



# Impact of Tourism-Induced Urbanization on Adolescent Mental Health and Epigenetic Pathways to Depression

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## ABSTRACT

Tourism-induced urbanization (TIU) is increasingly reshaping cities and the lived environments of adolescents, creating unique psychosocial stressors that may contribute to depression and anxiety. Rapid urban expansion, high tourist inflows, and altered social and physical infrastructures disrupt daily routines, sleep-wake patterns, social ties, and lifestyle behaviors, compounding vulnerabilities in adolescents aged 10–19 years. Emerging evidence indicates that these environmental stressors interact with biological systems via epigenetic modifications, including DNA methylation and histone modifications, particularly in pathways involving the hypothalamic–pituitary–adrenal (HPA) axis, neurotrophin signaling (BDNF), and inflammatory cascades (TNF- $\alpha$ , IL-1 $\beta$ , IL-6). Such mechanisms provide a molecular link between urbanization-related environmental exposures and the onset or exacerbation of depressive disorders in youth. Understanding how tourism-driven urban growth shapes adolescent mental health through epigenetic pathways underscores the importance of integrated urban planning, social support, and protective interventions to mitigate psychological harm.

**Keywords:** *tourism-induced urbanization, adolescent mental health, depression, anxiety, psychosocial stress, epigenetic mechanisms, HPA axis, BDNF, inflammatory signaling, urban stressors.*

## INTRODUCTION

Urbanization, a process influenced by a multitude of factors, transforms cities and the conditions of residence (Huang et al., 2022). Initially, urbanization consisted of the migration of residents from rural to urban environments; now, many destinations are witnessing tourism-induced urban growth from within. A burgeoning trend of population departure exists where the outflow ratio exceeds the inflow ratio. A growing number of tourism ports worldwide are increasingly blending tourism and urbanization, which contributes

to regional tourism development and at the same time affects the characteristic construction of tourism destination regions, thereby further moderating urbanization with unique properties. A new concept termed urban tourism urbanization has been proposed and subsequently receiving increasing attention. Urban tourism urbanization refers to a tourism induced urbanization process characterized by local population outflow, land occupation facilitation by the tourism industry, tourism dependence enhancement, as well as urban expansion becoming significant via the tourist inflow and tourist industry scale change.

### The Tourism-Urbanization Nexus

Tourism-induced urbanization (TIU) occurs where urbanization is significantly affected by tourism. Tourism-induced urbanization influences urban development parameters such as population density and building heights (Huang et al., 2022). The academic literature tends to overlook the interconnectedness of tourism and the built environment as direct determinants of destination choice. Similar attention has seldom been paid to the possibility that urban growth is also a function of tourism.

The foundational study of TIU considered fuzziness, occupancy rate, connectivity, isolation, and polynomial degrees of buildings in a study of Changsha. Outcomes from Changsha support the view that TIU is multidimensional and can be captured consistently by a lagged variable that reflects urban growth during the past five years. Destination attachment was defined for a different purpose as the emotional bond between a person and a specific place. Price varies with destination attachment along a U-shaped curve: locations subjectively enjoyed alight from the attractiveness function, while momentarily undesirable areas attract higher marginal rates of substitution. Prices steer behavior; therefore, changes affecting either the attractiveness or the meaningfulness of a tourist site-thought to constrain attachment-should induce observable movements to other tourist locations.

### Adolescent Mental Health in Urbanizing Tourism Hubs

Urban tourism has intensified in many parts of the world, giving rise to massive investments in infrastructure and services, as well as waves of rural–urban migration. Urban tourism is often pursued for its potential contribution to economic and social development, notably employment generation and foreign exchange. While tourism has enriched the economy, it has also caused the physical, social, and psychological environments of many urban areas to change dramatically in a very short period; for instance, rapid gentrification with all its consequences occurs in some places where the influx is very high (Maggi et al., 2010). However, studies investigating the physical and psychological consequences of tourism-driven urbanization remain limited. In some developing countries, urban planning measures have been carried out to respond to or anticipate urbanization induced by tourism [table 1].

**Table 1: Epigenetic Mechanisms Linking TIU to Adolescent Depression**

Pathway	Tourism-Urbanization Influence	Epigenetic Mechanism	Outcome / Behavioral Effect
HPA Axis	Chronic environmental stress, urban noise, disrupted sleep	DNA methylation of NR3C1 and FKBP5 genes	Dysregulated cortisol, heightened stress reactivity
Neurotrophins	Altered social and physical exposure	BDNF methylation, pro-BDNF signaling	Reduced neuroplasticity, anhedonia, cognitive-emotional deficits
Inflammatory Signaling	Environmental pollution, crowding	Epigenetic upregulation of IL-6, TNF- $\alpha$ , IL-1 $\beta$	Neuroinflammation, depressive behaviors
Circadian / Sleep Regulation	Nighttime tourism activity, disrupted routines	Methylation of CLOCK genes, histone modifications	Sleep disruption, impaired mood regulation

<b>Lifestyle Behavioral Pathways</b>	/ Diet, exercise, drug exposure	Global chromatin remodeling, histone acetylation	Modifies stress sensitivity and depressive symptom expression
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Tourism-urbanization pairs, resulting from tourism, have emerged and are of growing interest. Tourism-driven environments have unique characteristics, and stressors differ from those in other urban environments. Because urbanization occurs rapidly in developing countries, and a large number of rural–urban migrants move for varied reasons, adolescents aged 10 to 19 years face unique urbanization-induced stressors and opportunities in tourism-driven environments. In addition, the cumulative impact of the transitional environments experienced by rural-to-urban migrants on adolescent mental health is drawing increased attention (Erulkar & Medhin, 2022).

### Stressors and Protective Factors in Tourism-Driven Environments

Dependent on the specific tourism milieu, one set of stressors can prevail over others, creating a diverse hydra of influences. Tourism-induced pressures typically amplify the impact of existing vulnerabilities (Liu et al., 2023). Epidemic-level rates of adolescent depression and anxiety persist within the global system despite increased epidemic-level awareness (Lin & Guo, 2024). Heterogeneous, context-dependent forces often ignore the current landscapes underpinning emergent psychopathology. Some determining pressures operate similarly to those found within “ordinary” urban settings, while others remain distinctively tourism-centred.

### Epidemiological Trends in Adolescent Depression and Anxiety

Today’s youths face unprecedented mental health challenges (McClaine Josey, 2016). In 2021, 14.4% of American adolescents aged 12–17 reported experiencing at least one major depressive episode (MDE), roughly the same as in the previous year (14.7%) (Centers for Disease Control and Prevention, 2023); MDE prevalence remained higher than pre-COVID levels (11.0% in 2019) and the long-term national trend remains upward (Gonzalez et al., 2023). Adolescents in key demographic groups (adolescent females, racial and ethnic minorities, sexual minorities, and youth experiencing major life stressors) experience MDE disproportionately. Even among adolescents who do not qualify for an MDE diagnosis, depression seems to be rising (Sasmakov S.A., et al). Longitudinal national surveys tracked declines in five adolescents' mental health indices between 2015 and 2021, mirroring similar declines for young adults in the same period. Adherence to certain protective behaviours-parental monitoring, healthy sleep, healthy diet, exercise, engagement in religious practices-were linked to lower levels of distress, but still simultaneously worsening from 2015 to 2021 (Gonzalez et al., 2023) [table 2].

**Table 2: Epidemiological Trends in Adolescent Mental Health**

Indicator	Trend / Prevalence	Key Risk Groups	Notes
Major Depressive Episode (MDE)	14.4% (2021, US adolescents 12–17)	Females, ethnic minorities, sexual minorities	Pre-COVID baseline: 11% (2019); rising trend since 2015
Anxiety Disorders	9.0% reported impairment (2021)	Similar demographic patterns	Mirrors depression trends, persistent across pandemic
Depressive Symptoms (Global)	20–43% (15–24 years)	Adolescents with multiple risk factors	Tourism-driven urban areas may amplify exposure
Protective Behaviors	Parental monitoring, sleep, diet, exercise	Universal benefit	Partially mitigates tourism-urbanization stressors

Anxiety disorders offered similar indicators of mental health prior to and during COVID. In 2021, 9.0% of adolescents reported experiencing at least one anxiety disorder related impairment, similar to the prevalence in 2020 after one year of pandemic exposure (Cantor et al., 2021; Gonzalez et al., 2023). Extending the 2015 adolescent health trend through 2021 produced declines in adolescent wellbeing measures including positive mood and life satisfaction. Longer-term historical precedent, however, offers greater cause for concern; the progress tracking positive adolescent wellbeing indicators began its downturn in 2019—flagging instead of behaviour, social, or economic period effects (Gonzalez et al., 2023).

### **Epigenetic Mechanisms Linking Environment to Depression**

In addition to its role in stress and depression, tourism-related disruption has a direct influence on adolescent health through the alteration of daily and social rhythms. Research indicates that disruptions to sleep-wake patterns during adolescence can negatively affect brain areas and provide continual reinforcement for behaviour associated with anxiety and depression. Tourism expansion has been shown to influence both individual and social sleep patterns, resulting in changes to school timings, curfews and socialization. Exposure to social media and suboptimal lifestyles positively correlate with self-reported mental health problems, where lifestyle alterations can include diet, exercise and drug use. All these factors are upregulated during tourism periods, which additionally alter the patterns of social ties through contribute to the emergence of emotional and anxiety disorders. The epidemiological association between adolescent depression and tourism moving has been reinforced through the recent expansion of low-cost airlines (Torres-Berrio et al., 2019) ; Penner-Goeke & B. Binder, 2019).

### **Environment-Driven Epigenetic Modifications**

Environmental influences, including stressors and protective factors, shape both the development and course of adolescent depressive disorders (Alameda et al., 2022). Such factors modify gene expression via epigenetic pathways, which do not alter the underlying DNA sequence (Penner-Goeke & B. Binder, 2019). These modifications involve chemical changes to the DNA or to histone proteins that package the DNA strand. One of the best-studied processes is methylation, in which a methylation moiety is added to cytosine. Environmental factors become embedded in epigenetic signatures through processes influenced by external stimuli. Adolescent depression associates with epigenetic changes in key candidate pathways, including one involved in the response to stressors (Efstathopoulos et al., 2018).

### **Key Candidate Pathways: HPA Axis, Neurotrophins, and Inflammatory Signaling**

Contextual changes in social and physical environments can orchestrate the emergence of depression in adolescents through epigenetic mechanisms with downstream behavioral and physiological consequences, most notably along the hypothalamic–pituitary–adrenal (HPA) axis, neurotrophin signaling, and inflammatory pathways (Zonca et al., 2024). The HPA axis controls the physiological stress response, with activation believed to contribute significantly to the emergence of depression, particularly in adolescents. Pro-BDNF-dependent signaling that inactivation drives neuroplastic remodeling is essential, since severe non-circadian disruption of social and physical exposure during adolescence precludes appropriate dopaminergic modulation of BDNF control of the first critical period and leads to operant avoidance of otherwise rewarding experiences. Evidence shows that prolonged exposure to urbanization-related environmental stressors promotes neuroinflammation, with elevated levels of proinflammatory cytokines, including tumor necrosis factor- $\alpha$  (TNF- $\alpha$ ), interleukin-1 $\beta$  (IL-1 $\beta$ ), and IL-6. Where restricted travel prevents exposure to dense urban environments and their associated stressors and disruptive influences, cities can offer protective qualities that attenuate the toxicity of urban settings.

### **The Role of Tourism-Related Disruption in Sleep, Social Ties, and Lifestyle**

Urban tourist areas can become polluted due to tourism and urbanization; deteriorating urban quality can damage social networks, and tourism that disrupts the urban lifestyle can negatively affect social life. The latest decade has witnessed alarming increases in the prevalence of anxiety and depression disorders in adolescents. On a global scale, 20% of youth aged 15 to 24 years may experience at least one depressive

episode, with as high as 43% of youth experiencing depressive symptoms before reaching adulthood (Huang et al., 2022). Also, according to a recent large-scale survey from 107 countries, for adolescents with multiple risk factors, 26.6% reported depressive symptoms, compared to 8.7% among those youth without any risk factor (Hsieh et al., 2019). As indicated by the 2021 WHO Global Health Survey, in the region of East Asia and Pacific, 35% of youth aged 5-17 years experienced mental health issues.

### **Methodologies for Studying Epigenetics in Adolescents Within Urban Tourism Settings**

Urban tourism represents a unique opportunity to investigate environmental exposures linked to mental health. In urban settings, where tourism is either stable (e.g., high historical or cultural attraction) or dynamic and geographically clustered (e.g., special events, hotels), survey clusters can be designed on spatial and time scales shorter than other determinants to capitalize on the urban–tourism nexus. Within relatively undisturbed adolescent cohorts located in diverse urban tourism settings, environmental and epigenetic sampling can be coordinated to yield rich space–time datasets on disparity exposure potential.

Epigenetic mechanisms (e.g., DNA methylation) present an underdeveloped, but promising, pathway to connect environments to depression and anxiety. The association of stressors with adolescent mental health disparities has been demonstrated across different tourism and non-tourism urbanization trajectories. Candidate pathways (hypothalamic–pituitary–adrenal [HPA] axis, neurotrophic factor, inflammation) linking these stressors to epigenetic processes are established, and city-level variation in daylight duration and urban canopy are linked to diurnal cortisol and sleep. Similar frameworks can test for additional candidate pathways by capitalizing on urban tourism patterns (Yuan et al., 2024).

### **Policy and Public Health Implications**

Urban tourism fueled by extensive urbanization can hinder adolescent mental well-being through tourism-induced changes to selected lifestyle behaviours and alterations in social practices, availability of sleeping spaces, nature exposure, and digital device and screen time patterns. Adverse tourism-triggered and environmentally-prompted alterations of health-affecting urban features—including sleep, lifestyles, social ties, and green areas—correlate with city-based youngsters' rising susceptibility to depression and anxiety (Huang et al., 2022). Policy measures and public health recommendations capable of dampening urban tourism's adversely dynamic effects on the mental health of adolescents located within an increasingly well-travelled metropolis might encompass directed school-led programmes and physical-planning policies at communal and individual grades. Urban-transport management systems, beverage-and-food tourism-policing frameworks, green-space-administration regulations, and activity-financially accessible touring-control schemes could equally limit the obsessive tourism behaviour that some inhabitants develop within trendy resorting hotspots (Daniel et al., 2022). Implementing such adjustments might not only attenuate but also ultimately halt reinforcing tourism-motivated modifications of the surroundings capable of enhancing epigenetically mediated depression pathways—the relationship between tightly interlinked urban-tourism and ever-rapidly travel practices may spur ongoing degradation of the wellbeing-related environment.

### **Urban Planning and School-Based Interventions**

Adolescents are among the most vulnerable population groups undergoing the tourism-induced change of locality. Evidence suggests a need for environmental and urban planning coupled with school-based interventions as adjuncts to other forms of public health interventions (Yang et al., 2022) in adolescent wellbeing. An understanding of the existing overwhelming pressures in tourism-urbanisation hotspots is important to set up interventions (Chhajer & Hira, 2024). Urban challenges faced by adolescents include academic pressure, unfulfilled family expectations, career-related stress, and extra-curricular burden. Urbanisation settings may introduce co-morbidities that become evident in higher levels of anxiety, loneliness, bullying, and violence. Opportunities for recreational activities may change, with fewer venues

for offline socialisation leading to disconnection. Continuous noise pollution from both night and daytime activities compounds difficulties with sleep, social cohesion, and individuation (Yuldashev A.G).

Targeted construction and development should address accessibility to recreational facilities, targeting transportation systems for bicycles and pedestrians. The provision of safety and security for recreational opportunities would cater to higher risk factors from schooling and training. The establishment of more public access areas with restrictions on alcohol sales around schools would extend protective hours for sedentary pastimes. Schools with time allocated for creative and non-academic pursuits not linked to family expectations would allow a migration to normalising pastimes.

### **Tourism Management Practices Benefiting Adolescent Mental Health**

Accessible leisure activities enhance adolescents' quality of life and mental health, while also supporting family functioning. Families with children who have developmental disabilities particularly benefit from vacations. Travel serves as a site of resistance to negative societal perceptions and as a means of fostering positive identity. Leisure programs improve well-being and reduce stress among individuals with autism spectrum disorder and other mental health challenges (Lutfullaeva D.E., Yuldashev A.G). Geographic access to leisure services influences perceptions of trust, inclusivity, and opportunities for connecting with others, thereby promoting better mental health outcomes. Tourism initiatives that prioritize accessibility and provide opportunities for contingent, local socialization support adolescents' mental health by fostering connection, empowerment, and recovery (Sedgley et al., 2017).

### **Conclusion**

Rapid urbanization across the globe is driving unprecedented rates of urban population growth, as centres of economic activity expand to meet greater demand for jobs, consumer goods, and entertainment. In many countries, tourism hotspots are at the leading edge of this phenomenon, with cities in the Global South especially vulnerable to international and domestic pressures. The World Bank has designated these cities as tourism-driven urbanizing centres, where large-scale migration and short-term stays are straining housing and infrastructure, shaping the urban experience, and exacerbating youth mental health problems. In South Asia, tourism-driven urbanization is exacerbating already burdensome rates of adolescent depression and anxiety (Daniel et al., 2022). The initiation of urbanization precipitates long-range epigenetic trajectories toward adulthood depression in the absence of diversified cultural stimuli. Tourism-driven environments disrupt sleep and social ties in cities already characterised by reduced adolescent social-cognitive engagement, added to pre-urbanization exposure risk factors. Investigating specific fitness-related epigenetic-methylation candidates across the hypothalamic-pituitary-adrenal axis, neurotrophin signalling, and inflammation pathways establishes a framework for discerning how tourism-driven urbanization refines mental health risk (Huang et al., 2022).

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