Integrated Land Use Transportation Modeling Needs and Legislative Mandates

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Abstract: - Integrated land use transportation models have been evolved as the primary metropolitan planning vehicle in the last several decades as the world development and urbanization continues. Urban regions continue planning for development of their urbanized areas using these modeling processes. Land use/demographic forecasting models provide the main input for the travel demand models, yet until recently the rigorous application of such models in the integrated land use transportation process was scanty except for the largest metropolitan areas. Such models require consideration of environmental factors and modeling of metropolitan economic systems. Theoretical and technological advancement of the last few decades has instigated a new wave of attention, research and further developments of the models and techniques from a variety of disciplines. This article briefly discusses the advancements and provides a guideline for their future improvements. It also discusses importance of role of national government and legislative mandates in ascertaining quality of planning process by reviewing some excerpts from U.S. legislation.

Key-words: - Land-use planning, Integrated transportation models, Land-use and Demographic forecasting, Legislative mandates, Transportation planning, Metropolitan development, Environmental concerns, Economic development, Regional development, Regional policy

1 Introduction

Today, almost every metropolitan region all over the world is continuously planning for the future development of their region with a particular emphasis on transportation and land use. Implementing these plans affect almost every aspect of life in each of these regions at an enormous cost in terms of not only financial but also externalities. Urban systems are becoming ever larger and increasingly more complex, as urban economics, social and political structures, and transportation and other infrastructure systems continue to evolve. Both population and employment continue to grow rapidly in most cities throughout the world. Current population projections suggest continued and substantial growth over the next 50 years, with much of it occurring in metro areas. With this population and employment increase come a greater demand for residential, commercial, and office development, as well as transportation improvements to facilitate the needed interactions involved in commercial and residential activities. All of this implies the need for prudent planning to avoid problems such as congestion, pollution, environmental degradation, and a general decline in the quality of life.

There has been a long history and traditions related to transportation planning for more than a half a century. However, considering the growth and changes in population and employment distribution in metropolitan areas, as was briefly discussed above, as well as social and technological advancements there is a need for further improvements on the planning approaches in integrated land use transportation modeling and also the legislative and governmental aspects. This paper will briefly discuss these two important aspects and provide some general directions for future improvements.

2 Land Use and Travel Demand Modeling

Operational (mathematical) and theoretical models have long been used to attempt to reduce complexity and encode a clear and concise understating of some aspects of urban structure and transportation. The four-step model first developed in the late 1950s. The mid-twentieth century saw the development of a sequential process of estimating travel demand, based on aggregate approaches, that was known as the four-step model. A relatively disaggregate version of the four-step model is used to this day by several metropolitan planning organizations worldwide. Parallel to the development of the four-step model of travel demand, planners also recognized the intricate interactions between the transport network and the rest of the urban system.

2.1 Integrated Land Use Transportation Models

To address more operational needs in planning and policy decisions, computerized models, representing urban travel and land use, began to be developed and used from at least the 1960's in the United States, with the advent of Urban Transportation Planning System for travel demand forecasting [1]. Such models help make decision on future development of (urban) transport systems and forecasts travel patterns 20-30 years ahead most often in five years increments. Subsequent work on spatial interaction models for predicting locations of households and jobs across urban landscapes was carried out [2] which emerged out of earlier Lowry model work [3].

These operational land use models forecast and allocate population and employment to small areas/zones, in a way that is well suited for input into a travel demand model (TDM). While the land-use components of these land-use transportation models have been rapidly evolving from simple aggregate representations to complex economic and econometric models of the market processes, the four-step model continues to represent the transport modeling component. This type of model helps in projecting the travel patterns in the future in four steps of trip generation (how many trips?), trip distribution (where will the trips go?), mode split (what modes will they use?), and traffic assignment (what routes will they take?).

On the other hand, land use models calculates the amount of employment and population (households) that will be located in each zone, calculates the amount of land that will be used by the locating activities and forecasts employment and population demand for location in specific zones of a region. UrbanSim [4], PECAS [5] and TELUM [6] are a few examples of these types of models. These land use models are predictive in nature, using historical data and behavioral and economic theory to make forecasts of what the future will be like. A major strength of these models is their ability to integrate with TDM.

2.2 What Else Needs to be Considered?

The use of integrated transportation/land use models is increasing worldwide, as practical applications demonstrate the value of these sophisticated tools. Such models are evolving from simple GIS based forecasting models to extremely complex microeconomics- based integrated land use and transportation models. However, still remains a magnitude of challenges to be overcome in the conceptual and technical aspects of modeling.

The land development pattern of the past few decades has been associated with a variety of controversial and negative impacts, including a continuation of suburbanization, sprawl, and environmental problems. Land use and land cover decisions can have pronounced effects on water quality, erosion, and other environmental concerns. Integration of land use and transportation models can facilitate planners' and policymakers' understanding of the transportation, land use, and environmental impacts of new highway alignments, corridor expansions, and other major system investments. In addition, using land suitability models and Geographic Information System (GIS) environmentally sensitive areas can be identified and protected, natural hazards can be mitigated, and the reduction of impervious cover can be avoided. Watershed-based land use planning, stream buffering, and related goals can also be achieved. Policy analysis can be greatly aided by locating the least objectionable areas for specific types of development.

2.3 Why Models Need Improvements?

In discussing urban land use (or an urban activity system), transportation planners are referring to the spatial distribution of people and activities in a metropolitan area [7]. The distribution of population and employment provides the primary input into transportation demand models. This is

why it is so important to have land use planning done as best as we can to avoid providing wrong input into TDM. The spatial distributions of employment and households in a region are essential inputs to predict the travel time in the region. Travel time, in turn, influences employment and household locations in the future. Measures such as the total time spent by all users traveling in a network are used as indicators of congestion, and hence they are also used to gauge the effectiveness of transportation policies. Thus, it is necessary to develop a model that can make good forecasts of the locations of employment and households in order to predict the travel time accurately for the future.

2.4 Relationship Between Land Use and Transportation

Transportation and land use enjoy a two-way interaction. Spatial development, or land use, determines the need for spatial interaction, or transport, but that transport, by the accessibility it provides, also determines land use. Therefore, transportation planning needs to start from land use projection in order to produce the needed input data for the travel demand modeling process.

In general, the forces behind land use and transportation changes are mostly economic growth and decline or urban development in general. Therefore, land use models also have to use regional economic forecasts as input to the process to project demographic and economic changes in zonal levels. Most often, economic changes are represented by employment and population changes. Land use models include stages for projecting demographic changes including population and employment. Such projections need to be distributed spatially in the study area. It is important to distinguish and understand the three-stage interactions between economic, land use, and transportation systems in order to appropriately model the process of projecting employment and population changes, allocating them to land areas, and deriving land use/demographic forecasts in relation to transportation planning. New economic centers or growth decline of existing centers in metropolitan areas are result of market forces, the increase of economic competitiveness and influences of foreign and domestic firms on the urban/ spatial structure of the metropolitan regions [8, 9].

2.5 Land Use Models

Land use planning can be done in several ways. In practice, three main approaches to anticipating land use futures exist. These can be distinguished through the use of the following terms: (1) “mathematical land-use model” refers to a tool that forecasts and allocates population and employment to small areas/zones in a way that is well suited for input into a travel demand model (TDM); (2) “suitability process” refers to the use of land suitability analysis with the aid of Geographic Information System (GIS) to ascertain where land development of all types may best occur; and (3) the “general professional planning approach” refers to the use of only personal, expert opinions, often supplemented by readily available data from sources such as census data.

While the general planning approaches have been done by the professional urban planners most often for a smaller area or a city inside a metropolitan area the mathematical models have been used the operational models in an attempt to simulate structure of the metropolitan area and project demand for land uses. In contrast, suitability analysis is the traditional method for determining land use allocation and is a major stage in the Kaiser et al. (1995) [10] five step land-use planning process.

Land suitability analysis is a technique that has been used for the prudent allocation of land resources and for planning with ecological sensitivity. In more recent years, local and regional efforts have begun to recognize the effect of land use on the quality of the environment. Suitability analysis models could be helpful in all aspects of the land use-transportation modeling process and in achieving the desired objectives.

2.6 Environmental Factors

Along with modeling land use and transportation in an integrated fashion, consideration of environmental factors in land use-transportation decisions is becoming more and more important. A major concern of sustainable cities is transportation and its impact on the environment [11, 12]. Also, there has been growing interest in and need for spatial disaggregation in land use- transportation modeling efforts , which makes the use of geographic information systems (GIS) highly attractive – and practically necessary. These models require a great deal of data and generate many spatial results which need to be communicated to a broad range of experts, city

leaders, and the general public, via visually appealing and understandable presentations [13].

Land suitability analysis is a technique that has long been used for the ecologically-sensitive allocation of land resources and planning. With the advent of GIS, this technique has evolved and been integrated into existing GIS platforms; it may become a major contributor to the process of integrated land use-transportation modeling. Suitability analysis can readily identify environmentally sensitive areas meriting preservation and/or other special treatments. Provisions can then be made for restricting their use in the modeling process, in order to avoid (excessive) development of sensitive areas [14, 15]. The analysis could help in identifying vacant and under-utilized land well suited for future development, while protecting environmentally sensitive areas, mitigating natural hazards, and avoiding, for example, reduction in impervious cover.

Transportation and land use should not be viewed in isolation. Aside from both affecting environment they interact and relate to many issues of importance for metropolitan areas [11, 16]. Most importantly, land use development directly affects the form and characteristics of the transportation system, and transportation plays an integral part in shaping our land use and development. In all planning at the fundamental level, both transportation and land use modeling answer the same questions: "*how does our community grow, and what do we want our community to become?"* [17].

According to Berke et al. [18], the land use plan is vital to the transportation plan because the designated type and location of development proposed in the land use plan will influence demand for various transportation services in the future. They state, "The land use plan is connected to the transportation plan because the type and location of development that is prescribed in the land use plan will have impacts on future demand for transportation services" (p. 238). Ideally, local land use plans should be considered carefully in the transportation planning process.

While this paper emphasizes the role of land use modeling in transportation planning, ultimately policymakers and the public are in charge of what gets built and where development occurs. To the extent that suitability analysis and other tools can illuminate the effects of different land use policies and activity-siting decisions, the ideas and tools explained herein are relevant for prediction and planning, forecasting, and policy-making.

3 Land Use Planning and Government Policies

There is a long history of government involvement in transportation planning in the United States through adoption of different policies and regulations. A selection of these regulations and policies which might help other nations that are in the process of adopting similar regulations will be presented in this section.

3.1 Metropolitan Planning Organization

Federal regulations in the United States require each urbanized area over 50,000 in population to have a metropolitan planning organization (MPO) responsible for land use transportation planning. A metropolitan planning organization is an association of local agencies established to coordinate transportation planning and development activities within a metropolitan region. Establishment of the MPO is required, by law, in urban areas of over 50,000 population, if federal funds are to be used.

According to the federal legislations by agreement between the MPO and the Governor the boundaries of a Metropolitan Planning Area (MPA) shall be determined. *A* metropolitan planning area (MPA) is the geographic area in which the metropolitan transportation planning process is required. Based on the legislations, *at a minimum*, the MPA boundaries shall encompass the entire existing urbanized area (as defined by the Bureau of the Census) plus the contiguous area expected to become urbanized within a 20-year forecast period for the metropolitan transportation plan. There are several integrated land use transportation models that can be used for this purpose.

3.2 Importance of Land Use Forecasts

Relationships between land use and all transportation modes impact many activities of a metropolitan planning organization (MPO). The U.S. Department of Transportation states this in the following way:

> *"Effective travel demand forecasting depends on land use forecasts. Long-range transportation plans should consider regional and/or municipal land use plans and metropolitan development objectives.*

> *Creating and attaining metropolitan quality of life goals depends, in part, on land use strategies. New Starts projects are evaluated based on criteria including land use policies. Major investment studies must consider land use and economic development. Air quality models and goals depend on land use forecasts and plans" (p.8).* [17].

In addition, the effectiveness of congestion management and travel demand management strategies depends upon land use and development. Public involvement efforts should consider the public's desires for urban form and land use. The effectiveness of transit capital improvements and highway capacity enhancements may depend upon land use and development. In numerous other ways, land use deeply affects the activities of MPOs [17].

3.3 Federal vs. Local Governments

According to the FHWA [19], decisions affecting land use and transportation are often made in two independent environments, as follows:

> *"Transportation decision-makers consider the environmental and social impacts of proposed transportation improvements, but may not deal directly with the issue of how land use will be affected by the transportation investment. Other public investments (sewer, water, public facilities) also affect land development" (p. 1).*

> *"While Metropolitan Planning Organizations (MPOs), State Departments of Transportation, and the U.S. Department of Transportation are all involved in the transportation decision-making process along with local governments, land use decisions are typically made exclusively within the local government arena and for some areas fall completely outside of the planning process" (p. 1).*

3.4 Issues Related to MPOs

There are several issues that involve land use in relation to transportation planning. There are five major issues related to land use modeling that are relevant to MPOs [17]: land use and transportation modeling, travel behavior and land use, pedestrian- and transit-oriented land use issues, highways and land use, and suburban land use issues.

According to the USDOT [17], the first issue for MPOs is to accurately recognize, during the planning process, is the complex relationships among urban form, land use, urban design, and travel demand. Other issues include land use allocation techniques, incorporating urban design variables into travel demand models, and measuring transportation infrastructure constraints on land use

The next issue points to the relationships between land use and aspects of travel behavior and how municipal/regional policies can either support or undercut one another. Land use and travel behavior interact, and MPOs must work with local governments to thoughtfully develop consistent policies and programs that support metropolitan goals.

3.4 Sustainability and Smart Growth

The rise of the Smart Growth and New Urbanism movements has raised the awareness of pedestrian- and transit-oriented land use issues. These movements have brought together a diverse coalition of planners, developers, environmental experts, transportation professionals, government officials, and community leaders who have articulately advocated the importance of these issues to communities of all sizes.

MPOs in small- and medium-sized areas have an opportunity and a responsibility to consider these issues when developing metropolitan goals, plans, and programs, and to implement them in cooperation with local land use decision makers. One aspect includes addressing how pedestrian- and transit-oriented land use strategies could enhance livability and quality of life and address environmental quality concerns. It is also important to address how these strategies could calm traffic at appropriate locations, mitigate the negative effects of sprawl, implement regional growth management goals, and preserve, revitalize, or create community "Main Streets." All of these are based on the need for coordinating land use with transportation activities that include site design, neighborhood and corridor planning, and regional smart growth strategies [17].

3.5 Other Impacts

Highway expansions impact land use, urban form, and development in urban, suburban, and rural areas. In urban and suburban settings, issues include the impacts of capacity enhancements on land use and the related impacts of land development along capacity-enhanced highways capacity on traffic volume growth. Other issues include the effects of freeway grade on land value, the impacts of highway capacity expansions on urban form, the effects of freeway construction on land uses, and the effects of high-occupancy vehicle facilities on land uses. All types of areas are likely to be interested in the impacts of highways on metropolitan economic growth and development, particularly potential land development at freeway interchanges and the effects of such development on existing communities. Land use issues of this kind are alleviated with better environmental quality, and transit impacts can be addressed by designating strategic land uses.

A good majority of land development and transportation improvements occur within a suburban setting. Because of this, MPOs should be cognizant of the issues relating to land use and transportation in a suburban context. These issues include addressing suburban traffic congestion, understanding suburban travel behavior, transit- and pedestrian-sensitive suburban land uses and design, creating more efficient suburban activity centers, and analyzing the effects and costs of sprawl [17]. As such, one of the most difficult aspects of land use forecasting is the future distribution pattern and clustering of the employment and population in the undeveloped areas surrounding the present urbanized parts of the metropolitan regions which needs our close attention in modeling conceptualization.

4 Legislative and Government Role

There are important roles for national governments to play in order to facilitate the integrated land use transportation planning process in the metropolitan level and to ascertain the prudent planning and implementation of the planning policies. We will briefly present some excerpts and examples from the United States in this section. Several legislative acts and federal requirements in the United States created the need for land use modeling for transportation facilities. In order to get federal funding for transportation projects, municipalities, Metropolitan Planning Organizations (MPOs), and state agencies are required to follow the federal requirements regarding land use, in addition to the other titles of each act. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the Transportation Equity Act for the 21st Century (TEA-21) of 1998, and the Safe, Accountable, Flexible, Efficient Transportation Equity Act (SAFETEA-LU) of 2005 implemented better land use strategies as a main requirement. A brief summary of these major acts and a selection of important land use/transportation planning and modeling-related parts from these important acts are excerpted and presented here.

4.1 Intermodal Surface Transportation Efficiency Act (ISTEA)

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 was the first federal law to incorporate a major change to transportation planning and policy which was the first U.S. federal legislation on the subject in the post-Interstate Highway System era. ISTEA created the need of a multimodal transportation system emphasizing connectivity of pedestrian, transit, highway, and other modal elements. It also introduced an intermodal approach to highway and transit funding with collaborative planning requirements, giving significant additional powers to metropolitan planning organizations [20].

According to USDOT [17], ISTEA makes it important in considering land use in the metropolitan transportation planning process. For example, Planning Factor 4 requires MPO's to consider "*the likely effect of transportation policy decisions on land use and development and the consistency of transportation plans and programs with the provisions of all applicable short- and long-term land use and development plans.*" The existing ISTEA requirements outline several sections where land use for transportation planning must be coordinated in designating land use. Some of these sections include:

> *"Metropolitan Planning: In developing transportation plans and programs pursuant to this section, each metropolitan planning organization shall, at a minimum, consider the following: . . . (4) The likely effect of transportation policy decisions on land use and development and the consistency of transportation plans and programs with the provisions of all*

applicable short- and long-term land use and development plans."

"Discretionary Grants and Loans: "Criteria for Grants and Loans for Fixed Guideway Systems. - "(3) In making a decision under paragraph (2) of this subsection, the Secretary of Transportation shall - C) identify and consider mass transportation supportive existing land use policies and future patterns." [21]

4.1.1 Factors to be considered

According to the U.S. regulations [21] there are several factors that must be considered as part of the planning process for all metropolitan areas. As an example the following land use and transportation factors shall be explicitly considered, analyzed as appropriate, and reflected in the planning process products*:*

"The likely effect of transportation policy decisions on land use and development and the consistency of transportation plans and programs with the provisions of all applicable short- and long-term land use and development plans (the analysis should include projections of metropolitan planning area economic, demographic, environmental protection, growth management, and land use activities consistent with metropolitan and local/central city development goals (community, economic, housing, etc.), and projections of potential transportation demands based on the interrelated level of activity in these areas)."

In relation to Major Metropolitan Transportation Investments the regulations state: [21]

"To the extent appropriate as determined under paragraph (b) of this section, major investment studies shall evaluate the effectiveness and cost-effectiveness of alternative investments or strategies in attaining local, State and national goals and objectives. The analysis shall consider the direct and indirect costs of reasonable alternatives and such factors as mobility improvements; social, economic, and environmental effects; safety; operating efficiencies; land use and economic development; financing; and energy consumption."[21]

4.1.2 Transportation Planning Process

Regarding metropolitan transportation planning the regulations state that:

"The metropolitan transportation planning process shall include the development of a transportation plan addressing at least a twenty year planning horizon. The plan shall include both long-range and short-range strategies/actions that lead to the development of an integrated intermodal transportation system that facilitates the efficient movement of people and goods. The transportation plan shall be reviewed and updated at least triennially in non-attainment and maintenance areas and at least every five years in attainment areas to confirm its validity and its consistency with current and forecasted transportation and land use conditions and trends and to extend the forecast period. The transportation plan must be approved by the MPO." [21]

For major transportation actions also early coordination, public Involvement, and project development is regulated and encouraged. Such regulations focus on broad issues such as general location, mode choice, and area wide air quality and land use implications of the major transportation alternatives. They also address site-specific details on project impacts, costs, and mitigation measures.

4.2 The Transportation Equity Act for the 21st Century (TEA-21)

ISTEA was followed by the 1998 Transportation Equity Act for the 21st Century (TEA-21) enacted as Public Law 105-178 and preceded ISTEA which expired in 1997. TEA-21 authorizes the Federal surface transportation programs for highways, highway safety, and transit for the 6-year period 1998-2003.

According to USDOT (2004), TEA-21 condenses ISTEA's planning factors into seven general factors. The consideration of land use

is implicit in several of these factors. MPOs are required to consider projects and strategies that will support the economic vitality of the metropolitan area and increase accessibility and mobility options available to people. They must also consider projects and strategies that protect and enhance the environment, improve quality of life, and enhance the integration and connectivity of the transportation system. The explanatory materials for TEA-21 make clear that *"...metropolitan planning organizations are encouraged to consider the interaction between transportation decisions and local land use decisions appropriate to each are".*

4.2.1 Land Use Requirements

The TEA21 requirements outline several sections where land use for transportation planning must be coordinated in designating land use. The following sections are land use requirements in relation to transportation planning. The requirements and include:

> *"(1) It is in the national interest to encourage and promote the safe and efficient management, operation, and development of surface transportation systems that will serve the mobility needs of people and freight and foster economic growth and development within and through urbanized areas, while minimizing transportation-related fuel consumption and air pollution."*
>
> *"(2) The metropolitan transportation planning process for a metropolitan area under this section shall provide for consideration of projects and strategies that will--'(A) support the economic vitality of the metropolitan area, especially by enabling global competitiveness, productivity, and efficiency; '(B) increase the safety and security of the transportation system for motorized and non-motorized users;'(C) increase the accessibility and mobility options available to people and for freight; '(D) protect and enhance the environment, promote energy conservation, and improve quality of life; '(E) enhance the integration and connectivity of the transportation system, across and between modes, for people and freight; '(F) promote efficient system management and operation; and '(G) emphasize the preservation of the existing transportation system.'"* [21]

4.3 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)

The most recent legislation in this series is the 2005 Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) which has succeeded the TEA-21 and enabled additional requirements for land use planning for transportation. SAFETEA-LU builds on the same framework as the previous Acts but includes safety, equity, innovative finance, congestion relief, mobility and productivity, efficiency, environmental stewardship, and environmental streamlining in order to keep up with current growing transportation infrastructure. It "promotes more efficient and effective Federal surface transportation programs by focusing on transportation issues of national significance, while giving State and local transportation decision makers more flexibility for solving transportation problems in their communities." [22]

According to the FHWA [22], Additional land use requirements based on these regulations under the title of Transportation Planning and Project Delivery includes:

> *"In general.--In each metropolitan area, the metropolitan planning organization shall consult, as appropriate, with State and local agencies responsible for land use management, natural resources, environmental protection, conservation, and historic preservation concerning the development of a long-range transportation plan"* and that *"the long-range transportation plan shall be developed, as appropriate, in consultation with State, tribal, and local agencies responsible for land use management,*

natural resources, environmental protection, conservation, and historic preservation."

Overall, all of the federal guidelines from the Intermodal Surface Transportation Efficiency Act (ISTEA), the Transportation Equity Act for the 21st Century (TEA-21), and the Safe, Accountable, Flexible, Efficient Transportation Equity Act (SAFETEA-LU) regarding land use for transportation planning is required in order for municipalities, MPOs, and state to get federal funding for transportation planning and the transportation projects.

Conclusion

Every urban region is continuously planning for the future development of their region under rubric of land use and transportation with a particular emphasis on economic development and major concerns with environmental problems. Implementation of these plans which facilitate development affects almost every aspect of life in these metropolitan regions. While their costs are enormous and their environmental effects deserve close scrutiny, there is a universal agreement for the need for such planning practice and that development effects of their implementations are positive if it is done right. Since land use/demographic forecast provides the main input into the travel demand modeling in this planning process it is imperative that this phase of the integrated land use transportation planning to be conceptualized appropriately through modeling of the major economic and social processes. While the models and methods utilized in forecasting and planning towards these efforts has come a long way, and we have also seen the maturation of these approaches, there is still a lot left to be developed and to be included in these models and methods.

National and local governments have an important role in mandating requirements on consideration of environmental factors and economic development aspects in the land use forecasting, but it seems they all need to do more in order to ascertain a sound land use transportation planning process in place. There are important aspects that are not fully included in practice or theory, and are insufficient towards a comprehensive approach in land-use/transportation planning. The increasing social consciousness on environmental concerns has major implications on the modeling approaches because of land-use/transportation and the way in which developments impact the environment. All these aspects need to be fully considered and included in the national policies and also in the planning efforts.

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