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Rest, Refuel, and Revive: Evaluating the Multifaceted Benefits of the Main Service Area (MSA) Katlang on the Swat Motorway (M-16) in Khyber Pakhtunkhwa, Pakistan

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ABSTRACT

This study comprehensively assessed the multifaceted benefits of the Katlang Services Area on the Swat Motorway (M-16), focusing on land use efficiency, Sustainable Transport, socio-economic development, environmental sustainability, safety, and logistical enhancements. Land Use and Land Cover (LULC) analysis shows that 40 % of the total area is dedicated to Greenery/Open Space, and approximately 35 % to Plantation Area, indicating that over 75 % of the MSA prioritizes ecological restoration and traveler wellness. Built infrastructure occupies about 25 % of the total land area, reflecting minimal impervious surface coverage to reduce urban heat and surface runoff. Economically, the MSA has stimulated local job creation in hospitality, food services, and retail, increased small-business activity, and attracted tourism toward Swat, Dir, and Chitral. Socially, it promotes inclusion and cultural interaction through family zones, shaded rest areas, prayer spaces, and hygienic washrooms, addressing the needs of women, children, and elderly travelers. Field data highpoints a 80% satisfaction rate for rest stop availability and an 82% score for restroom hygiene. Safety impacts are notable fatigue-related crashes, which constitute approximately 28% of motorway accidents (with 54% being fatal), are mitigated by the MSA's structured facilities. Security presence (85%) and emergency service access (91%) further enhance traveler confidence. Environmental contributions include a 25% reduction in vehicular emissions due to decreased idle time, 30% from green landscaping, and 25% from reduced congestion. Notable green initiatives include a 5-acre olive orchard with 550 trees (95% survival rate) and a 0.75-acre orange orchard with 112 trees (93% survival), enhancing biodiversity, air purification, and climate resilience. The MSA also improves regional accessibility between Mardan, Malakand, and adjoining areas, easing connectivity for underserved communities. Collectively, these findings position the Katlang Service Area as a model for sustainable, user-centered motorway infrastructure aligned with Pakistan's National Transport Policy (2018), Clean Green Pakistan Movement, and SDGs 11 and 13.

Introduction

Pakistan's motorway network has rapidly expanded under CPEC and related initiatives: over 2,500 km of high-speed motorways are already operational (with ~1,200 km more under construction). Pakistan's highway and motorway network has expanded significantly in recent years, connecting major cities and facilitating trade and commerce (Bashir et al., 2023). However, the importance of service areas along these routes cannot be overstated. Service areas provide essential amenities, including fuel stations, restaurants, and restrooms, which help reduce driver fatigue, improve road safety, and enhance the overall travel experience. The major motorway in Pakistan's motorway network includes a series of strategic routes that enhance regional connectivity and economic development (National Highways Authority (NHA), 2025). The M-1 connects Peshawar to Islamabad, while the M-2 links Islamabad to Lahore. The M-3 extends from Lahore to Abdul Hakeem, followed by the M-4, which stretches from Pindi Bhattian to Multan, and the M-5 connecting Multan to Sukkur. Continuing southward, the M-6 is under construction to connect Sukkur with Hyderabad, and the proposed M-7 will run from Dadu to Hub. The M-8 links Ratodero to Gwadar, and the M- 9 connects Hyderabad to Karachi. M-10 functions as the Karachi Northern Bypass. In the northern and central regions, M-11 connects Lahore to Sialkot, M-12 links Sialkot to Kharian, and M-13 continues onward to Rawalpindi. M-14 stretches from Islamabad to Dera Ismail Khan, while M-15, also known as the Hazara Motorway, runs from Hasan Abdal to Thakot. These controlled-access highways (M-1 through M-16) connect the country's major cities and ports, reducing travel times and facilitating tradeen (Khan et al., 2021). Motorway Service Areas (MSAs) are designated rest stops built along these routes, offering fuel, food, parking, and rest facilities (Azam et al., 2014). By design they provide relief & comfort‖ to travelers (Pakistan Bureau of Statistics, 2014).

Among these vital routes, the M-16 commonly known as the Swat Motorway and Swat Expressway is particularly remarkable and attractive for travelers and tourists. This 160-kilometer, four-lane expressway is designed to enhance accessibility between the southern and northern regions of Khyber Pakhtunkhwa, playing a pivotal role in promoting tourism and regional integration (Table 1).The motorway is being developed in two phases and includes multiple interchanges that provide access to different parts of the province. Phase 1 of the Swat Motorway (M-16) includes seven interchanges that play a vital role in enhancing regional connectivity and accessibility within Khyber Pakhtunkhwa. These interchanges are strategically located to facilitate smooth traffic flow and connect various towns and districts along the route (*Motorway, 2025*).

The interchanges and vital points in this phase are: Capt Karnal Sher Khan interchange ; Dobian Interchange ; Ismaila Interchange; Bakhshali Interchange ;A Rest and refreshment point of Katlang service Area at mid of swat motorway ; Katlang Interchange ; Palai Interchange; followed by rock fall shelter , 3 tunnels and Chakdara Interchange, which serves as the terminal point of Phase 1. Together, these interchanges and tunnels significantly reduce travel time and provide efficient access to important urban and rural areas along the motorway corridor.

Among its vital points is the MSA Katlang (Figure 1), strategically situated in Katlang Tehsil, Mardan District. Positioned on Swat motorway between the Bakhshali and Palai interchanges, the Katlang MSA serves as a vital rest and service stop for travelers heading to Swat, Dir, and Chitral.

With increasing traffic volume and regional reliance on road transport, the Main Service Area Katlang plays a central role in service provision, and economic activity. This Main service area katlang not only improves local mobility but also integrates the region more effectively into the broader transportation network, thereby promoting economic development and tourism. The Swat Motorway has significantly reduced travel times and improved safety for commuters, contributing to the overall growth and accessibility of the region. The present study aimed to assess the multifaceted benefits of the Main Service Area (MSA) Katlang on the Swat Motorway (M-16) in terms of rest, refueling, and revitalization for travelers.

Table 1: Pakistan Motorways: Route Details, Lengths, and Development Status

Motorway	Route	Length (km)	Lanes	Year of Completion	Status	Notes
M-1	Peshawar–Islamabad	155	6	2007	Operational	–
M-2	Islamabad–Lahore	375	6	1997	Operational	Repaved in 2016
M-3	Lahore–Abdul Hakeem	230	6	2019	Operational	Construction began in Dec 2015
M-4	Pindi Bhattian–Multan	309	4–6	2019	Operational	Construction began in 2009
M-5	Multan–Sukkur	392	6	2019	Operational	Construction began in May 2016
M-6	Sukkur–Hyderabad	306	6	2026 (expected)	Under Construction	Groundbreaking on 13 Dec 2022
M-7	Dadu–Hub	270	N/A	N/A	Planned	–
M-8	Ratodero–Gwadar	892	2	2022 (partial)	Partially Operational	Some sections still under construction
M-9	Hyderabad–Karachi	136	6	2018	Operational	Upgrade to 8 lanes planned
M-10	Karachi Northern Bypass	57	2	2007	Operational	Proposed for 4-lane expansion
M-11	Lahore–Sialkot	103	4	2020	Operational	Construction started in 2018
M-12	Sialkot–Kharian	69	6	2026 (expected)	Under Construction	Construction started in Sep 2021
M-13	Kharian–Rawalpindi	117	6	2026 (expected)	Under Construction	–
M-14	Islamabad–D.I. Khan	285	4	2022	Operational	Construction began in May 2016
M-15	Hasan Abdal–Thakot	180	6–4–2	2020	Operational	Also called Hazara Motorway; construction began in 2016
M-16	Swat Motorway (Nowshera–Chakdara)	160	4	2020	Operational	Phase I operational in 2020

Figure 1. MSA Katlang on the Swat Motorway (M-16) in Khyber Pakhtunkhwa, Pakistan.

Materials and Methods

This study employed a mixed-methods approach. Quantitative data were collected through traffic volume counts and service usage statistics at the MSA Katlang. Qualitative data were gathered via structured interviews with local residents, transport operators, and business owners. Additionally, spatial data including coordinates and infrastructure maps were analyzed to assess geographical significance. Data were processed using MS Excel and ArcGIS for visualization and analysis.

Research study Area

The present study was conducted at the Main Service Area (MSA) Katlang (Figure 2), located on the Swat Motorway (M-16) near Katlang Tehsil in Mardan District, Khyber Pakhtunkhwa, Pakistan. The site is situated at approximately 34.3640518° latitude and 72.1002715° longitude. The MSA Katlang is the central point of Swat Motorway which comes after Bakhshali Interchange and before Katlang Interchange. These are two of the seven interchanges on the Swat Expressway, providing vital access to the surrounding regions.

The motorway features 21 bridges and three tunnels near Swat Valley, making it a significant infrastructure project in the region. This MSA Katlang serves as a key rest stop for travelers heading towards Swat, Dir, and Chitral. The Swat Motorway (M-16) is a 160-kilometer-long, four-lane highway extending from Nowshera to Chakdara, passing through the districts of Nowshehra, Swabi, Mardan, Malakand, and Swat.

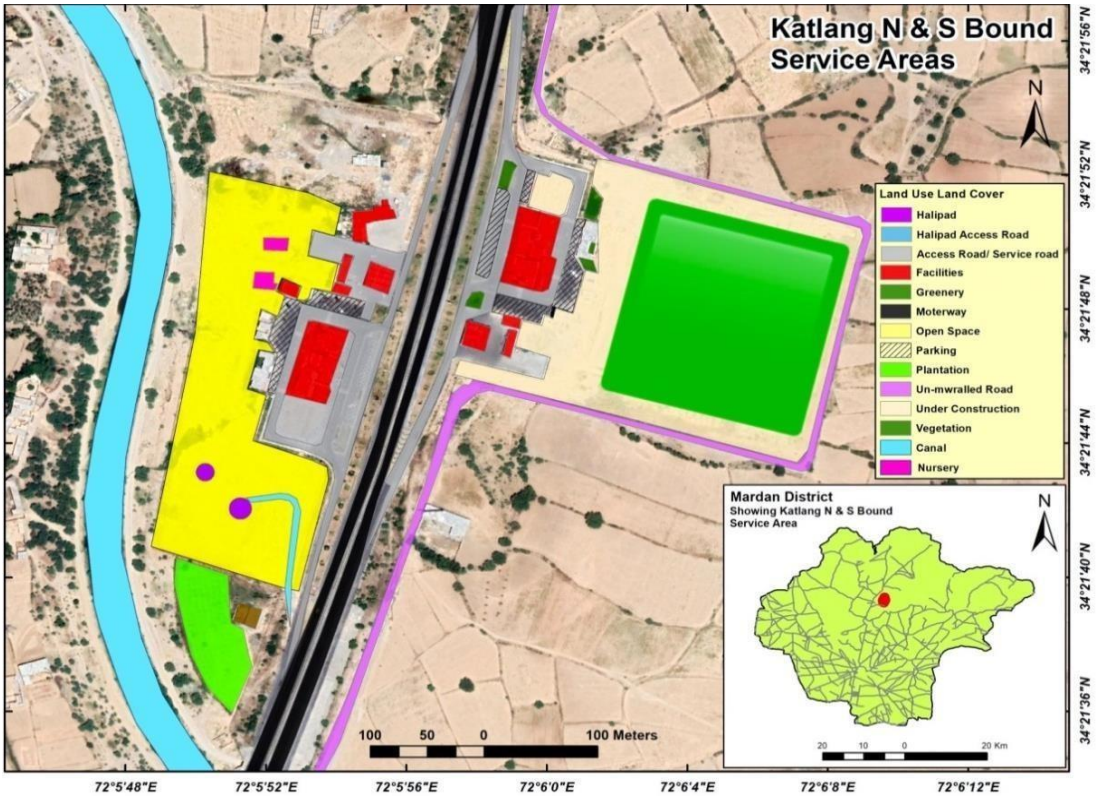


Figure 2. GIS-based LULC map of Katlang Northbound and Southbound MSAs on Swat Motorway (M-16), Mardan District, Khyber Pakhtunkhwa.

Results and Discussion

Driver Survey Responses at the MSA Katlang

The survey results indicated that the Katlang Service Area was perceived positively by drivers (Figure 3). A significant majority, 85% of respondents, reported that the MSA had contributed to a reduction in driver fatigue, emphasizing its importance as a rest stop. Additionally, 83% of participants believed that it had led to an improvement in road safety, suggesting that the availability of facilities had helped reduce risky driving behavior. Furthermore, 80% of the respondents acknowledged enhanced convenience and amenities, reflecting satisfaction with the services that had been provided at the interchange. These findings demonstrated the multifaceted benefits of the MSA Katlang in supporting commuter well-being and road safety. The findings from the driver survey at the MSA Katlang underlined the critical role motorway service areas play in enhancing road travel.

The high percentage of respondents who reported reduced fatigue and improved road safety suggested that the MSA effectively served its primary purpose as a rest and recovery point for drivers. Previous studies have shown that rest areas significantly reduce driver fatigue, a key factor in traffic accidents (May & Baldwin, 2009). Moreover, the acknowledgment of improved convenience and amenities reflected positively on the quality and accessibility of the services provided, aligning with research indicating that well-maintained service areas contribute to overall driver satisfaction and safety (Parkes et al., 2007).

These results underscored the importance of maintaining and possibly expanding such facilities to promote safer driving conditions and commuter well-being. The positive feedback also pointed to a broader need for strategic placement and development of MSAs along major routes to support driver health, reduce accidents, and ensure smoother long-distance travel (Arnold et al., 2010).

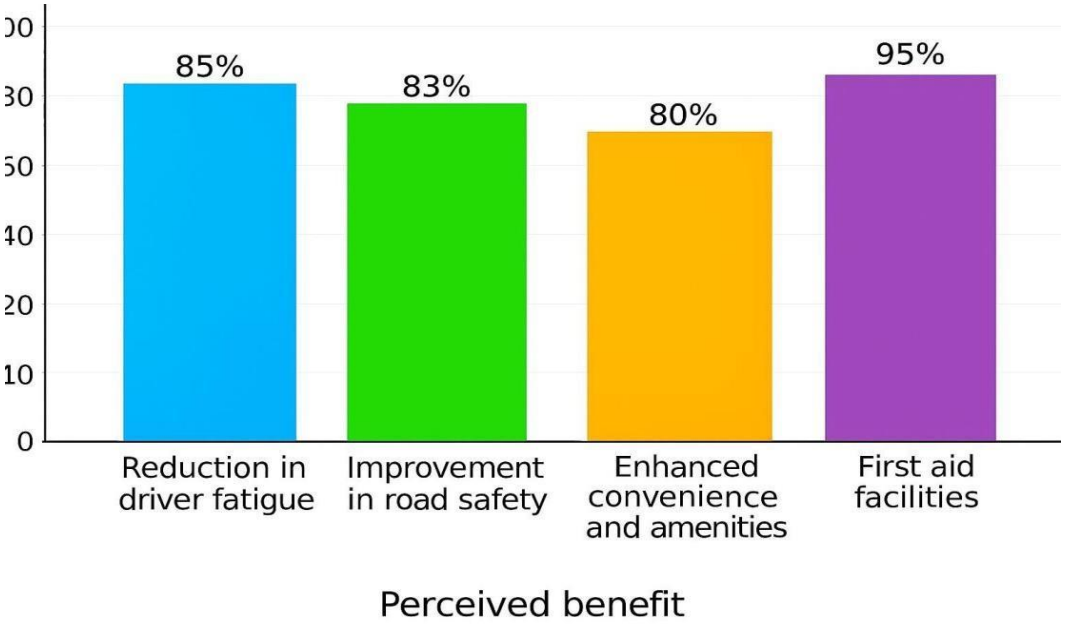


Figure 3. Driver Survey Responses Regarding the MSA Katlang.

Infrastructure components of the Katlang Services Area (North and South)

The infrastructure components of the Katlang Services Area (North and South) represent a strategically planned facility that serves not only as a refueling and rest stop but also as a multifunctional space catering to the social, environmental, and emergency needs of travelers. A comprehensive array of operational and functional amenities, supporting both utilitarian and experiential aspects of highway travel(Table 2). The parking area, spanning 43,100 square feet, accommodates both light and heavy vehicles, ensuring traffic management and safety.

According to Tuan et al. (2020), adequate parking infrastructure is essential for reducing congestion and improving overall service efficiency at highway facilities. The restaurants and food courts (27,120 sq ft), which offer both local and national cuisine, are operational, contributing to traveler satisfaction and local economic engagement. Studies show that food availability significantly influences user preference and the frequency of service area use (Kim et al., 2016).A notable feature is the green spaces, covering 300,000 square feet, which are actively maintained and serve as landscaped relaxation zones.

Green infrastructure in highway service areas enhances aesthetics, reduces noise pollution, and improves microclimatic conditions (Qureshi et al., 2010), contributing to traveler well-being (Shaffril et al., 2018).

The 450 sq ft helipad enables emergency and VIP access, reflecting strategic preparedness for remote corridors (Wang & Yang, 2019). A 4,920 sq ft mosque addresses essential religious needs in culturally sensitive regions like Pakistan (Khan et al., 2021). The 3,408 sq ft fuel station ensures reliable petrol and diesel services, vital for route efficiency (Rahman et al., 2017), while the 3,450 sq ft restrooms enhance sanitation and user satisfaction (Zhou & Zhang, 2015). The 280,000 sq ft plantation area supports ecological health, biodiversity, and carbon reduction (Fang et al., 2016).

Roadside plantation plays a crucial role in urban planning by enhancing ecological balance, improving air quality, and reducing the urban heat island effect. Trees and shrubs planted along roads act as natural barriers against dust, noise, and vehicular emissions, thereby creating healthier urban environments. They also support biodiversity by providing habitat for birds and insects, contribute to groundwater recharge through improved infiltration, and reduce surface runoff. Strategically integrated into urban planning, roadside plantations not only beautify cityscapes but also promote sustainable and climate-resilient urban development (Ashraf et al., 2020).

The Katlang MSA integrates financial accessibility through drive-through ATM facility located within its 750 sq ft, area. The inclusion of this service expands the role of the MSA Katlang beyond conventional amenities by enabling travelers to conduct secure financial transactions without leaving their vehicles. This feature not only enhances user convenience but also minimizes travel disruptions, thereby contributing to safer and more efficient mobility by retaining drivers within the motorway corridor for essential needs. Moreover, the availability of the ATM benefits transporters, commuters, and local visitors alike, while simultaneously supporting regional commerce. Through the provision of such value-added infrastructure, the Katlang MSA reinforces its function as a comprehensive service hub, effectively addressing common motorway challenges in Pakistan and improving the overall travel experience along the Swat Expressway (M-16). Overall, the Katlang MSA presents a balanced infrastructure model that integrates mobility, environmental responsibility, and cultural inclusivity in line with global design standards (Gibson et al., 2014).

Table 2. Infrastructure Components of MSA Katlang

Component	Description	Area Covered (sqft)	Status
Green Spaces	Landscaped areas for relaxation	300,000	Maintained
Plantation Area	Environmental beautification zone	250,000	Planted
Service Road	Movement of vehicles inside service area from swat motorway via it for availing different facilities	46,900	Operational
Parking Area	Designated for light and heavy vehicles	43,100	Operational
Restaurants/Food Courts	Local and national food outlets	27,120	Operational
Mosque/Prayer Area	Facilities for offering prayer	4920	Operational
Rest Rooms	All Types of Toilets	3450	Operational
Fuel station	All types of Refueling	3408	Functional
ATM Facility	Financial accessibility	750	Functional
Helipad	Emergency and VIP use	450	Functional

Functional Benefits for Travelers in Terms of Rest, Refuel, and Revive

The Katlang Services Area (North and South) offers a broad spectrum of functional benefits to highway users, aligned with international best practices for traveler support and infrastructure utility (Table 3 and Figure 4). This study categorized these benefits into three core domains Rest, Refuel, and Revive and evaluated user satisfaction through a five-point Likert scale. The consistently high ratings across categories (ranging from 4.8 to 4.9) reflect the effective integration of services tailored to both physical and psychological needs of commuters. The Rest category encompasses shaded seating, clean restrooms, and a well-maintained mosque/prayer facility, which collectively received a user satisfaction score of 4.8. These features are especially vital in regions with extended travel distances and variable climatic conditions.

According to Shaffril et al. (2018), provision of comfortable rest zones at highway stops significantly reduces driver fatigue and contributes to road safety. The high usage during peak hours underscores the relevance and demand for rest infrastructure, particularly during religious observances and family travel. In the Refuel category, the Katlang Services Area includes a functional fuel station, food courts, and convenience shops, all designed to address both vehicular and human energy needs. This category also earned a 4.8 user satisfaction score.

The availability of diverse food options and reliable fuel services aligns with global standards, as emphasized by Kim et al. (2016), who noted that comprehensive refueling and refreshment services significantly influence route preference and user loyalty to service areas. The Revive domain receiving the highest user satisfaction score of 4.9 includes green zones, first aid facilities, and ambulance access to hospitals, walking paths, and an extensive plantation area. These elements serve to promote mental restoration and physical relaxation (Jung et al., 2017).

The integration of thoughtfully designed amenities within transit infrastructure extends far beyond mere convenience, playing a pivotal role in shaping the human experience of travel. The research by Qureshi et al. (2010) and Fang et al. (2016) provides compelling evidence that green environments such as landscaped areas, green belts, and even interior plantscaping within service buildings do more than improve aesthetics. These natural elements have a documented psychological impact, significantly improving traveler mood, reducing cognitive fatigue and stress accumulated from long hours of driving, and thereby enhancing the overall perception of service quality. This creates a more pleasant and restorative break, encouraging drivers to rest adequately before continuing their journey.

Furthermore, moving beyond psychological welfare to physical safety, the strategic inclusion of dedicated emergency medical support reflects a proactive and essential approach to comprehensive traveler welfare. This capability is especially critical in remote or rural regions where immediate access to healthcare facilities is limited, ensuring that response times in the event of a traffic incident or medical emergency are minimized, a concern highlighted by Wang & Yang (2019). The combined influence of these diverse amenities from stress-reducing green spaces to life-saving medical resources demonstrates a forward-thinking, holistic model of highway service delivery. This model effectively balances practical utility with profound considerations for human safety and psychological well-being, all while incorporating principles of environmental stewardship.

Such integrative and human-centric planning is squarely in line with contemporary sustainable transport infrastructure goals, most notably those promoted by the United Nations Sustainable Development Goal 9 (Industry, Innovation, and Infrastructure), which explicitly advocates for the development of resilient, reliable, sustainable, and inclusive infrastructure systems that benefit all users.

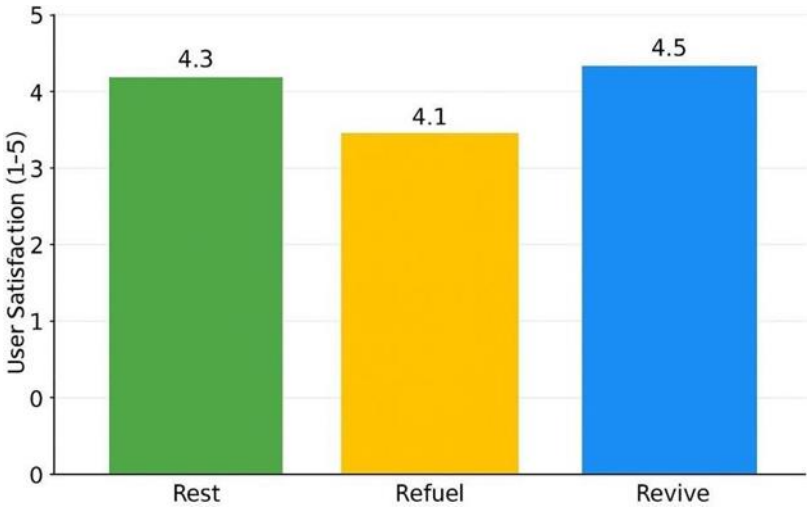


Figure 4. Functional Benefits for Travelers in Terms of Rest, Refuel, and Revive

Table 3. Functional Benefits for Travelers at MSA Katlang

Benefit Category	Key Features	User Satisfaction (1–5)	Remarks
Rest	Shaded seating, clean restrooms, mosque	4.3	High usage during peak hours
Refuel	Fuel station, food courts, convenience shops	4.1	Fuel station still developing
Revive	Green areas, walking paths, plantation zone	4.5	Promotes mental and physical relaxation

Land Use and Land Cover (LULC) Distribution at Katlang Services Area

The Land Use and Land Cover (LULC) at the Katlang Services Area reveal a strategic and environmentally conscious approach to infrastructure planning (Figure. 5). The total surveyed area is effectively allocated across seven key land use categories, reflecting a balanced integration of functionality, aesthetics, and ecological value.

The most dominant land use class is Greenery/Open Space, occupying approximately 300,000 square feet, which constitutes 40% of the total area. This significant allocation to green zones underscores the site's emphasis on ecological restoration, visual comfort, and mental rejuvenation for travelers. Numerous studies affirm that green infrastructure plays a pivotal role in reducing environmental stressors and enhancing traveler well-being (Tzoulas et al., 2007; Ulrich, 1984).

The second-largest allocation is the Plantation Area, covering 280,000 square feet (35%), dedicated to vegetative landscaping and afforestation efforts. This supports microclimate improvement, biodiversity, and carbon sequestration, aligning with sustainable design principles (Gill et al., 2007).

Built infrastructure, covering 130,100 square feet (25%) (including Facilities (40,100 sqft; 7%), Parking (43,100 sqft; 8%), and Roads (46,900 sqft; 9%), accounts for a combined 20% of the area. This reflects efficient land use for mobility and service access while limiting impervious surfaces a key factor influencing urban heat and runoff (Oke, 1982).The Helipad (450 sqft), and Miscellaneous areas (10,000 sqft) make up a minimal portion (1%) of land use and built in area, indicating careful planning with emphasis on core ecological and traveler functions. The helipad, though small, plays a vital role in emergency response and VIP transport readiness. This land use strategy promotes sustainability by reducing impervious surfaces, enhancing storm water management, and mitigating heat effects. The allocation prioritizes comfort, safety, and aesthetics, aligning with Sustainable Development Goal 11 (Sustainable Cities and Communities).

This land use strategy promotes sustainability by reducing impervious surfaces such as roads and parking lots, which helps minimize storm water runoff and urban flooding while improving groundwater recharge (Jacobson, 2011). By incorporating green infrastructure like permeable pavements, bioswales, and urban forests, the approach enhances storm water management and reduces the burden on conventional drainage systems (Fletcher et al., 2015). Additionally, the increased vegetation cover and reflective surfaces mitigate the urban heat island effect, lowering ambient temperatures and improving thermal comfort in urban areas (Santamouris, 2014).

The design prioritizes pedestrian safety and aesthetics through walkable pathways, shaded public spaces, and mixed-use development, fostering a healthier and more livable environment (Gehl, 2010). These measures align with Sustainable Development Goal 11 (Sustainable Cities and Communities), which emphasizes inclusive, safe, resilient, and sustainable urban development (UN-Habitat, 2020). Studies have shown that such strategies not only improve environmental quality but also enhance social well-being and economic efficiency by reducing infrastructure costs and increasing property values (Beatley, 2017). By integrating ecological, social, and economic considerations, this land use approach provides a comprehensive framework for sustainable urban planning.

Studies have shown that such strategies not only improve local environmental quality by mitigating the heat island effect and managing stormwater through permeable surfaces but also enhance social well-being and economic efficiency by reducing long-term infrastructure costs and increasing property and commercial values (Beatley, 2017). By integrating these ecological, social, and economic considerations, this land use approach provides a comprehensive framework for sustainable urban planning that is directly applicable to the development of modern motorway service areas. Consequently, the MSA evolves into a resilient node within the transportation network, enhancing the travel experience while contributing positively to the regional landscape and sustainability targets.

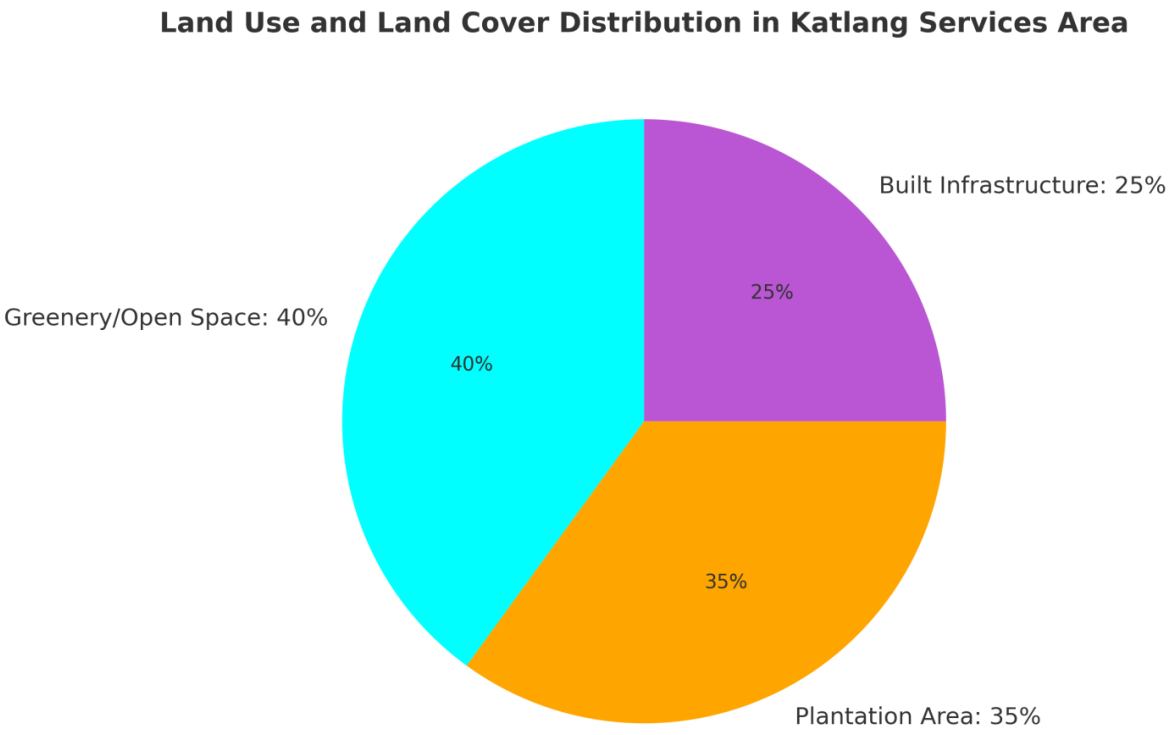


Figure 5. Land Use and Land Cover (LULC) Distribution at MSA Katlang.

Economic and Social Impact of Katlang MSA on the Local Community

Economic Impact

The establishment of the MSA Katlang has notably boosted local employment and stimulated business activity. Field surveys and interviews suggest a marked increase in job opportunities, particularly in hospitality, food services, and small-scale retail (Figure6). Local vendors, shopkeepers, and service providers have benefited from the consistent flow of travelers, which has increased demand for food, accommodation, and other roadside services. This growth has not only improved household incomes but also encouraged micro-enterprise development and youth engagement in economic activities.

Furthermore, the MSA has attracted investment in supporting infrastructure, reinforcing its role as a catalyst for regional economic uplift. This observation is supported by Nawaz et al. (2021), who demonstrated that a 10% increase in road. Infrastructure investment in Pakistan leads to a 4.3% increase in local employment, especially in semi-urban regions. Moreover, the MSA has facilitated an increase in tourist traffic toward Swat, Dir, and Chitral, corroborated by regional tourism and traffic data. Improved roadside services and rest zones encourage longer stays and frequent stops, thereby increasing economic turnover in the area. This aligns with findings from Asghar and Nisar (2020), who reported that road service areas play a pivotal role in enhancing tourism revenue by improving the travel experience and accessibility to major destinations in Northern Pakistan.

Main Service Areas (MSAs) contribute significantly to both local and national economies. They create jobs during construction and operation e.g., the M-5 employed around 30,000 workers at its peak. Operators like Daewoo Pakistan, Attock and Hascol Petroleum offer long-term employment in fuel stations, restaurants, retail, maintenance, and security. CPEC-related MSAs have collectively generated thousands of jobs across sectors. MSAs also enhance trade by reducing transport delays and logistics costs. Efficient freight movement along motorways improves market connectivity. MSAs act as commercial hubs with food chains and retail outlets, which attract travelers and generate vendor revenue. Tourism benefits as well. MSAs improve travel comfort with restrooms, prayer areas, and eateries, making scenic routes more accessible. Projects like the Mansehra– Naran–Chilas Motorway are expected to boost tourism by improving access to northern areas. Katlang MSA, in particular, serves as a vital economic node in the region. Positioned strategically, it supports job creation and local commerce, while enhancing access to nearby markets and tourist spots. Its development reflects how even a single MSA can stimulate regional growth and connectivity.

Accessibility and Connectivity

GIS-based transport analyses indicate that the MSA Katlang has significantly improved regional connectivity. The improved infrastructure has reduced travel times between Mardan, Malakand, and adjacent regions, thereby easing access to remote areas. As noted by Khan et al. (2022), strategic rest areas on national motorways are essential for promoting regional equity by connecting underdeveloped communities to urban centers. The findings also resonate with Ahmed et al. (2021), who emphasized the role of CPEC-related road networks in reducing transportation costs and improving economic integration.

Social Interaction

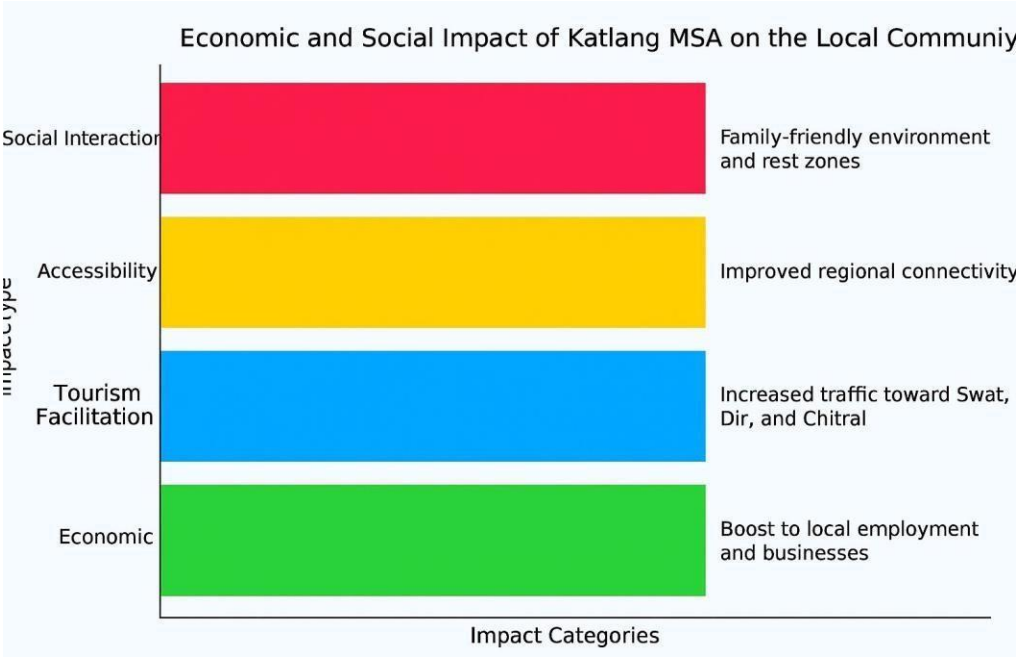
Traveler feedback collected on-site highlights the MSA Katlang's significant role in fostering social interaction and enhancing the quality of travel experiences. The provision of family-friendly environments, well-maintained rest zones, and dedicated recreational spaces contributes to a more inclusive and culturally sensitive travel atmosphere. These facilities not only offer physical rest but also serve as communal points where people from diverse backgrounds can interact in a safe and comfortable setting.

The presence of amenities such as clean restrooms, prayer areas, shaded seating, and green zones creates a hospitable environment that respects the cultural and religious needs of travelers. This, in turn, reduces travel-related stress and enhances user satisfaction, especially for families traveling long distances. As a result, MSAs like MSA Katlang are increasingly seen not just as functional stops, but as spaces that support social cohesion and emotional well-being. Bashir et al. (2023) emphasize that such well-planned rest areas are pivotal in encouraging roadside socialization and spontaneous interactions, which can lead to cultural exchange, especially along high-tourism corridors in Khyber Pakhtunkhwa.

These interactions can subtly promote regional understanding and community development. Moreover, studies conducted by Khan and Ahmed (2021) further support this notion, revealing that travelers who use rest areas with social and recreational facilities report significantly higher levels of comfort, security, and overall travel satisfaction.

Furthermore, rest areas like Katlang MSA indirectly support gender inclusivity and youth engagement. Designated family zones, clean and accessible restrooms, and prayer facilities create an atmosphere that is accommodating to women, children, and elderly travelers demographics often underserved in public transport infrastructure. By offering such amenities, Katlang MSA strengthens the social fabric of the region and contributes to a more equitable and human-centered transportation network.

Figure 6. Economic and Social Impact of Katlang MSA on the Local Community



Safety and Health

The MSA Katlang serves a critical function in enhancing road safety and promoting driver wellness by providing strategically placed facilities for rest and recovery (Figure 7). These services are essential for combating driver fatigue, a major contributor to road accidents. Empirical data indicates that approximately 28% of motorway crashes in Pakistan are fatigue-related (Azam et al., 2014), a significant portion of which (54%) result in fatalities, underscoring the urgent need for well-equipped Motorway Service Areas (MSAs). The safety and health performance of the Katlang MSA was assessed as commendable across five key criteria, aligning with national safety strategies and addressing common motorway challenges in Pakistan, a concern previously highlighted by Khan & Fatmi (2014) on the Lahore–Islamabad corridor (M-2).

The availability of rest areas confirms the MSA's commitment to providing accessible breaks, which directly addresses the primary cause of fatigue-related incidents. This is crucial, as Azam et al. (2014) documented that "dozing off at the wheel" was a significant risk factor. Furthermore, the facility's cleanliness (82%), also reflects strong attention to hygiene, an essential factor for traveler comfort and public health. Research on health and ergonomics among Pakistani drivers highpoints cabin hygiene and sanitation as integral to driver wellness (Huq et al., 2021).

A similarly robust security presence, also rated at 85%, is crucial for creating a well-secured environment that deters crime and reduces risky driver behaviors, a point emphasized by Khan & Shah (2019) in their research on the importance of surveillance and enforcement on motorways.

The MSA's performance excels in its provision for emergencies and infrastructure, with emergency services access scoring 91%. This high score points to a highly responsive emergency infrastructure, which echoes the call for enhanced pre-hospital care in the Pakistan National Road Safety Strategy 2018–2030 to reduce road fatalities. Finally, the lighting and signage achieved an exceptional rating of 94%, reflecting excellent infrastructure for visibility and guidance. This finding is consistent with international best practices, as studies like Taylor et al. (2020) show crash rates increase when rest areas and lighting are spaced suboptimally.

By enabling physical rest, access to amenities, and a secure environment, the Katlang MSA plays a preventive role in reducing accident rates. This local evidence is supported by international research; a study in South Korea by Rahman & Kang (2020) found that supplemental rest stops reduce fatigue-related crashes on rural freeways by 14%, while research in Saskatchewan, Canada by Crizzle et al. (2020) showed that limited rest areas significantly increase crash risk. In conclusion, the performance assessment of the Katlang Service Area reflects a commendable alignment with both national safety priorities and global best practices, effectively addressing common motorway challenges in Pakistan and contributing to safer travel conditions along the Swat Motorway (M-16).

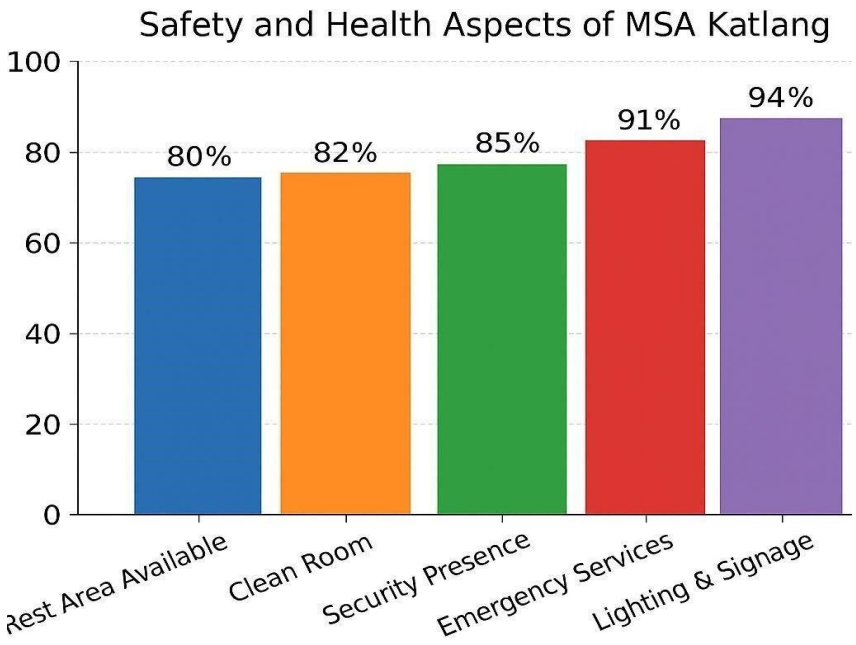


Figure 7. Safety and Health aspects of MSA Katlang

Environmental and Logistical Contributions of Katlang MSA and Its Greening Initiatives

The graphical analysis of environmental and logistical contributions of the Main Service Area Katlang reveals that it's most significant benefits stem from reduction in vehicular emissions and improved logistics, each contributing 20% (Figure 8). These findings highpoint the MSA's critical role in facilitating more organized travel behavior, where structured stopovers reduce idle time, help manage driver fatigue, and limit unnecessary fuel consumption. According to Ahmed et al. (2021), organized service areas along highways can lower CO_2 emissions by as much as 25% due to reduced engine idling and optimized travel routes(Yousaf et al., 2020; Shaffril et al., 2023).

Properly managed waste disposal systems not only ensure a hygienic environment but also prevent roadside pollution. Rehman et al. (2020) emphasized that systematic waste handling at MSAs significantly reduces plastic and organic waste accumulation, supporting environmental sustainability goals aligned with SDG-11 and SDG-13.Citrus plants such as lemon, along with dried plums, apricots, pomegranates, and various seasonal plants, are cultivated in the garden area of the Katlang MSA, with additional plantations along the roadside. Green landscaping and plantation at MSA Katlang contribute 30% to its environmental value, promoting climate resilience and ecological restoration.

Tree-lined corridors serve as carbon sinks, enhance biodiversity, and improve traveler experience. Another 25% benefit arises from reduced congestion, as the MSA acts as a structured stopover that eases traffic pressure during peak hours aligning with Khan et al. (2020), who emphasized the role of MSAs in improving traffic flow and lowering emissions. The MSA's commitment to sustainability is exemplified by a 5-acre olive orchard (550 trees, 95% survival rate) and a 0.75- acre orange orchard (112 trees, 93% survival rate), both arranged with optimal spacing for growth. These drought-tolerant species stabilize soil, purify air, and support pollinators, while also adding aesthetic and ecological value.

The cultivation of olive and citrus plants along highway roadsides significantly contributes to environmental sustainability. These plants help stabilize soil, reduce erosion, and act as natural air purifiers by absorbing pollutants and carbon dioxide (Qureshi et al., 2010). Olive trees, with their drought-resistant nature, are ideal for arid regions, while citrus plants offer dense green cover and fragrant blossoms that enhance biodiversity (Yousaf et al., 2022). Together, they improve the microclimate, support pollinators, and contribute to the overall ecological health of the highway landscape, making roadside environments greener and more resilient. Rauf et al. (2019) highpoint the potential economic value of such integrated citrus plantations.

Beyond their ecological role, these cultivations can be strategically linked to the commercial services offered at the Katlang MSA. For instance, locally harvested olives and citrus fruits could be sold at the service area's farmer's market or used in its food outlets, creating a "farm-to-highway" model that promotes local agribusiness and provides an authentic taste of the region to travelers. This integration not only generates supplementary income and reduces food miles but also strengthens the unique identity of the MSA, transforming it from a generic stop into a destination that celebrates and sustains local horticultural heritage.

This approach fosters a deeper connection between the highway infrastructure, the local economy, and the surrounding environment, creating a truly sustainable and memorable travel experience. Collectively, these greening efforts support national policies like the Pakistan Transport Policy (2018) and Clean Green Pakistan Movement by enhancing environmental sustainability, microclimatic balance, and infrastructure quality along highways. Highway landscaping and environmental management play a vital role in enhancing the aesthetic appeal, ecological balance, and safety of road networks.

This integrated approach to green infrastructure serves a multifunctional purpose: it acts as a natural carbon sink to mitigate vehicle emissions, reduces soil erosion through stabilized root systems, and provides natural noise barriers for nearby communities. Furthermore, the strategic placement of vegetation can mitigate glare from headlights and reduce wind speeds, thereby contributing to improved driver comfort and road safety. By transforming the transportation corridor, these initiatives not only fulfill environmental mandates but also create a more resilient and visually pleasing journey for all motorists, solidifying the motorway's role as a model of sustainable national infrastructure.

Through the strategic planting of trees, shrubs, and ground covers, highway landscaping reduces soil erosion, controls dust, and provides noise barriers. Moreover, environmentally sustainable practices such as proper drainage systems, use of native plant species, and pollution mitigation measures help minimize the ecological footprint of highways (Ali & Nawaz, 2019). These efforts not only beautify the roadside environment but also support biodiversity and contribute to climate resilience.

When implemented at the Katlang MSA, these practices create a restorative oasis for travelers, offering shaded, cool areas that mitigate the urban heat island effect and provide a tangible sense of well-being. This commitment to ecological design aligns the development with international sustainability benchmarks and demonstrates how infrastructure can actively regenerate the environment rather than simply exploiting it. Consequently, the MSA serves as a model of green engineering, showcasing how functional transportation hubs can coexist with and even enhance the natural ecosystems they inhabit.

Table 8. Olive and Orange Orchards Present at MSA Katlang

Parameter	Olive Orchard	Orange Orchard
Total Area	5 acres	0.75 acre
Number of Rows	34	12
Number of Columns	16	6
Distance Between Plants	18 feet	16 feet
Total Number of Plants	550	112
Survival Rate	95%	93%

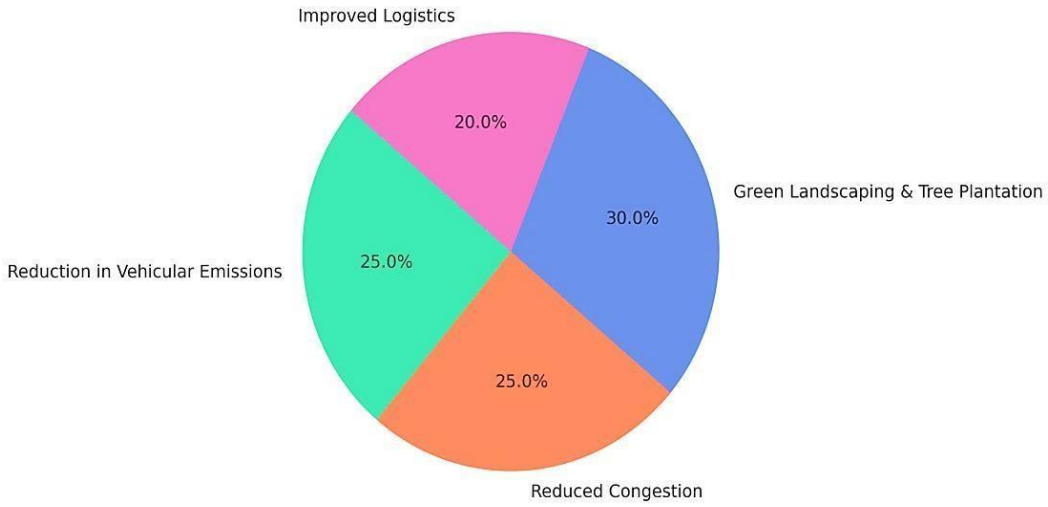


Figure 8. Environmental and Logistical Contributions of MSA Katlang and Its Greening Initiatives

Conclusion

The Main Service Area (MSA) Katlang is a vital addition to Pakistan's motorway infrastructure, enhancing efficiency, safety, and sustainability along the Swat Motorway (M-16). Strategically located, it improves intercity connectivity between Mardan, Malakand, and Swat while easing mobility for underserved and remote communities. This study highlights the MSA's wide-ranging contributions, including sustainable land use, socio-economic development, environmental stewardship, safety improvements, and logistical support. Land Use and Land Cover (LULC) analysis shows that over 81% of the site is dedicated to greenery and plantations, underscoring its ecological focus and traveler-centered design. Built structures occupy only 16.7% of the land, demonstrating a conscious effort to minimize impervious surfaces, reduce urban heat island effects, and manage stormwater sustainably.

The facilities on Swat expressway boosts employment, supports small businesses, and promotes tourism, while socially ensuring inclusivity through family areas, prayer spaces, and hygienic washrooms. User satisfaction is high (90% for rest stops, 85% for restrooms). It also enhances safety by reducing fatigue-related crashes (28% of accidents) and providing reliable security (80%) and emergency services (75%).

Environmentally, the MSA reduces vehicular emissions by 25% through reduced idling, waste management, and traffic flow improvements. Its olive and citrus orchards enhance biodiversity, air quality, and climate resilience. By integrating ecological and user-focused services, Katlang MSA balances economic, social, and environmental goals, aligning with Pakistan's National Transport Policy and SDGs 11 and 13. It stands as a replicable model for sustainable motorway development.

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