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INDICATORS OF URBAN SUSTAINABILITY IN MEXICO

Silverio HERNÁNDEZ-MORENO
Universidad Autónoma del Estado de México, Cerro de Coatepec s/no., Ciudad Universitaria, C. P. 50100 Toluca, Estado de México, México
silverhm2002@yahoo.com.mx

Jesús DE HOYOS-MARTÍNEZ
Universidad Autónoma del Estado de México, Cerro de Coatepec s/no., Ciudad Universitaria, C. P. 50100 Toluca, Estado de México, México
consultoria.jesus@gmail.com

Abstract
The principal objective of this project is to summarize the characteristics that define urban sustainability in Mexican cities; its basic principles and the advantages of their application in the development of future cities, as well as the description of the indicators of urban sustainability that directly affect the development of communities, from households, colonies or neighbourhoods to cities or regions. The project's method is based on the analysis of bibliographical information and the revision of some practical cases that refer to the development of sustainable indicators in urban environment.
Keywords: Indicators, sustainability, urbanism, development, cities.

1. INTRODUCTION

The 2007-2012 National Development Plan (PND) of the Executive Branch of the Government of Mexico, in the fourth of five central themes on public policy described (PND, 2007), sums up *environmental sustainability* in three main aspects: the sustainable use of natural resources, protection of the environment and the knowledge and culture needed for sustainability; and even though this theme has errors in some concepts and is incomplete with respect to the definition of sustainable development presented by the *Brundtland Report* (UN, 1982), emphasizes the sustainability as an important factor in the development of the country, particularly in the use of water, forests, jungles and biodiversity; at the same time it emphasizes environmental management and ecological order leading to controlling climate change and appropriate management of dangerous solid waste. Though it is not the central theme of this paper, we should mention that this national plan, in the section of that theme or chapter 4, there is no mention of the sustainable management of energy, of raw materials or how economic and social aspects should interact with the environment, in order to complete the triangle of

sustainable development in every way; in any case, the paper also mentions that scientific environmental research is necessary for social development, as well as education and environmental cultures (PND, 2007). On the other hand, Mexico has been taking steps towards the moderation and reduction of environmental impact in diverse sectors of production, like fisheries, forestry and industry, with the dispositions and considerations described in the General Law of Ecological Equilibrium and Environmental Protection, in the section of environmental impact (LGEEPA), but when it comes to city planning and construction there are no existing norms which directly regulate the design of architectural and urbanization projects or products. Recently the National Housing Commission (CONAVI, 2007) published a code for the construction of housing which includes in part VI a reference to sustainability, chapter 27 is entitled Sustainability where an approximation is made to what could be an urban-architectural sustainable design, including some consideration about energy, bioclimatic design at an urban and architectural level, water, green space, climatic maps and small section referring to thermal materials, which can be of great use for home design though not at a norm or regulation level for sustainable construction, and in the case of an individual wanting to apply these recommendations, there is a lack of methodology which would help to apply the recommendations to any type of project.

This paper is an introduction to Sustainable Urban Development or sometimes called *New Urbanism*, and will discuss the principles and advantages of its application (CNU, 2008), to understand *the indicators of sustainability* which are must be taken into account for there to be good planning in sustainable urban development, and to understand the factors that influence cities in particular, specifically through the concrete study of: housing, neighborhoods and whole communities.

2. THE CONCEPT OF SUSTAINABLE URBAN DESIGN

Sustainability is when the current society can satisfy all of its needs without compromising the needs of future generations (UN, 1982), taking advantage of the natural resources while controlling and changing the environmental impact caused by any productive activity (Ingwe and all, 2009). On the other hand, design is a creative process in the production of objects, projects and services that serve to satisfy any necessity. In the case of architecture and urbanism design serves to satisfy the needs of inhabitability. So, sustainable urban design is a creative process for the implementation of urban projects under sustainable premises and practices. The sustainable principles and practices in terms of urbanism are (Serrano-Barquín et al., 2009):

- Pedestrian space
- Urban connectivity

- Diversity in the use of soil
- Diversity in materials for housing
- Architectural and urban quality
- Increments in urban density
- Intelligent transportation
- Sustainability of the site
- Sustainable management of project sites
- Sustainable management of the energy for the Project. It is important to mention that the energy variable is linked to climate change and does not only affect transportation and agriculture but also the construction industry and the urbanization of cities as well as other industries indirectly related to construction. (Musatescu et al., 2009).
- Sustainable management of the water for the project
- Sustainable management of the construction materials
- Sustainable management of the waste during the entire cycle of life of the project
- Sustainable management of the comfort of the interior and exterior in urban architectural projects
- Improvement of the quality of life of the user and inhabitants of cities

Sustainable design is a very important and basic tool in the production and implementation of sustainable urban projects, as indicated above, it is a creative process in which premises of sustainability are used, such as the better use of natural, financial and human resources to lessen the environmental impact caused by these activities of product generation and urban services. According to Kim (1998), there are three general principles of sustainable design: firstly the saving of resources by applying the premises of reduction, reuse and recycling; secondly the methodology of life cycle design, which helps evaluate and design the product according to the impact it will cause in each part of the useful life of the product; and thirdly the "human design" focused on attending to the social and esthetic needs which instigate the project or product (Kim, 1998). These last points are very similar to the methodology proposal from LEED® (Leader in Energy and Environmental Design), which is a method used in construction processes for the production of sustainable or partially sustainable buildings.

In sustainable urban design, methodology is also based on these points, in other words, sustainable design as a design tool applied to urbanism. Therefore, sustainable urbanism is a new and intelligent way to manage urbanism in the world.

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3. BENEFITS OF SUSTAINABLE URBANISM

The benefits of the application of new urbanism are not only for the user or inhabitant, but also for developers, businesses and governments (Hernández-Moreno, 2008). The following shows the main benefits for each one:

Benefits for inhabitants:

- Better quality of life
- Less traffic from vehicles
- Life with less stress
- Better workplaces and recreational areas
- Better displacement from one location to another
- An important reduction in pollution and environmental impact

Benefits for businesses:

- Increase in sales due to more pedestrians in cities
- Less stress in supplying each customer
- Saving money on transportation
- Rental costs decrease in commercial zones and an increase in opportunities for small and large businesses

These benefits for retailers also bring benefits for the development of cities as well as the optimal use of city infrastructure, not only improves the look of business but the quality of life of the inhabitants and the improvement of the urban image (Popescu, 2009). At the same times, it is important that new technologies are used in the management of public services in cities, for example, electronic services through e-mail is an important tool for the improvement in the administration of government services, in order to transform and improve the interactions between public administration and their clients (citizens and investors) who invest in the development of the (Plumb and Zamfir, 2009).

Benefits for developers:

- Better opportunities for real-estate development due to the increase of density and the organization of cities
- More sales per square meter of land
- And added value to the land
- Cost savings due to time saving, in the cities that adopt intelligent growth (Duany, 2006)
- Space saving in parking areas that serve as a commercial area as well

- Less need for parking areas due to an increase in pedestrians
- Reduction of impact on urban infrastructure due to a reduction in the use of automobiles
- Decrease in expenses for environmental impact

Benefits for local governments:

- More stability in the payment of taxes
- Less per-capita expense for infrastructures compared with traditional urbanism
- Less vehicle traffic
- Less expense in public safety due to the increase in people day and night
- Better image and identity of the community or city
- Less risk in excessive or unsafe urban growth
- Better relationship between authorities and citizens
- Reduction in costs for environmental impact

By summing up the benefits for all sectors, it can be stated that the reduction of environmental impact, the better use of natural and economical resources and an improvement of quality of life for the inhabitants are the main benefits of the application of sustainable urban development.

In order for sustainable development to be applied in Mexico, there are various **obstacles which must be overcome** (Hernández-Moreno, 2008):

- The high initial cost of adopting an environmental mentality within urbanism, and other areas as well.
- An obvious technological and scientific delay which impedes the implementation of the necessary mechanisms to make cities sustainable; example: The mechanisms and devices to implement modern photovoltaic, wind power, geothermal power and mini-hydraulic systems, as well as the implementation of intelligent transportation, the treatment of dangerous waste, the recovery and treatment of sewage and run-off, etc.
- Extend and modify current norms according to sustainable development and sustainable urban planning, as well as public policy.
- Restore political and social interest in land use.
- And correct buildings constructed previously in an excessive and unplanned fashion.

4. DESCRIPTION OF THE INDICATORS OF URBAN SUSTAINABILITY

Before describing these sustainability indicators according to sustainable urbanism, it is important to mention that this type of urbanism works at various levels, specifically two types: local or regional and

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global. This paper will describe the most important indicators at a regional level for neighborhoods, as an essential part of the development of cities. The following are all the levels at which the criteria and premises of urban sustainability can be applied (Ewin, 1996):

- Buildings
- Groups of buildings
- City blocks
- Neighborhoods
- Networks of neighborhoods
- Downtowns
- Sections of cities
- Cities
- Regions
- Countries

In this paper the indicators are described which help us to make decisions on the appropriate implementation of sustainable urban planning and at the same city development of services, equipment, urban infrastructure, transportation and quality housing; for example, after analyzing the variables related to the system of transportation with mathematic models and methods, there would be a partial improvement in air pollution caused by transportation (Hadipour et al., 2009), proposing solutions to the problems of the technology of transportation, as an indicator of urban sustainability.. It is well known that the development of infrastructure, equipment and construction of buildings in general should be of quality so that cities can grow, from planning to implementation, which requires models, indicators and methodologies which help us with the task of decision making and planning of architecture or urbanism projects. One of the models that we can use to elevate quality in the area of construction is the Quality Management framework which suggests various elements of total quality in construction processes or engineering and architectural projects by means of initiatives which should be implemented to elevate quality of some construction products (Delgado-Hernández and Aspinwall, 2008). One of the elements and initiatives that require elevating and securing quality in the construction process is knowing the factors that intervene in the planning of a project which are determined by the treatment of its variable of study like factors that insist on the success and quality of the projects, and at the same time, of the factors that give us the necessary information for decision making about design and planning of these development projects. Therefore, this paper focuses on the study of generic themes or categories as central themes of development in the urban part of cities, considering the fact that other factors influence the development of cities, but because of the importance of the development of *sustainable*

criteria concerning sustainable urbanism, sustainable design, urban connectivity, urban transport and its relationship with the architectural part, etc., it is necessary that the urban indicators revolve around the premises of sustainability, classified into distinct categories.

What is a sustainability indicator? It is a statistics tool which captures and measures a particular aspect of sustainable development in a way that is easy to understand and communicate, permitting monitoring and subsequently the execution and conduction of a public policy or process of management (Ryding et al., 2003). The number of indicators of sustainability depends on the level of analysis that needs to be carried out as well as the variables and categories which define each case. In general the indicators of sustainability are numerous and comprise categories of each field of sustainable development (social, environmental and economic), but other fields can also be added as cultural, political and institutional. These fields are not directly related to sustainable development according to the basic definition (UN, 1982), but are incorporated due to the fact that political aspects are directly part of management and culture is a question of education. As mentioned above, sustainable urbanism is developed at various levels, as well as its indicators which can be local, regional or global, depending on the case and the objectives of the study, revision, planning or design, and can arise as partial or total.

At a local level, authorities are interested in indicators to help them in the decision-making process for urban development. At a regional level, institutions and various service agencies are also interested in knowing these indicators to have comparable information for the management of diverse projects and programs of regional development. At an international level, the knowledge of these indicators can be useful for financing a regional development project with international resources, or wherever necessary, and can generally be urgent and worrisome for the development of cities and communities of the third world.

5. METHODOLOGY FOR THE IDENTIFICATION AND ANALYSIS OF URBAN SUSTAINABILITY

Starting from the list of chapters on sustainable development from the *Agenda 21*, according to his table of contents (UN, 1996), we observe in the section of categories and chapters, specifically about social aspects, that there is a category dedicated especially to the promotion of development of sustainable human settlements and total 8 indicators, only for sustainable development in this rubric; and another 55 indicators in the category of environmental aspects. At the same time, there are another 23 having to do with economic aspects and other indicators of institutional aspects. All of these reflect a situation of

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sustainable development by themes. En total there are 134 indicators for sustainable development in a region or country. To identify and analyze the sustainable indicators only from the urban chapter and the breakdown of its categories, it is necessary to define a methodology which is described in the next paragraph.

The information for this study consists of a bibliography of sustainable development, tools to evaluate the environment like LEED® and BREEAM®, as well as related theory with environmental impact, new urbanism and regional development. With this information, the main topics were analyzed and evaluated in a qualitative way as well as the categories of urban sustainability that influence the identification of the main urban sustainability indicators. The INEGI study of sustainable development in Mexico was used as a foundation and classifies sustainable topics by category: economic, social, environmental and institutional, which allows us to place the development part of human settlements within a sustainable and urban focus (INEGI, 2000). Subsequently, a process of codification and identification of themes to interpret was carried out, derived from the sustainable urban context, which in theory cities should contain (Hsieh and Shannon, 2005). Finally themes were included and the indicators for each category broken down to the field of sustainable development. The capacity of an urban field to aid in sustainability is understood as a reflection of the diversification of dependant variables (which can be managed as categories) which impact the quality of life and satisfaction of the inhabitants (Parkes et al., 2002).

6. INDICATORS OF URBAN SUSTAINABILITY

Whenever a large number of variables exist, it is more difficult to determine or predict the response or answer, so topics and categories must always be eliminated to arrive at a smaller, controllable number. Figure 1 shows the field of sustainable development which could be defined as the dimensional framework, which limits all the variables presented and consequently the categories of study, from where these indicators arose referring only to urban sustainability.

This dimensional framework was enlarged to include the categories about sustainability criteria, specifically about the urban themes, in a way that the attributes of the urban environment are obvious. Table 1 shows the categories identified using the sustainability criteria, which could also be called urban sustainability topics, also called topics of urban sustainability, from which urban sustainability indicators can be extrapolated. It is important to note that the categories referred to in table 1 only show sustainability topics about urbanism, since in global terms of sustainable development, other factors exist and other variables should be taken into account.

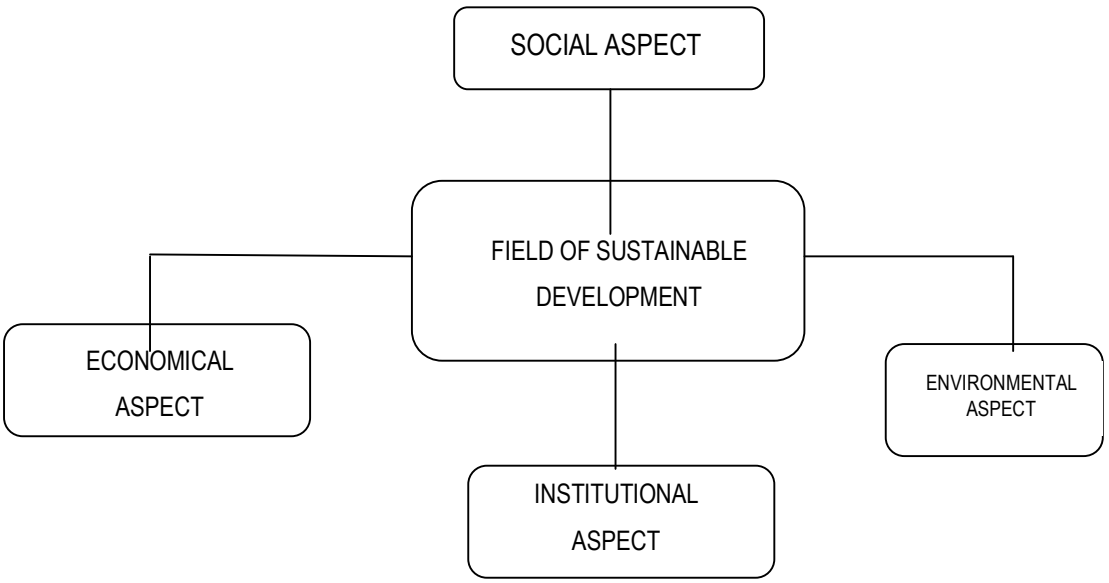

FIGURE 1 - FIELD OF SUSTAINABLE DEVELOPMENT

TABLE 1 - CATEGORIES OF URBAN SUSTAINABILITY ACCORDING TO THE DIMENSIONAL FRAMEWORK

Field or Dimensional Framework	Category of Sustainability
Economic Framework	• Productivity • Growth • Development • Consumption • Infrastructure, equipment • Transportation • Housing
Social Framework	• Demographics • Education • Health • Combating poverty • Urban and Regional Development • Equality
Environmental Framework	• Global Climate Change • Air pollution • Soil pollution • Water pollution • Other types of pollution • Biodiversity • Integrity of ecosystems • Energy consumption • Water consumption • Raw materials consumption • Other intermediate goods • Environmental quality • Urban reforestation and green spaces
Institutional Framework	• Policies and decision-making • Environmental management • National legal instruments • International legal instruments • Information and statistics • Science and investigation for sustainable development

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In table 2 the *sustainability indicators* are shown directly applied to urban sustainable development; these indicators help in decision-making not only for policies, but also for development, planning and urban sustainable design. The indicators shown in table 2 are taken or derived from the aforementioned categories and are useful for characterizing and indicating, in values which could be qualitative or quantitative, the actual state of a phenomenon or urban problem within the sustainable field, not only environmental, but economic, social and political.

TABLE 2 - INDICATORS OF URBAN SUSTAINABILITY

Categories of Sustainability	Indicators of Urban Sustainability
1. Productivity	• Gross Domestic Product • Net Domestic Product adjusted environmentally for each inhabitant • Annual consumption of energy per inhabitant • Fossil Fuel Reserves
2. Growth	• Expenditure on research and experimentation in Sustainable Development
3. Consumption	• Consumption of fossil fuels • Consumption of Renewable Energy • Goods from environmentally clean capital
4. Infrastructure, Services and Urban Equipment	• Energy networks • Potable water networks • Sewage and drainage • Residual water treatment • Hospitals • Schools • Workplaces • Recreation sites • Markets • Outdoor markets • Social Security or Health Care buildings • Firehouses • Parks and gardens
5. Transportation	• Train Infrastructure • Train Tracks • Subway Tracks • Light Rail Tracks • Trolley Lines • Bus Lines • Bicycles • Motorbikes • Private Cars • Density of passenger per vehicle • Highways, roads or streets per 1000 inhabitants • Density of taxis • Number of roads, highways or streets per type of transportation • Density of pedestrian areas • Bike paths • Density of restricted traffic zones • Number of parking spaces and paid parking lots • Number of parking spaces and free parking • Number of parking spaces and free parking lots close to public transportation • Public transportation for passengers
6. Education	• School population • Study programs in higher education directly related to sustainability

Categories of Sustainability	Indicators of Urban Sustainability
7. **Housing**	• Access to housing • Availability of housing • Quality of housing • Type of housing • Cost of housing • Family homes • Rental properties • Percentage of financed housing • Vacant housing • Abandoned housing • Condition of the housing • Ecological housing • Partially ecological housing • Housing without running water • Housing without electricity • Housing without sewage and drainage
8. **Demographics**	• Area of the city • Population density • Number of homes • Growth rate of the urban population • Life expectancy • Loss of life in natural disasters • Immigration (as part of the management, provision and organization of the urban population in cities) (Chen, 2009).
9. **Health**	• Exposure to heavy metals in urban areas • Exposure to NO2 in urban areas • Exposure to CO2 in urban areas • Exposure to Volatile Organic Substances in urban areas • Exposure to urban noise • Deaths due to violence and delinquency • Deaths due to traffic accidents • Number of sidewalk food stands • Diseases caused by fecal matter • Diseases caused by drinking contaminated water
10. **Combating poverty**	• Minimum wage • Groceries and food • Dignified housing • Paid work • Farming
11. **Regional Development**	• Agriculture • Livestock • Fishing • Extractive industries • Heavy industries • Commerce • Sources of employment
12. **Equality**	• Justice in the distribution of wealth • Justice in the exposure of polluting agents • Justice in the distribution of potable water • Socio-economic segregation
13. **Global Climate Change**	• Greenhouse gases (CO2) caused by transportation • Greenhouse gases (CO2) caused by industry • The measuring of local and global warming
14. **Generation of waste**	• Generation of municipal solid waste • Generation of dangerous waste • Recycling and use of waste

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Categories of Sustainability	Indicators of Urban Sustainability
15. Air Pollution	• Emissions from other pollutants • Air quality in urban zones • Monitoring air pollution • Number of days vehicles do not circulate • Acidification of gases from transportation • Quality of Compound Volatile Organic Material from transportation • Heavy metals in the atmosphere around transportation
16. Soil Pollution	• Changes in the use of soil • Solid residual deposits • Dangerous residual deposits • Sediments with toxic substances • Erosion and desertification • Land-fills • Area of protected forest • Area of protected urban soil at risk of a change in use
17. Water (Contamination and Consumption)	• Monthly precipitation • Annual water extraction • Concentration of fecal particles in fresh water • Biochemical demand for oxygen in bodies of water • Consumption of water per inhabitant • Consumption of residential water per inhabitant • Consumption of water per area(industrial, residential, commercial, agricultural and other services) • Quantity of water wasted from its origin to its destination • Quantity of treated water • Population with access to treated water • Quantity of rain water wasted and going to drains • Polluted water
18. Other types of contamination	• Light pollution • Vibration pollution • Sound pollution • Smell pollution
19. Biodiversity	• Modification of biological diversity
20. Integrity of Ecosystems	• Modification of ecosystems
21. Energy Consumption	• Consumption by area • Consumption of electricity • Butane gas / Carbon gas / Natural gas • Diesel / Gasoline • Wood burning • Other intermediate goods • Consumption of renewable energy • Consumption of alternate energies (photovoltaic, wind power, geothermal power, hydrogen power)
22. Consumption of Raw Materials	• Consumption of renewable raw materials • Consumption of non-renewable raw materials • With recycled content • Recycled • Materials composed of a ceramic base • Materials composed of a metallic base • Materials composed of a polymer base • Natural materials • Synthetic materials
23. Quality of the environment	• Quality of the biotic resources • Quality of abiotic resources • Quality of the landscape • Quality of the socio-cultural and urban environment

Categories of Sustainability	Indicators of Urban Sustainability
24. Urban Reforestation and Green Spaces	• Reforested areas in urban zones • Creation of green spaces and gardens
25. Changes in the use of urban soil	• Area of changed soil • Type of changed soil
26. Changes in the use of rural soil	• Area of changed soil • Type of changed soil
27. Policies and decision-making	• Evaluation of the laws about environmental impact
28. Environmental Management	• The group of evaluators of environmental impact
29. Consumption of other intermediate goods	• Various materials and combustibles
30. National Legal Instruments	• Creation and updating of urban regulations and sustainable architecture
31. International Legal Instruments	• Revision of international normsUse of international methodologies for a decrease in environmental impact • Available environmental information
32. Information and statistics	• Number of times urban architectural information about the environment is offered
33. Science and research for sustainable development	• Number of scientists employed in the research of sustainable development

These sustainability indicators, shown in Table 2, should be a guide to better decision making in Urban Development Programs for cities or master plans, starting with strategies and initiatives which include the construction of cities in different phases of implementation (Nallathiga, 2009).

7. CONCLUSIONS

It is concluded that sustainable urbanism is a new way of urbanizing, bringing us towards a reduction in environmental impact through the construction of large cities, to raise the quality of life for the inhabitants and ease the processes of economic, social, environmental, political and cultural construction of an urban city or community. For this, sustainable design and planning of the cities is needed, taking into account the premises of sustainable development and applying them to regional development from the creation of housing starting with neighborhoods and up to entire cities and groups of cities. At the same time, we must consider variables and indicators of sustainability that help us make decisions to improve the urban planning at distinct levels: political, planning and urban design, methods, techniques and processes of regional sustainable development.

On the other hand, it is necessary to consider that in Mexico there is a lot to do when it comes to sustainable development and even more when applied to urbanism. It is necessary that sustainable construction and planning regulations be put into place, which does not exist in Mexico at the moment, as well as more scientific research in order to guide development. At the same time, architects and urban planners require information and statistics of the urban environmental type to aid in the urban

environmental projects, as well and technical and legal instruments. We need, then, to reduce our consumption of soil, energy, water, raw materials and avoid the pollution of air, soil, water, and consequently reduce environmental impact, giving a better quality of life to each inhabitant.

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