Urban Climate and Challenges of Tropical Cities

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Abstract
This study examines the nature of urban climate, features and the challenges on the developing tropical cities in the 21st century. It argues that the use of principles of urban climate would help in providing comfortable living conditions and problem immune working environments for the inhabitants of tropical cities. The findings reveal that owing to poor environmental planning, inadequate geotechnical landscape surveys prior to the development of urban infrastructures, and non-adherence to the principles of urban climate, challenges of landscape degradation, excessive flooding of the built infrastructures, heat-island effects, and collapse of buildings have emerged. Suggested measures to avert these deplorable conditions in the developing tropical cities include moderate turn-out of rough surfaces, even spacing of buildings, green zone rehabilitation, controlled disposal of wastes, utilization of suitable building materials, establishment of climate data-banks, adherence to urban climate principles, and employment of skilful personnel for project execution and monitoring.

Keywords: Urban Climate, Principles, Tropical City, Features, Application.

Introduction
Urban environments refer to recognized towns and cities which are characterized by high population densities, different social infrastructures, tamed flora and fauna, altered atmospheric elements, and modified hydrogeomorphic basins. These spatial urban phenomena coupled with other human activities which are practically demonstrated in industry, transportation, communication. Commerce, education, recreation and waste disposal tend to influence the climate of the immediate environment to produce 'Urban Climate' (Oguntoyinbo, 1994; Okhakhu, 2010).

Urban climate, as Oguntoyinbo (1994) argues, exhibits its distinct characteristics through the differences between the city-centre and the surrounding country-side in such climatic parameters as precipitation, temperature, humidity, wind, atmospheric content and solar radiation. While such variations in climatic parameters have been adequately documented in respect of many cities in the temperate latitudes, a search through current literature reveals that similar studies in the tropical cities are very few (Oguntoyinbo, 1978; Jauregui, 1981; Adebayo, 1985; Ojo, 1988; 1991; Okhakhu, 2010).

This condition shows our first major limitation with regard to urban climate studies and our inability to utilize adequate and accurate climatic statistics in effecting positive environmental developments in the tropical latitude of the world.

It must be mentioned that planned cities with standard urban facilities and services anchored on the use of essential climatic parameters particularly precipitation, temperature, wind and humidity are always immune from the environmental challenges in our contemporary time. In these cities also, there is improved human safety which ushers in stable efficiency in the work place. No doubt, tremendous output and political security which promote safety of wealth are practically realized in these locations.

According to Oke (1986), the adoption, adherence to, and utilization of simple and inexpensive urban climate principles would assist in providing better living and working environments for the inhabitants living in the cities. Such benefits, as he argues, relate to healthier conditions, greater personal safety, improved efficiency, less wastage of energy and water, reduced property damage, and increased output. These positive benefits, no doubt, represent some of the overriding
interests in 'contemporary urban climate studies' in the world.

In tropical cities of the Less Developed World, particularly in Mexico, Ecuador, Nigeria and Cote D’Ivoire, owing to poor planning of urban activities, inadequate geotechnical pre-landscape evaluation, and non-adherence to climatic essentials in the urban development process, urban environmental problems which relate to excessive erosion and flooding, landslides, emergence of heat-effects and infrastructural decay among others have evolved.

The peculiar characteristics of the twenty-first century urban atmosphere revolve around reduction in water vapour, relative humidity, could cover, increased temperature, and occurrence of torrential precipitation. Other identifiable atmospheric features include increased noise and air pollutions, ozone layer depletion and distorted solar radiation (Okhakhu, 2010). There are other urban environmental hazards like destructive flood, landscape erosion, heat-island effects, and dark could cover which regularly affects visibility both on the highways and in the airports.

These occurrences do have fundamental consequences on the health and socio-economic activities of the urban residents. However, it is hoped that the inclusion of climate-sensitive concerns in the physical arrangement, design, construction and operation of tropical cities would prevent these challenges. It is centred on this goal that this study examines, among other, the climatic features of tropical cities and explores some strategies required to curb the emergence of urban challenge.

**Research Objectives**

The specific objectives of the this study are to examine the nature of urban climate and assess the climatic features of developing tropical cities. Also, the study examines the challenges of tropical cities and offers suitable strategies to ameliorate the deplorable conditions observed.

**Research Methods**

This study utilized both primary data and the documentary information. The primary data were derived from field surveys of some tropical cities in Nigeria. The cities were Lagos, Abuja and Maiduguri. The choice of the cities is based on their climatic experiences which are sub-equatorial, tropical hinterland and tropical continental over the years. The findings from the surveys were used to generalize current conditions in other cities in developing humid tropics of the world. The documentary information was obtained from published textbooks and journals. The use of this type of information enabled the study to review past climatic characteristics of developing tropical cities including their challenges down to the current period. Recent climate information on developing tropical cities available in Atlas (Collins, 2010) was obtained and used to augment the previous data available in textbooks. Conventional climatic approach was employed in the discussion of findings.

**The Nature of Urban Climate in the Developing Tropics**

The scientific observation, recording and assessment of urban climates particularly the climate in and around cities of the world is referred to as Urban Climatology. This scientific study extends further to include the physical and chemical processes which cause changes in the mean state of the atmosphere in contemporary cities. The assessment and predications of atmospheric conditions in human settlements which depend on the macroclimatic regime, regional, local, and the micro-scale effects caused by the landscapes, topography and urbanization are not excluded in this regard (Oke, 1984; 1986; Roger, 1986; Okhakhu, 2009).

Multi-dimensional modifications have been observed in contemporary cities of the developing humid tropics of the world. From Abidjan to Lagos in West Africa and from Sao Paolo to Buenos Aires in Latin America, widespread vegetal clearance from the natural landscapes has been carried out by the various urban authorities. The bare surfaces created have also been replaced with compactly arranged houses, concrete surfaces and paved streets. These artificial features created tend to make the city surfaces relatively rougher and drier particularly during the dry season in the humid tropics. Further, the buildings which constitute the various
streets in towns and cities do form urban street canyons which cause the urban surface to take on a distinctly three-dimensional character. These empirical modifications do regularly affect the absorption of solar radiation, the surface temperature, rates of evaporation, storage of heat and turbulence, and the wind climate of tropical cities.

High human population and different human activities in cities do contribute to emissions of heat, water vapour and pollutants which directly impact the rainfall, temperature, humidity, visibility and air quality in the atmosphere above cities. In fact, most tropical cities today have become the fundamental sites for greenhouse gas emissions owing to the high energy demands by urban residents and their various activities in industries, transportation, education, commerce, and disposal of waste materials.

The surfaces of contemporary tropical cities generally have a lower albedo, greater heat conduction capacity, minimized infiltration possibility owing to the presence of concrete surfaces, and reduced wind turbulence. In fact, the established drainage systems in cities do remove surface water quickly hence adequate moisture is seldom available to promote urban cooling. As observed by Oguntoyinbo (1994) and Okhakhu (2010), a temperature difference of 6°C was observed between the city centre and the countryside in studies using Ibadan and Benin City in Nigeria as case studies. These studies helped in establishing the existence of heat-island challenges in these tropical cities.

Different high-rise buildings and towers are erected in most tropical cities of the developing world. The presence of these structures has two main implications on the immediate urban surfaces below and the city surfaces above. First, the pressure gradient force which controls the rise and motion of the underlying city air is reduced and directly weakened by these high-rise facilities through frictional impact. This leads to heat energy accumulation alongside the generation of anthropogenic energy that eventually builds up the heat-island crisis in the developing tropical cities. Second, the urban atmosphere in dispersing the aerosols and other accumulated pollutants is frictionally retarded at its source as a result of weakened pressure gradient force and absence of the deflective momentum.

In some parts of the urban atmosphere, torrential precipitation would be experienced with a fall-back acid effect while on the other parts absence of precipitation with excessive heat wave would be observed. These environmental effects are currently experienced in the Horn of Africa and in the Niger Delta Region and the Sahel Zone of Nigeria.

The contemporary focus of urban climate studies throughout the world is on the causes, processes and patterns of atmospheric circulation, effects of torrential precipitation on the urban landscapes, air quality standards and pollution of the atmosphere, and atmospheric turbulence. Other aspects relate to causes and impacts of heat-island, urban climate and the health of city residents, use of green space with vegetation to improve urban climate and to standardize urban planning, collection of urban climate data, observation and recording of urban events as they affect the urban atmosphere, and the global climate change jinx.

In view of this background, the relevance of current urban climate studies is centred on the following themes:

- Providing better living and working environment for the urban people;
- Devising effective means to conserve scarce energy and water resource;
- Reducing much property damage and providing greater human safety in the event of disasters;
- Preventing massive air pollution and reducing he effects of acid rains on cities;
- Preventing the hazards of floods, heat stress and dust storms on city resident;
- Averting communication and transportation challenges;
- Determine the best locations for buildings and choice of building materials that would last for long period;
- Utilizing urban climate data for predicting the occurrences of hurricanes and tornadoes in cities (Okhakhu, 2010).

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It is harmony with these vital climatic themes that this current study is selected to assess the nature of urban climate, features and challenges of the developing tropical cities of the world in contemporary time.

**Research Problems and Literature Review**

Most of the studies in Climatology over the years have focused on urban climates in the temperate and mid-latitude industrialized countries whereas conditions in the humid tropics and sub-tropical latitudes have not been given adequate attention (Roger, 1986). In contemporary time, urbanization in the humid tropical particularly in West Africa takes place at an extremely rapid rate. This rate is most often devoid of sustainable planning. This situation, according to Roger (1986), results in severe challenges which are associated with environmental deterioration, unhealthy living conditions. Shortage of energy, food and water, infrastructural decay, and increased exposure of the population to floods and gusty winds. Many of these problems would have been mitigated if climatic principles were incorporated in the planning and development of these urban areas.

In a study which examined urban settlements planning and extreme climatic forces, Davis (1986) explained that the prevalence of poverty, increased population, unplanned urbanization and the random location of settlements in flood plains, steeps slopes, river valleys and coastal estuaries were the causes of urban landscape degradation and flooding of houses and streets in the humid tropics. Other associated effects, as Davis (1986) rightly argued, include frequent occurrences of landslides and collapse of buildings. In a related study, Luis (1986) points out that the presence of unstable grounds for buildings, absence of basic services, and the deteriorating physical environments influenced by extreme climatic forces such as heavy rainfall and gusty winds are the main problems of some towns in tropical Latin America. Observed in these studies are the problems of inadequate geotechnical pre-landscape evaluation and negligence of climatic elements in the development process of these towns.

In most parts of tropical Africa particularly in Niger, Togo, Chad, Sudan and Nigeria, urbanization preceded industrialization (Mabogunje, 1968; Oke, 1986). This situation resulted from the continuous human migration from the vast agricultural regions. The towns and cities established then, although generally poor in terms of wealth, were inadequately planned by the urban authorities (Onokerhoraye, 1988; Sada, 1988). Specifically, essential climatic elements namely precipitation, solar radiation, wind and humidity were not incorporated in the urban development spectrum. As a result, these tropical town and cities could not provide the basic human needs and services in terms of foods, stable energy, employment, healthcare, sanitation, education, transport and communication networks, and responsive political security (Segynola, 2005; Okhakhu, 2010).

As African Economic Research Consortium (2008) explained, the earth's surface temperatures particularly in tropical cities have increased and their associated impacts on the physical and biological systems are increasing also. Climate change is bringing about numerous environmental changes including sea-level rise and shifts of climatic zones because of higher temperatures and altered precipitation patterns. Increased frequency and magnitude of extreme weather events such as droughts, floods and storms are being observed both in the tropical and temperate latitudes and these extreme weather phenomena are attributed to human-induced climate change.

These extreme weather events have both short-term and long-term socio-economic and political consequences, including environmental degradation, damage to forms and crops, destruction of infrastructures such as houses and roads (Okhakhu, 2010), displacement of people, and increased spread of endemic water and vector-borne diseases. The ravaging effects of drought persist in the desert areas of sub-Saharan Africa. In fact, communities living in
these regions are continuously in a state of poverty, and are as a consequence, prone to civil strife and political turmoil (African Economic Research Consortium. 2008).

Thomas (1986) notes that in many tropical cities, storm drainage problems are extreme for three main reasons: first, that rainstorms are often intense; second, that urban growth is frequently rapid and uncontrolled so that neither time nor resources are available to mitigate the storm run-off problem. As a result, the uncontrolled storm run-off would over-tax the originally adequate storm sewer system which leads to serious inundation of the lower-town area; third, that the impact of sediments deposited in the drains and natural channels are specifically severe because of the highly erosive rainstorms of some tropical regions and the widespread unpaired but heavily used roads and poorly designed construction sties (Thomas, 1986).

Currently, most tropical cities are not only disrupted of their natural vegetations through various human activities but they are also built with different foreign construction materials. These include cement, marble, glass, iron railings, steel, tars, stones, aluminum roofing sheets, and extensive security wires. While it is essential to note that some of these materials do not comfortably suit the tropical climate of the developing countries, it is also vital to state that their application has turned out a variety of artificially compact urban surfaces with two main implications. First, the rough surfaces are favourably disposed to high solar energy reception and extensive heat storage.

Also, the rough surfaces do not encourage regular urban evaporation which in turn affects the natural thermal structures of the cities. These conditions, no doubt, result in heat-island effect with its negative implications on the health of the urban residents. Cases of profuse perspiration, restlessness, chronic dehydration and general body weakness are rampant. Second, these compact and extensive rough urban surfaces do not allow easy infiltration of excess surface rainwater which is derived from torrential atmospheric precipitation. This leads to severe urban erosion and devastative flooding of social infrastructures (Okhakhu, 2010).

From the on-going review, it is clear that most tropical cities are inadequately planned by the various urban authorities. Also, the use of essential climatic elements such as precipitation, temperature and wind in urban construction is neglected. This is why current challenges of urban floods. Mudflows, traffic delays, heat-island effects, infrastructural decay, human displacement and dwindled socio-economic activities are rampant. It is against this problem background that this current study explores essential climatic strategies which could help reverse these adverse climatic conditions in the developing tropical cities of the world.

Characteristics of Development Tropical Cities

In many developing tropical cities, most of the erected buildings are generally arranged in a compact configuration. This higher structural density may be a traditional response to the need to minimize solar penetration to street-level, or a more basic expression of the transportation modes, the land-holding system, absence of land, or poverty. It is also common to find a preponderance of single storey-buildings along the main streets with poor few drains. These geometric features, in combination with the prevalence of higher solar elevations, make the building roofs relatively more important than their walls in terms of surface energy and mass exchange. This has implications on the urban surface albedo, surface emissivity, shade and diffuse lighting, day length, screening of outgoing long wave radiation, aerodynamic roughness and the interaction between streets and the air above roof level (Oke, 1986).

Different building materials are used in tropical cities of the world. In the hot, humid locations, light construction is favoured so as to promote beneficial ventilation in and outside of the buildings while in the hot-dry areas which have a large daily temperature range, materials with high thermal mass such as stones and bricks are regularly adopted in order to procrastinate the penetration of the temperature wave (Oke, 1986; Achempong, 1988; Okhakhu, 2010).

Using the most recent United Nations’ estimates, the total World population would climb from 4.4 billion in 1980 to 6.1 billion in 2000, and to 8.2 billion in 2025 before leveling at about 10.2 billion in 2100 (Peterson, 1984). Of much concern here is the fact that this population is increasingly tending to
congregate in urban environments so that by the year 2025, more than 60% would be living in cities. Within these population statistics, according to Oke (1986), lies an even more dramatic shift of urbanization activity to the Less Developed tropical pasts of the world. On this consideration, the Less Developed parts of the world are projected to grow rapidly in both total population and the proportion of people (Oke, 1986) who are urban dwellers. This feature, no doubt, would be truly realized in countries located in Africa and South America.

Unfortunately, these dense human populations would certainly not be satisfactorily accommodated by the meager services available in these rapidly growing cities. Owing to inadequate housing, more urban slums with their attendant crimes would likely emerge. As a result of high human congregations in the few available industrial establishments in the cities, human-induced climate change would occur, with serious negative impacts on the geomorphic, hydrological, atmospheric, fauna and vegetal resources. In other words, the over-stressed industries would release some pollutants into the urban atmosphere with fundamental impacts on the received and emitted solar energy. Such pollutants would also affect the natural purity of the landscapes, water bodies, plants and animals, and the thermal properties of the rough urban surfaces. The aggregate consequences of these attributes would be observed in terms of poor human health, reduced work efficiency, weathering of physical infrastructures, heat-island effects, poor environmental sanitation and urban insecurity involving both human lives and properties.

Most of the urban canopy spheres of the Less Developed tropical cities to exhibit rough sky line geometry. In fact, varieties of erected buildings and steel towers dominate the first layer of the urban atmosphere referred to as the troposphere. In Lagos, Accra, Mexico, Sao Paolo and Kenya, high-rise buildings showing foreign architectural decorations dot the urban sky lines. While these erected infrastructures naturally obstruct the free circulating breezes and reduce the efficiency of the urban atmosphere in combating human-induced pollutions, they also receive, store and emit solar radiation at different hour-intervals. These conditions tend to influences significantly the rates of ventilation in tropical cities which, in the long run, manifest in serious heat crises for the peoples (Okhakhu, 2010).

Finally, tropical cities are serving as vital commercial centres. Agricultural products and different industrial goods are received, bought and resold in cities. The carelessly dumped wastes from these domestic and international trades do constitute huge mass of urban environmental problems to the city residents. This is in terms of ill-health derivable from human regular contact with the surface water resources, vegetal, fauna and landscape elements, among others. Waste obstruction of traffic flow on the city highways and the offensive odour which the resident breathe in must be mentioned here. The decayed remains of these wastes or the original wastes would find their way into the city drains where they prevent the regular flow of excess precipitation.

The result would be felt in excessive urban flooding of adjoining buildings and workplaces. Sporadically, when these wastes are burnt within the city, they do release smokes and some particulates into the urban atmosphere. If these pollutants are not disseminated timely in the urban atmosphere through the natural purification process carried out by the planetary winds, they tend to affect the natural quality of the received precipitation on the city landscape. Negative impacts could be observed on many weathered urban social infrastructures and destroyed domestic agricultural activities. Other noticeable effects are related to poor human health in terms of sight, respiratory stomach disease.

Policy Recommendations
One of the significance of urban climate studies is to devise a pragmatic strategy where essential climatic elements and diverse human activities in cities are mutually related such that urban environmental problems are prevented at their early stage of development. This is true because climate influences both natural and human process occurring on the city landscapes. Where, on the reverse, unplanned human activities modify the urban climate system, adverse consequences are observed on the environment. These include increased temperatures stormy precipitation, gusty
winds, urban erosion and floods, collapsed social infrastructures, traffic obstruction by fogs, poor human health and plummeted socio-economic activities. It is against this adverse climate background that we make some recommendations in this study.

First, controlled and planned urbanization is recommended for the developing tropical cities of the world. Government regulations which concern reduction in birth rates and less focus on urban migration benefits are foremost in the aspect. When these objectives are realized, severed problems associated with environmental deterioration, unhealthy living conditions, shortage of energy, food and water, infrastructural decay and increased exposure of the people to floods and gusty winds would be averted. In addition, essential climatic concerns should be incorporated in most urban planning, design and physical infrastructural development. This strategy would ensure long-time durability of the established infrastructures against the prevailing destructive climatic forces, particularly torrential precipitation and gusty winds.

Establishment of settlements in flood plains, steep slopes, river valleys and coastal estuaries which are fundamentally prone to landslides, flooding and building collapse should be avoided in the developing tropical cities. Also, all fragile ecological zones must be left unused for construction purposes in these parts of the world. In the areas where the lands are regarded as relatively stable for construction activities, geotechnical landscape surveys are recommended. These surveys would help determine the actual stability and suitability of the lands for the planned development purposes.

Selective and controlled clearance of urban vegetations for different projects execution is necessary. This measure would make the tropical city landscapes retain some vegetation alongside the built rough urban surfaces. The positive implication of this practices would be seen on the ability of the urban landscapes to absorb much of the excess atmospheric precipitation which would have caused excessive flooding of houses, work-places and destruction of valuable properties. Also, the release of soil moisture to the tropical city atmosphere through the hydrological cycle would enhance the mitigation of increased temperatures affecting the diverse human populations. In fact, this process of temperature mitigation would be completed through the occurrence of precipitation. This natural temperature reduction in tropical cities does not stand as a permanent substitute for the artificial benefits derivable from the routine usage of different electrical fans and improved modern air-conditioners. The provision of stable power by the governments of tropical cities to facilitate the efficient function of these electrical air-conditioners is a necessity in this regard.

Adherence to compact building configuration tends to cause heat-island effects in tropical cities and this should be avoided through respect for stipulated building codes which strongly recommend separation and spacing among houses. This separation process would encourage natural circulation of land and sea breezes and the emission of accumulated heat energy into the city atmosphere. The process would also enhance the dispersion of some aerosols in the urban canopy sphere. The realization of these measures, no doubt, would result in healthy urban environments for the people and their diverse activities.

Deposition of waste products in urban drains must be prevented and controlled. This requires the concerted efforts of the residents and governments of tropical cities of the World. Prevention of flooding and enhancement of traffic flow are the envisaged benefits of this measure when realized. Financial institutions, commercial centres, industrial establishments, tourist spots, health centres and educational institutions would also benefit immensely. With improved standards of living, therefore, many socio-economic problems especially unemployment and starvation would cease to exist. Almost permanently in these cities. On this note, functional political stability would evolve with its widespread benefits in the areas of improved work-place efficiency, environmental sanity, standard transport networks. Jobs creation, food provision, and improved domestic and international trades, among others.

Wealth and climate data-banks should be put in place in most tropical cities. Their establishment could be realized through the set up of land, sea and air meteorological stations using both private and government
funds in addition to employment of skilful meteorological engineers. The use of weather satellites would further assist immensely in the process of gathering recent climate information. The availability of these data would enable climatologists to know the current weather conditions of these cities. Also, the predictions of future weather conditions in terms of could spread, thunderstorm occurrence, hurricane development, precipitation commencement, temperature variability, and high humidity build-up would be feasibly carried out. The positive implications of this precise prediction would be seen in many aspects of urban activities such as erection of buildings. Construction of roads and the daily administration of cities which are protected from these violent climatic occurrences. Prevention of aviation disasters, road and railway crashes, erosion and flood damages of landed properties, and safety of people in the cities are other benefits derivable from the use of weather data-banks.

Excessive rough surface development and other heat generating activities should be discouraged in the tropical cities where high temperature incidents are natural phenomena. Rather, urban green zones with artificial water channels should be established. These urban features, through the release of fresh breezes and natural moisture, would be able to mitigate the heat-island effects in the cities. The precipitation effects caused by these zones and channels would further reduce the heat challenges in this part of the world.

The overall success of these recommendation depend on the incorporation of climatic essentials in the urban development process, provision of adequate capital, existence of functional political stability, utilization of experts in projects execution, and the authentic readiness of governments of the developing tropical cities to accept contemporary positive changes with their widespread benefits.

Conclusion
It must be mentioned that planned cities with standard urban facilities and services anchored on the use of essential climatic parameters particularly precipitation, temperature, wind and humidity are always immune from the environmental challenges in our contemporary time. In these cities also, there is improved human safety which ushers in stable efficiency in the work places. No doubt, tremendous output and political security which promote safety of wealth are practically realized in these location. According to Oke (1986) the adoption, adherence to, and utilization of simple urban climate principles would assist in providing better living and working environments for the inhabitants living in the cities. Such benefits, as he argues, relate to healthier conditions, greater personal safety, improved efficiency, less wastage of energy and water, reduced property damage, and increased output. These objectives represent some of the overriding interests in contemporary urban climate studies' which have been practically demonstrated in the temperate cities of the USA, Paris, London and Sydney.

In tropical cities of the Less Developed World, particularly in Mexico, Ecuador, Nigeria and Cote D’Ivoire, owing to poor planning of urban activities, inadequate geotechnical pre-landscape evaluation, and non-adherence to climatic essentials in the urban development process, urban environmental problems which relate to excessive erosion and flooding, landslides, emergence of heat-effects and infrastructural decay among others have evolved.

The study concludes with a number of achievable recommendations which include moderate turn-out of urban rough surfaces, selective vegetal clearance and use of suitable building materials. Others are the establishment of weather and climate date-banks, green-zone development, even spacing of buildings and the avoidance of wastes in constructed urban drains. The realization of these measures greatly depend on fund availability, supply of adequate material resources, skilful personnel, political security, regular predictions of tropical weather and the existence of mutual co-operations in the exchange of climate data among tropical cities of the developing World. The invaluable contributions of urban dwellers, corporate agencies, industrial establishments and governments of tropical cities are needed in this regard.
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