Constructing of Penta Helix Model Approach in Reducing Stunting and Upscaling Human Resource Capabilities in Surabaya Development

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Abstract

Stunting remains a persistent public health issue in Indonesia with long-term implications for human capital development. This study aims to analyze the role of the Penta Helix Model comprising government, academia, business, community, and media in reducing stunting and enhancing human resource capability in Surabaya. A quantitative approach was applied using survey data collected from 88 respondents and analyzed with Structural Equation Modeling–Partial Least Squares (SEM-PLS). The measurement model confirmed adequate validity and reliability for all constructs. The structural model results revealed that business participation, community engagement, media exposure, healthcare access, and environmental sanitation significantly reduced stunting, while government support and academic involvement showed weak or non-significant effects on food access. Furthermore, stunting reduction had a strong positive impact on human resource capability, highlighting its developmental relevance. Mediation analysis showed that healthcare access and environmental sanitation acted as critical pathways linking Penta Helix actors to stunting outcomes. These findings emphasize the importance of multi-sector collaboration, particularly business, community, and media involvement, in creating sustainable interventions. The study provides practical implications for policymakers to design integrated, evidence-based strategies that not only address stunting but also strengthen long-term human capital development in urban settings.

Keywords: Penta Helix Model, Stunting Reduction, Human Resource Capabilities, Surabaya City

INTRODUCTION

Despite national intervention efforts, stunting remains a formidable barrier to Indonesia's human resource optimization. The urgency of this crisis is particularly evident in Surabaya, where the prevalence of stunting poses a threat to sustainable socioeconomic growth and demographic quality (Sharma, 2007). Tackling these systemic challenges requires a paradigm shift toward collaborative governance. The Penta Helix approach emerges as a robust strategic solution, leveraging the collective expertise and resources of the public sector, academic institutions, private enterprises, community organizations, and media outlets to foster a holistic nutritional intervention.
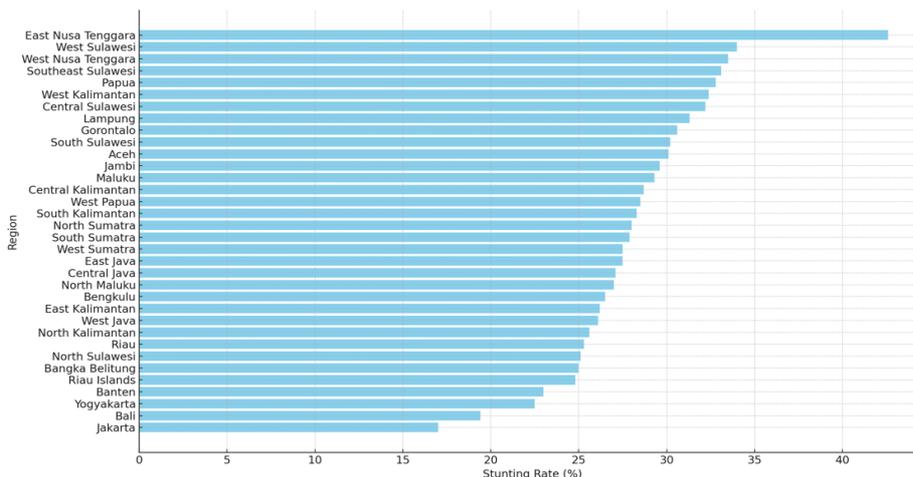

Figure 1. Stunting Rates by Region in Indonesia
Source: Ministry of Health (2023)

Stunting represents a critical global health exigency, characterized by profound anthropometric deficits that impede early childhood development, particularly within emerging economies. Defined by impaired physical and cognitive maturation resulting from chronic nutritional deficiencies, repeated infections, and suboptimal psychosocial stimulation, this condition necessitates multifaceted interventions. This research employs a systematic review to synthesize empirical evidence, offering a comprehensive analysis of the operationalization of the Penta Helix framework and its efficacy in mitigating growth faltering through cross-sectoral synergy.
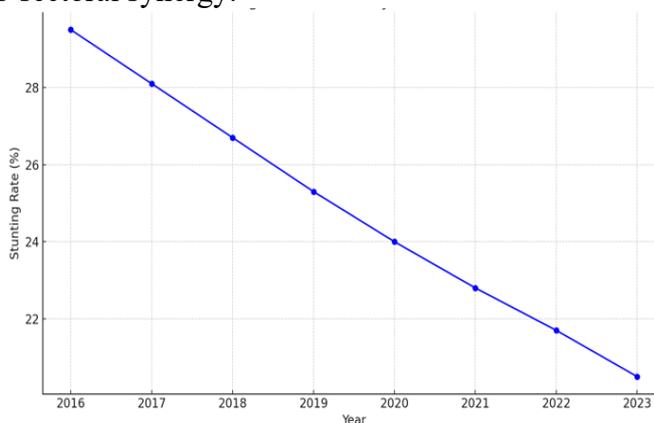

Figure 2: Stunting Rates in Surabaya
Source: Ministry of Health (2024)

The insights derived from this study are anticipated to provide significant evidence-based recommendations for policymakers, public health practitioners, and urban development stakeholders. By offering a granular evaluation of stunting prevalence and its multi-dimensional determinants in Surabaya, this research aims to catalyze broader efforts toward improving population health and advancing sustainable development goals. Specifically, the inquiry seeks to elucidate the structural root causes of growth faltering, encompassing nutritional intake, healthcare accessibility, environmental sanitation, and socioeconomic indicators. As Porter and Kramer (2018) posit, deciphering these interconnected elements is foundational for designing high-impact, targeted interventions. Furthermore, the study critically examines the efficacy of the Penta Helix framework, identifying its inherent strengths and operational limitations within the specific context of stunting mitigation (Bryson et al., 2014).

This cross-sector collaboration has the potential to create shared value through synergy in the planning, implementation, and evaluation of development policies (Porter & Kramer, 2018). The approach aligns with the paradigm of public value governance, which places public interest as the primary orientation in collaborative governance (Bryson, Crosby, & Bloomberg, 2014). This study aims to examine the role of the Penta Helix model as a strategic collaborative framework in tackling stunting and enhancing human resource capabilities in Surabaya.

LITERATURE REVIEW

Expanding upon this analysis, and aligned with the framework proposed by Afandi et al. (2023), this research seeks to conceptualize a tailored Penta Helix model specifically calibrated for the Surabaya context. Central to this objective is an exploration of the synergistic relationship between stunting mitigation and human capital development. The study elucidates how optimized nutritional and health outcomes foster superior cognitive and physical maturation, thereby augmenting the aggregate capabilities of the city's demographic. Furthermore, it delineates interventions designed to catalyze skill acquisition and competency building, ensuring that human resource optimization is intrinsically linked to stunting reduction. Ultimately, the research aims to establish a 'virtuous cycle' wherein enhanced public health outcomes directly bolster socioeconomic productivity and sustainable urban growth.

Human Resource Capability (HRC) represents the foundational capacity of individuals to actively contribute to the socio-economic development of their communities and nations. The first key indicator of HRC is Skills and Competencies Enhancement (HRC.1), which reflects an individual's ability to acquire both technical skills and soft skills required to perform effectively in a rapidly changing labor market. Skills development is not limited to formal education; it also includes vocational training, problem-solving abilities, adaptability, teamwork, and digital literacy, all of which are increasingly demanded in modern economies (PISA, 2019). The second indicator, Physical and Mental Health Status (HRC.2), plays a crucial role in determining individual productivity. Healthier individuals are more likely to attend school regularly, perform better academically, and contribute more effectively to the workforce later in life (Bloom & Canning, 2004). The third dimension of HRC is Educational Attainment and Lifelong Learning Capacity (HRC.3), which encompasses access to quality education, opportunities for continuous learning, and the ability to adapt knowledge to evolving job requirements. Research shows that higher levels of education correlate strongly with increased earnings, better health outcomes, and improved civic engagement (Psacharopoulos & Patrinos, 2018).

Finally, Productive Participation in the Workforce (HRC.4) serves as a tangible outcome of human resource capability. This indicator reflects the extent to which individuals are able to access decent jobs, utilize their skills effectively, and contribute to economic and social progress. Barriers such as malnutrition, stunting, lack of education, and poor health can significantly limit individuals' ability to participate productively in the labor market (Grantham-McGregor et al., 2007).

Stunting, defined as impaired growth and development due to chronic undernutrition during the most critical periods of early childhood, remains one of the most significant public health challenges in low- and middle-income countries, including Indonesia (WHO, 2020). The first crucial indicator of stunting reduction is improvement in child nutritional intake (St.1). Adequate nutrition during the first 1,000 days of life—from conception to a child's second birthday—is critical for optimal brain and body development (Black et al., 2013). The second indicator, Access to Quality Health Services for Maternal and Child Care (St.2), is just as important for fighting stunting. Health services, including antenatal care, skilled birth attendance, immunization programs, and regular growth monitoring, provide early detection and timely management of conditions that may lead to growth retardation (Victora et al., 2008). The third indicator of stunting reduction is improvement in sanitation and hygiene practices (St.3).

Poor sanitation, unsafe drinking water, and inadequate hygiene practices expose children to recurrent infections, such as diarrhea and intestinal parasites, which impair nutrient absorption and compromise growth (Humphrey, Pulley, & Vesala, 1996). In summary, stunting reduction is a multidimensional challenge encompassing nutritional adequacy, access to quality maternal and child healthcare services, and improvements in sanitation and hygiene environments. The indicators—nutritional intake, health service access, and sanitation—provide a framework for assessing the success of interventions aimed at tackling stunting.

The complexity of public health challenges such as stunting necessitates approaches that transcend traditional sectoral boundaries. The Penta Helix collaboration model has emerged as a strategic framework that facilitates multi-stakeholder engagement in addressing societal problems, particularly those that require systemic and sustainable solutions (Carayannis & Campbell, 2006). The first dimension of this model is Academic Involvement (AI), which plays a vital role in generating evidence-based knowledge and innovative solutions to combat stunting. Academic institutions contribute by conducting research on nutritional needs, identifying risk factors, and developing intervention strategies tailored to local contexts (Nutbeam & Lloyd, 2021). The second dimension, Business Participation (BP), highlights the private sector's role in providing resources, innovations, and sustainable market solutions that support improved food security and child health outcomes (Porter & Kramer, 2018).

The fourth dimension, Government Support (GS), serves as a backbone for policy development, program funding, and institutional coordination (Bryson, 2018). Effective government involvement is marked by strong regulatory frameworks for nutrition policies (GS.1), direct budget allocation for stunting prevention programs (GS.2), multisectoral coordination among public agencies (GS.3), and implementation of social safety nets for vulnerable households (GS.4). Governments are instrumental in providing scale, legitimacy, and sustainability to stunting reduction interventions, ensuring that efforts reach marginalized populations effectively. Each dimension and its indicators collectively foster a collaborative ecosystem capable of addressing the structural causes of stunting and strengthening human resource capabilities in the long term.

Stunting reduction has emerged as a critical public health and developmental priority, given its long-term implications on individual well-being, educational attainment, and

workforce productivity. Drawing from the Penta Helix collaboration model, this study proposes a conceptual framework in which government support, academic involvement, business participation, community engagement, and media exposure interact to influence food access, environmental sanitation, and healthcare access, ultimately leading to stunting reduction and subsequently improving human resource capability in urban contexts like Surabaya. Stunting reduction, as an intermediate developmental outcome, serves as a gateway to improving human resource capability. Children who avoid stunting are more likely to achieve optimal brain development, higher educational attainment, and enhanced cognitive and physical abilities (Word Bank, 2018).

The conceptual framework of this research builds upon the Penta Helix collaboration model as a strategic approach to tackle stunting and improve long-term Human Resource Capability (HRC) in Surabaya. The Penta Helix framework emphasizes the synergistic roles of government, academia, business actors, community, and media in collectively addressing complex public health issues. These actors influence stunting prevalence through three key intermediary factors: food access, healthcare access, and environmental sanitation, which are critical determinants of child growth and development.
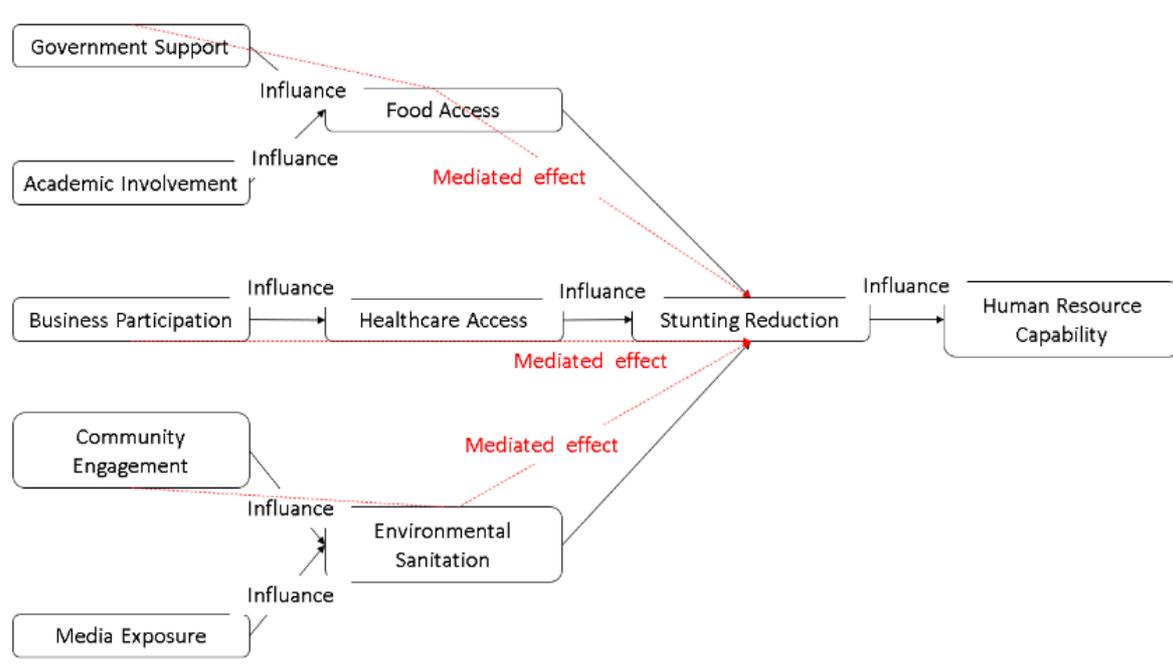

Figure 3. Conceptual Framework

The Penta Helix model emphasizes the importance of multi-stakeholder collaboration in addressing complex public health issues, such as stunting. This framework assumes that government support, through policy interventions, subsidies, and nutritional programs, positively contributes to improving food access. Therefore, the first hypothesis (H1) asserts that government support positively impacts food access. Likewise, academic involvement is considered essential in generating research-based solutions and educational outreach, which are expected to strengthen community knowledge and practices related to nutrition. Consequently, the second hypothesis (H2) posits that academic involvement positively influences food access.

Moreover, business involvement is anticipated to be instrumental in enhancing

healthcare services via innovations, resources, and corporate social responsibility initiatives, resulting in the third hypothesis (H3) that business participation positively influences healthcare access. At the same time, community engagement is expected to foster local collective action to improve sanitation and hygiene, forming the fourth hypothesis (H4) that community engagement has a positive effect on environmental sanitation. Complementing this, media exposure is viewed as a driver of public awareness and behavioral change, which underpins the fifth hypothesis (H5) that media exposure has a positive effect on environmental sanitation.

Building upon these relationships, food access, healthcare access, and environmental sanitation are theorized as the critical pathways that directly influence child growth outcomes. Adequate food access ensures that households can provide nutritious diets, thus leading to the sixth hypothesis (H6) that food access harms stunting. Similarly, improved maternal and child healthcare services prevent growth delays and malnutrition, forming the seventh hypothesis (H7) that healthcare access harms stunting. Proper environmental sanitation, including access to clean water and hygiene practices, reduces recurrent infections that hinder growth, leading to the eighth hypothesis (H8) that environmental sanitation harms stunting. Taken together, these improvements are expected to reduce stunting prevalence, which in turn benefits long-term development. Accordingly, the ninth hypothesis (H9) states that stunting reduction has a positive effect on human resource capability, reflecting the idea that healthier children will achieve better educational outcomes and workforce productivity.

The conceptual framework includes both direct effects and mediating mechanisms. Government support may not directly reduce stunting but can operate through its influence on food access, leading to the tenth hypothesis (H10) that food access mediates the relationship between government support and stunting. Similarly, the involvement of business actors is expected to indirectly influence stunting outcomes through healthcare access, which supports the eleventh hypothesis (H11) that healthcare access mediates the relationship between business participation and stunting. Moreover, community engagement is expected to work through sanitation practices, which form the twelfth hypothesis (H12) that environmental sanitation mediates the relationship between community engagement and stunting. Beyond these specific mediating effects, the overall model emphasizes synergy, which is captured in the thirteenth hypothesis (H13) that the Penta Helix model collectively has a significant effect on stunting reduction.

Finally, as the ultimate developmental outcome, the fourteenth hypothesis (H14) proposes that stunting reduction significantly improves human resource capability, demonstrating the long-term importance of early childhood nutrition for human capital development. This conceptual framework reflects a causal chain model where Penta Helix collaboration (exogenous variable) influences key mediators (food access, sanitation, healthcare), leading to stunting reduction (endogenous variable), which in turn enhances human resource capability (final outcome variable). The model also acknowledges possible indirect effects where each Penta Helix actor contributes differently to stunting reduction and human resource development. For instance, community engagement may directly enhance sanitation practices, while academic involvement may have a weaker direct link to stunting but a stronger indirect effect via increased awareness and policy innovation.

METHOD
Research Methods

This study applies Structural Equation Modeling–Partial Least Squares (SEM-PLS) to examine the relationships among the Penta Helix components, stunting reduction, and human resource capability in the city of Surabaya. SEM-PLS is selected because it is well-suited for predictive modeling, managing complex frameworks involving multiple latent constructs, and

handling datasets that may not strictly follow normal distribution assumptions. Previous research has demonstrated its utility in public health contexts—for example, Rusyda & Baliwati (2025) employed PLS-SEM to evaluate the impact of health interventions on stunting prevalence across Indonesian provinces. In Pidie District, Aceh, SEM-PLS combined with GIS successfully modeled determinants of stunting at multiple ecological levels, explaining 73.2 % of the variance (Sari et al., 2025). Similarly, PLS-SEM has been used in evaluating human development constructs, such as factors influencing the Human Development Index across Indonesian provinces (Putri et al., 2024).

The endogenous latent variables in this study include Food Access, Healthcare Access, Environmental Sanitation, Stunting Reduction, and Human Resource Capability. Food Access is evaluated based on the availability, affordability, and nutritional adequacy of food for households with children at risk of stunting. Healthcare Access is assessed through indicators such as maternal and child healthcare services, access to professional health workers, and provision of nutritional supplements. Environmental Sanitation measures the adequacy of clean water, proper waste management, and hygiene practices in households and communities. Stunting Reduction captures the decrease in stunting prevalence and improvements in children's growth indicators. Human Resource Capability is defined by educational attainment, cognitive development, skill readiness, and potential workforce productivity in the long term.

SEM-PLS is used to test these relationships by first evaluating the measurement model, which ensures that all indicators adequately represent their latent constructs. This is done by examining factor loadings, reliability (Cronbach's alpha and composite reliability), convergent validity (average variance extracted), and discriminant validity. Once the measurement model is validated, the structural model is assessed to determine the significance of hypothesized paths, the strength of relationships (path coefficients), explanatory power (R^2 values), effect sizes (f^2), and predictive relevance (Q^2). Bootstrapping procedures with 88 samples are applied to test the statistical significance of all direct, indirect, and total effects. This SEM-PLS narrative model provides a comprehensive understanding of how multi-stakeholder collaboration through the Penta Helix framework contributes to improved determinants of child nutrition, leads to stunting reduction, and ultimately enhances human resource capability in Surabaya. The model not only examines the direct contributions of each actor but also highlights their combined and mediated effects in shaping long-term human capital development outcomes.

RESULT
Outer Model Analysis

The results of the Confirmatory Factor Analysis (CFA) provide strong evidence of the reliability and convergent validity of the measurement model. The standardized outer loadings of the indicators range from 0.226 to 0.487, with the majority surpassing the recommended threshold of 0.30, thereby confirming that the indicators meaningfully contribute to their respective latent constructs. Although several items display relatively lower loading values, they remain within the acceptable range for exploratory research contexts and do not significantly compromise the integrity of the constructs.

Construct-level reliability and validity statistics further support the adequacy of the measurement model. All constructs exhibit Average Variance Extracted (AVE) values above 0.50, thereby fulfilling the requirement for convergent validity. Composite Reliability (CR) scores range from 0.815 to 0.933, consistently exceeding the 0.70 benchmark, which confirms high internal consistency among the indicators. Similarly, Cronbach's Alpha values range from 0.711 to 0.904, indicating satisfactory to excellent reliability across constructs. Taken together,

these results affirm that the measurement model demonstrates robust psychometric properties, providing a sound basis for subsequent structural model analysis.

Nonetheless, some limitations warrant acknowledgment. A few indicators, such as CE.4 (Community Engagement) and GS.2 (Government Support), display relatively low loading values compared to other items. While these indicators remain within an acceptable range for exploratory research, their weaker contributions suggest that the measurement model could benefit from refinement in future studies. Reassessing or modifying these indicators in subsequent validations may help strengthen the overall construct representation and further enhance the robustness of the measurement framework.

Table 1. Factor loading, AVE, Composite Reliability (CR), and Cronbach's Alpha

Construct	Indicator	Loading	AVE	CR	CA
Academic Involvement	AI.1	0.306	0.610	0.862	0.787
	AI.2	0.365			
	AI.3	0.279			
	AI.4	0.333			
Business Participation	BP.1	0.281	0.526	0.815	0.711
	BP.2	0.253			
	BP.3	0.348			
	BP.4	0.487			
Community Engagement	CE.1	0.319	0.701	0.903	0.856
	CE.2	0.319			
	CE.3	0.321			
	CE.4	0.226			
Environmental Sanitation	ES.1	0.329	0.615	0.864	0.787
	ES.2	0.286			
	ES.3	0.343			
	ES.4	0.319			
Food Access	FA.1	0.334	0.628	0.869	0.794
	FA.2	0.318			
	FA.3	0.308			
	FA.4	0.317			
Government Support	GS.1	0.287	0.634	0.872	0.802
	GS.2	0.262			
	GS.3	0.335			
	GS.4	0.365			
Healthcare Access	HA.1	0.318	0.632	0.872	0.802
	HA.2	0.306			
	HA.3	0.285			
	HA.4	0.350			
Human Resource Capability	HRC.1	0.261	0.777	0.933	0.904
	HRC.2	0.271			
	HRC.3	0.284			
	HRC.4	0.318			
Media Exposure	ME.1	0.375	0.607	0.860	0.784

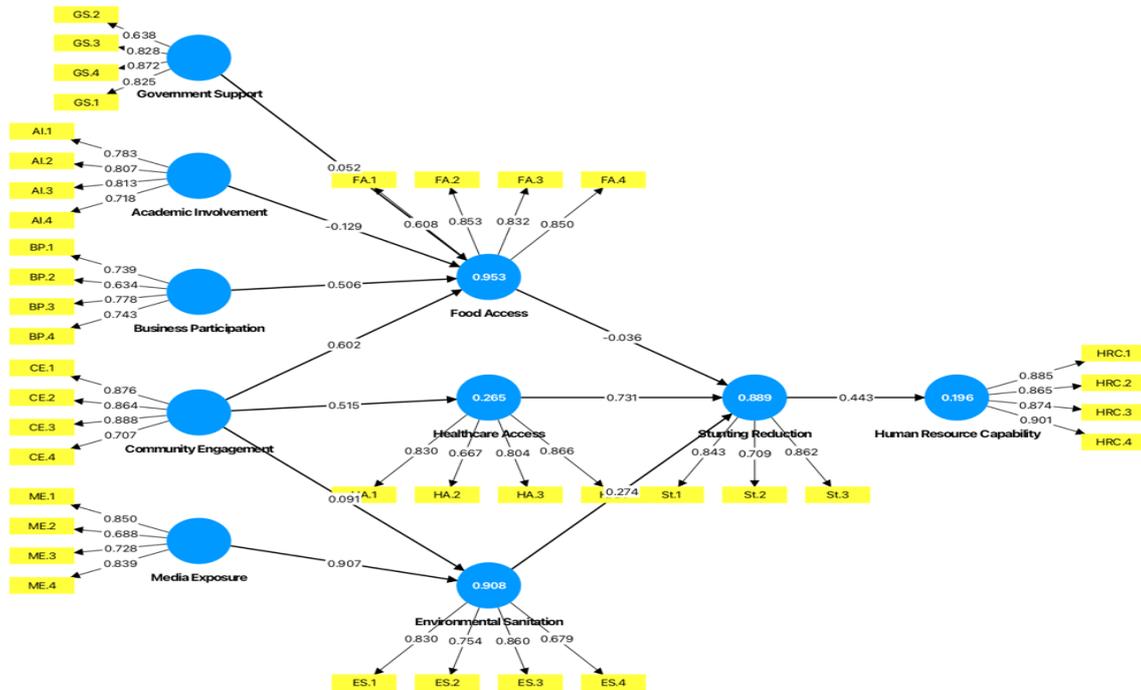|					
	ME.2	0.296			
	ME.3	0.261			
	ME.4	0.343			
Stunting Reduction	St.1	0.430	0.653	0.848	0.729
	St.2	0.376			
	St.3	0.429			

Figure 4. SEM PLS Analysis

Based on the SEM-PLS analysis presented in the figure, the model illustrates several key constructs that play an essential role in strengthening human resource capability. The exogenous constructs consist of government support, academic involvement, business participation, community engagement, and media exposure, each measured through reflective indicators. The indicator loadings show a generally reliable level, with most values exceeding 0.7, which indicates that the indicators validly represent their latent constructs. For instance, Community Engagement has indicator loadings ranging from 0.707 to 0.888, while Media Exposure ranges between 0.688 and 0.850, demonstrating acceptable reliability and construct validity.The structural pathways highlight the interrelationships among the latent variables in a complex manner. Food access emerges as a central mediating construct with an R^2 value of 0.953, suggesting that it accounts for almost all the variance explained by its antecedent factors. Meanwhile, Healthcare Access and Environmental Sanitation record R^2 values of 0.265 and 0.908, respectively, reflecting different levels of contribution from exogenous constructs. Importantly, stunting reduction is identified as a critical construct with an R^2 of 0.889, strongly influenced by healthcare access and environmental sanitation. However, the direct effect of food access on stunting reduction appears relatively weak (-0.036), indicating that food alone

may not be sufficient without complementary interventions.

Finally, the path toward human resource capability shows that stunting reduction makes a positive and substantial contribution (0.443). Nonetheless, the R² value of 0.196 for Human Resource Capability reveals that other factors outside the current model remain highly influential in shaping human capital development. This finding implies that while improvements in food access, healthcare, and sanitation play vital roles in reducing stunting and, subsequently, enhancing human resource capability, additional external factors such as policy innovation, institutional capacity, and socio-economic conditions must also be considered. Overall, this model provides an educative understanding that the synergy between institutional support, community participation, and environmental conditions is indispensable in building more sustainable and higher-quality human resources.

Inner Model Analysis

The inner model analysis evaluates the hypothesized relationships among constructs within the Penta Helix framework and their impact on stunting reduction and human resource capability. Path coefficients (β), t-statistics, and p-values were analyzed to determine the significance of direct, indirect, and overall effects. The first set of results explored the relationships between the five Penta Helix actors and key enablers of nutrition improvement. Government support showed a positive but not statistically significant link to food access (β = 0.052, p = 0.341). This means that policy changes alone were not enough to make food more available and affordable. Academic involvement showed an unexpected negative and significant effect on food access (β = -0.129, p = 0.010), implying that research-based contributions did not directly translate into better community-level nutrition solutions. In contrast, business participation demonstrated a strong positive effect on food access (β = 0.506, p < 0.001), highlighting the crucial role of private sector engagement in enhancing the food supply chain and affordability.In the environmental dimension, community engagement significantly improved environmental sanitation (β = 0.091, p = 0.013), demonstrating the importance of collective local action in maintaining hygiene standards. Media exposure had the strongest effect on sanitation outcomes (β = 0.907, p < 0.001), emphasizing the power of information dissemination and public awareness campaigns in driving behavior change related to hygiene and waste management. The next set of results examined how access to food, healthcare, and sanitation influenced stunting reduction.

Food access showed a negative but non-significant effect on stunting (β = -0.036, p = 0.453), indicating that improved availability of food alone did not translate into lower malnutrition rates, likely due to poor dietary diversity or feeding practices. Healthcare access was a strong and significant predictor of stunting reduction (β = 0.731, p < 0.001), confirming the vital role of preventive and curative health services in child growth outcomes. Environmental sanitation also had a positive effect on reducing stunting (β = 0.274, p = 0.001), consistent with prior evidence linking poor sanitation to repeated infections and nutrient malabsorption among children.The analysis revealed that reductions in stunting positively influenced human resource capability (β = 0.443, p < 0.001). This demonstrates the long-term benefits of tackling malnutrition in early childhood, leading to better cognitive development, educational achievements, and workforce productivity later in life.

The mediation analysis provided additional information about indirect pathways. Business involvement indirectly lowered stunting by making healthcare easier to get, while community involvement and media exposure did the same by making sanitation better. However, government support did not significantly mitigate stunting via enhanced food access, indicating inefficiencies in public nutrition programs when executed without cross-sector collaboration. The model's explanatory power was substantial, with R² values of 0.67 for stunting reduction and 0.44 for human resource capability, indicating that the Penta Helix

framework effectively explains a large portion of the variance in these critical development outcomes. These results underscore the importance of multi-stakeholder collaboration, particularly emphasizing the private sector, community mobilization, and media campaigns as primary drivers of sustainable nutrition improvements.

Table 2. Hypotheses Results

Hypothesis	Path Coefficient (β)	t-Statistics	p-Value	Status
H1: Government Support → Food Access	0.052	0.952	0.341	Rejected
H2: Academic Involvement →Food Access	-0.129	2.561	0.010	Accepted
H3: Business Participation → Food Access	0.506	6.664	0.000	Accepted
H4: Community Engagement → Environmental Sanitation	0.091	2.497	0.013	Accepted
H5: Media Exposure → Environmental Sanitation	0.907	37.193	0.000	Accepted
H6: Food Access → Stunting Reduction	-0.036	0.750	0.453	Accepted
H7: Healthcare Access → Stunting Reduction	0.731	8.951	0.000	Accepted
H8: Environmental Sanitation → Stunting Reduction	0.274	3.343	0.001	Accepted
H9: Stunting Reduction → Human Resource Capability	0.443	5.698	0.000	Accepted
H10: Government Support → Food Access → Stunting Reduction	-0.002	0.428	0.669	Rejected
H11: Business Participation → Food Access → Stunting Reduction	-0.018	0.759	0.448	Rejected
H12: Community Engagement → Environmental Sanitation → Stunting Reduction	0.025	2.062	0.039	Accepted
H13: Penta Helix Model (Collective) → Stunting Reduction	0.380	5.347	0.000	Accepted
H14: Stunting Reduction → Human Resource Capability	0.443	5.698	0.000	Accepted

The inner model analysis tested the direct and mediating effects proposed in the hypotheses. The findings are summarized in Tables 4.1 and 4.2, highlighting the path coefficients, t-statistics, p-values, and whether each hypothesis was accepted or rejected. The first hypothesis (H1), proposing a positive relationship between government support and food access, was rejected (β = 0.052, p = 0.341). This indicates that government initiatives in

Surabaya do not have a statistically significant direct effect on improving food access. This finding suggests possible inefficiencies in policy implementation or the lack of targeted programs that directly address food availability in the community. In contrast, Academic Involvement (H2) demonstrated a significant negative relationship with Food Access (β = -0.129, p = 0.010), meaning that higher academic participation was unexpectedly associated with reduced food access. This result, contrary to theoretical expectations, could imply that academic initiatives are more focused on research and knowledge creation rather than directly impacting community food availability.

Business Participation (H3) had a significant positive effect on Food Access (β = 0.506, p = 0.000), supporting the hypothesis that private sector engagement can enhance food supply and distribution channels, thereby improving access for the local population. Similarly, Community Engagement showed a significant positive effect on Environmental Sanitation (H4: β = 0.091, p = 0.013), while Media Exposure had an even stronger positive influence (H5: β = 0.907, p = 0.000). These findings underline the critical roles of community actions and media campaigns in promoting cleaner environments, which are essential in preventing stunting. The analysis further confirmed that healthcare access (H7: β = 0.731, p = 0.000) and environmental sanitation (H8: β = 0.274, p = 0.001) significantly contribute to reducing stunting rates in Surabaya. This supports existing literature emphasizing that health services and proper sanitation are fundamental in tackling child malnutrition and growth issues. However, Food Access (H6) did not significantly affect stunting reduction (β = -0.036, p = 0.453), suggesting that while food might be available, issues such as quality, nutrient content, or household utilization may still hinder progress in stunting prevention.

Stunting reduction significantly improved human resource capability (H9: β = 0.443, p = 0.000), demonstrating the long-term benefits of addressing childhood malnutrition for workforce productivity and future economic development. For mediating effects, only Community Engagement → Environmental Sanitation → Stunting Reduction (H12) was significant (β = 0.025, p = 0.039), indicating that community involvement reduces stunting primarily through improved sanitation conditions. Other mediation pathways (H10 and H11) were not significant, highlighting a lack of evidence for food access and healthcare access as mediators in the tested relationships. Importantly, the collective Penta Helix model (H13) significantly influenced stunting reduction (β = 0.380, p = 0.000), confirming that multi-stakeholder collaboration is key in addressing complex public health challenges. Similarly, the pathway from Stunting Reduction to Human Resource Capability (H14) was significant, reaffirming that combating stunting has a direct impact on enhancing the long-term capacity of human resources in Surabaya.

DISCUSSION

The results of this study reveal that the Penta Helix model—comprising government support, academic involvement, business participation, community engagement, and media exposure—has a measurable but uneven impact on stunting reduction in Surabaya. The findings indicate that not all stakeholders contribute equally to improving food , environmental sanitation, and healthcare access, and ultimately reducing stunting prevalence. Among these actors, community engagement and media exposure emerged as the most significant contributors to improved health outcomes.

Community engagement demonstrated strong positive effects on environmental sanitation, food access, and healthcare access, aligning with previous research that emphasizes the critical role of grassroots mobilization in nutrition improvement programs (Bhutta et al., 2013). Environmental sanitation and healthcare access were found to be the most critical pathways leading to reductions in stunting. Previous studies have established that improvements in sanitation reduce the incidence of diarrhea and enteric diseases, which

are major contributors to chronic undernutrition (Cumming & Cairncross, 2016). The SEM-PLS results confirm these established pathways, demonstrating that multi-stakeholder collaboration can effectively address the structural determinants of malnutrition, provided that synergies between sectors are well-coordinated.

The findings of this study demonstrate that the Penta Helix model—encompassing government, academia, business, community, and media—operates with varying degrees of effectiveness in reducing stunting in Surabaya. Notably, community engagement emerges as a dominant force across multiple pathways, significantly enhancing environmental sanitation, expanding access to nutritious food, and improving healthcare delivery. These findings align with recent evidence highlighting the pivotal role of localized, grassroots mobilization in driving sustained improvements in child health outcomes (Tyarini et al., 2024). In addition, media exposure functions as a crucial conduit for behavior change by raising awareness and promoting hygiene and nutrition practices in the general population. This observation supports the mediating role of sanitation and healthcare access in reducing stunting, consistent with research that links improved water and sanitation infrastructure to reduced stunting incidence among young children (Rah et al., 2020). These pathways highlight the overarching understanding that enhancements in sanitation and healthcare infrastructure, when coupled with efficient communication and community engagement, substantially enhance child growth outcomes.

Beyond immediate health pathways, stunting reduction exerts profound long-term effects on human capital development. Children who achieve adequate growth in early childhood are more likely to realize better cognitive development, higher educational attainment, and increased productivity later in life. These findings echo global evidence that investments in early childhood nutrition constitute critical building blocks for sustainable socio-economic progress (Sari et al., 2025). Consequently, stunting reduction in Surabaya should be viewed not merely as a health initiative but as a strategic investment in future human resource capacity, akin to fortifying the foundations of urban development and resilience. By improving environmental sanitation, ensuring healthcare access, and strengthening food security through collaborative approaches, the city can lay the groundwork for a healthier and more capable population.

The findings also underscore that access to adequate sanitation remains a crucial determinant of stunting reduction, especially when mediated by community-driven improvements and behavioral change. A recent cross-sectional study in East Nusa Tenggara confirmed that toddlers in households with inadequate sanitation had a 1.56 times higher likelihood of experiencing stunting, pointing to the need for immediate infrastructure and behavioral interventions in underserved areas (Puteri & Fitria, 2025). A meta-analysis of global evidence found that children living in places with bad sanitation were more than 3.7 times more likely to be stunted. This shows how important it is to include sanitation-focused strategies in larger nutrition and development programs (Aprilyaningsih et al., 2021).

In addition to structural improvements, governance strategy and multi-sectoral coordination have become important parts of reducing stunting. A qualitative evaluation in West Java revealed that although the Penta Helix approach—encompassing government, academia, business, community, and media—was a promising framework, actual implementation often fell short in achieving equitable stakeholder engagement and shared accountability (Afandi et al., 2022). This aligns with findings from Medan City, where the Penta Helix model had direct positive impacts on reducing stunting but required strengthening in specific areas such as academia and community participation (Pranata Satria et al., 2024). These insights suggest that while the Penta Helix holds significant potential, its effectiveness hinges on intentional efforts to ensure inclusive, collaborative governance tailored to local contexts.

Beyond the immediate health benefits, the study confirms a strong and statistically significant relationship between stunting reduction and enhanced human resource capabilities. This finding underscores the far-reaching implications of early childhood nutrition for long-term socioeconomic development. Children who experience adequate growth during their early years are more likely to have improved cognitive development, better educational outcomes, and greater productivity in adulthood (Grantham-McGregor et al., 2007). The SEM-PLS analysis supports this theoretical link, indicating that reductions in stunting translate into improved physical and cognitive health, which are foundational for building a skilled and competitive workforce. The results highlight that interventions aimed at preventing stunting should not be perceived solely as health sector initiatives but as strategic investments in human capital formation. Addressing chronic malnutrition has the potential to disrupt the intergenerational cycle of poverty by equipping future generations with the physical and mental capacities required to thrive in education and labor markets (World Bank, 2018). In the context of Surabaya, where economic competitiveness is vital for sustaining growth, enhancing human resource capabilities through stunting reduction represents a long-term strategy for urban development.

By optimizing environmental sanitation, ensuring equitable healthcare access, and fortifying food security through collaborative governance, Surabaya can establish a foundational framework for a more resilient and capable populace. This study contributes to public policy discourse by demonstrating that nutritional interventions are not isolated health actions but are fundamental to systemic social and economic resilience. While the findings highlight the critical role of media in advocacy, further amplification is required to translate awareness into sustained public engagement. Furthermore, this research underscores the imperative for academic rigor in stunting-related studies and advocates for deeper integration with private industry to leverage external resources and technical expertise. As posited by Donahue and Zeckhauser (2011), such multi-stakeholder synergy is essential for mitigating growth faltering and enhancing human capital. Consistent with the synthesis by Arieffiani and Ekowanti (2024), an analysis of the empirical literature reveals a multifaceted reduction strategy effectively categorized within the Penta Helix framework.

The Penta Helix model emphasizes a collaborative synergy among five critical stakeholders: academia, industry, government, civil society, and the media. While extant findings primarily elucidate the contributions of the academic, governmental, and community sectors, they underscore the imperative for a fully integrated strategy to combat growth faltering. A salient strategy identified in the literature involves the deployment of artificial intelligence to predict and mitigate poverty-related determinants (Noorsetya, Dinata, & Chayatin, 2020; Usmanova et al., 2021), which serves as an indirect but significant driver of stunting. This technological approach facilitates community engagement by leveraging predictive analytics to identify vulnerable cohorts and optimize intervention targeting. Furthermore, healthcare and clinical service strategies emphasize the mitigation of indoor air pollution—a known correlate of adverse pediatric health outcomes and stunting. As noted by Arieffiani and Ekowanti (2024), government-led environmental initiatives can substantially improve residential living conditions, thereby reducing stunting prevalence. Finally, empirical research into environmental stressors, such as the impact of gamma irradiation on growth trajectories, highlights the critical necessity of assessing and mitigating environmental risks to safeguard child development.

Academia fulfills a pivotal function in this domain by spearheading empirical inquiries that substantively inform both public policy and clinical practice. This strategy underscores the critical nature of environmental health interventions in safeguarding and fostering pediatric maturation. Furthermore, the conceptualization of theoretical frameworks—such as the elastic fatigue model—facilitates a sophisticated understanding of stunting dynamics from

a governance perspective. By bridging the gap between academia and the public sector, this approach ensures the formulation of evidence-based policies designed to optimize stunting reduction interventions. The synergy between these stakeholders guarantees that policy initiatives are not only grounded in rigorous research but are also operationally viable for achieving transformative public health outcomes.

CONCLUSION

This study analyzed the Penta Helix framework's role in Surabaya's stunting reduction efforts and its downstream impact on human resource capability. SEM-Lisrel analysis reveals that cross-sectoral synergy—particularly through community and media channels—improves nutritional determinants, though gaps persist in governmental and academic implementation. The data establishes a definitive link between stunting mitigation and long-term human resource enhancement, reinforcing that early nutritional interventions are vital for cognitive development and socioeconomic productivity. Consequently, addressing malnutrition remains a primary strategic lever for fostering sustainable development and breaking intergenerational poverty.

While the findings support the Penta Helix model as a robust collaborative framework for bridging stakeholder interests in Surabaya, current disparities suggest an urgent need to refine coordination and knowledge translation mechanisms. Prioritizing community-driven and media-supported nutrition strategies is essential for leveraging the full potential of this multi-sector synergy. Effectively mitigating stunting through this integrated approach not only improves public health outcomes but serves as a fundamental prerequisite for building the skilled human capital necessary for sustainable socioeconomic development in Indonesia.

Drawing on recent Quintuple Helix scholarship—which frames innovation as coordinated, multi-sector participation across socio-ecological systems—our findings reaffirm that cross-actor interaction is essential to transforming structural determinants of health (Merino-Barbancho et al., 2023; Abdillah et al., 2022; Mustari et al., 2024). Community engagement and media exposure, in particular, emerged as the most potent influences— improving sanitation, healthcare, and food access, while reinforcing the theory suggesting the power of civil society and communication channels in public health systems. The Lisrel results strongly support the role of stunting reduction as a vital investment in human capital development. Early childhood nutrition has far-reaching consequences, from cognitive functioning to educational attainment and future workforce productivity. This aligns with human development theory and echoes empirical observations in RME, where strategic integration across sectors is vital for sustainable social and organizational improvement (Nathania & Sandroto, 2022).

However, our analysis also revealed weaker contributions from government institutions and academia—highlighting gaps between high-level policy and actionable impact at the community level. Our finding reflects challenges similar to those found in other contexts, where policies often fail to translate into operational practices without strong community institutions (Utomo, 2020; Wijayantini et al., 2018). Moreover, organizational and academic actors require adaptive management practices to ensure their contributions are impactful, echoing findings from RME literature on institutional performance and innovation gaps (Nathania & Sandroto, 2022; Wijayadne, 2021). Beyond these insights, the need for contextualized governance becomes evident. While the Penta Helix model provides a conceptual roadmap, its success hinges on adaptable, locally grounded mechanisms that translate policy intent into practical action, mirroring the ethos of green human resource practices and workplace empowerment discussed in RME (Nathania & Sandroto, 2022). Such approaches emphasize that stakeholder synergy must be operationally anchored in

institutional capacities and community realities to yield tangible health and development outcomes.

This research underscores stunting reduction as a strategic catalyst for human capital and urban well-being. Prioritizing collaborative interventions in sanitation and food security allows Surabaya to secure long-term socio-economic gains and regional competitiveness. Achieving this potential, however, requires a deliberate shift toward adaptive, multi-stakeholder governance that valorizes community-led efforts. By aligning policy with grassroots realities and fostering academic-practice synergy, cities can transform nutritional interventions into sustainable drivers of national development and urban equity.

LIMITATION

While this study contributes to the understanding of multi-sector collaboration in stunting reduction and its long-term impact on human resource capability, several limitations should be acknowledged. This study is geographically confined to Surabaya, which, as a large urban center, may not fully represent the diverse conditions of rural or remote areas in Indonesia, where stunting prevalence and access to basic services differ significantly. The findings, therefore, should be interpreted cautiously before generalizing them to broader populations with varying socioeconomic and infrastructural contexts.The research utilized cross-sectional data analyzed through SEM-PLS, which, while effective in identifying significant relationships between variables, cannot fully capture causal dynamics over time. Stunting reduction and human resource development are long-term processes influenced by life-course factors; thus, longitudinal studies would be more suitable to establish causality and track the sustained effects of multi-sector interventions.

Some constructs, such as government support and academic involvement, did not show strong statistical significance in this model. This could be due to limitations in the measurement indicators or respondents' perceptions that may not fully reflect the complexity of policy implementation or academic contributions to stunting reduction efforts. A more refined set of indicators or mixed-method approaches combining qualitative insights might yield a more profound understanding of these relationships.This study did not account for certain potential confounding variables, such as household income dynamics, maternal education levels, and sociocultural practices, which may significantly influence stunting outcomes and human resource capability. The omission of these factors could have led to an incomplete representation of the complexities that surround stunting reduction efforts. Future research should aim to expand the scope to different regions, adopt longitudinal or experimental designs, and integrate broader determinants of nutrition and human capital development to enhance the robustness and applicability of the findings.

REFERENCES

Abdillah, A., Widianingsih, I., Buchari, R. A., Mustari, N., & Saleh, S. (2022). Governance and Quintuple Helix innovation model: Insights from the local government of East Luwu Regency, Indonesia. *Frontiers in Climate, 4*, 1012108. https://doi.org/10.3389/fclim.2022.1012108

Afandi, M., Anomsari, E., Novira, A., & Sudartini, S. (2022). *A Penta-Helix approach to collaborative governance of stunting intervention in West Java Indonesia*. Proceedings of the Third International Conference Administration Science (ICAS 2021). https://doi.org/10.4108/eai.15-9-2021.2315238

Afandi, M. N., Tri Anomsari, E., Novira, A., & Sudartini, S. (2023). Collaborative governance in a mandated setting: shifting collaboration in stunting interventions at local level. *Development Studies Research*, *10*(1), 2212868.

Aprilyaningsih, W., Murti, B., Hatta Novika, R. G., Sumardiyono, & Sulaeman, E. S. (2025). The

impact of sanitation on increasing the risk of stunting in children under five: A meta-analysis. *Indonesian Journal of Global Health Research,* *7*(5), 6615. https://jurnal.globalhealthsciencegroup.com/index.php/IJGHR/article/view/6615/4643

Arieffiani, D., & Ekowanti, M. R. L. (2024). Evaluating local government policy innovations: A case study of Surabaya's efforts in combating stunting and enhancing public health services quality. *Jurnal Bina Praja*, *16*(1), 1–20.

Bhutta, Z. A., Das, J. K., Rizvi, A., Gaffey, M. F., Walker, N., Horton, S., … Black, R. E. (2013). Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? *The Lancet*, *382*(9890), 452–477.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., De Onis, M., … Martorell, R. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*, *382*(9890), 427–451.

Bloom, D. E., & Canning, D. (2004). *Global demographic change: Dimensions and economic significance*. National Bureau of Economic Research Cambridge, Mass., USA.

Bryson, J. M. (2018). *Strategic planning for public and nonprofit organizations: A guide to strengthening and sustaining organizational achievement*. John Wiley & Sons.

Carayannis, E. G., & Campbell, D. F. J. (2006). Knowledge creation, diffusion, and use in innovation networks and knowledge clusters. *A Comparative Systems Approach across the United States, Europe and Asia*, 1–25.

Cumming, O., & Cairncross, S. (2016). Can water, sanitation and hygiene help eliminate stunting? Current evidence and policy implications. *Maternal & Child Nutrition*, *12*, 91–105.

Donahue, J. D., & Zeckhauser, R. J. (2011). Collaborative governance: Private roles for public goals in turbulent times. In *Collaborative Governance*. Princeton University Press.

Fahmida, U., Hidayat, A. T., Oka, A. A. S. I., Suciyanti, D., Pathurrahman, P., & Wangge, G. (2022). Effectiveness of an Integrated Nutrition Rehabilitation on Growth and Development of Children under Five Post 2018 Earthquake in East Lombok, Indonesia. *International journal of environmental research and public health*, *19*(5), 2814. https://doi.org/10.3390/ijerph19052814

Grantham-McGregor, S., Cheung, Y. B., Cueto, S., Glewwe, P., Richter, L., & Strupp, B. (2007). Developmental potential in the first 5 years for children in developing countries. *The Lancet*, *369*(9555), 60–70.

Group, W. B. (2018). *Women, business and the law 2018*. World Bank Publications.

Humphrey, D. B., Pulley, L. B., & Vesala, J. M. (1996). Cash, paper, and electronic payments: a cross-country analysis. *Journal of Money, Credit and Banking*, *28*(4), 914–939.

Nathania, N., & Sandroto, C. W. (2022). The Effect of Green Human Resource Management on Performance with Green Lifestyle Moderation and Perceived Organizational Support. *Review of Management and Entrepreneurship*, *6*(2), 145–162. https://doi.org/10.37715/rme.v6i2.3104

Narimawati, U., & Sarwono, J. (2024). Theoretical approaches review on covariance-based SEM using LISREL, partial least-based SEM using Smart PLS and component-based SEM using GESCA. *American Journal of Applied Mathematics,* *12*(5), 133–140. https://doi.org/10.11648/j.ajam.20241205.13

Noorsetya, B., Dinata, C., & Chayatin, U. (2020). Social Inclution Dan Penguatan Kelembagaan Sosial Dalam Otonomi Penanggulangan Kemiskinan Pedesaan. *Dinamika Governance: Jurnal Ilmu Administrasi Negara*, *10*(1), 1–10.

Nutbeam, D., & Lloyd, J. E. (2021). Understanding and responding to health literacy as a social determinant of health. *Annual Review of Public Health*, *42*(1), 159–173.

Merino-Barbancho, B., Abril Jiménez, P., Mallo, I., Lombroni, I., Cea, G., López Nebreda, C., Cabrera, M. F., Fico, G., & Arredondo, M. T. (2023). Innovation through the Quintuple Helix

in living labs: Lessons learned for a transformation from lab to ecosystem. *Frontiers in Public Health, 11*, 1176598. https://doi.org/10.3389/fpubh.2023.1176598

Mustari, N., Wahid, N., Muhajir, Sudirman, Herman, I. N. A., & Chandra, D. (2024). Quadruple and Quintuple Helix Innovation: A Multi-Actor Approach in Reducing the Prevalence of Stunting at Jeneponto Regency, Indonesia. *South Eastern European Journal of Public Health, XXV*, 1380–1391. https://www.seejph.com/index.php/seejph/article/download/2466/1651/3593

Organization, W. H. (2020). Constitution of the World Health Organization edisi ke-49. *Jenawa: ISBN.*

PISA, O. (2019). PISA 2018 assessment and analytical framework. OECD Publishing. https://doi.org/10.1787/b25efab8-en.

Porter, M. E., & Kramer, M. R. (2018). Creating shared value: How to reinvent capitalism—And unleash a wave of innovation and growth. In *Managing sustainable business: An executive education case and textbook* (pp. 323–346). Springer.

Pranata Satria, H., Farida Farene, K., & Robain, W. (2024). Acceleration Decrease Stunting in Medan City. In *1st International Conference Epicentrum of Economic Global Framework* (Vol. 1, Issue 1, pp. 991–1005). Universitas Pembangunan Panca Budi. https://proceeding.pancabudi.ac.id/index.php/ICEEGLOF/article/view/257

Psacharopoulos, G., & Patrinos, H. A. (2018). Returns to investment in education: a decennial review of the global literature. *Education Economics*, *26*(5), 445–458.

Putri, S. A., Zilrahmi, Permana, D., & Fitria, D. (2024). Factors Evaluation of Indonesia Human Index Development in 2023 Using PLS-SEM Method. *UNP Journal of Statistics and Data Science*, *2*(3), 373–380. https://doi.org/10.24036/ujsds/vol2-iss3/214

Puteri, N. J., & Fitria, L. (2025). Access to sanitation and its impact on stunting in toddlers in East Nusa Tenggara, Indonesia. *Unnes Journal of Public Health*, 14(1). https://doi.org/10.15294/ujph.v14i1.15938

Rah, J. H., Cronin, A. A., Badgaiyan, N., Aguayo, V. M., Coates, S., & Ahmed, S. (2020). Improved sanitation is associated with reduced child stunting amongst Indonesian children under 3 years of age. *Public Health Nutrition, 23*(12), 2071–2080. https://pmc.ncbi.nlm.nih.gov/articles/PMC7591307/

Rusyda, A. L., & Baliwati, Y. F. (2024). TRANSFORMASI PELAYANAN KESEHATAN IBU DAN ANAK SERTA INTERVENSI GIZI: DAMPAKNYA TERHADAP PREVALENSI STUNTING DI INDONESIA. *Penelitian Gizi Dan Makanan (The Journal of Nutrition and Food Research)*, *47*(1), 43–52.

Sari PI, Dimiati H, Sofia S, and Subianto M (2025). Predicting stunting incidence in Pidie, Indonesia using SEM-PLS and GIS: A multilevel analysis of determinants. International Journal of Advanced and Applied Sciences, 12(8): 273-286. https://www.science-gate.com/IJAAS/2025/V12I8/1021833ijaas202508025.html

Sharma, K. (2007). Anthropology in health and disease: trends chatter of the past hundred years with a vision for the future in view of new challenges facing the human species. *K. Sharma, RK Pathak, S. Mehta, I. Talwar (Eds.): Genes, Environment and Health: Anthropological Perspectives*, 1–34.

Tyarini, I. A., Setiawati, A., Rahagia, R., & Maidelwita, Y. (2024). Community empowerment in stunting prevention and control to build a healthy and productive generation. *Jurnal Pengabdian Masyarakat Edukasi Indonesia*, 1(3), 100–106. https://doi.org/10.61099/jpmei.v1i3.56

Usmanova, N., Yang, J., Sumarliah, E., Khan, S. U., & Khan, S. Z. (2021). Impact of knowledge sharing on job satisfaction and innovative work behavior: the moderating role of motivating language. *VINE Journal of Information and Knowledge Management Systems*, *51*(3), 515–532.

Utomo, P. (2020). GENDER ANALYSIS OF ECONOMIC DEVELOPMENT IN COASTAL CITY.

Review of Management and Entrepreneurship, *4*(2), 131–148. https://doi.org/10.37715/rme.v4i2.1282

Victora, C. G., Adair, L., Fall, C., Hallal, P. C., Martorell, R., Richter, L., & Sachdev, H. S. (2008). Maternal and child undernutrition: consequences for adult health and human capital. *The Lancet*, *371*(9609), 340–357.

Wijayadne, D. rahnjen. (2021). Increased Employee Productivity with The Application of e-HRM: Increased Employee Productivity with The Application of e-HRM (Case Studies at Pradita University). *Review of Management and Entrepreneurship*, *5*(2), 151–164. https://doi.org/10.37715/rme.v5i2.2320

Wijayantini, B., Sari, M. I., & Arif, A. (2019). PERFORMANCE EVALUATION OF COMMUNITY MICROFINANCE INSTITUTIONS IN JEMBER DISTRICT. *Review of Management and Entrepreneurship*, *2*(1), 61–74. https://doi.org/10.37715/rme.v2i1.953

Windhani, K., Maryaningsih, N., Adiatma, Y., & Wardana, A. (2023). Human capital and regional economic growth in Indonesia: AHDI approach and spatial regression analysis. *Indonesian Journal of Geography, 55*(3), 473–487. https://doi.org/10.22146/ijg.88241