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Use Urban Green as a Mitigation Strategy to Combat Urban Heat Island Effect: A Case of Puri-Cuttack Road, Bhubaneswar, Odisha

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ABSTRACT

Environmental issues destabilize sustainable development of cities. In urban setting today urban greenery, vegetation and plants fall prey to the perils of increased levels of pollution. Roads and pavements constitute a major portion of the urban areas and are one of the highest contributors to the development of heat island effect in its tussle against the menace of imprudent urbanization; the go-green movement is a combatant that requires further reinforcement with regards to roads and pavements. Besides being a resource for the city, the urban green is a key player in countering the heat island effect.

The Puri Cuttack road in Bhubaneswar spans between two important nodes: The Rasulgarh Square and Kalpana Square. This stretch of 5.1 kms is abutted by a palette of commercial, industrial, healthcare, hospitality and residential settlements. The road also gives way to a secondary entrance to the Bhubaneswar Railway Station. The heat generated from structures, road materials and related anthropogenic activities has modified the neighborhood's natural state of vegetation and greenery.

The primary aim of this paper is to arrive at mitigation strategies for combating UHI at the Urban Design level. The paper uses the strategies of how one of the coolest cities in the world (Stuttgart, Germany) has been able to mitigate the effects of industrialization and improved the air quality issues in spite of its geographical set up. A set of recommendations to develop the urban environment of the Puri Cuttack road is prescribed based on the concepts comprehended from Stuttgart.

Introduction

History is testimony to the fact that gentrification and urbanization have had negative impacts on the environment owing to the changes it brings about in the physical and chemical properties of the existing atmosphere. A cumulative result of these impacts is called urban heat island (UHI). Due to the contribution to the green-house effect, primarily felt as temperature rise in manmade areas; UHI's have been indirectly a part of the global warming process.

The Research Question

Rapid urbanization has increased the whole range of urban infrastructure, services, housing and land. The increase in the traffic levels is the most unsustainable repercussion of this

development. There is hence an urgent need to respond to mitigate the indicators of the increased UHI. Figures3 and 4 refers to the traffic volumes in the 2 nodes of the paper's case. This paper makes an attempt to answer the following questions:

- What are the notable consequences of UHI on roads which are a highway but cut across a portion of the city?
- How best can the design principles deduced from Stuttgart be implemented to diminish the UHI on stretches like Puri Cuttack Road?

Research Objectives

Optimizing the UHI effect on urban stretches using Urban Design and Planning measures is the main aim of this paper as discussed earlier. A series of objectives act as a guide to achieve the primary aim.

1. Arrive at mitigation measures that can reduce the UHI effect on the 5.1 km stretch of Puri Cuttack Road.
2. Increase the resilience of the stretch against global warming by using green corridors at the urban design level.
3. Apply green infrastructure principles to improve the air quality of the vicinity.
4. Formulate generic measures that can be applied to a particular stretch that can improve the micro climate with focus on the heat mitigation strategies.

Methodology Adopted

A three-step approach is adapted for this paper. In the first step, which is analytical, a study for the city of Stuttgart is carried out to understand the measures that have been taken in order to mitigate the UHI. Based on the inferences from the analytical study of Stuttgart, the results are formulated into a framework and then applied to the context of Puri –Cuttack road in the second step. The last step is to suggest recommendations for developing the urban environment with special emphasis on roads.

UHI Mitigation using Stuttgart as a Precedence Concept

What Is UHI ?

This is a phenomenon in which predominance of dark, impermeable surfaces and concentrated human activity cause urban surface, air, and atmospheric temperatures to be several degrees hotter than those in the suburban or rural surroundings (Akbari 2005). UHI has major and varied effects on public health, air quality, energy consumption, climate adaptation, quality of life, storm water management, and environmental justice.

Primary Aim of Stuttgart in Mitigating UHI

The concepts applied by Stuttgart are one of the sustainable urban solutions for the city of tomorrow that depends on the application of the principles of urban heat management. It is the

key factor to diminishing the urban heat release, creating solutions of future climate change by reducing the volume of global emissions and creating smart growth and cool community scenarios' (Rehan,2016).

Applications of the Concepts in Urban Design and Planning

Europe and USA have been actively developing mitigation strategies and risk prevention measures concerning UHI phenomenon since many years. "UHI Project is developed in 8 of the most relevant metropolitan areas and Mega Urban Regions of the Central Europe cooperation program; one of them is Stuttgart city. UHI Project aims at developing mitigation and risk prevention and management strategies concerning the Urban Heat Island (UHI) phenomenon. This activity is supported by the Central European Programme and the European Regional Development Fund". The time span of this project was from 1st may 2011 to 30th April, 2014.(*Available Online at* https://www.met.hu/en/omsz/palyazatok_projektek/uhi/)

Amongst the 8 cities, Stuttgart was chosen as a case study for the paper since in spite of 60% of the city being covered by green, the industrial belt of the city is a major contributor to the UHI generated. Also, since the city lies in the valley basin, the heat generated remains trapped within the city itself. Similar to Bhubaneswar, Stuttgart also has numerous parks. The governing bodies have been instrumental in being able to mitigate the effects of UHI of this industrial town by applying effective climate planning strategies in the city's Urban Design and Planning interventions. Some of the interventions are described below:

Protection of Green Spaces

In order to achieve resilience against global warming, Stuttgart with the help of detailed local climatic maps has stopped construction activities in the recent years on land parcels which are green. These land parcels have been identified as green corridors and any construction in these areas would hinder wind movement and add to the UHI. As a result, at night, clean air sweeps down from the surrounding hills, runs through a series of 'ventilation-corridors' which have been kept open as wide, tree-flanked arteries within the city's street infrastructure.

Provision of Green Infrastructure

Cities have less vegetation than their surrounding rural areas. The UHI effect is exacerbated by this lack of vegetation because of reduced natural cooling potential from shade and plant evapotranspiration (Akbari 2002). During evapotranspiration, plants take in ambient carbon dioxide and other inputs and release oxygen and water vapor. The water vapour cools the leaves and when the wind blows, the surrounding area cools. Hence the provision of green infrastructure is a mandate to mitigate and combat UHI effects. For Stuttgart, "A new method for the strategic planning of green investments was directed towards the improvement of essential linkages between green spaces and places of employment and living. The essential linkages for commuters within Stuttgart Region are the 'development axes' mainly along the river valleys like the Neckar, the Rems and the Fils." Also, the city has 65,000 trees in parks and 35,000 along streets. Since the 70's, the city has integrated green areas into a large green 'U,' which now makes it possible to go through park environments all the way from the central royal gardens to the forests at the city's edge.

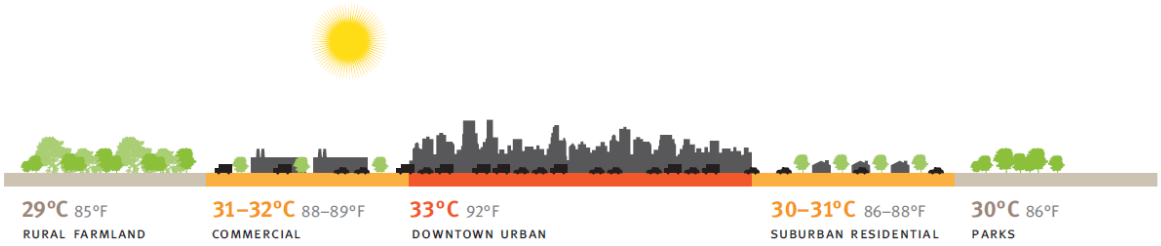

Figure 1: Indicating the effect of UHI in various neighborhoods highest being indicated by orange in Downtown Urban. *Source:UHI Mitigation Strategies, The institute national de santé publique,2009*

Materials

At least two of the three main causes of the urban heat island effect—dark surfaces and lack of vegetation- can be mitigated through policies and programs related to buildings and city planning. Installing reflective and lighter-coloured surfaces on city roadways, walkways and roofs is a primary UHI mitigation strategy. Surfaces store solar energy as latent heat and release it through contact (conduction) or slowly into the air (convection). The darker a surface, the more potential it has to store heat. A light-colored or reflective surface has a very small potential to store heat because of its high albedo, or reflective power. Surfaces that reflect solar energy stay cooler themselves, release less heat into the surrounding air, and allow for night-time cooling in a city. The EPA (2013a) reports that conventional asphalt pavements can reach summertime temperatures of 120-150°F. In contrast, a "cool" pavement can be 50-70°F cooler. In Stuttgart, not only at the surface, but also in the third dimension- facades, the heat is absorbed. That's where most of the facades in Stuttgart benefit from light colours.

Compact Urban Green

Stuttgart's land-use plan is urban-compact-green, of which a good example is the project of Stuttgart 21: ''The Stuttgart 21 project was a sustainable vision in urban design and planning due to its objectives of making the city more sustainable and cooler through maintaining the continuity of Rosenstein Park by transforming the present rail tracks into green urban spaces It is also possible to link the green areas of the park through passages of so-called green connections'' (Rehan 2016). Also, most of streets in Stuttgart are scarcely planted; sometimes trees have been planted just on one side of the street, sometimes not at all, or with a lot of space in between. Thus, urban compact green is a key factor to diminishing the urban heat release.

Water

Water has been a successful medium in reducing the temperature and water applications generally, are more effective when water is moving or dispersed as done by a fountain. The temperature reduction happens by evaporation which causes cooling. In case of Stuttgart, the use of fountains in the urban area and numerous lakes are visible along the Rosenstein Park (green U park), which is located in central Stuttgart. The two massive fountains that grace the park in front of the New Palace in central Stuttgart are quite beautiful (Wells et all 2017).

Framework for Urban Heat Management

As discussed earlier, the second step is to formulate framework based upon the inferences drawn from the interventions at Stuttgart. The strategies and interventions summarized from the previous section are vegetation, water, green infrastructure and the materials.

Case of Puri Cuttack Road

Benefits/Gains	Interventions/ Strategies	Actions	Scale
Improve the visual image of the environment.	Develop the Urban Green	Green Infrastructure, Urban Parks and green and water installations	Neighborhood
Improve the water quality.			
Reduce the temperature with the intent of betterment of the lives of the residential communities along this stretch.	Albedo	Reflective materials	Neighborhood
	Environmental Management	Develop strategies	City Level- Statutory body

Table 1: Analytical Framework

The Puri Cuttack road faces major issues that are caused by the rise in the micro temperature of this stretch. The main goal of this paper is to reduce the UHI effects on the stretch of 5.1 kms through a set of sub targets. They are:

- To improve the air quality by oxygen production and vegetation.
- To reduce the temperature with the intent of betterment of the lives of the residential communities along this stretch.
- To improve the water quality.
- To develop the visual image of the environment.

Role of air pollution in UHI

Recent studies on climate change issues suggest that air pollution is one of the significant factors, which influences the Earth's radiation budget through perturbing radiation balance (IPCC, 2017). A major research focus has been on the high levels of urban air pollution (e.g. particulates, aerosols, and ozone and volatile organic compounds) that emanated from various emission sectors including fossil fuel (coal of oil or gas) combustion from vehicles, industry and house-hold usages and open burning from waste burning from road-side or from dumping yard (Roth, 2007). Taking into account the seasonal mean day- (8:00 am-8:00 pm, IST) and night-time (8:00 pm to 8:00 am, IST) wherein observations were obtained from KIIT-DU station, an experiment using regression analysis was carried out at the 5 - study nodes (Rasulgarh node, Kalpana Node, Jharpada Node, New Bomikhal Flyover and old station road

crossing). It involves the analysis of effect of vehicular volume on air pollution (e.g. particulate matter of aerodynamic size less than 10 µm) levels in the ambient air.

Results reveal that regression coefficient of noise and air pollution levels are to be 0.44, which represents the moderate correlation between the levels of noise (L_n) and air pollution (PM_{10}). Due to the unavailability of ground-based air pollution (PM_{10}) data at the study nodes, we used statistical equation from regression curve of KIIT-DU station observations in order to estimate air pollution levels (PM_{10})at the corresponding nodes.

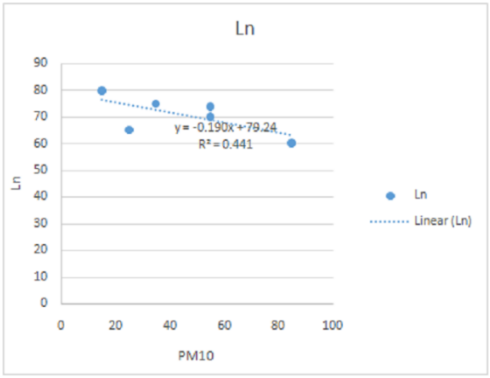

Figure 3: Computation of the regression coefficient

KIIT	PM10	Ln	T	RH
Monsoon (D)	15	80	30	86
Monsoon (N)	25	65	27	98
Winter (D)	55	70	32	40
Winter (N)	85	60	11	98
Summer (D)	35	75	40	50
Summer (N)	55	74	26	80

Figure 2: seasonal mean readings (day and night). *Source: KIIT(DU) station*

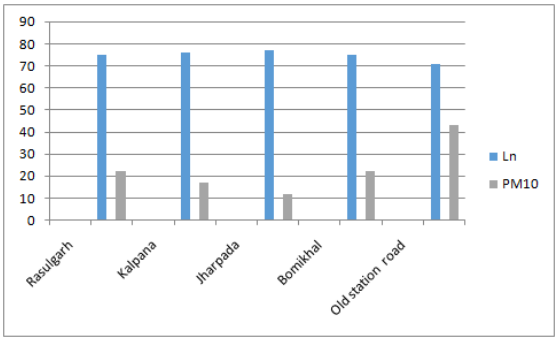

Figure 4: Computation of night time pollution levels

Inference

It is clearly visible from both the graphs that Kalpana node and the old station area have the maximum pollution levels which are imperative due to the anthropological heat and the vehicular movement in these 2 zones.

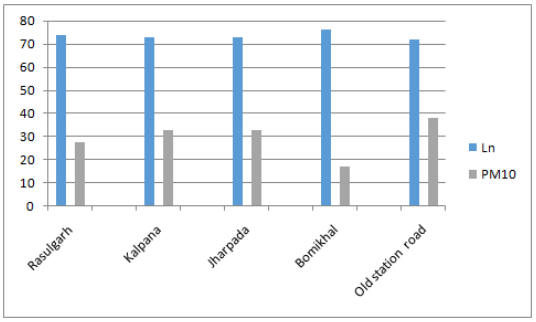

Figure 5: computation of day time pollution levels

Bomikhal and Jharpada have residential projects with urban green which reduces the values of pollution.

Rasulgarh as indicated in the photograph below has a larger expanse than all of the other nodes. This could probably be the reason for the pollution levels being lower than station road which is narrow and cluttered.

Documentation of the Important Junctions/Stops on the Stretch


Node 1


Node 2


Junction 4


Junction 3


Junction 5

Node 1: Rasulagarh Node: A major transit point and an entrance to Bhubaneswar from Kolkata via Cuttack. Since this area houses industrial estates, a huge mall, residential zones the generation of urban heat island effect is but inevitable. However, as the picture denotes, there is no sign of vegetation or water in spite of the fact that there is ample scope for placing the same.

Node 2: Kalpana Chowk: This is the one end of our paper's case, the Puri Cuttack Road, the other being the Rasulgarh Node. This is one of the exit/entrance gateways to Bhubaneswar while going to Puri, Konark and further regions in coastal Odisha. Plantation is scanty and mainly in the median.

Junction 3: Old Station Road Crossing: A busy node which gives way to a secondary entrance of the Bhubaneswar railway Station lacks any form of vegetation. Cluttered roads and archaic infrastructure are the identity of this connection. The junction of the connecting road and the main Puri Cuttack road is always a traffic bottleneck due to the inadequacy of its width. The air quality in this junction is the worst in the entire 5.1kms stretch.

Junction 4: Jhadpara Junction: As discussed earlier, the stretch of Puri Cuttack road, is home to several and important connecting roads of Bhubaneswar. The Jharpada flyover is one such junction. In spite of the traffic volume at this crossing being one of the highest in Bhubaneswar, no vegetation is witnessed in this area.

Junction 5: New Bomikhal Flyover: The newest chip of the block, this flyover is an additional connection to the prime vehicular spine of Bhubaneswar-The Janpath.

Inferences stemming from the Stuttgart clearly indicated that in response to local climate characteristics, areas of vegetation have an important effect on the local climate, due to cooling and shading, in particular by trees. Therefore, vegetation should be provided to surrounding developments and larger, connected green spaces should be created or maintained throughout developed areas. Also, the material used for the roads throughout is bitumen. An alternate finish for the roads, on the stretch abutting residential areas in particular with a higher solar reflective value would be recommended.

Implementing the Initiative

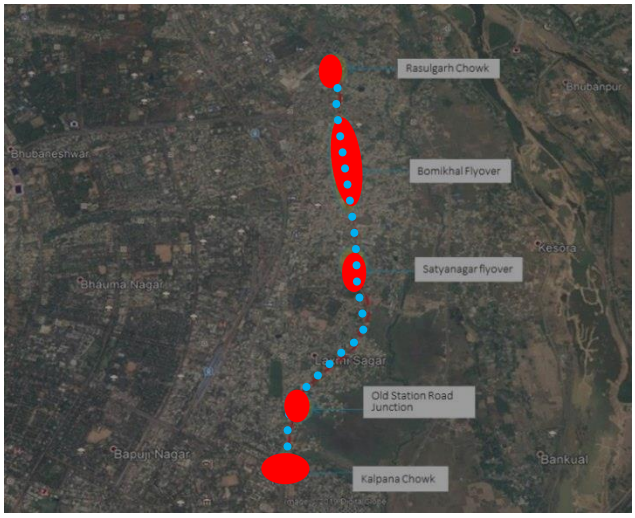

Figure 6: Five locations for implementation

As indicated in figure 6, the five area locations have been identified for implementation. In addition to the recommendation given, the patch of the road between any of the aforesaid locations will comply to the concept of connected green spaces as in Stuttgart.

In areas where there is a vehicular or pedestrian crossover, interventions indicated in figure 7 is to be followed. Each recommendation mentioned below has precedence in India and are supported with images for the same.

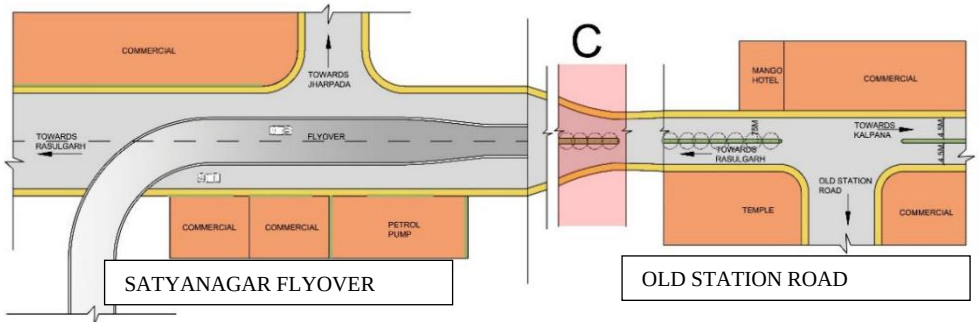

Figure 7: Satyanagar Flyover, Old station road and connection

Recommendation 1: Figure 7 represents the Satyanagar flyover and the old station road wherein the traffic volume is maximum. These two junctions are also the secondary entrance to the Janpath and the Bhubaneswar Railway station respectively. Hence the intervention proposed in these areas is minimal. Trees are proposed in the median and the underside of the flyover will be treated in the same manner as that proposed below the Bomikhal flyover.

However as discussed earlier, the idea is to propose a compact and connected green. Hence the median of the roads between any two junctions per say the old station road and Satyanagar flyover have also been proposed to have trees in the median indicated in the area marked C in figure 7. The adjoining images represent precedence in Lajpatnagar, Delhi where these practices have been implemented.

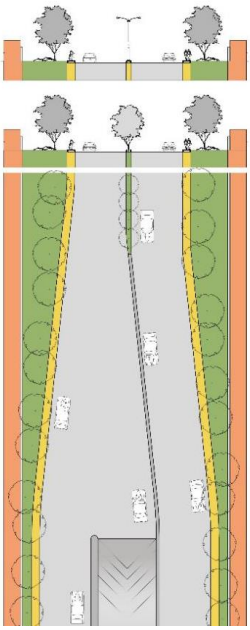

Figure 7 :Rasulgarh Node

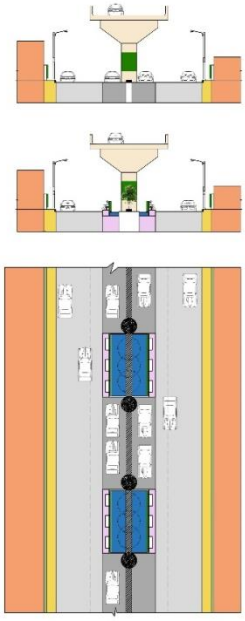

Figure 8: Bomikhal Flyover

Recommendation 2: Refer Figure8: New Bomikhal Flyover: As inferred from Stuttgart's study introduction of water and green reduced the micro temperature. Hence the area beneath the flyover which is currently being only for parking is proposed to have:

- Alternate pockets of water flanked with seating and the columns of the flyover to be covered with green.
- The following images wherein this intervention has been done in New Delhi.

Recommendation 3: Refer Figure7 for Rasulgarh Chowk: Unpaved Areas flanking the road to have native canopy trees planted. This will not only give the area the avenue look and feel but the augmented vegetation will reduce the temperature

CONCLUSION:

Studies on urban heat island and its effects have been happening since decades by urban climatologists, but the concern from the community and the statutory bodies has been recent. This interest is triggered due to heat related health issues. Development of heat island reduction strategies, mainly trees and vegetation, green roofs, and cool roofs are no more confined to the research fraternity. Literature reveals that the apparent strong influence of vegetation and water availability on the energy partitioning irrespective of the climate type, however, is an important result from the experiments carried out so far. Vegetation seems to be a useful way to reduce heat storage uptake during daytime and hence has the potential to effectively mitigate the nocturnal heat island.

The experiment conducted at the 5 study locations also reveals that the pollution levels are low in the zones with green sprawl available in the residential pockets. The most cluttered zone with the maximum anthropological and vehicular movement records the hightse level of pollution.

The aforesaid paper discussed and recommends enough possibilities to implement the design principles that can reduce the accumulation of the urban heat. Any renovation activity wherein mitigation of heat issues is involved, calls in for combined implementation of measures that are necessary to improve the social, physical or economical condition with urban heat island reduction strategies. If we take green as an example, besides cooling it has a positive effect on the human psyche in preventing depressions, etc. Green also produces oxygen and filters particulate matter and ozone out of the air.

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