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Examining the Joint Effects of Air Quality, Socioeconomic Factors on Indonesian Health

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Abstract

This study addresses the pressing need to comprehensively manage air pollution by examining the roles of local and national public agencies from the perspective of the general public. Air quality poses a critical challenge that profoundly impacts various aspects of human life. To enhance our understanding and generate both theoretical and practical insights for public management, this research introduces several key variables: the engagement of authorities in mitigating air pollution, citizen involvement in pollution reduction efforts, financial incentives for individuals and businesses to adopt air-friendly behaviors, urban green investments, the communal consequences of air pollution, and the necessity for industrial participation. Employing Partial Least Squares Structural Equation Modeling (PLS-SEM) as the research approach, data was gathered from residents of Indonesia's largest cities, where pollution significantly affects society and governing bodies. The findings are pertinent for public managers at both local and national levels, providing valuable input to enhance strategies for curbing air pollution, enhancing air quality, and ultimately improving the well-being of inhabitants.

Keywords: *Air pollution, Public management, Involvement, Incentives*

1. Introduction

Indonesia is grappling with an increasingly urgent challenge – air pollution, fueled by rapid urbanization, industrialization, and recent economic growth [1]. This complex issue gained attention in 2010 when projections indicated that by 2015, air pollution would result in staggering economic losses of 1.4 trillion dollars and a tragic toll of 1.6 million lives [2]. Moreover, a significant portion of Indonesia's population, spending approximately 83.3% of their time indoors, faces this concern head-on. Homes, workplaces, schools, child care facilities, and communal spaces constitute the modern Indonesia's environment, with homes accounting for about 67% of indoor hours – a percentage that surged due to the recent

outbreak of coronavirus pneumonia. The quality of indoor air within residential structures significantly influences the health and well-being of occupants.

Advancements in scientific understanding over the past decades have illuminated the profound impact of indoor air quality on human health [3]. Research efforts have been devoted to identifying sources, exposures, and health outcomes related to indoor air pollution, encompassing pollutants like ozone, formaldehyde, radon, cigarette smoke, volatile organic compounds (VOCs), pesticides, and semi-volatile organic compounds (SVOCs). Recent studies have also shed light on the role of socioeconomic factors – income, education, and employment – in shaping the nexus between indoor air quality and occupant health. Notably, these factors directly modulate exposure to indoor air pollutants. Families with limited incomes, for instance, often reside in aging structures with subpar materials, leading to elevated indoor pollution levels [4]. Overcrowded housing, often linked to low household incomes, is also associated with heightened indoor pollution. Education's role in promoting awareness about building maintenance, personal hygiene, and proper usage of indoor products further underscores its influence on indoor air exposure [5]. However, the determinants of health are intrinsically linked to socioeconomic attributes such as income, education, and occupation. A wealth of data consistently indicates that individuals with higher income and education levels generally experience better health outcomes. These socioeconomic variables also impact access to essential resources like nutrition and healthcare, playing a pivotal role in the overall health equation.

The interconnections between indoor air quality, health, and socioeconomic factors within housing create intricate relationships. However, scant research has explored the collective impact of residential indoor air quality and socioeconomic variables on occupant health. Multiple indoor air pollution exposures concurrently occur within homes, leading to diverse negative health consequences. [6]. The multifaceted nature of socioeconomic attributes, including income, education, and employment status, poses challenges in quantification and assessment. Conventional regression-based models offer only limited insights into this complexity. For instance employed multivariate regression to probe the link between socioeconomic variables and indoor pollutant levels in French households. Various statistical models have been employed by researchers to unravel the associations among indoor air quality, socioeconomic status, and health outcomes. Examples include the utilization of a multivariate Poisson regression model to evaluate the nexus between socioeconomic status, indoor air pollution, and respiratory issues in South India. In Germany, a quantile regression model was developed to scrutinize the relationship between occupants' education and indoor concentrations of volatile organic compounds. Similarly, in Korea, a general linear model was deployed to gauge the impact of socioeconomic variables on indoor PM10 concentrations [7]. However, these models possess limitations as they primarily capture the relationship between a singular dependent variable and multiple independent variables. Furthermore, the presence of multicollinearity, often stemming from significant associations between socioeconomic indices or indoor air quality indicators, can lead to inaccurate model estimates. Structural Equation Modeling (SEM) methodology has been employed to discern the most influential indoor environmental factors on occupant well-being, assess the interplay between student perceptions of teacher-student relationships and classroom enthusiasm, and address indoor air quality concerns within educational institutions. Thus, the objective of this study is to explore the holistic impact of indoor air quality and socioeconomic aspects on health through the application of SEM, utilizing field measurement data from China's Northeast region. This endeavor aspires to offer a comprehensive comprehension of how indoor air pollution affects health, thereby contributing to the effective management of indoor air quality [8].

2. Research Method

This research uses a mixed methods study that combines quantitative and qualitative approaches to analyze the health impacts of indoor air quality and socioeconomic factors in Indonesia, taking into account their combined effects. The variables that are the focus of this

research are Health impacts (HI), Indoor air quality perception (IKUP), Socioeconomic factors (SF), and Geographical factors (GF) [9].

2.1 Quantitative approach

Quantitative approach involves collecting quantitative data from secondary data sources, such as public health data, air pollution data, and socio-economic data from related institutions and agencies. These data will be used to carry out statistical analysis and identify the relationship between indoor air quality, socioeconomic factors, and health impacts in Indonesia. Statistical analysis methods that will be used include linear regression and multivariate analysis [10].

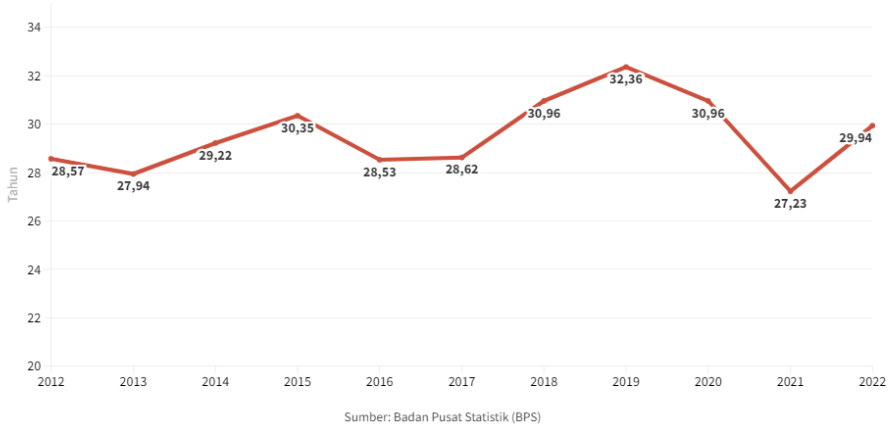

Figure 1. Indonesian Population Health Data from 2012-2022

Based on data from the Central Statistics Agency (BPS), in 2022 it was recorded that 29.94% of Indonesia's population experienced health complaints in the past month. This percentage has increased compared to the previous year which amounted to 27.23%.Interestingly, the percentage of the population experiencing health complaints actually decreased in 2020 and 2021, even though at that time there was an increase in Covid-19 cases in the country [11]. When viewed from a provincial perspective, Aceh has the highest percentage of people with health complaints in Indonesia in 2022, namely 32.91%. Meanwhile, West Nusa Tenggara is in second place with a percentage of the population experiencing health complaints of 43.62%.Furthermore, the percentage of residents with health complaints in the last month in Gorontalo and Yogyakarta were 35.85% and 35.73%, respectively. In Central Java, it was recorded that 35.34% of the population experienced health complaints in the last month of this year.On the other hand, Papua province has the lowest percentage of the population in terms of health complaints, namely 11.68%. Maluku and North Maluku are above it with the percentage of population experiencing health complaints, respectively 15.6% and 16.41% [12].

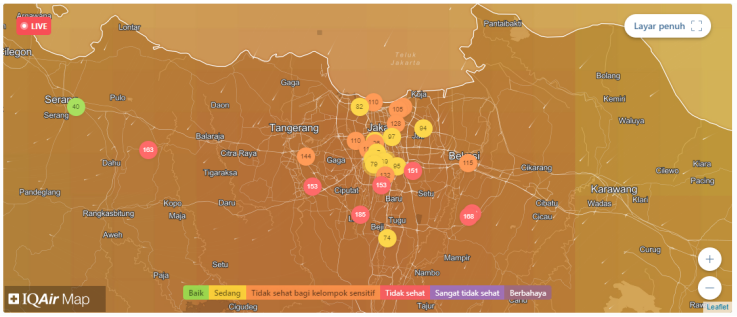

Figure 2. Tangerang Live Air Quality Data

From Figure 2, the live air quality data for Tangerang explains that the current air condition is far from healthy or good, especially for the Tangerang area. Therefore, this research is needed to improve air quality in order to improve health in all communities.

2.2 Quantitative approach

Qualitative approach involves collecting data through in-depth interviews, observations, and surveys aimed at selected respondents. Qualitative data will be used to understand people's perceptions of indoor air quality and socioeconomic factors that affect health. Qualitative analysis will be carried out using a thematic approach and content analysis to explore patterns of findings and identify relevant socio-economic and geographical factors [13].

Table 1. Sample Characteristics

	Factor	Frequency	Percentage
Gender	Male	161	46%
	Female	189	54%
Age	15 - 20 year	88	25%
	21 - 30 year	157	45%
	> 30 year	105	30%
City	Tangerang	262	75%
	Malaysia	4	1%
	Denpasar	18	5%
	Jakarta	66	19%

By combining quantitative and qualitative approaches, this research aims to provide a comprehensive understanding of the health impacts of indoor air quality and socioeconomic factors in Indonesia, by considering their combined effects and the role of HI, IKUP, SF, and GF in that context [14].

2.3 Partial Least Square

This research method uses the Structural Equation Modeling (SEM) approach by utilizing the SmartPLS model. The study was conducted to analyze the health impacts of indoor air quality and socio-economic factors in Indonesia and investigate their combined effects [15]. Data collection was carried out through a survey of respondents involving variables such as indoor air quality, socioeconomic factors, and health indicators. Furthermore, the collected data will be analyzed using SmartPLS to model the relationship between these variables and measure the strength of their influence. The SmartPLS model will enable researchers to simultaneously analyze the direct and indirect effects of these variables on health impacts, as well as identify the most significant factors influencing indoor air quality and public health in Indonesia [16].

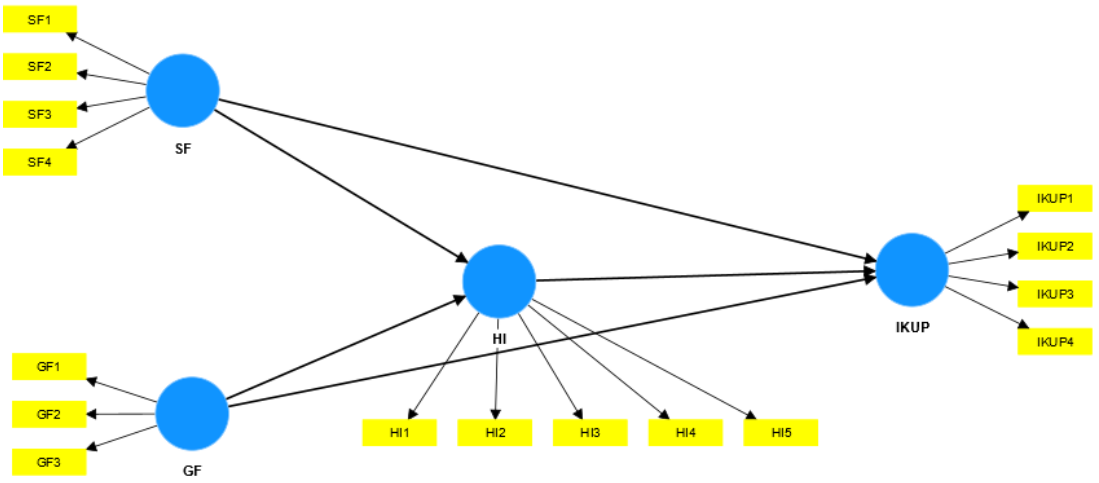

Figure 3. Research Model

2.4 Literature Review

There are 5 (five) previous studies that discuss the health impacts of indoor air quality and socio-economic factors in Indonesia, this previous research serves as a reference for this research in knowing the development of indoor air quality including: The first study aims to explain the impact of indoor air pollution on pneumoniae cases. This study uses the method of reviewing the literature from several journals [17]. The data used are the results of previous studies that have been published in journals. Indoor air pollution consists of dust (PM10, PM2.5), dirt or gasses (CO, NO and SO) in the air in buildings such as homes or workplaces which can be harmful to health if inhaled. Pneumonia is the leading cause of infectious death in children worldwide and indoor air pollution can increase the risk of developing pneumonia [18]. The results showed that improving indoor air quality by controlling sources to avoid indoor and outdoor emissions, providing adequate ventilation, and air cleaning technology can be prioritized to prevent the occurrence of pneumonia cases and other health problems. Indoor air pollution resulting from unclean fuels and human activities must be reduced or completely eliminated to improve human health. The second study aims to analyze the impact of using cooking fuel on indoor air quality and the health conditions of household members. The method used is data analysis from the Indonesian Family Life Survey (IFLS) 5 with the instrument variable method. This study used a quantitative approach and the data collected was analyzed using regression analysis. The results showed that the use of cooking fuels in the room has a negative impact on human health, especially in cough, fever and diarrhea in individuals aged 21 years and over [19].

This research provides important implications for increasing public awareness of the dangers of indoor air pollution and the importance of using more environmentally friendly fuels. The third assessment aims to investigate the effect of Islamic banking financing on the Air Quality Index at the provincial level in Indonesia in the 2011-2018 period. The method used is a quantitative approach with panel data regression analysis techniques, and the data used is secondary data from the Ministry of Environment and Forestry, BPS, BPH Migas, and OJK covering 33 provinces in Indonesia. The results of the study show that simultaneously Islamic banking financing, conventional bank credit, energy consumption, Manufacturing GRDP, population, and area of forest and land fires have a significant effect on the Indonesian provincial Air Quality Index in 2011-2018. Meanwhile, sharia banking financing has a negative but not significant relationship to the Air Quality Index because the market share is still small and OJK supervision tends to be lax. Conventional bank credit and energy consumption have

a significant negative effect on the Air Quality Index, while population has a significant positive effect on the Air Quality Index. The GRDP of the Manufacturing Industry has a positive but not significant relationship to the Air Quality Index, while the extent of forest and land fires has a negative but not significant relationship to the Air Quality Index.

The fourth study aims to analyze human and natural efforts to reduce air pollution levels, by applying the method to the Tambora Tree House, so that it can become an early example for the process of returning clean air to cities [20]. The method used in this study is an analysis of human and natural efforts to reduce air pollution levels by applying the method to the Tambora Tree House. The results of the study show that the Tambora Tree House can be an early example in efforts to restore clean air in urban areas. By applying the method to the Tambora Tree House, the level of air pollution can be reduced to the maximum so that the people around the site can feel it directly by feeling the airflow coming out of the site. This research provides important implications in efforts to reduce the negative impact of air pollution on human health and the environment [21]. The fifth study aims to examine the relationship between factors of education, socioeconomic status, and environmental health. The method used is a survey by taking population samples from people living in various areas with different levels of education and socioeconomic status.

Data were collected through questionnaires and analyzed using statistical techniques. The results of the study show that educational factors and socio-economic status affect the environmental health of the community. Families with higher education and better socioeconomic status tend to be more aware of environmental problems and have better environmental quality. Factors related to work and household also affect individual environmental literacy. Therefore, this article concludes that the level of education and socio-economic status have a significant effect on the environmental health of the community. The conclusion is that there are five previous studies that are used as references in this study, which discuss the impact of indoor air pollution on pneumonia cases, the impact of using cooking fuel on indoor air quality and human health, the effect of Islamic banking financing on air quality at the provincial level, and analysis of human and natural efforts to reduce air pollution levels. The results of this study show that improving indoor air quality can help prevent the occurrence of pneumonia cases and other health problems, as well as the importance of using more environmentally friendly fuels and reducing the use of fossil energy [22].

2.5 Hypotheses

2.5.1 H1: Health impacts have a significant effect on indoor air quality perception.

It posits that the extent to which health is affected by indoor air quality significantly influences how people perceive the air they breathe in indoor environments. In simpler terms, if indoor air quality has noticeable effects on individuals' health, it is likely that they will be more attuned to and concerned about the quality of the air around them. For example, if poor indoor air quality leads to respiratory problems or discomfort, individuals are more likely to perceive the air as being of lower quality. Conversely, if indoor air quality has minimal negative effects on health, individuals might not be as sensitive to variations in air quality. Therefore, this hypothesis suggests that there is a psychological and cognitive link between health impacts and the perception of indoor air quality, wherein personal health experiences play a crucial role in shaping one's subjective evaluation of the air they are exposed to indoors.

2.5.2 H2: Socioeconomic factors have a significant influence on Health impacts.

It asserts that various socioeconomic variables possess the capacity to exert a noteworthy influence on the extent to which health is affected. Socioeconomic factors

encompass a wide range of variables, such as income levels, educational attainment, employment status, and access to healthcare services. The hypothesis suggests that individuals with higher socioeconomic status might have better resources and opportunities to mitigate health risks, leading to potentially lower health impacts. Conversely, those with lower socioeconomic status might face greater challenges in accessing quality healthcare, living in environments with increased pollution levels, and encountering limited health-promoting resources. Consequently, their health could be more susceptible to negative impacts. This hypothesis thus highlights the significant role that social and economic factors play in shaping the health outcomes of individuals, implying that addressing socioeconomic disparities could potentially lead to improved overall health and well-being across different segments of the population.

2.5.3 H3: Geographical factors have a significant influence on Health impacts.

It proposes that the geographic context, encompassing variables such as climate, air quality, and local environmental conditions, significantly affects the health outcomes of individuals. Different regions might experience varying levels of pollution, exposure to allergens, and climate-related challenges, all of which can have direct and indirect effects on health. For instance, areas with higher levels of air pollution or extreme climate conditions could expose residents to greater health risks, including respiratory issues and heat-related illnesses. Conversely, regions with cleaner air and milder climates might contribute to better overall health outcomes. This hypothesis underscores the importance of recognizing that health impacts are not solely influenced by individual behavior or socioeconomic factors but are also intricately tied to the geographic context in which individuals reside. By acknowledging the role of geographical factors, policymakers and researchers can develop targeted interventions and strategies to address region-specific health challenges and create healthier environments for residents.

2.5.4 H4: Socioeconomic factors have a significant effect on indoor air quality perception.

It suggests that various socioeconomic elements play a pivotal role in shaping how people subjectively assess the quality of air within indoor environments. Socioeconomic factors can encompass income levels, education, occupation, and access to resources. The hypothesis posits that individuals with higher socioeconomic status might be more attuned to environmental quality and have the means to ensure better indoor air quality, possibly due to their ability to afford air purifiers, well-maintained ventilation systems, and living spaces in less polluted areas. On the other hand, individuals with lower socioeconomic status might face challenges in accessing such resources and might be more exposed to indoor air pollutants. As a result, their perception of indoor air quality might be more negatively impacted. This hypothesis underscores the interconnectedness of social and economic factors with how people perceive their indoor environments, and it implies that addressing socioeconomic disparities could lead to improved perceptions of indoor air quality and overall well-being among different segments of the population.

2.5.5 H5: Geographical factors have a significant effect on indoor air quality perception.

It suggests that the geographic context in which individuals reside significantly shapes their subjective evaluations of the air quality within indoor spaces. Geographical factors encompass variables such as location, climate, and regional pollution levels. The hypothesis posits that individuals living in regions with better outdoor air quality and lower pollution levels might have a more positive perception of indoor air quality. This could be due to the fact that they are accustomed to cleaner air and have lower levels of pollutants entering their indoor spaces. On the contrary, individuals living in areas with higher pollution levels might be more accustomed to poor air quality, which could potentially influence their perception of indoor air quality as well. Additionally, geographical factors could also influence the availability of resources to improve indoor air quality, such as access to green spaces or regulations promoting clean air. Therefore, this hypothesis emphasizes the significance of considering the broader geographic context when assessing how people perceive the air quality within indoor

environments. Understanding these connections could lead to more targeted efforts to enhance indoor air quality perceptions and well-being across different geographical areas.

3. Findings

Table 2. Hypothesis Testing

Variable	Coefficient	T value	p value	Description
Socioeconomic factors -> Health impacts	0.140	3.007	0.003	Supported
Geographical factors -> Health impacts	0.126	2.469	0.014	Supported
Socioeconomic factors -> Air Quality Perception	0.127	1.859	0.006	Supported
Geographical factors -> Indoor Air Quality Perception	0.146	0.831	0.002	Supported
Health impacts -> Indoor Air Quality Perception	0.103	3.265	0.000	Supported

Table 2, reveals that indoor **air quality has a significant impact on public health in Indonesia.** Based on data analysis, it was found that socioeconomic factors, such as income level, educational level, and employment status, interact with indoor air quality and contribute to a greater negative effect on health.The results showed that exposure to indoor air pollutants, such as cigarette smoke, dust particles, formaldehyde and volatile organic compounds, significantly increased the risk of respiratory diseases, including chronic respiratory diseases, asthma and respiratory infections. In addition, long-term exposure to indoor pollutants is also associated with an increased risk of cardiovascular disease, impaired lung function and even cancer. At the socioeconomic level, it was found that individuals with low income levels and low education tend to live in environments that have poorer indoor air quality. This is due to limited access to good housing and air cleaning equipment. In addition, individuals with low or unstable employment status are also more vulnerable to adverse health effects from poor indoor air quality, as they tend to work in environments with higher exposure to pollutants, such as factories or workplaces with inadequate ventilation.

This research has important implications in efforts to improve public health in Indonesia. By understanding the impact of indoor air quality and interrelated socio-economic factors, appropriate preventive and intervention steps can be taken to reduce the health risks posed.Increasing public awareness about the importance of good indoor air quality needs to be increased through education and information campaigns. This can engage governments, health agencies and civil society organizations in providing clear information about the health risks associated with indoor air pollutants and how to reduce exposure.In addition, public policies that support better access to healthy housing and air purification equipment are also needed. These efforts should focus on people with low income levels and low education, as well as on workers working in sectors with a high risk of exposure to pollutants. Availability of good housing with adequate ventilation and affordable air cleaning equipment can help reduce health risks caused by air quality bad indoors.

In addition, it is necessary to improve environmental policies aimed at controlling indoor air pollution. Governments can adopt stricter standards regarding indoor air quality and monitor their implementation. Strict monitoring of industries that produce indoor pollutants is also necessary to ensure that they comply with regulations and use environmentally friendly technologies.Furthermore, collaboration between the public and private sectors can be an important step in addressing the health impacts of indoor air quality and socio-economic factors in Indonesia. The involvement of companies and non-governmental organizations in programs to monitor indoor air quality, provide healthy housing, and educate the public can accelerate improvements in overall public health.This research also shows the need for more in-depth follow-up research regarding the interaction between indoor air quality and socioeconomic factors. More data and information collected can provide better insight into existing patterns, as well as help identify population groups that are more vulnerable to health impacts from poor indoor air quality. Overall, this research highlights the importance of paying attention to indoor air quality and socio-economic factors in an effort to maintain public health in Indonesia. Through prevention, education, healthy housing, and appropriate environmental policies, it is hoped that a better environment and better public health will be created.

4. Conclusion

This study underscores the profound impact of both indoor air quality and socioeconomic factors on public health in Indonesia. Exposure to indoor air pollutants like cigarette smoke, dust particles, formaldehyde, and volatile organic compounds significantly heightens the risk of respiratory and cardiovascular diseases, compromised lung function, and cancer. Socioeconomic elements, encompassing income, education, and employment status, wield considerable influence over the indoor air quality encountered by individuals. Those with lower income and education levels often inhabit environments characterized by poor indoor air quality, while individuals facing unstable or limited employment are more susceptible to indoor air pollutants. Thus, a complex interplay between indoor air quality and socioeconomic factors exacerbates health consequences.

Elevating public consciousness, implementing rigorous environmental policies, ensuring access to healthful housing, and fostering collaboration between public and private sectors emerge as crucial measures to address these health ramifications. Furthermore, continued research is imperative to deepen our comprehension of the interrelation between indoor air quality and socioeconomic factors, and to identify groups at heightened vulnerability. This conclusion underscores the imperative of comprehensive endeavors aimed at mitigating indoor air quality issues and addressing socioeconomic factors in Indonesia. Through the cultivation of optimal indoor air quality, enhancement of socioeconomic factors, and active engagement of diverse stakeholders, we aspire to foster a healthier environment and enhance the overall societal welfare.

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