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# The impact of land-use planning, “zoning,” on rural-urban sprawl

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## Abstract

Industrial growth and a lack of effective zoning regulations decreased environmental sustainability and spacing between rural and urban areas in Lebanon’s Chweir Ain Al Hanout region. This study defined the relationship between unregulated industrial development and environmental loss and how zoning failures lead to spatial conflicts and urban sprawl in Chweir. A qualitative case study design was used, and 22 semi-structured interviews with municipal officials, planners, NGO representatives, and some long-term residents were conducted. Thematic analysis indicated seven main themes, namely: 1) Environmental Degradation, 2) Inconsistent land use, 3) Health and Safety, 4) Social Displacement, 5) Lack of planning and zoning Incoherence, 6) Industrial and Residential Functions Overlap, 7) Use of Emerging Technologies. Findings indicated failures that occurred during the governance of land. It suggests immediate regulatory changes, zoning enforcement, and planning with innovative sensor-based Artificial Intelligence (AI) and Internet of Things (IoT) devices. The results will help gain better knowledge concerning land-use conflicts in peri-urban settings. This study provided a scope of understanding concerning the sustainable development of cities in developing countries. Interviews with technology developers and local governments should be conducted to establish how to fulfil the technological capacity-regulatory reform gap.

**Keywords:** Urban Sprawl, Land Use Planning, Zoning, Environmental Sustainability, Peri-Urban Development, Industrialization, Internet of Things, Artificial Intelligence.

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## 1. Introduction

The land use planning is significant to the development of a region within urban and rural settings and is influenced by the zoning rules (Kalfas et al., 2023). When it is inappropriately carried out, it might yield adverse outcomes by creating uneven industrial growth and the absence of protection of natural environments. However, spatial mismanagement, environmental abandonment, and incurable socio-economic consequences have been caused by land use planning in most regions, especially those undergoing rapid rural-urban transition and ineffective zoning procedures (Kalogiannidis et al., 2023).

Chwier District is characterized by a firm reliance on its rural economic base, supported by various rural-oriented low-industry activities, including food processing, small rural and craft services, and manufacturing value-added products associated with primary production. Chwier’s future industrial demand as the village urban growth is expanding over time will be based around the post-harvest sector, its associated logistics, and the continuing

opportunities for value-added processing, which will directly impact the expanding urban fabric. Primary sector production and its logistics will be the major industry drivers in the future; the flow-on effect is significant in service industries. Such industries have direct opportunities to serve the productive sector. Still, they also have substantial footprints in harming the existing domestic, lifestyle, and visitor industry markets if expanded and nourished at the expense of the existing small craft industry.

The urban sprawl and land-use expansion that is disorganized continues to be an urgent issue in most of the fast-growing areas. As noted in the literature concerning zoning and urban sprawl, the lack of strict delineations of land uses and appropriate enforcement tools results in uncontrolled development and conflicts of land uses (Rizk et al., 2024). The traditional Euclidean zoning models that have traditionally formed the basis of urban planning have come under intense criticism due to their lack of flexibility and dynamic behavior to meet the needs of present times. Such models have been cited as ineffective regarding land

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usage, vehicle infrastructure reliance, and low-density sprawl expansion (Raven et al., 2018). The challenges involved have been acute in the case of Lebanon, especially in peri-urban settings such as in Ain Al Hanout, where mixed use of residential, education, and industry serves as a metaphor of a decentralized and essentially competing space formation. Faulty zoning policies and uncoordinated planning and enforcement also compound the discrepancy (Wang et al., 2023). Although this issue is of critical importance, the existing body of literature contains a gap in the lack of empirical research concerning the impact of zoning practices on rural-urban transition areas in Lebanon. Although the adverse effects of inadequate zoning on urban growth have been documented widely in the international literature, local case studies that assess these forces within the Lebanese context, particularly at the village or district scale, are rare.

This current study was conducted on the impact of haphazard land-use planning, in particular the “zoning” footprint, in Chweir village. This case study was chosen for citizens and the local municipality, who have been in this unpleasant and unbearable situation since the late nineties of the last decade, especially when this village was under study and supervision for more than twenty years. This study analytically assessed the impacts of the non-controllable rate of industrialization and ineffective zoning strategies across the Chweir-Ain Al Hanout area and contemplates its consequences on environmental sustainability and the future livability of the rural fringe.

### **1.2 Research Questions**

1. To what extent does the expansion of industrial plants in Ain Al Hanout impact environmental sustainability and the future livability of the rural fringe?
2. How does the lack of effective zoning regulation influence spatial conflicts and contribute to rural-urban sprawl in Chweir’s transitional zones?
3. Suggest how emerging technologies like AI and IoT can be applied to mitigate health and environmental risks.

### **1.3 Theory of Land Use**

Land-use theory covers both patterns and approaches to assigning and using land for many human activities, such as residential, industrial, agricultural, and institutional processes (Connell, 2023). It looks at how spatial alignments are affected by economic usefulness,

accessibility, environmental restriction, and planning policies (Githinji et al., 2023). The present study applies land-use theory to discuss spatial dynamics in the Chweir-Ain Al Hanout region. The lack of zoning enforcement has also led to chaotic growth and incompatible land use.

It is especially applicable in explaining the development of rural-urban transition zones, where various land functions are practiced under ineffective regulatory measures (Nie et al., 2023). The unplanned expansion of industrial production sites into the lives of industries and rural areas represents the failure of structural organization in the study area. Such spatial conflicts can be analyzed regarding the relations between land values, where that land is situated, and how that land is used (land-use theory) (Wu et al., 2024). This paper utilizes the land-use theory to measure the effect of ineffectively regulated zoning activities on spatial development and the environment as a sustainability priority.

## **2. Literature Review**

### **2.1 Industrial Expansion, Environmental Sustainability, and Urban Livability**

As an ongoing process in recent decades, the expansion of industrial plants to rural or peri-urban areas of settlement has always been linked to environmental degradation and decreased livability of the urban environment. Gu et al. (2024) defined that industrial intrusion into previously agricultural or urban sites disrupts the ecological balance by causing air and noise pollution, water pollution, and soil degradation. Industrialization in Chweir and the lack of sustainable measures disturbed the ability of the rural fringe to maintain biodiversity, farming, and a clean living environment. It is proven by several empirical studies that industrial clusters located close to residential and learning places pre-expose the populations to particulate matter, toxic emissions, and vibration interferences, which diminish health performance and livelihood (Gu et al., 2024). These impacts are especially extensive where industrialization outstrips infrastructure planning and land-use planning, as is commonly the case with peri-urban locations such as Chweir.

It is also evident in the fast character development of urban environments that environmental sustainability is directly correlated to zoning integrity. Kamana et al. (2024) highlighted that uncontrolled space-dependent growth of industrial areas causes disordered land cover, which condenses irreparably in the land fragmentation issue and

survivability of natural buffer areas (Kamana et al., 2024). According to Lebanese municipal records and case studies, Ain Al Hanout, which was once an agricultural extension of Chweir, has been rendered environmentally susceptible even as there has been a rise in the number of industrial plants since the late 1990s. Deficiency of emission checks, intensive car flow, and the refusal of green zoning have highly worsened the quality of air, drinking water, and sound situations. Such states reduce the livability of the area and discourage younger generations from staying around it in terms of residential unloading (Al-Shaar & Bonin, 2021). Consequently, the supposition that industrial growth harms environmental sustainability and urban liveability is sound in both on-ground experience and global research (Jichi, 2025).

### ***2.2 Ineffective Zoning, Spatial Conflict, and Rural-Urban Sprawl***

Zoning is a strict control of land-use conflicts and a control of urban expansion. Lack or inability of zoning enforcement usually triggers spatial chaos, especially on the rural-urban fringe, where various land-use activities fight (Al-Shaar & Bonin, 2021). In Chweir transition zones, ineffective zoning has led to the overlapping of land uses that include industrial, residential and boundaries between land uses define the spatial relationship between industrial, residential and the use of public spaces, which lack coordination and thus leading to the predisposing conditions of social tension, infrastructural overloading and ineffective resource distributions (Order, 2022). Rural and urban fringes are defined as zones of transition, and they must be accommodated through sensitive, flexible zoning patterns. Where the zoning is either old-fashioned or politically inclined, as in most of the Lebanese municipalities, the lack of clarity can easily lead to uncontrolled developments and land speculation (Tuéni, 2019). The alleged penetration of such gaps by developers, who set up their industrial or commercial activities in an area not originally intended to be used in such a way, increased the problem of spatial incompatibility and deteriorated communal ties (Jensen et al., 2019).

In Chweir, zoning adjustments that have occurred since 1997 have proved uneven, with areas designated industrial zones frequently being done after the fact to fit already established factories. Not only has this strategy failed to solve the land-use tensions, but it has also increased them by institutionalizing the terms of spatial contradiction (Taleshi

& Zianoushin, 2018). The consequence is the creation of what the researchers term as the fragmentation of land-use mosaics in which the incompatible functions truncate continuity, efficiency, and equity in space development. Furthermore, a lack of strategic zoning is a factor that increases rural-urban sprawl by permitting the leapfrog and ribbon forms of development, resulting in land-consuming inefficiencies in transportation and electrical systems (Scott, 2019). Such sprawl configuration, which is sometimes induced by industrial interests, results in low density and diffused settlement, which is unsustainable and unserviceable. This situation is similar to the case of Chweir, where the parasitic character of the development beyond the industrial centers makes the development possess socio-spatial discontinuity, disregarding the possibility of a built urban destiny.

## ***3. Methodology***

### ***3.1 Research Design***

This study utilized the case study research design to investigate zoning practices' implications on urban sprawl contradictions and land-use in the Chweir-Ain Al Hanout within the Mount Lebanon region. The study was conducted in Chweir. This method was selected to produce an in-depth, context-based interpretation of the spatial development concerns in the peri-urban setting, where informal growth and lack of adequate regulatory enforcement impact the spatial development problems.

### ***3.2 Data Collection***

Semi-structured interviews were used to collect primary data, which provided both the freedom to discuss predetermined themes and the opportunity for participants to bring forward new points of view. The total number of participants was 22, including municipal officials, architects, planners, NGO professionals, members of social organizations, and long-term residents well aware of the area's history of land use and land-use patterns and the land's zoning. Interviewees were asked questions on land-use integration, diffusion of industrial, environmental impacts, and state practice.

### ***3.3 Sample and Population***

The sampling technique employed was purposive sampling, in which participants were selected based on their relevant professional or experience-based opinions. Snowball sampling was used to reach out to other

informants whom the original participants suggested. The approach was also able to cover different land-use functions and orientations since there are residential, industrial, and institutional land uses in the area under study.

### 3.4 Data Analysis

Thematic analysis was conducted on interview transcripts to identify essential patterns regarding zoning failings, spatial conflict, and environmental change. The themes developed were reflected based on the Theory of Land Use and triangulated to secondary sources of information, including zoning plans, policy documents, and historical facts, to increase validity and contextual depth.

Thematic analysis was selected to interpret meaningful themes, which include five significant steps to follow:

**Data Familiarization:** This was done by thoroughly reviewing and revising the interview transcripts to develop a clear picture of the material and context.

**Initial Coding:** Relevant data were descriptively marked, inferring recurring patterns, phrases, or other observations by marking the data with relevant codes.

**Theme Identification:** Identifying themes involves re-grouping codes into a wider-level conceptual grouping related to the study's research questions.

**Themes Review:** The emerging Themes were reviewed and validated by triangulating them against the coded data and measuring their consistency.

**Final Report:** The finalized themes were organized according to the study's aim and accompanied by illustrative quotations.

### 3.5 Validity and Reliability

Several measures were made to justify and guarantee the validity and reliability of such a qualitative study. Triangulation was used to cross-check the information obtained in interviews, observations, and secondary

sources. This increased internal validity, as it helped to verify the consistency and credibility of results between various types of data and gold opinions of government officials, representatives of the civil society, and industrial participants. Member-checking was done where possible, and this helped the participants to confirm the correctness of the interpretations based on their responses. Moreover, semi-structured interview protocols were pre-tested to ensure the questions were clear, relevant, and compelling to collect meaningful information. To enhance reliability, an audit trail was kept during the research process to record the choice of coding and how the research was carried out to allow transparency and permit replications. All these made the thematic analysis trustworthy and rigorous.

## 4. Results and Discussion

The thematic analysis of these semi-structured interviews revealed seven key themes, as shown in Table 1. Four themes were identified about RQ1, i.e., the impacts of industrialization in Ain Al Hanout on environmental sustainability and future livability. Among the participants, industrial plants harm residents, and the health of residents and the environment are severely affected by industrial effects. A participant claimed that he has a permit to do all kinds of work, regardless of pollution and noise.

According to P6, Pollution leads to damage to the environment. P9 stated that the existing situation is awful. However, for him, there is a chance to overcome people's displacement, and he is convinced that there is no conflict between industry and residential. However, Zoning map designations do not reflect on-ground land use, creating confusion, as stated by P12. According to the suggestions given by P20, AI-sensor-powered and IoT devices can significantly help detect and reduce noise pollution and contamination. It can lower health and environmental risks, reflecting the theme, using emerging technologies including IoT and AI.

*Table 1: Thematic Analysis*

RQ	Code	Theme	Name of Participants	Data Collected
RQ1	E1	Environmental Degradation	P1, P2	<ul style="list-style-type: none"> <li>The pollution indices on industry prompt an active interface of social groups, mitigating this problem.</li> <li>Industrial plants harm residents.</li> <li>The health of residents and the environment was severely affected by industrial effects.</li> </ul>

RQ	Code	Theme	Name of Participants	Data Collected
RQ1	E2	Inconsistent land use	P4,P5	<ul style="list-style-type: none"> <li>• He claimed that he has a permit that allows him to do all kinds of work, regardless of pollution and noise, because he has an official permit to do work.</li> <li>• He claimed that the permit issued for him enabled him to exercise all kinds of industry as his plant was transferred from a small concrete block to a ready mix concrete plant, so he is on the proper track, whatever his license includes.</li> </ul>
RQ1	E3	Health & Safety Concerns	P6	<ul style="list-style-type: none"> <li>• The proximity of factories to homes and schools is causing physical and psychological health risks.</li> <li>• Pollution leads to damage to the environment.</li> <li>• Noise pollution is damaging the health of people and mainly affecting children.</li> </ul>
RQ1	E4	Social Displacement	P9	<ul style="list-style-type: none"> <li>• Although the existing situation is awful, for him, there is a chance to overcome people’s displacement, and he is convinced that there is no conflict between industry and residential.</li> </ul>
RQ2	Z1	Lack of Planning and Zoning Incoherence	P12	<ul style="list-style-type: none"> <li>• Zoning designations on maps do not reflect on-ground land use, creating confusion.</li> </ul>
RQ2	Z2	Land price decreases due to the overlapping of industrial and residential functions.	P15	<ul style="list-style-type: none"> <li>• His point focused on the fact that he was fully convinced that although this mess decreased land prices, he went on the contrary and built a new residential building for his children next to an old industrial plant.</li> </ul>
RQ3		Use of emerging technologies	P20	<ul style="list-style-type: none"> <li>• AI-sensor-powered and IoT devices can significantly help detect and reduce noise pollution and contamination. It can lower health and environmental risks.</li> </ul>

#### 4.1 Environmental Degradation

Due to a lack of equal and sustainable practices, the environment in Ain Al Hanout and Chweir became worse. According to the Nguyen et al. (2023) study, environmental degradation is unsuitable for the climate. Another study conducted by Sanidas et al. (2025) explained that environmental degradation causes the destruction of the ecosystem and harms human health. According to the view of P1 and P2;

“The plants integrated for industrial purposes lack measures of sustainability, which has become the major cause of pollution, which is not good for human health and the natural habitat”

#### 4.2 Inconsistent land use

The interview responses indicated deep concerns about unplanned industrial growth in Ain Al Hanout. According to P4 and P5;

“I have an official permit that allows me to do all kinds of work, regardless of pollution and noise.”

“The permit issued for him enabled him to exercise all kinds of industry as his plant was transferred from a small concrete block to a ready mix concrete plant, so he is on the true track, whatever his permit includes within.”

The inconsistent land use theme emphasizes the contradictory and overlapping enforcement of zoning laws, which apply in Ain Al Hanout and Chweir. The participant criticized the licensed land use that was afforded. This indicates the system’s failure in spatial planning enforcement. Participants acknowledged that they had an

official permit, so maybe there was a lack of regulations. This indicates a tendency for most incompatibilities between land uses to intrude on other applications without regulations (Haldar et al., 2024). Such inconsistencies have been noted adequately in studies where land zoned agricultural or housing was converted informally to industrial purposes using permits that were either outdated or facilitated by politics (Lu et al., 2023). Haldar et al. (2024) also defined the peri-urban areas within the rapidly urbanizing regions as not having a consistent land-use policy, resulting in incompatible developments. Lack of consistency in land use impairs the urban areas' purpose and utility, leading to a conflict between the stakeholders, a lack of trust in the planning operation, and rendering the urban areas uninhabitable and unsustainable (Li et al., 2023).

#### **4.3 Health and Safety**

P6 indicated that the absence of sustainability resulted in a high pollution rate, which impacts human health and the environment. It shows that previously green zones in Chweir were primarily converted into industrial zones, which caused environmental vulnerability. This aligns with the study of Lopez et al. (2025), which found that continuous industrial expansion causes environmental pollution and CO<sub>2</sub> emissions, which is bad for the environment.

P6 said;

“Noise pollution is damaging people’s health and mainly affecting children.”

#### **4.4 Social Displacement**

Chweir is characterized by political interference in rational planning. According to P9;

“The existing situation is awful, but for him, there is a chance to overcome people’s displacement, and he is convinced that there is no conflict between industry and residential.”

This theme highlights that social displacement is caused by continuous urban sprawl, which disturbs residents’ lifestyles due to relocation. A study by Alzain (2021) defined noise pollution as health problems resulting from industrial growth and a lack of community nuisance. The study showed that a lack of attention to health concerns creates a global health cost burden. The trend is common in Chweir due to the continuous expansion of industries. It contributes to the expense of communities and residents.

#### **4.5 Lack of planning and zoning Incoherence**

The participants answered that a lack of planning resulted in zoning incoherence, which means factory operations took place in residential areas. Previous studies described how zoning often failed to regulate urban sprawl (Gardner, 2024; Zhu et al., 2024). According to P12; “The zoning map shows that areas are residential, but factories are present.”

“The land shows residential on the map, but factories run 24/7.”

A situation characterized by incongruence between formal land-use plans and the reality of development is known as zoning incoherence. The participant pointed out that factory production is paired against municipality maps in residential areas.

#### **4.6 Industrial and Residential Functions Overlap**

According to the views of P15;

“I am convinced that although this mess decreased land prices, it established a new residential building for his children next to an old industrial plant.”

The overlapping use of incompatible activities in land use creates a conflict in space (Tan et al., 2024). P15 accepted that the residential environment was disrupted due to his industrial business. He agreed that relying on losing spatial distance will result in devaluation and tension. It is evidence of industrial-residential closeness. According to Tan et al. (2024), the conflict is a characteristic feature of neglected peri-urban planning. This leads to the resentment that causes displacement, legal issues, and suspicion of government systems. It refers to one significant violation of the governmental principles when a factory or any other industrial enterprise continues its work despite the legal license being over, and at the same time evolves beyond the specifications according to which it was initially planned to be built (Nuhu, 2019).

#### **4.7 Use of emerging technologies**

According to P20;

“AI-sensor-powered and IoT devices can significantly help detect and reduce noise pollution and contamination, lowering health and environmental risks.”

P20 stated that implementing AI and IoT sensor devices that detect noise, pollution, and carbon emissions could reduce health and environmental risks. A recent study by Popescu et al (2024) on AI and IoT-driven technologies defined that AI and IoT-based devices help detect real-time problems and allow quick response to contamination. It

shows emerging technologies can note rapid environmental changes in Ain Al Hanout and Chweir. Therefore, it may be important to safeguard the environment and human health. Another study stated that AI and IoT-based low-cost devices can measure air quality, particularly in areas with industries or urban areas. This increases the chance of decreasing allergic reactions due to pollution and other health hazards (Felici-Castell et al., 2023; Popescu et al., 2024).

## 5. Conclusion

Inappropriate zoning enforcement and unrestricted industrial growth in Ain Al Hanout and Chweir have devastated environmental sustainability and the livability of the rural fringe. The resulting spatial conflicts, characterized by co-existence of incompatible functions, zoning incoherence, and juridical grey areas, speak loudly of a fractured governance system. These processes generally reflect trends in peri-urban areas of developing nations, as formal planning systems are often (directly or indirectly) corrupted.

### 5.1 Recommendations

To successfully address the challenges in Ain Al Hanout and Chweir related to the environment and health, the approach involving particular AI and IoT-based technologies needs to be implemented. AirVisual Pro and PurpleAir sensors are devices that can monitor the quality of air in real-time, measuring substances, including PM2.5, CO<sub>2</sub>, and VOCs (Domazetovska et al., 2023; Emvolidis et al., 2024). Such sensors, powered by IoT, can be placed in residential areas, as well as in industrial areas, to notify the residents and the authorities when the pollution in those areas is high. Intelligent noise detectors such as the NoiseCapture app or BRÜEL & KJÆR sound sensors should be implemented to monitor dangerous levels of noise produced by industry, to implement zoning regulations, and safeguard the population, especially near schools and residential buildings (Zaidan et al., 2023). The gadget can be connected to the cloud-hosted AI services that detect noise patterns and suggest mitigation measures. Besides, AI is also used in the Green Horizons project by IBM to predict air pollution and simulate industrial emissions that can be replicated at the local level by municipalities. Predictive maintenance of industrial equipment is also possible through the use of AI, which helps to analyze the data of sensors in order to prevent leaks or emissions

before they can take place (Ali et al., 2024).

### 5.2 Strengths, Limitations, and Future Implications

The study defined that a continuous expansion of industrial plants in Ain Al Hanout impacts the rural fringe's environmental sustainability and livability by defining interview respondents' clear views. It defined that the lack of effective zoning regulation influences spatial conflicts and contributes to rural-urban sprawl in Chweir's transitional zones, indicated by themes: Lack of planning and zoning Incoherence, Industrial and Residential Functions Overlap, Political Contradictions, and continued operation without Renewal and expansion. The study limited the use of the survey questionnaire and statistical test results.

AI and IoT-based technologies can protect the environment by detecting early signs of pollution, emissions, and other key indicators, which allows cities to plan accordingly and minimize risks to people and the lifespan of natural resources, without industry and population relocation. Future research studies should investigate AI-IoT systems in the affected areas to determine their real-time efficiency. Studies should address the discussion in the future based on zoning frameworks, which must be designed with innovative technologies to sustain an industry-community coexistence. Interviews with technology developers and local governments should be conducted to establish how to fulfil the technological capacity-regulatory reform gap.

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