity, administrative capacity, and community engagement mechanisms. Without these preconditions, vertical cemetery policies risk remaining theoretical. Thus, the SD model should be interpreted as identifying potential capacity, not guaranteed implementation outcomes.

The findings of this research reinforce the strategic policy findings of previous studies, including those considered as elements of urban architecture (Suriandjo et al., 2023, 2025). However, this study stands out for its use of SD analysis, which produces more measurable projections. Therefore, the findings of this study can provide support for strategic policies in the development of urban public cemeteries, as part of urban architectural planning and design, given the increasing scarcity of land currently and in the future.

Conclusion

This study achieves its objective of demonstrating the applicability of SD in urban cemetery planning and contributes theoretically by positioning mortality reduction as an indirect land-use control mechanism. The findings confirm that SD modeling provides a robust framework for understanding public cemetery provision as a dynamic urban policy issue. By integrating mortality reduction, land availability, and cemetery configuration within a feedback-driven system, the study advances theoretical discussions on urban land management under conditions of scarcity. Moreover, the results demonstrate that health-oriented policies can function as indirect spatial planning instruments, thereby extending the theoretical scope of cemetery planning beyond conventional land supply paradigms.

Building on these theoretical insights, the study recommends that urban public cemetery development under limited land conditions be guided by three complementary policy strategies: (1) promoting healthy lifestyles, (2) expanding burial land, and (3) implementing vertical cemeteries. Among the evaluated scenarios, Scenario Two—incorporating interventions across these three key leverage parameters—emerges as the optimal strategy up to 2045. Implementation of this scenario reduces the annual number of deaths by 313 individuals, from 5,275 to 4,961, lowering the Crude Death Rate from a high category (22.20) to a moderate category (19.80). This policy combination also decreases the required cemetery land from 42.99 hectares to approximately 11.86 hectares by 2045 and increases cemetery land carrying capacity by 16.62 hectares relative to the projected deficit of 46.37 hectares.

Further research opportunities can be explored based on these findings, such as refining the policy strategies into more detailed and measurable programs by continuing use SD or by employing other policy simulation tools like MULTIPOL, a multi-criteria policy analysis tool.

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